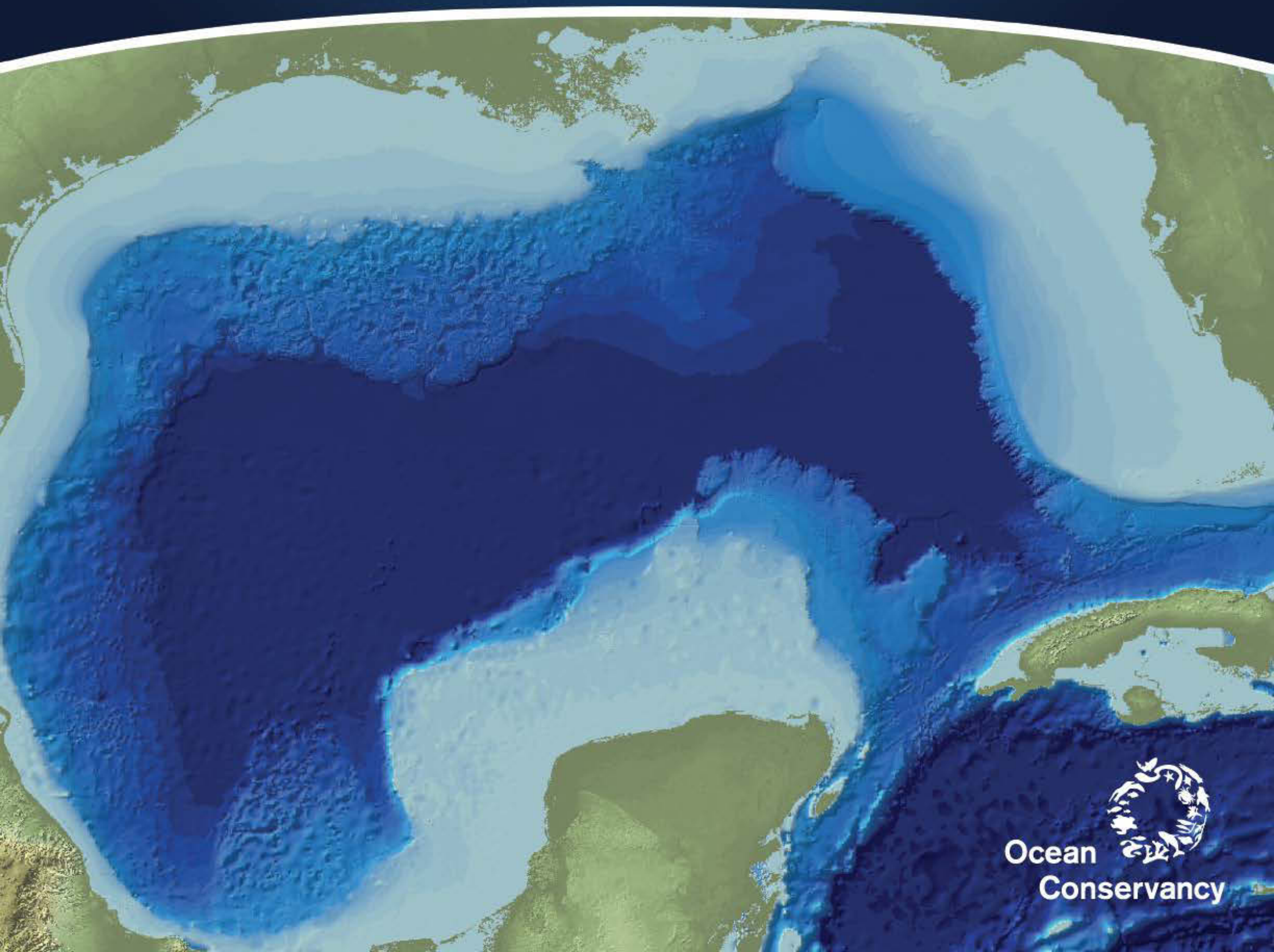
THE GULF *of* MEXICO ECOSYSTEM

A COASTAL & MARINE ATLAS



Ocean Conservancy

THE GULF of MEXICO ECOSYSTEM

A COASTAL & MARINE ATLAS

Authors
Matthew S. Love
Alexis Baldera
Carmen Yeung
Christopher Robbins

Major Contributors
Rachel Guillory
Todd Phillips
Stanley Senner
Robert Spies

OCEAN CONSERVANCY
Gulf Restoration Center
400 Poydras Street, Suite 1990 // New Orleans, LA 70130

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If you have questions about or comments on the maps and narratives provided here, please contact the authors at **gulf@oceanconservancy.org**.

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1.0 Introduction

The Gulf of Mexico is a large, productive, warm-water marine and coastal ecosystem that provides extraordinary goods and services to Gulf Coast communities and the entire nation. The BP Deepwater Horizon (DWH) oil disaster and associated response and cleanup activities caused extensive and, in some cases, severe impacts on the Gulf's ecosystem, inhabitants and economies. The resulting damage occurred against a backdrop of decades-long challenges, ranging from the loss and degradation of coastal wetlands and barrier islands to the formation of seasonal "dead zones" in the northern Gulf to overfishing and the substantial loss of productivity in many fisheries. The DWH oil disaster triggered a national call for action to go beyond the impacts of the oil well blowout and address the long-term degradation of the region.

Combined with historical and current stresses on the environment, the DWH oil disaster put at further risk the Gulf's natural resources and the many ocean-based industries and jobs they support. Fishing, tourism, and oil and gas production, to name a few multibillion-dollar businesses and activities, were adversely and severely affected. The Gulf's ecosystem, natural bounty, economy and quality of life are all inextricably intertwined. Restoring the Gulf and managing its natural resources effectively are as much an economic and cultural necessity as they are an environmental one.

There is now intensive focus on ecosystem restoration in the Gulf. Some early restoration efforts are underway, and still more will take shape and be implemented in the coming years. However, based on past experiences with other oil spills, the daunting scope and scale of the DWH oil disaster, and the Gulf's history of ongoing and cumulative environmental degradation, successful restoration of the area will almost certainly require a sustained and coordinated effort with consistent support over a period of decades.

An effective Gulf ecosystem restoration program needs to be developed that addresses not only the immediate effects of the DWH oil disaster, but also the abatement and reversal of long-term environmental degradation. It should be carried out with a clearly articulated vision and plan that begins with a multilayered understanding of how the ecosystem functions while identifying its sources of stress. Preventing and mitigating future environmental impacts through informed planning and effective management also requires an understanding of the Gulf ecosystem in its entirety, including human influences and uses.

Credit: SeaWIFS Project, NASA/Goddard Space Flight Center, ORBIMAGE

It is in this context that Ocean Conservancy offers *The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas* as a tool to aid current and future Gulf restoration efforts and improve the ongoing management of the Gulf ecosystem. Through these maps and accompanying narratives, we aim to provide resources that will engage and inform the public and decision-makers and, we hope, ultimately facilitate successful, science-based restoration and management of the Gulf's natural resources.

As described below, Ocean Conservancy compiled current and, in some cases, historical geospatial data on selected natural resources, related human uses and other environmental attributes in the Gulf ecosystem. This compilation was done for the entire ecosystem, including the waters and coasts of Cuba and Mexico, to the fullest extent possible. The particular features described and depicted here were selected for a variety of reasons. In general, we sought subject material that, when relayed collectively, broadly characterizes:

- Physical features and processes that define and drive the Gulf ecosystem;
- Fish and wildlife resources, emphasizing species and habitats of concern that were affected by the DWH oil disaster as well as species of commercial or other importance;
- Systemic environmental stressors; and
- Related human uses, influences, and their effects on the Gulf ecosystem.

Considering how long the Gulf Coast region has been settled and how many universities and research institutions operate in the region, it is perhaps surprising that publicly available data are relatively scarce. As a result, lack of geospatial data significantly limited our choice and description of subjects for this atlas. These data gaps highlight the need for targeted scientific research, ocean observing systems and ecosystem monitoring.

Ocean Conservancy endeavors to update periodically the maps and narratives for this atlas, which may be accessed at www.oceanconservancy.org. Ocean Conservancy also contributes to the National Coastal Data Development Center's Gulf of Mexico Data Atlas (http://gulfatlas.noaa.gov/) under the umbrella of the National Oceanic and Atmospheric Administration (NOAA), which includes a large array of individual data layers, though without the integration and synthesis provided in Ocean Conservancy's atlas.

The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas provides a new and unique perspective on the Gulf ecosystem. In several cases, the atlas includes environmental data that, to our knowledge, have never been synthesized and mapped. It is our hope and intent that it will engage and inform decision-makers, resource managers, community leaders, businesses and others with interests in a healthy and productive Gulf. This atlas offers an easily accessible, regionwide perspective that should be especially relevant to individuals and institutions engaged in Gulf restoration planning as well as related disaster prevention, mitigation and response efforts. It should also serve as a consolidated research resource for anyone interested in the environmental impacts of industrial and other activities in the area and for those who are involved in managing natural resources and related human uses in the Gulf.

Geospatial Data: Methods and Sources

Ocean Conservancy has corresponded with numerous scientists, resource managers and regulators to identify and illustrate the spatial distribution of key Gulf attributes that are important for conservation and management applications. Various geospatial datasets (such as rasters, netCDF files, shapefiles, ArcInfo interchange files and geo-referenced digital maps) along with other non-geospatial data (such as tabular spreadsheets, technical reports, direct communication with researchers and published literature) were compiled in the development of this atlas. While these data have been maintained in the original source format in many instances, the creation of an integrated Esri file geodatabase was employed to create a more comprehensive and useful database presentation. All data compilation, editing, metadata management and the creation of the atlas maps were developed in the Esri ArcInfo 10.0, Service Pack 4 software environment.

The atlas was designed to be printed with maps at a page size of 11 by 17 inches with the entire extent of the Gulf marine environment displayed. At this page size, 1 inch on the page equals 5,575,680 inches on the ground, or 1 inch equals 88 miles. The reference base map (used as the template for all atlas maps herein) includes the general topography of the terrestrial and marine environments as well as major rivers (See Project Area Map, Map 1). Undersea features of ecological or physiographic significance are also labeled for reference. Additional reference points selected are key cities in each of the U.S. and Mexican Gulf states, administrative boundaries for states, and exclusive economic zones.

Ocean Conservancy made every effort to locate reliable data that are relevant to understanding resource and related human-use distributions in the Gulf, and the most reliable data covering the greatest extent of the Gulf were used to develop each map. Priority was given to datasets that represented the most recent state of the resources, but with the greatest extent in coverage. While there may be many local and regional datasets covering specific resources available from individual research projects or institutions, the level of effort required to integrate these many disparate datasets into a seamless unified database was beyond the scope and resources of this project. For a variety of reaons, including both pending publication of data by researchers and litigation related to the DWH oil disaster, the data originators did not release some of the most current datasets that document the distribution and abundance of resources.

Data Quality and Gaps

The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas draws on datasets ranging in quality from poor to excellent as defined by Ocean Conservancy's data quality criteria. This atlas also draws on datasets that span the range of geographic coverage from sparse to continuous for the entire Gulf. Developing maps for an area of this size highlights gaps in geospatial data that are critical for management and conservation of the marine environment. While there are reasonably good data available for the waters of the U.S., equivalent data for the waters of Cuba and Mexico are often not available.. Research funded by the U.S. is typically restricted to the U.S. exclusive economic zone, resulting in an incomplete dataset for many Gulf-wide resources, such as pantropical spotted dolphins or benthic chemosynthetic communities. While some of these datasets may in fact exist in the research institutions of these countries, many of the datasets needed for complete Gulf-wide coverage of habitats or species occurrences were not located during the development of this atlas.

This atlas includes spatial data from 173 different sources or datasets. Data used in the atlas were obtained from a wide variety of sources as there is not a single, comprehensive data source for geospatial data in the Gulf. The 1985 *Gulf of Mexico Coastal and Ocean Zones Strategic Assessment: Data Atlas* was the most recent mapping compilation of marine resources and related human uses in the Gulf prior to the creation of this atlas and other recent mapping efforts, such as the NOAA Gulf of Mexico Data Atlas and the Multipurpose Marine Cadastre.

The multitude of data formats, variations in geographies, lack of supporting metadata and different spatial scales of source data posed a significant challenge for compiling and integrating a comprehensive collection of data to illustrate natural resources, related human uses and environmental attributes of the Gulf. To assist in the interpretation of each attribute, the maps were assigned a data quality rating of poor, fair or good relative to the broad scale of the project area. Although portions of many maps are based on data that, in isolation, could be rated as excellent, without full data coverage of the Gulf by that dataset, none of the maps would be appropriately labeled as excellent.

Details of the data quality scale used for rating the maps are further explained below:

Good: The map provides near Gulf-wide coverage of the habitat or resource. Data are consistent and of acceptable quality for mapping these resources at the scale of this atlas (1:5,575,680).

Fair: The map provides partial Gulf coverage of the habitat or resource. Data are variable with some portions of the map covered by high quality data while, for other portions of the project area, data may be of lower resolution, outdated or missing altogether.

Poor: The map provides an incomplete geographic view of the habitat or resource. Information is missing, outdated or deficient, but the best-known available data are used.

The most complete datasets included herein often resulted from efforts by resource management agencies or research institutions combining previously published studies of occurrence records to develop a more comprehensive database, such as the work to collect all known records of deep-water corals into a single database by NOAA (Etnoyer, 2009; Etnoyer et al., unpublished report). In other instances, high quality datasets are derived from a comprehensive dataset that was compiled by a resource management agency in order to develop occurance models that better inform marine management issues, as was the case with the Cetacean Sound and Mapping Working Group database (Reed et al., 2010).

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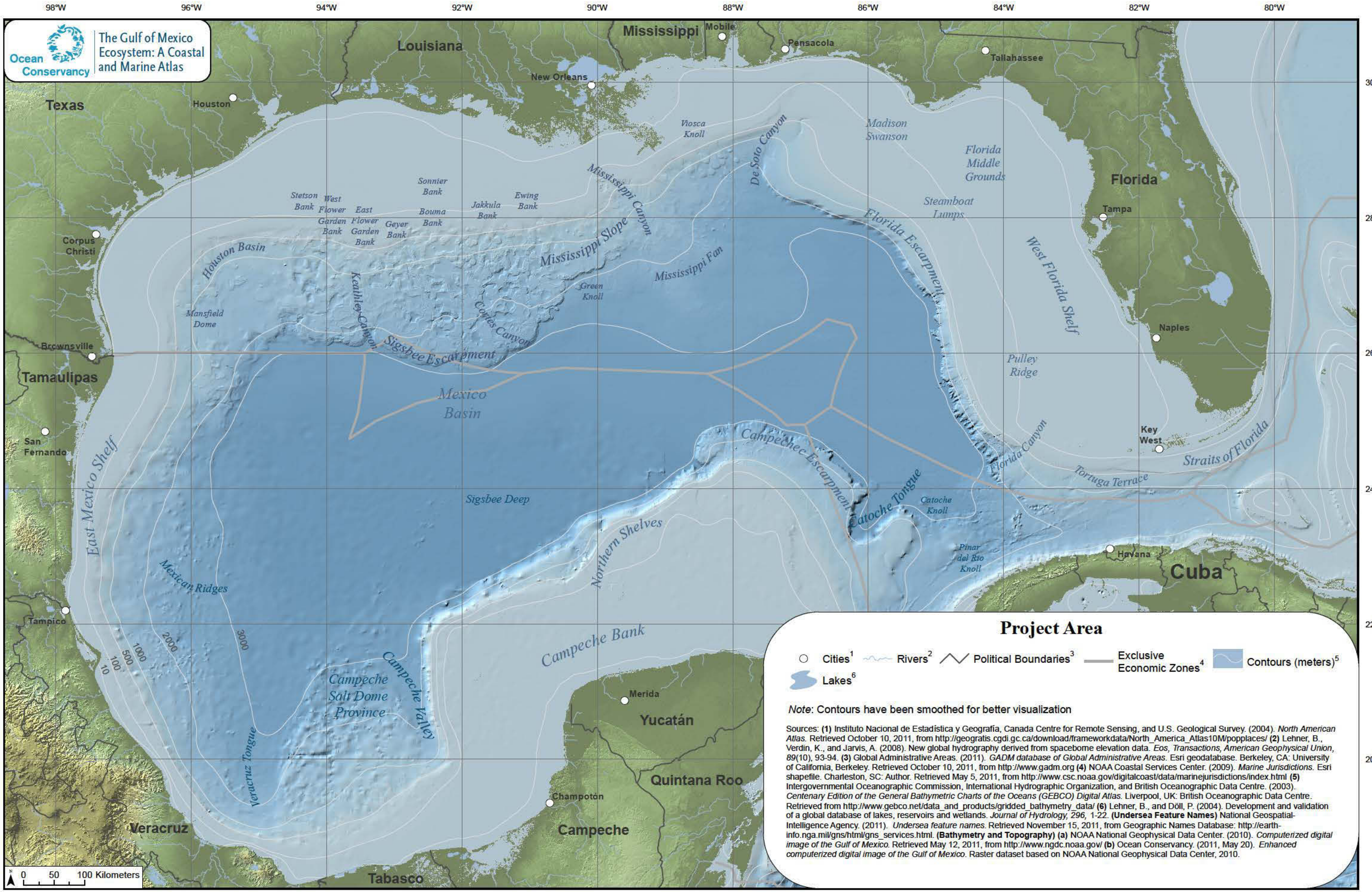
MAP 1 *(next page)*. **PROJECT AREA MAP**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Project Area
Cities[1]
Rivers[2]
Political Boundaries[3]
Exclusive Economic Zones[4]
Contours (meters)[5]
Lakes[6]
Note: Contours have been smoothed for better visualization
Sources: (1) Instituto Nacional de Estadística y Geografía, Canada Centre for Remote Sensing, and U.S. Geological Survey. (2004). North American Atlas. Retrieved October 10, 2011, from http://geogratis.cgdi.gc.ca/download/frameworkdata/North_America_Atlas10M/popplaces/ (2) Lehner, B., Verdin, K., and Jarvis, A. (2008). New global hydrography derived from spaceborne elevation data. Eos, Transactions, American Geophysical Union, 89(10), 93-94. (3) Global Administrative Areas. (2011). GADM database of Global Administrative Areas. Esri geodatabase. Berkeley, CA: University of California, Berkeley. Retrieved October 10, 2011, from http://www.gadm.org (4) NOAA Coastal Services Center. (2009). Marine Jurisdictions. Esri shapefile. Charleston, SC: Author. Retrieved May 5, 2011, from http://www.csc.noaa.gov/digitalcoast/data/marinejurisdictions/index.html (5) Intergovernmental Oceanographic Commission, International Hydrographic Organization, and British Oceanographic Data Centre. (2003). Centenary Edition of the General Bathymetric Charts of the Oceans (GEBCO) Digital Atlas. Liverpool, UK: British Oceanographic Data Centre. Retrieved from http://www.gebco.net/data_and_products/gridded_bathymetry_data/ (6) Lehner, B., and Döll, P. (2004). Development and validation of a global database of lakes, reservoirs and wetlands. Journal of Hydrology, 296, 1-22. (Undersea Feature Names) National Geospatial-Intelligence Agency. (2011). Undersea feature names. Retrieved November 15, 2011, from Geographic Names Database: http://earth-info.nga.mil/gns/html/gns_services.html. (Bathymetry and Topography) (a) NOAA National Geophysical Data Center. (2010). Computerized digital image of the Gulf of Mexico. Retrieved May 12, 2011, from http://www.ngdc.noaa.gov/ (b) Ocean Conservancy. (2011, May 20). Enhanced computerized digital image of the Gulf of Mexico. Raster dataset based on NOAA National Geophysical Data Center, 2010.
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Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
De Soto Canyon
Mississippi Canyon
Sonnier Bank
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Mississippi Slope
Mississippi Fan
Green Knoll
Florida Escarpment
West Florida Shelf
Mansfield Dome
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Sigsbee Deep
East Mexico Shelf
Northern Shelves
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
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Oceanography & Benthos

2.0 Bathymetry

Description

Bathymetry, or topography, is the shape of the sea bottom as defined by depths below sea level. Map 2 illustrates the underwater topography of the Gulf of Mexico seabed. Shallow and intertidal areas (<20 meters [65 feet]) make up roughly 38 percent of the Gulf, the continental shelf (20 to <180 meters [65 to <590 feet]) accounts for 22 percent, the continental slope (180 to 3,000 meters [590 to 9,842 feet]) accounts for 20 percent and the abyssal areas (>3,000 meters [>9,842 feet]) make up the remaining 20 percent of the area (Gore, 1992). The Gulf has a broad, shallow continental shelf, which generally extends 100 to 200 kilometers (62 to 124 miles) offshore (Henderson & Varner, 2011). The shelf is narrowest off Louisiana and widest off Florida and the Yucatán Peninsula. Some river-derived canyons, most notably the Mississippi and DeSoto Canyons, incise the continental shelf in the northern Gulf. The continental shelf descends to the deep abyssal plain via the continental slope. Geologic features of the slope include rises that formed from ancient reefs, and salt diapirs and sediment fans that are extensions of river deltas. The deepest portion of the Gulf is the Sigsbee Deep, a canyon-like triangular area in the west-central Gulf, which is more than 4,000 meters (>13,120 feet) below sea level. The shapes of undersea basins, ridges and canyons influence ocean circulation and thereby the flow of heat, nutrients and pollutants. Bathymetric data are essential for monitoring the ecology of different habitats and assessing circulation dynamics.

Salt domes, or salt diapirs, are common features on the continental slope of the northwestern (Murray, 1961; Halbouty, 1967) and southwestern Gulf (Worzel et al., 1968). These features form both as subsurface (below the seabed) and emergent structures and are important areas for oil and gas production and fishing (Henderson & Varner, 2011). Salt domes are the result of hypersaline deposits from ancient seas that are pushed up from the weight of overlying continental shelves. Salt structures also form unique habitats that support chemosynthetic communities and reef fish, such as red snapper (Henderson & Varner, 2011).

See related maps and narratives on Sea Surface Temperature, Sea Surface Currents, Net Primary Productivity, Hydrocarbon Seeps and Chemosynthetic Communities, Red Snapper, Oil and Gas Distribution, Current U.S. Oil and Gas Leases and International Activity, Oil and Gas Drilling Platforms and Boreholes, and Selected Oil and Gas Pipelines.

Data Compilation and Mapping Methods

The bathymetry image and contours were created from a 9 arc-second digital elevation model of the Gulf. It should be noted that 9 arc-seconds equal about 300 meters (roughly 984 feet) at the latitude of the Gulf. The source bathymetry dataset was built by the National Geophysical Data Center using the most recent data available from several sources, including the National Geophysical Data Center at NOAA, a 30 arc-second Generalized Bathymetric Chart of the Ocean model, high-resolution coastal digital elevation models of the region, bathymetric soundings from the NOAA National Ocean Service and the Shuttle Radar Topography Mission.

Data Quality

This map has good data quality because it is based on a complete geographic picture of the dominant bathymetric features of the Gulf with a consistent minimum resolution of 9 arc-seconds. In some areas, higher resolution data were used, such as those covered by the high-resolution coastal digital elevation models, while portions of the deeper Gulf are represented by lower resolution data.

Synthesis and Conclusions

The Gulf has a broad continental shelf that descends via the continental slope to the deep abyssal plain. Salt formations are common features on the continental slope and create important habitat for reef fish. The shapes of undersea basins, ridges and canyons influence ocean circulation and, thereby, the flow of heat, nutrients and pollutants. Bathymetric data are essential for monitoring the ecology of different habitats and assessing circulation dynamics.

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Map Data Sources

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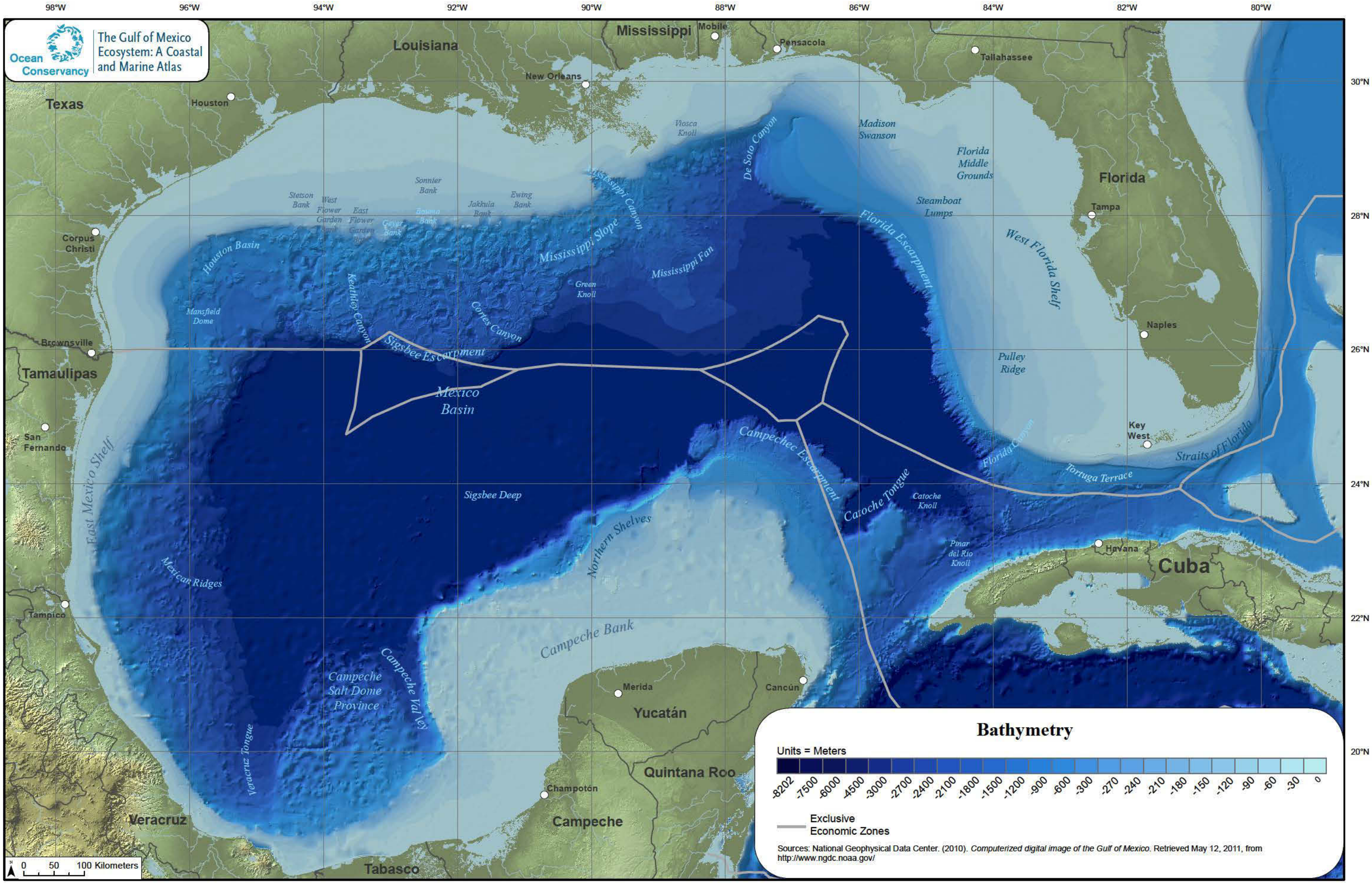
MAP 2 *(next page).* **BATHYMETRY**



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Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Viosca Knoll
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
West Florida Shelf
Florida Escarpment
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bank
Jakkula Bank
Ewing Bank
Houston Basin
Mansfield Dome
Keathley Canyon
Mississippi Slope
Mississippi Canyon
Mississippi Fan
Green Knoll
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
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Bathymetry
Units = Meters
-8202 -7500 -6000 -4500 -3000 -2700 -2400 -2100 -1800 -1500 -1200 -900 -600 -300 -270 -240 -210 -180 -150 -120 -90 -60 -30 0
Exclusive Economic Zones
Sources: National Geophysical Data Center. (2010). Computerized digital image of the Gulf of Mexico. Retrieved May 12, 2011, from http://www.ngdc.noaa.gov/

2.1 Bottom Sediments

Description

The bottom sediments in the central deep-water area of the Gulf of Mexico and off the coasts of Texas, Louisiana and Mississippi are predominantly mud (Balsam & Beeson, 2003) (Map 3). On the continental shelf and slope, these sediments are primarily terrigenous types of mud derived from continental land erosion and delivered mainly by the Mississippi and Atchafalaya rivers. The bottom sediments just offshore from the barrier islands in Louisiana are predominantly sand, as are large areas of the sea bottom off of the coasts of Mississippi and Alabama. These sands appear to be derived from terrestrial sources originating in the American southwest regions (Elwood et al., 2006). Nearly all of the sea bottom off of the Florida coast is sand (Map 3), which is composed mostly of biogenic carbonates derived from corals, mollusks and other calcareous organisms. The seafloor off of the Veracruz coast and the Yucatán Peninsula also has significant amounts of sand. Though limited in extent, gravel and rock substrates occur at the outer edge of the continental shelf off of Texas, Louisiana, Mississippi, Alabama and southern Florida. Some of these gravels and rocks are the remains of ancient reefs and biogenic carbonate from bacterial activity around cold seeps.

Bottom sediments provide habitat for a variety of organisms, primarily meiofaunal communities, including nematodes, protists and diatoms. These organisms perform key ecological functions, such as nutrient cycling and sediment stabilization (Snelgrove et al., 1997). The community structure and distribution of these organisms are largely unknown. Further research is needed to understand how benthic communities interact with the environment and pollutants. This knowledge would become especially important in informing restoration efforts for these habitats following human disturbances (e.g., oil spills) (Bik et al., 2012).

See related maps and narratives on Bathymetry, Net Primary Productivity, Hazardous Materials Spills, Oil and Gas Distribution and Offshore Shrimp Trawl Fishery.

Data Compilation and Mapping Methods

Data on dominant bottom sediment types for the Gulf were obtained from the NOAA Gulf of Mexico Data Atlas. These data were derived from the global dbSEABED database developed by a number of cooperating institutions and maintained at the University of Colorado's Institute for Arctic and Alpine Research. This database provides information on the ocean bottom, particularly the materials that make up the seafloor, by integrating thousands of individual datasets compiled over decades of research in marine geology, biology, engineering and surveys (Jenkins, 2012).

Data Quality

Although sampling coverage along the continental margin of the U.S. is good, the overall data quality for this map in U.S. waters is fair due to the lack of sampling coverage over a wide area in deeper waters of the Gulf. Data quality for this map in the southern Gulf in Mexican and Cuban waters is poor, based on the paucity of sampling locations available from these substrates. No data are available for large portions of these areas.

Synthesis and Conclusions

The bottom sediments of the Gulf range from fine particles to gravel and rock. The predominant substrates along the U.S. continental shelf are made of mud and sands. Bottom sediments provide habitats for a variety of organisms, primarily meiofaunal communities. Field studies are essential to expand our knowledge of the biology of microscopic organisms living in marine sediments, their geographic distribution and the long-term biological effects of pollutant contamination (H. Bik, personal communication, 2011). More extensive sampling of bottom sediments is needed in the southern Gulf to better characterize the ocean bottom and its biological significance.

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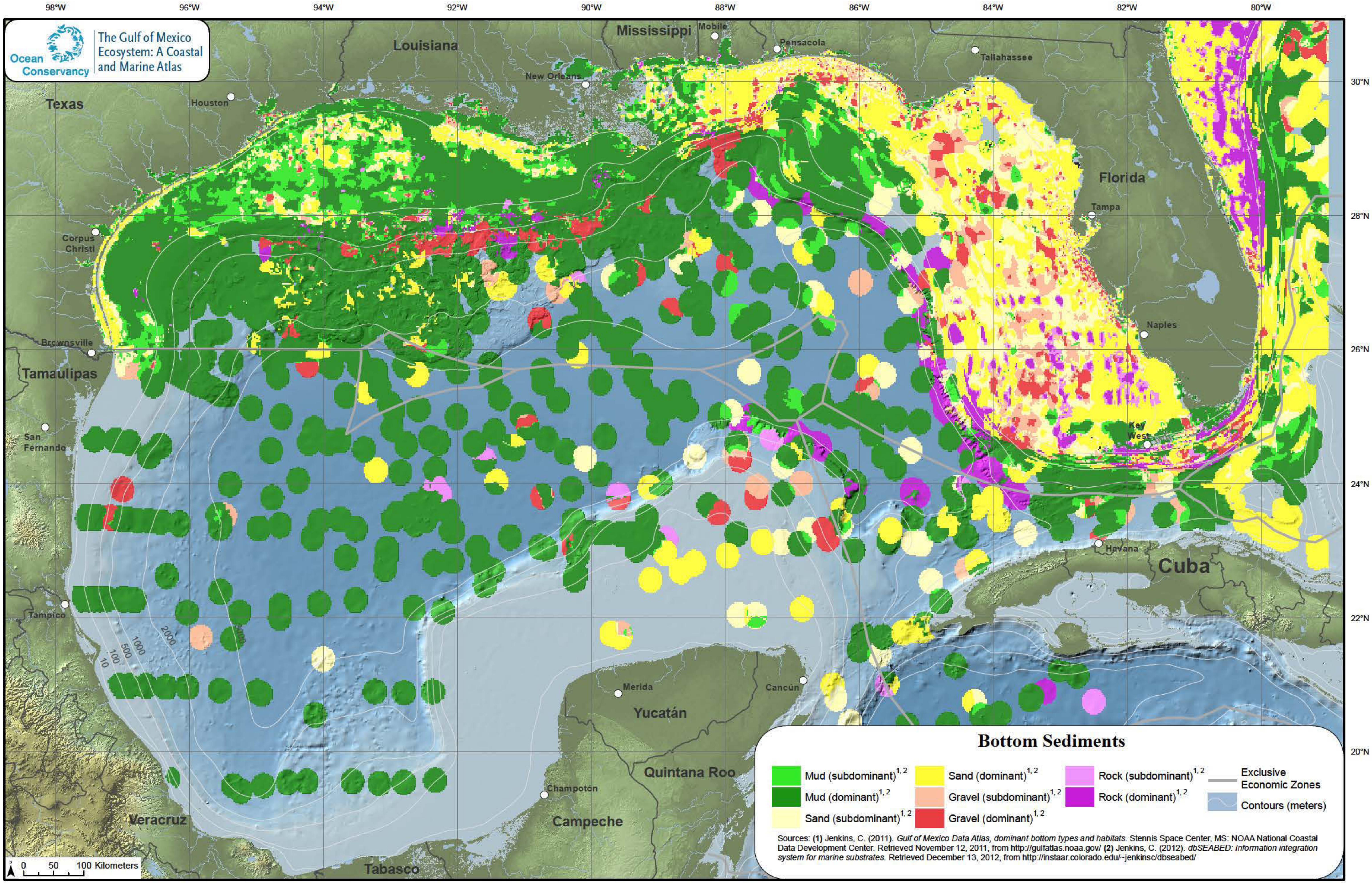
MAP 3 *(next page)*. **BOTTOM SEDIMENTS**


Ocean Conservancy
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Louisiana
New Orleans
Texas
Houston
Corpus Christi
Brownsville
Florida
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Naples
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Tamaulipas
San Fernando
Tampico
Havana
Cuba
Merida
Cancún
Yucatán
Quintana Roo
Champotón
Campeche
Veracruz
Tabasco
10
100
500
1000
2000
0 50 100 Kilometers
Bottom Sediments
Mud (subdominant)1, 2
Mud (dominant)1, 2
Sand (subdominant)1, 2
Sand (dominant)1, 2
Gravel (subdominant)1, 2
Gravel (dominant)1, 2
Rock (subdominant)1, 2
Rock (dominant)1, 2
Exclusive Economic Zones
Contours (meters)
Sources: (1) Jenkins, C. (2011). Gulf of Mexico Data Atlas, dominant bottom types and habitats. Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retrieved November 12, 2011, from http://gulfatlas.noaa.gov/ (2) Jenkins, C. (2012). dbSEABED: Information integration system for marine substrates. Retrieved December 13, 2012, from http://instaar.colorado.edu/~jenkinsc/dbseabed/

2.2 Seawater Characteristics

Description

Sea surface temperature and salinity, representing spring conditions and derived from long-term averages, are shown in Map 4 and Map 5, respectively. There are complex patterns in the surface temperature gradients in the Gulf of Mexico in the spring, ranging from 24 degrees Celsius (75 degrees Fahrenheit) in the north-central and western offshore Gulf to 27-28 degrees Celsius (80 to 82 degrees Fahrenheit) in nearshore waters near Galveston, Texas as well as Veracruz, Mexico and around Cuba. Solar radiation intensity, the distance to landmasses and large river outflows, and vertical flux of seawater from depth all influence sea surface temperature. The mean spring salinity shows a gradient of gradually increasing levels of salinity from the north-central Gulf to the offshore environment and to the south, from 24 to 36 practical salinity units.

Seawater density is determined by temperature and salinity, which in turn influences water dynamics; for example, the colder and saltier the water, the greater the density of the water. Along with winds, differences in water density affect ocean current strength and direction. In addition, water column stratification (warm surface waters resting above cooler subsurface waters) is an important factor leading to the spring plankton bloom.

Seawater temperature influences the metabolism, growth rates, reproduction and other activities of most marine organisms. Large quantities of fresh water discharge into the ocean and mix with salt water in nearshore estuaries, resulting in lower salinity water that defines this transition zone between freshwater and marine environments. For example, estuaries are important habitats for young life stages of shrimp, crab, and commercially and recreationally important fish species.

Salinity levels are at their lowest levels in offshore waters near the north-central Gulf in the spring when river flows and freshwater discharges peak. In summer, the area of low salinity retracts toward the coast. Summertime surface water temperatures are considerably warmer and winter temperatures cooler than are depicted in Map 4.

See related maps and narratives on Bathymetry, Sea Surface Currents, Brown Shrimp, White Shrimp, Blue Crab and Gulf Menhaden.

Data Compilation and Mapping Methods

Sea Surface Temperature

Temperature data and associated isotherms (temperature contours) were derived from the mean regional climatology of the Gulf for spring (April – June) conditions (NOAA National Oceanographic Data Center, 2011). Data used to develop this long-term regional climatology are from samplings conducted from approximately 1864 through 2010. Surface temperature values of the objectively analyzed mean were provided at .25 degree grid points for the region. Objectively analyzed climatology points are the interpolated mean fields for temperature at standard depth levels for the ocean. The surface values of these points were interpolated using spline with barriers, which is a deterministic predictor method for estimating non-sampled values. The ArcInfo version 10.0 geostatistical analyst extension was used to access this predictor interpolation method. The resulting surface information was used to generate isotherms at every 0.5 degree Celsius (32.9 degree Fahrenheit) interval.

Salinity and River Flow

Salinity data and associated isohales (salinity contours) were derived from the mean regional climatology of the Gulf for spring (April – June) conditions (NOAA National Oceanographic Data Center, 2011). Data used to develop this long-term regional climatology are from sampling conducted from 1864 through 2010. Surface salinity values of the objectively analyzed mean were provided at .25 degree grid points for the region. Objectively analyzed climatology points are the interpolated mean fields for salinity at standard depth levels for the ocean. The surface values of these points were interpolated using kernel smoothing, which is a statistical, moving window predictor method for estimating non-sampled values. ArcInfo version 10.0 geostatistical analyst extension was used to access this predictor interpolation method. The resulting surface was used to generate isohales at every 0.5 interval of the practical salinity scale. The practical salinity scale is a method for measuring salinity independent of the component minerals of sea water using electrical conductance values, as opposed to the method of measuring mineral weight per thousand pounds of seawater, or parts per thousand.

Mean annual river flow was obtained from the U.S. National Hydrography Dataset. Mean annual flow values were derived from gauge adjusted flow values at the most downstream segment of each river/stream, i.e., terminal flow rates, and span the date range 1971-2000. Only features with flow greater than 2.8 cubic meters per second were included on this map, resulting in 113 rivers and streams illustrated along the U.S. Gulf Coast.

Data Quality

Sea Surface Temperature

This map has good data quality for sea surface temperature estimates because of the extensive time record available and the nearly complete spatial coverage of samples with .25 degree resolution used throughout the Gulf to develop the interpolated sea surface temperature raster.

Salinity and River Flow

This map has good data quality for salinity estimates because of the extensive time record available and the near complete spatial coverage of samples at .25 degree resolution to develop the interpolated surface. River flow data quality for the U.S. is good due to the complete coverage of the national hydrography dataset and the high number of gauge adjusted flow segments. Data quality for river flow in Mexico and Cuba is poor due to the lack of analogous data.

Synthesis and Conclusions

Salinity and temperature are important seawater characteristics that, along with wind, influence water dynamics such as ocean current strength and direction. In general, salinity is lowest in the spring when river flows and discharges into the Gulf are at their highest. The functionality and condition of estuaries are linked to the amount of freshwater they receive. Many marine species of economic significance depend on the low salinity environment of estuaries for survival, particularly during early-life stages.

Map Data Sources

Sea Surface Temperature
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Salinity and River Flow
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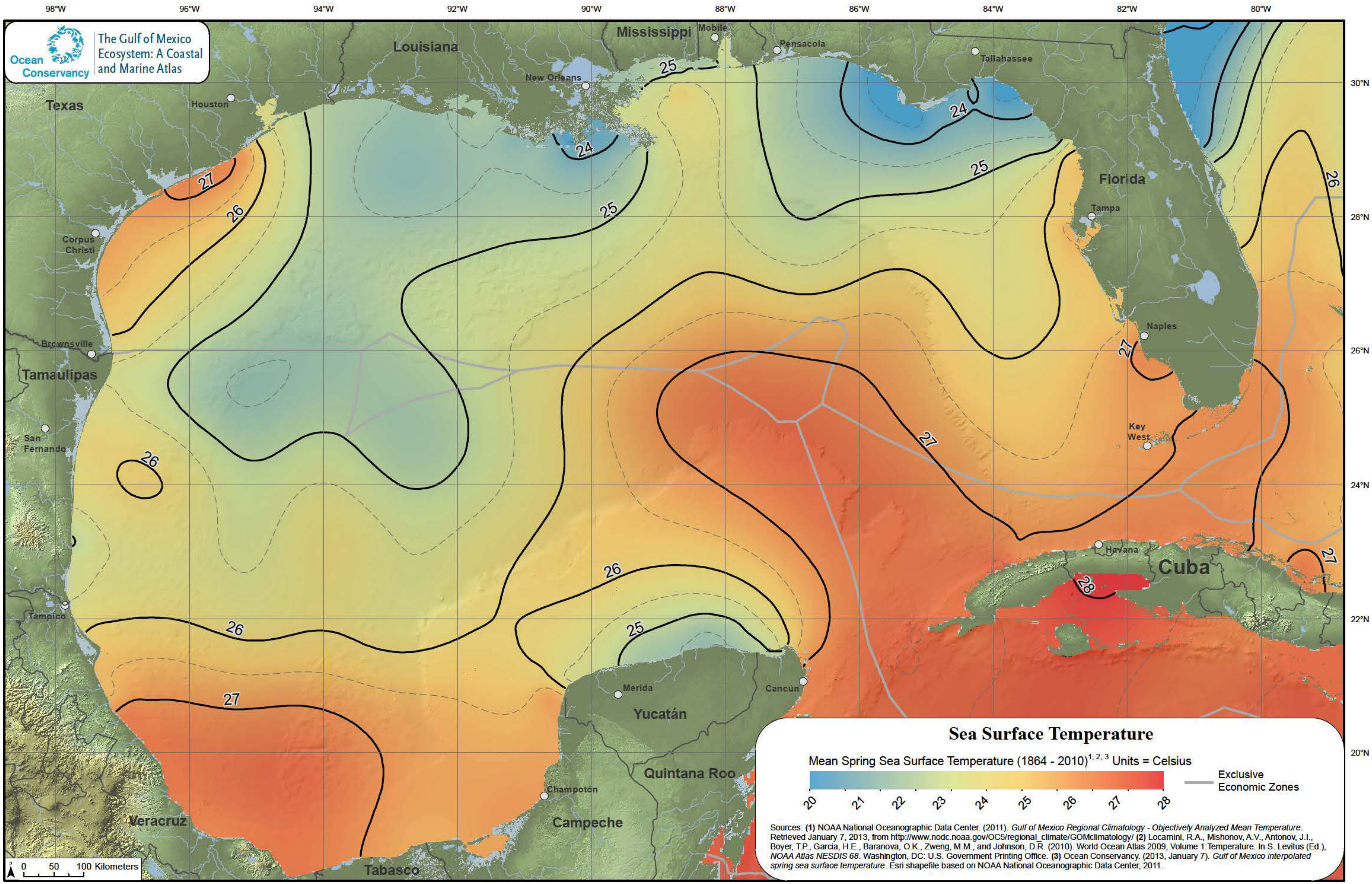
MAP 4 *(next page)***. SEA SURFACE TEMPERATURE**
MAP 5. SALINITY AND RIVER FLOW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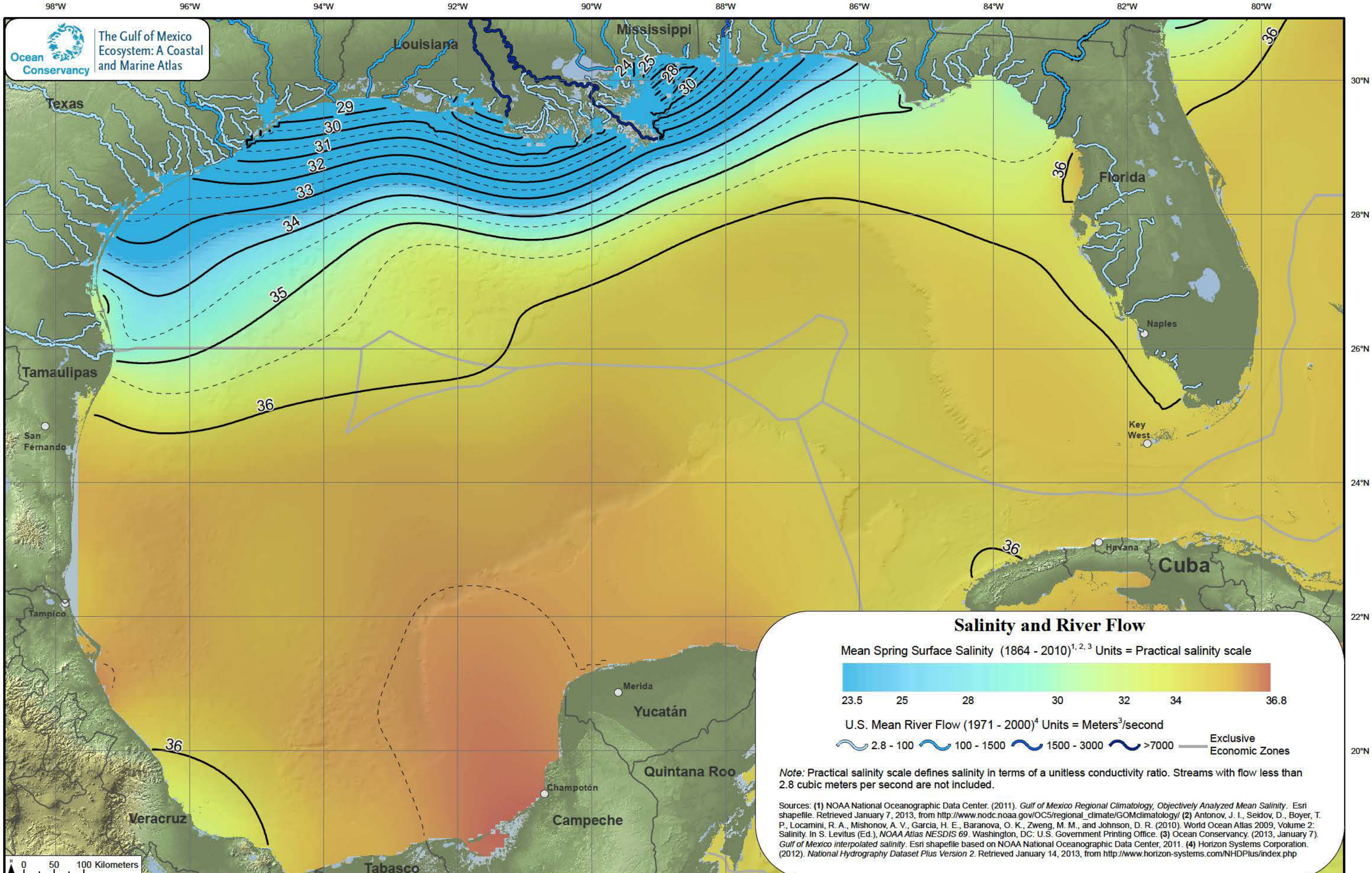
Mobile
Pensacola
Tallahassee
Louisiana
New Orleans
Texas
Houston
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champotón
Yucatán
Merida
Cancún
Quintana Roo
Florida
Tampa
Naples
Key West
Havana
Cuba
24
25
26
27
28
0 50 100 Kilometers
Sea Surface Temperature
Mean Spring Sea Surface Temperature (1864 - 2010)[1, 2, 3] Units = Celsius
20 21 22 23 24 25 26 27 28
Exclusive Economic Zones
Sources: (1) NOAA National Oceanographic Data Center. (2011). *Gulf of Mexico Regional Climatology - Objectively Analyzed Mean Temperature*. Retrieved January 7, 2013, from http://www.nodc.noaa.gov/OC5/regional_climate/GOMclimatology/ (2) Locarnini, R.A., Mishonov, A.V., Antonov, J.I., Boyer, T.P., Garcia, H.E., Baranova, O.K., Zweng, M.M., and Johnson, D.R. (2010). World Ocean Atlas 2009, Volume 1:Temperature. In S. Levitus (Ed.), *NOAA Atlas NESDIS 68*. Washington, DC: U.S. Government Printing Office. (3) Ocean Conservancy. (2013, January 7). *Gulf of Mexico interpolated spring sea surface temperature*. Esri shapefile based on NOAA National Oceanographic Data Center, 2011.



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Salinity and River Flow
Mean Spring Surface Salinity (1864 - 2010)1, 2, 3 Units = Practical salinity scale
23.5
25
28
30
32
34
36.8
U.S. Mean River Flow (1971 - 2000)4 Units = Meters3/second
2.8 - 100
100 - 1500
1500 - 3000
>7000
Exclusive Economic Zones
Note: Practical salinity scale defines salinity in terms of a unitless conductivity ratio. Streams with flow less than 2.8 cubic meters per second are not included.
Sources: (1) NOAA National Oceanographic Data Center. (2011). Gulf of Mexico Regional Climatology, Objectively Analyzed Mean Salinity. Esri shapefile. Retrieved January 7, 2013, from http://www.nodc.noaa.gov/OC5/regional_climate/GOMclimatology/ (2) Antonov, J. I., Seidov, D., Boyer, T. P., Locarnini, R. A., Mishonov, A. V., Garcia, H. E., Baranova, O. K., Zweng, M. M., and Johnson, D. R. (2010). World Ocean Atlas 2009, Volume 2: Salinity. In S. Levitus (Ed.), NOAA Atlas NESDIS 69. Washington, DC: U.S. Government Printing Office. (3) Ocean Conservancy. (2013, January 7). Gulf of Mexico interpolated salinity. Esri shapefile based on NOAA National Oceanographic Data Center, 2011. (4) Horizon Systems Corporation. (2012). National Hydrography Dataset Plus Version 2. Retrieved January 14, 2013, from http://www.horizon-systems.com/NHDPlus/index.php
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Texas
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Mississippi
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San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champotón
Merida
Yucatán
Quintana Roo
Naples
Key West
Havana
Cuba
24
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0 50 100 Kilometers

2.3 Sea Surface Currents

Description

The Loop Current and its influence dominate sea surface currents in the Gulf of Mexico for areas in the upper 200 meters of the water column. Showing the average fall sea surface currents from 1993 to 2011, Map 6 depicts the Loop Current flowing into the southern Gulf in a northerly direction between western Cuba and the Yucatán Peninsula. The Loop Current makes a clockwise loop in the central Gulf and exits the eastern Gulf through the Straits of Florida between northern Cuba and southern Florida. Eddies pinch off the Loop Current, and are often in warm-core, clockwise (anti-cyclonic) and cold-core, anti-clockwise (cyclonic) pairs (Sturges & Lugo-Fernandez, 2005). These eddies slowly move into the western Gulf over a period of weeks and months (Sturges & Leben, 2000). Eddies interact with each other and the shelf edge as they move westward, having important consequences for local biological production. Upwelling occurs in cold-core eddies and downwelling in warm-core eddies, resulting in the onshore and offshore transportation of nutrients and organisms. Sea surface currents create connectivity between ecosystems within and outside of the Gulf by transporting nutrients, larvae, sargassum and other organisms important for sustaining ocean life.

Water circulation on the continental shelf is quite variable, controlled mainly by fluctuating local wind fields, but also by the major rivers, deep-water circulation and, to some small extent, tides. The prevailing winds in the Gulf are from the southeast and contribute to eddy formation in the northern Gulf.

Average current speeds range from near 0.0 to 0.7 meters (0.0 to 2.3 feet) per second (Johnson, 2008). Currents on the continental shelf in the northern Gulf can be grouped into the summer season and all of the remaining seasons. Average summer surface currents are generally weak and variable over most of the Gulf, but there are strong easterly flowing offshore currents on the outer shelf from the Mississippi River Delta through central Florida. During the rest of the year, the strongest currents are on the inner shelf of western Louisiana and Texas (Johnson, 2008). Understanding ocean currents is important to improving our knowledge of the Gulf ecosystem and will assist in tracking and predicting the effects of hazardous materials spills. For example, models incorporating sea surface currents were used to track and predict the trajectory and distribution of oil, gas and dispersants following the BP Deepwater Horizon oil disaster.

See related maps and narratives on Bathymetry, Seawater Characteristics (Sea Surface Temperature, and Salinity and River Flow), Net Primary Productivity, Corals, Pelagic Sargassum, Kemp's Ridley Sea Turtle and Hazardous Materials Spills.

Data Compilation and Mapping Methods

These data were compiled from the NOAA Ocean Surface Current Analyses – Real Time (OSCAR) project, which develops a processing system and data center to provide operational ocean surface velocity fields from satellite altimeter and vector wind data. These estimates are developed indirectly by combining satellite observations of the height of the sea surface, estimates of ocean wind vectors (direction and velocity), and sea surface temperature. The goal of the OSCAR project is to provide estimates that are more accurate than those based on sea surface height alone and it does this by combining geostrophic, Ekman and Strommel shear dynamics along with a complementary term from the surface buoyancy gradient (Bonjean & Lagerloef, 2002).

In order to illustrate the seasonally dynamic and broad-scale oceanographic currents that influence the Gulf, the means for the late summer months of July, August and September were compiled for the years 1993 through 2011. This season was selected since it shows the typical period when the Loop Current is at its most northerly position within the Gulf. These data were processed using the Marine Geospatial Ecology Tools (Roberts et al., 2010) in the ArcGIS 10.0 environment.

Data Quality

This map has good data quality for surface currents (<1000 meters deep) because it is based on a complete geographic illustration of the Gulf-wide, broad-scale oceanographic currents that dominate this large marine ecosystem. Ocean circulation is complex and varies with depth. This map is not intended to represent mesoscale patterns of deep ocean circulation driven by thermohaline (temperature and salinity) forces, which are often quite different from the forces that drive surface current patterns.

Synthesis and Conclusions

The Loop Current and its influence dominate sea surface currents and influence biological production in the Gulf. Wind, river inputs and deep-water circulation also influence sea surface currents. Understanding sea surface currents helps ships save fuel, informs fisheries management and assists in weather and pollutant dispersal prediction. Substantial oil development in the Gulf makes studying currents in this region a key priority.

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Ocean Conservancy. (2012, February 3). *Climatological velocity and directional mean (July-September), Ocean Surface Current Analyses-Real Time (OSCAR), 1993-2011.* Esri shapefile based on PMEL, 2012 using Marine Geospatial Ecology Tools.

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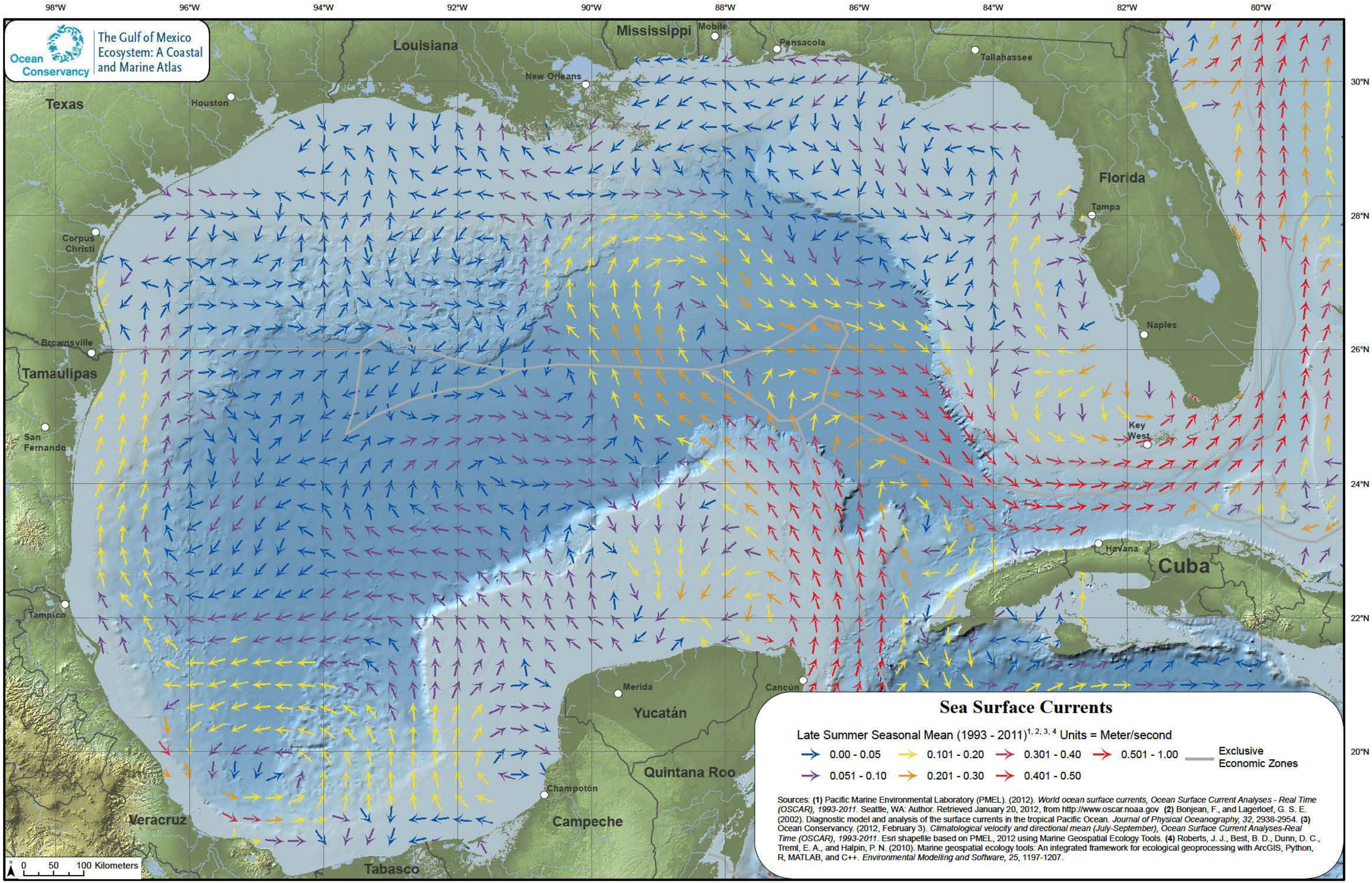
Roberts, J. J., Best, B. D., Dunn, D. C., Treml, E. A., & Halpin, P. N. (2010). Marine geospatial ecology tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. *Environmental Modelling & Software, 25,* 1197-1207.

MAP 6 *(next page)***. SEA SURFACE CURRENTS**



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Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Mobile
Pensacola
Tallahassee
New Orleans
Houston
Corpus Christi
Tampa
Naples
Key West
Brownsville
San Fernando
Tampico
Havana
Merida
Cancún
Champotón
0 50 100 Kilometers
Sea Surface Currents
Late Summer Seasonal Mean (1993 - 2011)1, 2, 3, 4 Units = Meter/second
0.00 - 0.05
0.051 - 0.10
0.101 - 0.20
0.201 - 0.30
0.301 - 0.40
0.401 - 0.50
0.501 - 1.00
Exclusive Economic Zones
Sources: (1) Pacific Marine Environmental Laboratory (PMEL). (2012). World ocean surface currents, Ocean Surface Current Analyses - Real Time (OSCAR), 1993-2011. Seattle, WA: Author. Retrieved January 20, 2012, from http://www.oscar.noaa.gov (2) Bonjean, F., and Lagerloef, G. S. E. (2002). Diagnostic model and analysis of the surface currents in the tropical Pacific Ocean. Journal of Physical Oceanography, 32, 2938-2954. (3) Ocean Conservancy. (2012, February 3). Climatological velocity and directional mean (July-September), Ocean Surface Current Analyses-Real Time (OSCAR), 1993-2011. Esri shapefile based on PMEL, 2012 using Marine Geospatial Ecology Tools. (4) Roberts, J. J., Best, B. D., Dunn, D. C., Treml, E. A., and Halpin, P. N. (2010). Marine geospatial ecology tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling and Software, 25, 1197-1207.

2.4 Net Primary Productivity

Description

All photosynthesizing plants contain chlorophyll-a, which reflects green light and absorbs red and blue light. Chlorophyll-a is considered an indicator of net primary production, and is incorporated into ecological models with other oceanographic data to estimate net primary productivity. The reflectance of chlorophyll-a can be measured using satellite imagery. A modeled estimate of net primary production is displayed in Map 7 for the Gulf of Mexico. In general, net primary productivity in the Gulf decreases along an inshore to offshore gradient. Areas of high primary productivity include the continental shelf off of the coasts of Louisiana and Mississippi and the western coast of Florida. In general, coastal areas account for 25 percent of the ocean's primary productivity, but only occupy 10 percent of the area (Walsh, 1988). The remaining 75 percent of the ocean's primary production comes from the offshore marine environment, which is less productive on a per unit basis, but covers such a large area that its total contribution is actually greater.

Primary production is the creation of energy-rich carbon compounds either through photosynthesis by converting carbon dioxide and water (the majority of primary production) or through chemosynthesis by converting other chemicals (common around cold seeps and deep-sea hydrothermal vents). Primary production is the base of the food web and supplies energy and carbon to organisms at higher trophic levels (e.g., herbivores and predators). Gross primary production is the total amount of energy produced, and net primary production is gross primary production minus the energy used by the producers for basic life functions. As shown in Map 7, primary productivity is measured in grams of carbon per meter squared per day (gC/m^2/day). In the coastal environment salt marshes, mangroves, seagrasses, phytoplankton and algae all contribute to primary production. In the offshore environment, phytoplankton, algae and bacteria are the main sources of primary production. Areas of high productivity indicate biological hotspots for multiple trophic levels where large concentrations of prey and predator species might be located (Davis et al., 2002). These hotspots are important foraging habitats for organisms at different life stages.

See related maps and narratives on Bathymetry, Sea Surface Currents, Salt Marshes and Mangrove Forests, Seagrasses, Hydrocarbon Seeps and Chemosynthetic Communities, and Low Oxygen Areas.

Data Compilation and Mapping Methods

Net primary productivity grid data were compiled using annual sums for each year from 2003 through 2010 from data provided via Oregon State University's Ocean Productivity website. These net primary productivity data are based on the original descriptions and findings included in the Vertically Generalized Production Model (Behrenfeld & Falkowski, 1997), Moderate Resolution Imaging Spectroradiometer surface chlorophyll concentrations (Chl_{sat}), Moderate Resolution Imaging Spectroradiometer sea surface temperature data and Moderate Resolution Imaging Spectroradiometer cloud-corrected daily incident photosynthetically active radiation data.

Cumulative sums were created for each 12-month period from 2003 through 2010 to capture the full net primary productivity of each year during this period. The annual mean was then calculated over these eight years to create the average net primary productivity for a calendar year for the entire Gulf.

Data Quality

This map has good data quality because it is based on a complete geographic assessment of net primary productivity over the entire Gulf basin at a consistent 7.5-kilometer (4.7-foot) resolution. A model describing potential changes in primary productivity caused by climate change would increase our understanding of this resource and is a possible area for future research..

Net primary productivity data are limited because the satellite-based sensors used to measure the chlorophyll concentrations, sea surface temperature and photosynthetically active radiation can detect only those parameters at the water's surface. While a majority of the chlorophyll-based production occurs at or near the surface, any production below the surface is excluded from these estimates. Regardless of this limitation, these modeled net primary productivity data are of good quality and considered reliable.

Synthesis and Conclusions

Net primary productivity in the Gulf decreases along an inshore to offshore gradient. Areas of high primary productivity include the continental shelf off of the coasts of Louisiana and Mississippi and the western coast of Florida with specific areas that indicate biological hotspots for multiple trophic levels. Ongoing monitoring of net primary productivity and chlorophyll-a in the Gulf is important to help scientists measure and track the impacts of climate change and other large-scale, long-term events. Information on the historical status, present condition and dynamics of key sources contributing to net primary productivity would improve our knowledge of how it reacts to episodic events and stressors.

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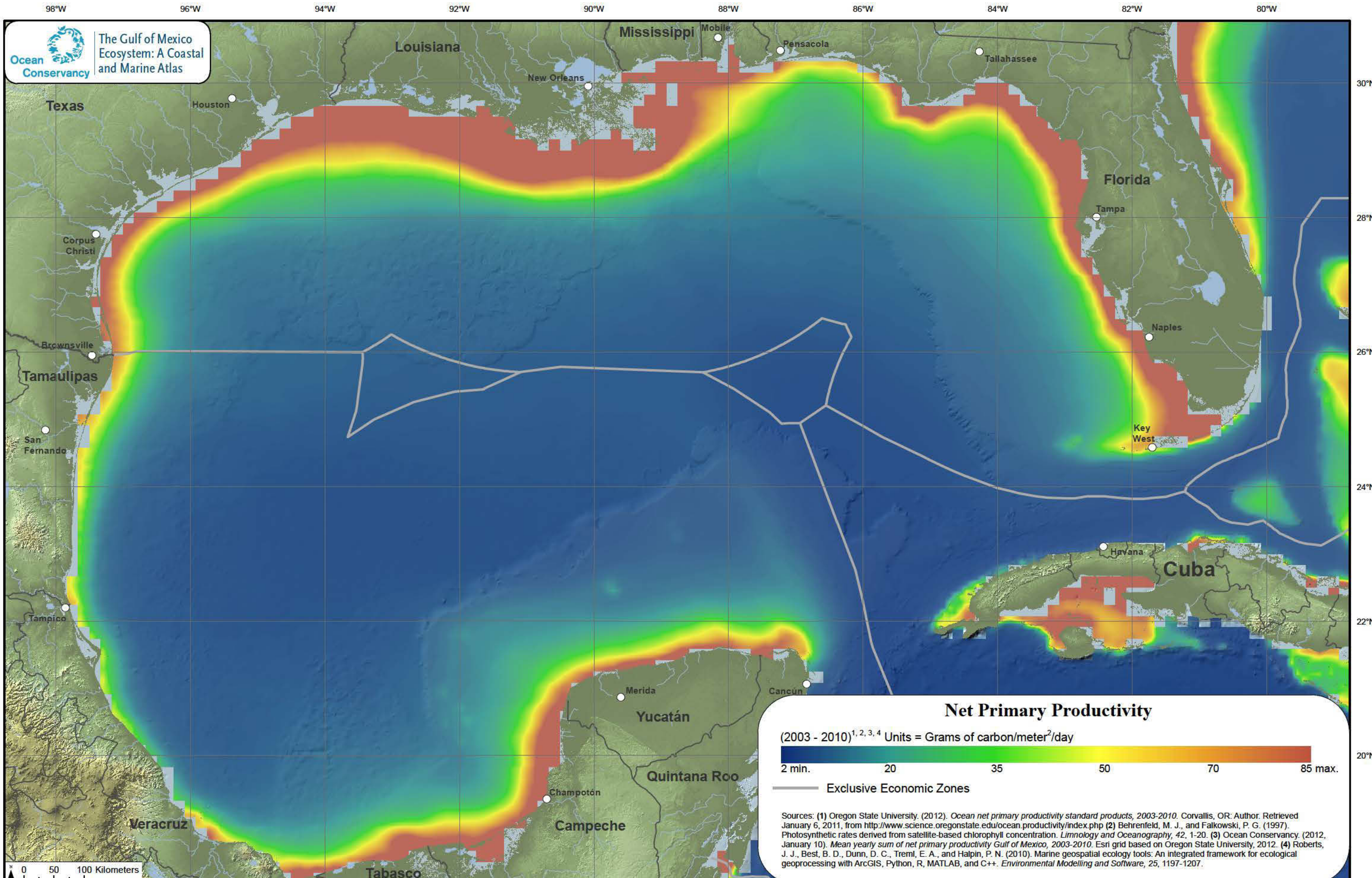
MAP 7 *(next page)*. **NET PRIMARY PRODUCTIVITY**



98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Mississippi
Mobile
Pensacola
Louisiana
Tallahassee
New Orleans
Houston
Texas
Florida
Tampa
Corpus Christi
Naples
Brownsville
Tamaulipas
Key West
San Fernando
Havana
Cuba
Tampico
Merida
Cancún
Yucatán
Quintana Roo
Champotón
Campeche
Veracruz
Tabasco
0 50 100 Kilometers
Net Primary Productivity
(2003 - 2010)[1, 2, 3, 4] Units = Grams of carbon/meter²/day
2 min.
20
35
50
70
85 max.
Exclusive Economic Zones
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Habitats

3.0 Salt Marshes & Mangrove Forests

Description


A brackish marsh in the Mississippi River Delta. Credit: K. L. McKee / USGS

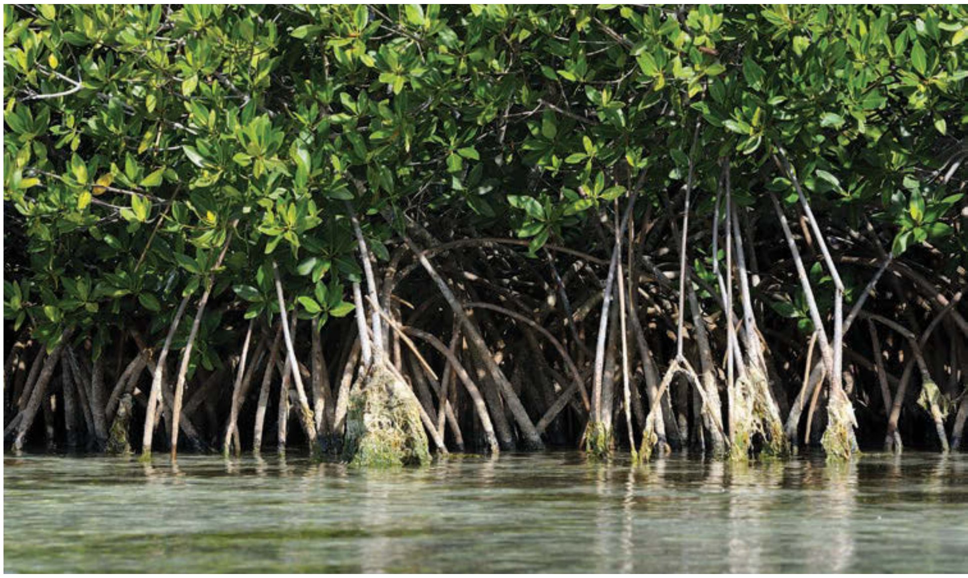
Salt marshes and mangroves are among the main types of intertidal wetlands (coastal areas periodically inundated by tides) in the Gulf of Mexico. Salt marshes occur along the Gulf Coast from 25 degrees to 42 degrees north latitude (IFAS, 2011) and mangroves occur between approximately 30 degrees north and 30 degrees south latitude (Giri et al., 2011). Coastal Louisiana, Texas and northwest Florida have large areas of salt marsh (Map 8). Salt marshes are also common along the coasts of Alabama and Mississippi. Florida's southwest coast supports a large mangrove swamp (the Everglades), and smaller populations of mangroves occur along the coasts of Texas, Louisiana and northern Florida. In addition, mangroves occur along nearly the entire coasts of both Mexico and Cuba (Map 8).

Salt marshes are salt-tolerant grasslands that are regularly flooded by seawater. Salt marshes form in flat transitional areas, usually with the protection of barrier islands, estuaries or low energy shorelines. They are influenced by both upland freshwater sources and tidal saltwater influxes. Gulf salt marshes are dominated by smooth cordgrass (*Spartina alterniflora*), saltmeadow cordgrass (*Spartina patens*), spike grass (*Distichlis spicata*) and black needlerush (*Juncus roemerianus*). The salinity, temperature, oxygen and frequency and extent of flooding of the marsh determine the types of plants and animals found within this habitat (Mendelssohn & Morris, 2002). Plants and animals have physical or behavioral adaptations to deal with the stressful physical and chemical conditions present in salt marshes and mangrove forests. For example, *Spartina alterniflora* adapts to the extreme conditions of the marsh by having tough, narrow blades that reduce water loss from evaporation and glands that secrete excess salt.

Mangroves are salt-tolerant trees that grow in the intertidal zones with hypoxic soils and where slow-moving waters allow fine sediments to accumulate (USGS, 2012). Levels of tidal flooding, soil salinity and nutrient availability determine the species of mangroves that can survive and grow (NOAA, 2008). In the northern Gulf, three species of mangroves are dominant: red mangrove (*Rhizophora mangle*), black mangrove (*Avicennia germinans*) and white mangrove (*Laguncularia racemosa*) (EPA, 2012).

Salt marshes and mangroves are key habitats for a variety of ecologically, recreationally and commercially important organisms, such as birds (e.g., clapper rails), juvenile fish, insects, mammals and crustaceans (e.g., fiddler crabs and white shrimip). These habitats can provide sheltered feeding grounds, nursery grounds and refuge from predators. Marshes and mangroves also act as filters, treating rainwater and wastewater from such sources as farms, parking lots, and small sewage plants. As water moves slowly through a marsh, sediment and associated pollutants settle to the substrate and excess nutrients are removed. Salt marshes and mangroves protect the coast by building shoreline, buffering wave energy during storm events and reducing damage from floods by slowing and storing floodwater (USGS, 2012). Loss of these habitats will also mean the loss of these valuable ecosystem services (Craft et al., 2009).

Climate change impacts, such as sea level rise coupled with human activities, such as channelization and oil extraction, have caused the erosion of intertidal wetlands (Blum & Roberts, 2009; Hoegh-Guldberg & Bruno, 2010). Salt marshes and mangroves along the northern Gulf Coast, particularly in Louisiana, also sustained negative impacts resulting from the BP Deepwater Horizon oil disaster (Silliman et al., 2012).



Red mangroves in Florida. Credit: Arto Hakola / Shutterstock

See related maps and narratives on Net Primary Productivity, Brown Shrimp, White Shrimp, Blue Crab, Clapper Rail, Projected Sea Level Rise, Land Area Change and Low Oxygen Areas.

Data Compilation and Mapping Methods

Salt marshes and mangrove forest coverage and delineations were derived by combining their respective data throughout the Gulf from various available sources. Salt marsh data in the U.S. were obtained from the Coastal Change and Analysis Program administered by NOAA. The Landsat Thematic Mapper satellite data were extracted and classified to produce a nationally standardized database of land cover and land change information for the coastal regions of the U.S. Data on Gulf Coast salt marshes outside of the U.S. were not significant in this compilation because they are limited in extent in both Mexico and Cuba.

Data for the extent of mangrove forests were obtained from the World Conservation Monitoring Center of the United Nations Environment Programme. These data were compiled by the U.S. Geological Survey using the Global Land Survey and a combination of supervised and unsupervised digital image classification techniques of the Landsat archives to show the global extent of mangrove forests.

Data Quality

This map has good data quality for the U.S. coast due to the comprehensive mapping program maintaining a consistent 30-meter (98-foot) resolution for salt marshes and because of the ample amount of surrogate data available for ground truthing mangrove forests in the U.S. Data quality for mangrove forests in Mexico and Cuba is good because of the satellite-based data available for these regions. These data represent the most comprehensive, globally consistent and highest resolution (30-meter [98-foot]) global mangrove database ever created, although scientific understanding of the extent and distribution of mangrove forests in the world is still inadequate (Giri et al., 2010).

Synthesis and Conclusions

Salt marshes cover large areas of coastal Louisiana, Texas and northwest Florida. Salt marshes are also common along the coasts of Alabama and Mississippi. Mangroves are most common along the coasts of southwest Florida, Mexico and Cuba. Salt marshes and mangroves provide a critical suite of ecosystem services that includes shoreline stabilization, fish and crustacean habitat preservation, and nutrient retention. Continuing field and modeling studies will increase our understanding of the role, function and value of salt marshes and mangrove forests and their susceptibility to climate change and human activities such as oil spills. The organized and systematic protection of these habitats will play a vital role in ensuring the future sustainability of the invaluable ecosystem services that they provide.

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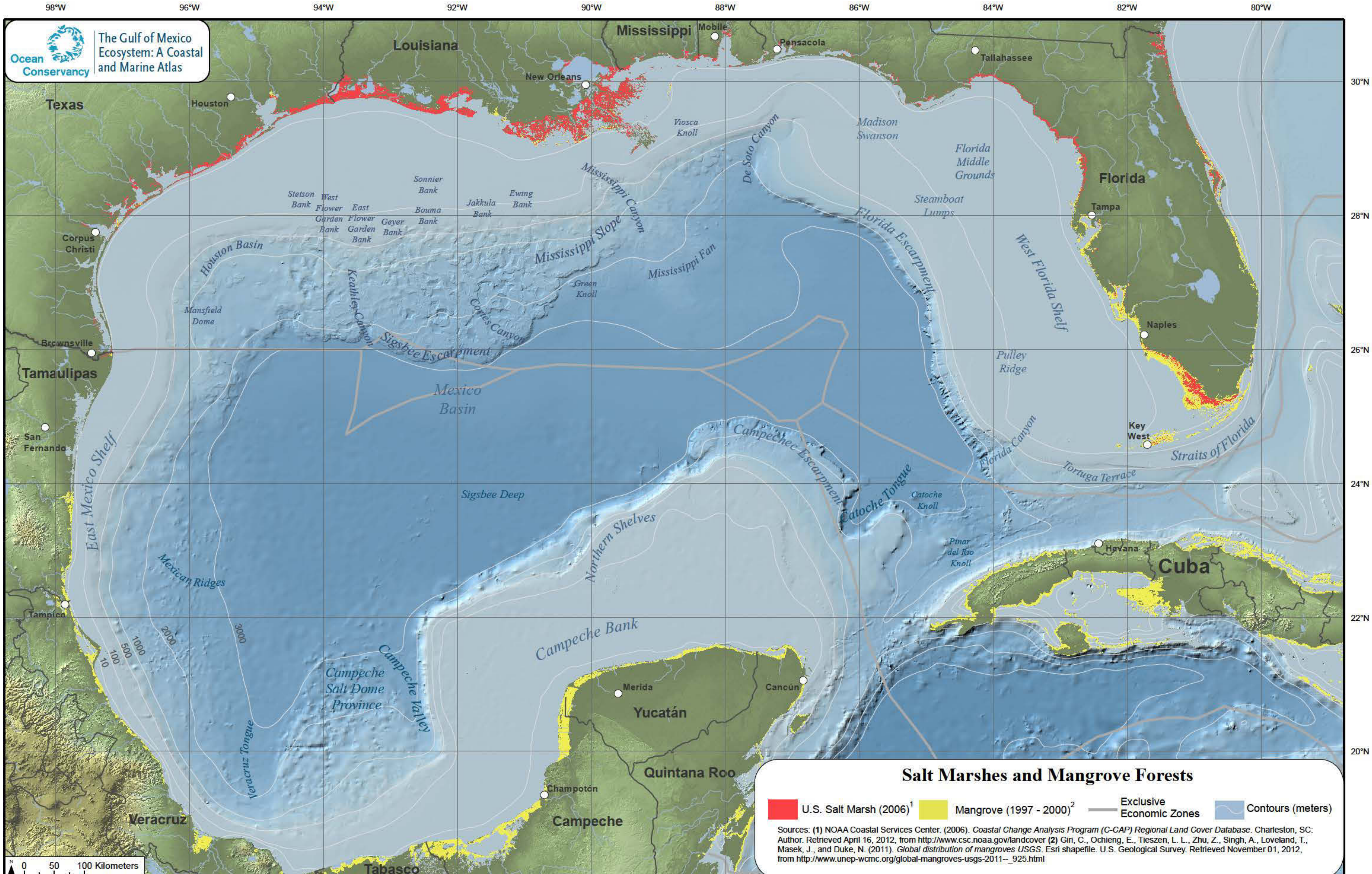
MAP 8 *(next page)***. SALT MARSHES AND MANGROVE FORESTS**



Salt Marshes and Mangrove Forests

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3.1 Eastern Oyster Reefs *Crassostrea virginica*

Description

This oyster bed near St. Petersburg, Florida serves as a foraging spot for a spotted sandpiper (*Actitis macularia*). Credit: David Mathews

The Eastern oyster's range covers the entire Gulf of Mexico, extending north to the Gulf of St. Lawrence in Canada and south to the West Indies (Eastern Oyster Biological Review Team, 2007). Eastern oysters grow in subtidal or intertidal estuarine environments such as shallow saltwater bays, lagoons and estuaries (Map 9). They can tolerate a wide range of temperatures, but will become severely stressed at high salinities and temperatures over 32 degrees Celsius (89 degrees Fahrenheit). In the Gulf, their optimal salinity range is 15 to 30 parts per thousand (Hofstetter, 1990). To attach, survive and grow, oyster larvae require a clean, hard substrate (e.g., rock or shell) where water circulates and sufficient food is available. They are filter feeders that pump water through their gills to remove suspended particles, such as plankton, algae and detritus. During filter feeding, oysters recycle nutrients and reduce the total amount of suspended material and contaminants in the water, thereby improving water quality and clarity (Breitburg et al., 2000). In turn, this improves the growing conditions for seagrasses and other nearby vegetation.

Oysters build reefs (assemblages of oysters) and create habitats that promote species diversity by providing refuge and foraging habitats for a variety of juvenile and adult finfish and invertebrates, such as crabs, shrimps and barnacles (Eastern Oyster Biological Review Team, 2007). The Eastern oyster is an indicator species, meaning its status and health reflect the condition of the larger ecosystem in which it occurs (Volety et al., 2009). It is also a foundation species that creates stable conditions, defines much of the surrounding community structure, and affects and benefits overall ecosystem functionality (Dayton, 1972; Ellison et al., 2005).

Within the U.S., the Gulf region leads the nation in the commercial production of Eastern oysters, landing approximately 85 percent of the nation's total in 2011 (NMFS, 2012). Louisiana typically accounts for more than 50 percent of the Gulf landings and has an annual oyster fishery with a dockside value typically greater than $35 million (LDWF, 2011). Florida and Texas also have substantial oyster harvests concentrated in Apalachicola Bay and Galveston Bay, respectively (Eastern Oyster Biological Review Team, 2007). Although oyster fisheries are still productive, the abundance of oysters in the Gulf has declined dramatically. All areas of the Gulf have experienced at least a 50 percent loss in oyster abundance and oyster reefs as compared to historic (at least 20 years ago) estimates. The Gulf is one of the major remaining regions in the world where a fishery of wild native oysters still exists; these relatively healthy populations of oysters create an opportunity to manage the fishery with the goal of sustaining native populations (Beck et al., 2011).

Current natural and anthropogenic threats to Gulf oysters include disease, habitat destruction (e.g., dredging and mechanical harvesting), coastal development, nutrient runoff and pollution. As a result of the BP Deepwater Horizon (DWH) oil disaster, oyster beds were also exposed to hydrocarbons, chemical dispersants and low salinities; the latter were caused by freshwater diversions used as a response measure during the oil disaster (NOAA, 2012). The total collective and synergistic effect of these threats is most likely much larger than each individually (VanderKooy, 2012).

See related maps and narratives on Seagrasses, Blue Crab, and Fish and Shellfish Hatcheries.

Data Compilation and Mapping Methods

Distribution data were obtained from the NOAA Gulf of Mexico Data Atlas (Anson et al., 2011). These data were compiled from data sources provided at the state level by Florida, Alabama, Mississippi, Louisiana and Texas. These data represent varying time periods for portions of the overall area with surveys conducted in the late 1960s in parts of Alabama and Louisiana and more recent collection of data in parts of Texas, Florida and Alabama. Most of these state-level mapping projects were confined to a limited number of estuaries or bays due to the lack of financial resources to undertake more comprehensive mapping projects. Delineations of oyster reefs in each state used various methods from on-the-ground surveys in the early years, to side-scan sonar, aerial photography and random transects sampling. Each state contributed the best data available at the time for the development of a U.S. Gulf-wide Eastern oyster dataset for the NOAA Gulf of Mexico Data Atlas.

Data Quality

Data quality for this map is fair for U.S. waters due to the long time period over which the full dataset was developed. Some areas have not been remapped for decades, while others reflect conditions documented during the past few years. Data were not found for this species in Mexico or Cuba. While it is known that Eastern oysters occur in the southern Gulf, distribution there is not well documented.

Synthesis and Conclusions

The Eastern oyster's range covers the entire Gulf of Mexico. Oyster populations are threatened by habitat destruction, pollution and coastal development. Eastern oysters play a critical role in the functioning of estuarine ecosystems by providing habitats for various organisms, and they also serve as a substantial fishery resource. Gaps in knowledge or areas where further study is needed include: connectivity between oyster populations, source/sink dynamics, catch and fishing efforts, oyster contamination from chemicals and pathogens, impacts and recovery from DWH oil disaster, and the effects of synergistic and chronic stressors, such as climate change, coastal development, harvest pressure, disease and pollutants (VanderKooy, 2012).

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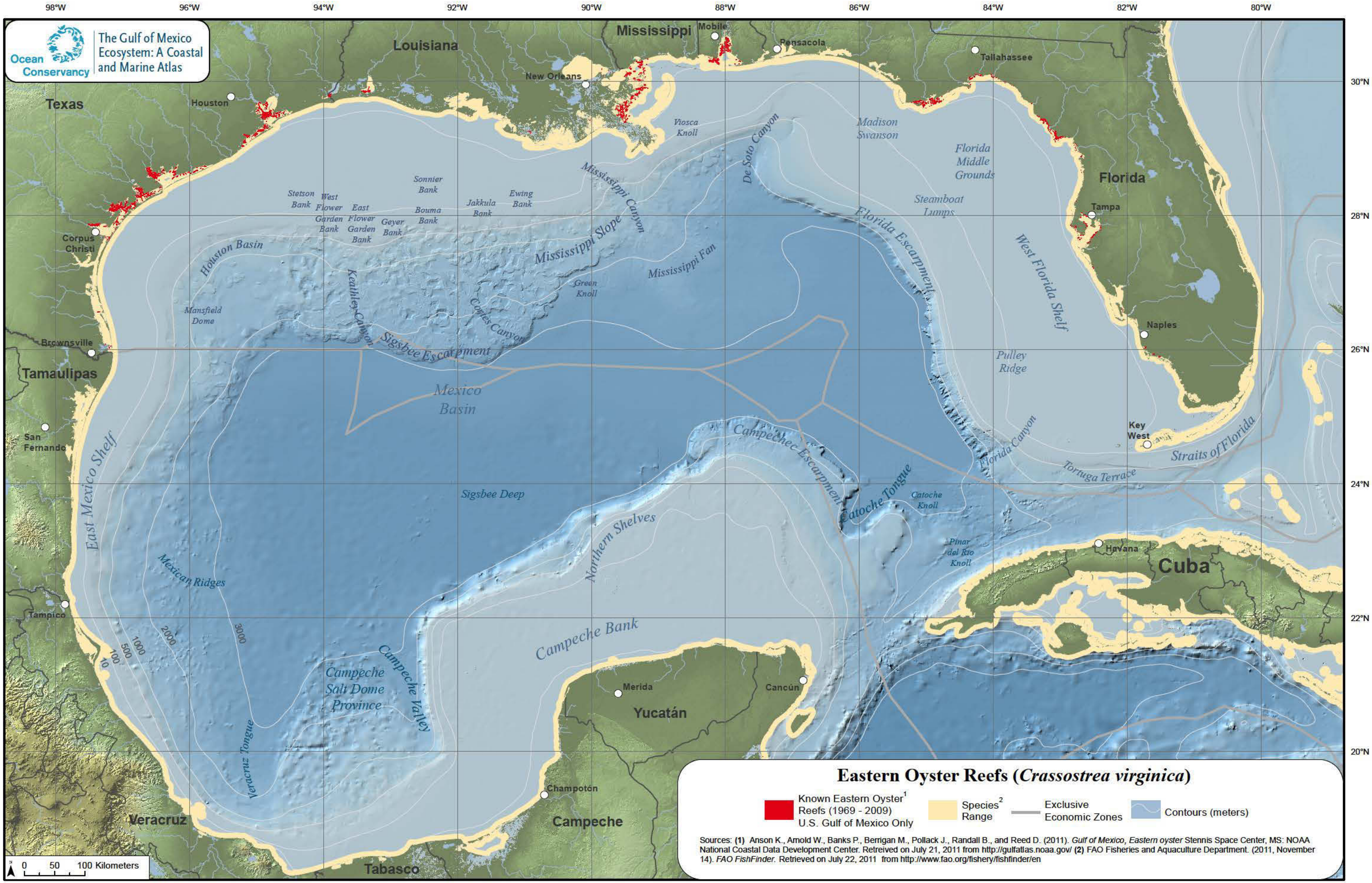
MAP 9 *(next page)*. **EASTERN OYSTER REEFS**



Eastern Oyster Reefs (*Crassostrea virginica*)

Sources: **(1)** Anson K., Arnold W., Banks P., Berrigan M., Pollack J., Randall B., and Reed D. (2011). *Gulf of Mexico, Eastern oyster* Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retreived on July 21, 2011 from http://gulfatlas.noaa.gov/ **(2)** FAO Fisheries and Aquaculture Department. (2011, November 14). *FAO FishFinder.* Retrieved on July 22, 2011 from http://www.fao.org/fishery/fishfinder/en

3.2 Seagrasses

Description

Seagrasses occur in shallow, low energy areas along the coast of the Gulf of Mexico, such as protected bays and lagoons. The coasts of Florida, southern Texas, northern Mexico and Cuba are important areas for seagrasses (Map 10). Light availability, water clarity, water temperature, salinity, sediment characteristics, nutrient distribution, wave energy and tidal range all affect the growth and survival of seagrasses (Livingston et al., 1998; Koch, 2001). Seagrasses are types of submerged aquatic vegetation that form large underwater meadows. These flowering plants grow and reproduce in the marine environment of the Gulf. Similar to terrestrial plants, these plants have leaves, roots, flowers and seeds, and produce organic compounds and oxygen through photosynthesis. A strong root structure enables seagrasses to withstand waves and currents. Seagrasses reproduce underwater by releasing filamentous pollen grains into currents or asexually through rhizomes that produce new roots and shoots. Six species of seagrass are common in the Gulf: manatee grass (*Syringodium filiforme*), shoalgrass (*Halodule wrightii*), widgeon grass (*Ruppia maritima*), turtle grass (*Thalassia testudinum*), paddle grass (*Halophila decipiens*) and star grass (*Halophila engelmannii*) (USGS, 2004).

Turtle grass (*Thalassia testudinum*) is a type of seagrass. Credit: Texas Parks and Wildlife Department

Seagrasses provide habitat and food sources for many coastal and marine animals including waterfowl, fish and invertebrates during one or more of their life stages. They are also an important food source for green sea turtles and West Indian manatees (Williams & Heck, 2001). Examples of commercially and recreationally important fish that use seagrass beds as nursery grounds are drums, sea bass, porgies, grunts and snappers (USGS, 2004).

Seagrass beds provide numerous ecosystem services, such as buffering shorelines against storm surges, stabilizing sediments, trapping fine sediments, and filtering nutrients and contaminants (USGS, 2004). Major causes of seagrass degradation are nutrient loading, scarring from boat propellers and trawl nets, dredging activities and coastal development (USGS, 2004). Seagrasses sustained impacts resulting from response measures used during the BP Deepwater Horizon oil disaster (NOAA, 2011; NOAA, 2012).

See related maps and narratives on Sea Surface Currents, Net Primary Productivity, Red Drum, Red Snapper and West Indian Manatee.

Data Compilation and Mapping Methods

Seagrass data were compiled from the most recent statewide datasets provided by each of the five U.S. states along the Gulf Coast, but the datasets vary in age. Data for Cuba and Mexico are more generalized, representing broad areas of seagrass occurrence as opposed to delineated beds. Data for Florida were provided by the Florida Fish and Wildlife Conservation Commission and were compiled from datasets that varied in age from as early as 1987 to as recent as 2009. Data in Alabama, produced in 2009 and not included in data from other states, were provided by the Mobile Bay National Estuary Program. The dataset includes several species of submerged aquatic vegetation not classified as true seagrasses in the lower salinity zones of northern Mobile Bay. Data for Mississippi and Louisiana were obtained from a 2004 online dataset provided by the NOAA National Coastal Data Development Center. Data for Texas waters were provided by the Texas Parks and Wildlife Department and were compiled from data spanning various dates from 1988 through 2007. The Texas dataset excludes widgeon grass (*Ruppia maritima*), which is included in data from the other states. Mexico and Cuba seagrass areas are provided by the global compilation of seagrasses produced in 2005 by the United Nations Environment Programme World Conservation Monitoring Center.

Data Quality

This map has fair data quality. While there is relatively good geographic coverage across datasets, gaps in temporal coverage (resulting from combining older and newer data) on seagrass delineation reduce the quality and continuity of these data.

Synthesis and Conclusions

Seagrasses occur in shallow, low energy areas all along the Gulf Coast. Major threats to seagrasses are natural disturbance, nutrient pollution, scarring from boat propellers and trawl nets, dredging activities, coastal development and climate change. Seagrass beds provide habitats for a variety of commercially and recreationally valuable fishery species. Seagrass coverage can expand and contract in relation to water quality and other environmental conditions, so consistent methods are needed to accurately assess seagrass coverage and decline in the Gulf (Carter et al., 2011). The relationship between the extent of seagrasses and seagrass-associated species abundance needs to be better quantified, because the true conservation costs of seagrass decline are likely underestimated (Hughes et al., 2009).

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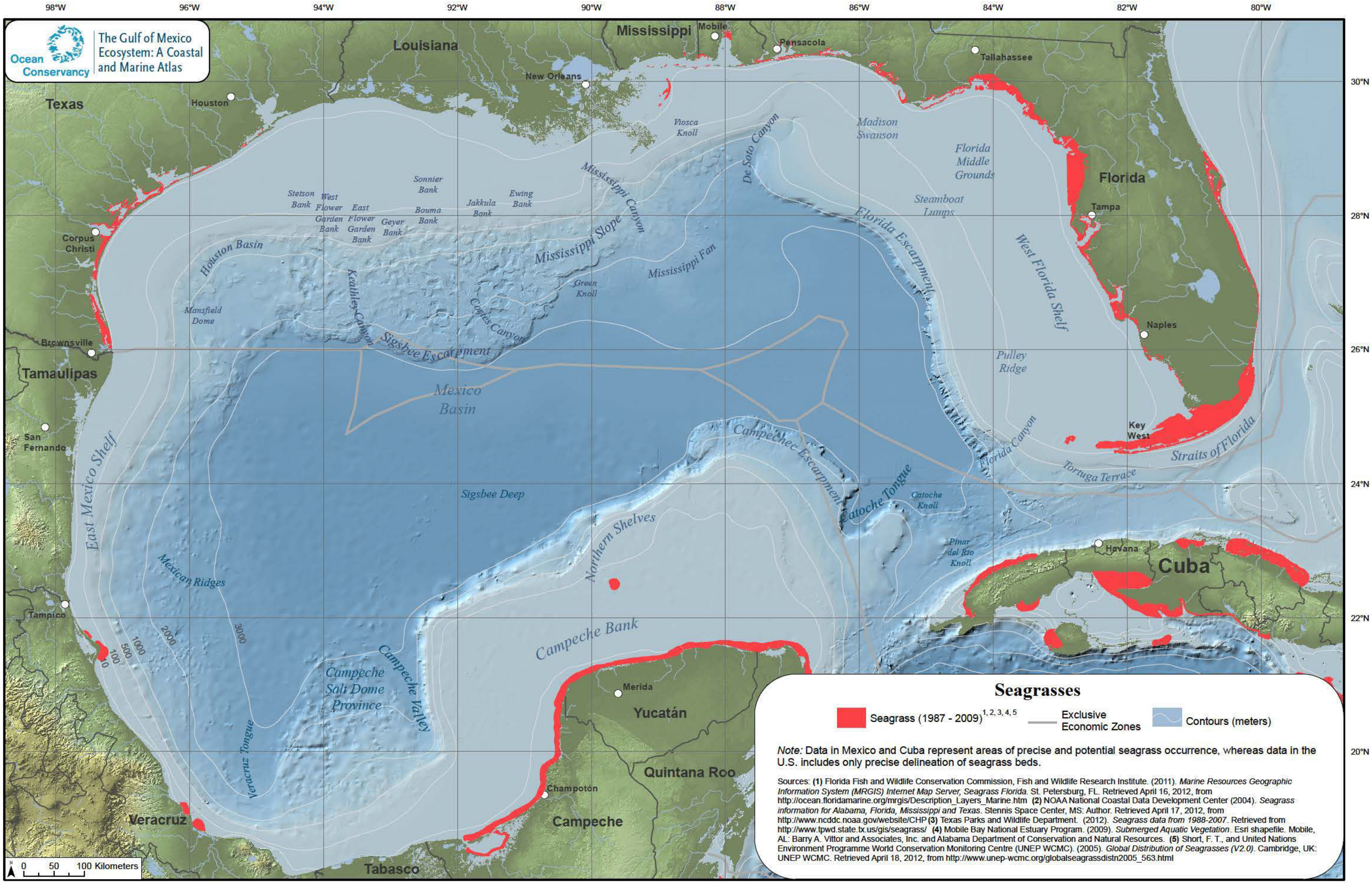
MAP 10 *(next page)*. **SEAGRASSES**



Seagrasses

Seagrass (1987 - 2009)[1, 2, 3, 4, 5]

Exclusive Economic Zones

Contours (meters)

Note: Data in Mexico and Cuba represent areas of precise and potential seagrass occurrence, whereas data in the U.S. includes only precise delineation of seagrass beds.

Sources: **(1)** Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute. (2011). *Marine Resources Geographic Information System (MRGIS) Internet Map Server, Seagrass Florida*. St. Petersburg, FL. Retrieved April 16, 2012, from http://ocean.floridamarine.org/mrgis/Description_Layers_Marine.htm **(2)** NOAA National Coastal Data Development Center (2004). *Seagrass information for Alabama, Florida, Mississippi and Texas*. Stennis Space Center, MS: Author. Retrieved April 17, 2012, from http://www.ncddc.noaa.gov/website/CHP **(3)** Texas Parks and Wildlife Department. (2012). *Seagrass data from 1988-2007*. Retrieved from http://www.tpwd.state.tx.us/gis/seagrass/ **(4)** Mobile Bay National Estuary Program. (2009). *Submerged Aquatic Vegetation*. Esri shapefile. Mobile, AL: Barry A. Vittor and Associates, Inc. and Alabama Department of Conservation and Natural Resources. **(5)** Short, F. T., and United Nations Environment Programme World Conservation Monitoring Centre (UNEP WCMC). (2005). *Global Distribution of Seagrasses (V2.0)*. Cambridge, UK: UNEP WCMC. Retrieved April 18, 2012, from http://www.unep-wcmc.org/globalseagrassdistn2005_563.html

3.3 Barrier Islands

Description


An aerial view of Cat Island off the coast of Mississippi. Credit: USGS

Barrier islands are long, narrow offshore deposits of sand or other sediments that generally run parallel to the mainland coast. They are dynamic coastal sedimentary features that vary in their state of development, meaning some islands have well developed sandy shores with an extensive landward lagoon while others are separated from the mainland by only a narrow channel. Barrier islands usually occur in chains, consisting of anything from a few islands to more than a dozen, as found along the Gulf Coast and the East Coast of the U.S. Narrow tidal inlets separate the individual islands in chains.

In the Gulf of Mexico, barrier islands occur along the coasts of the U.S. and Mexico (Map 11). Barrier islands in the Gulf have different formations and movements depending on their location and surrounding natural and anthropogenic influences. Barrier islands in Louisiana depend on sediment deposited by the Mississippi River (Rosati & Stone, 2009). Some of the barrier islands in Louisiana are eroding due to a combination of rapid relative sea level rise, lack of sediment due to the channelization of the Mississippi River, and erosion on both Gulf and bay shores (Penland et al., 2005; Rosati & Stone, 2009). The barrier islands from Mississippi to Dauphin Island, Alabama are migrating rapidly from east to west (Rosati & Stone, 2009). Researchers have suggested that channel maintenance activities for deep-draft shipping along the inlets of the Mississippi and Alabama barrier islands have reduced the sediment supply for these islands (Morton, 2008). However, the barrier islands from Fort Morgan Peninsula, Alabama to Grayton Beach, Florida have remained relatively stable (Rosati & Stone, 2009).

A barrier island has a high-energy beachfront where wave action carries sand to and away from the shore. On the back or bay side of the island, a marsh habitat develops that is generally characterized by *Spartina* flats, tidal creeks and intertidal mudflats. Some islands may be more developed with extensive maritime forests while others may be newly formed from emergent sand bars. Others may be so heavily eroded they barely constitute islands. Barrier islands are dynamic, changing shape and migrating in response to erosion and deposition processes as sea levels rise and fall. The dynamic nature of sand movement links the islands. As a result, changes in one location or island, either natural or anthropogenic, may have significant impacts on other locations or islands by changing currents or wave patterns and tidal ranges, which in turn, will change erosion and deposition rates (NOAA, 2013b).

These islands reduce the impacts of ocean waves and storm surges to coastal communities and important habitats such as lagoons, estuaries, marshes and inland areas. The wetlands protected by barrier islands support commercially important fish species as well as migratory birds, sea turtles and other diverse wildlife and plants. Barrier islands also serve as popular vacation destinations that support local coastal economies (NOAA, 2012b). In Louisiana, the chain of islands fronting Barataria Bay is particularly important since it helps protect the most inhabited portion of the Louisiana coastal zone from hurricane storm surge (NOAA, 2013a). As a result of subsidence and climate change, this island chain is experiencing one of the highest sea level rise rates in the entire country (NOAA, 2013c).

The principal causes of land loss on barrier islands are frequent and intense storms, a relative rise in sea level, subsidence, and a sediment-budget deficit (Morton, 2008). Hurricane Katrina caused Dauphin Island in Alabama to migrate landward and stripped away most of the sand on the Chandeleur Islands in Louisiana (Sallenger et al., 2007). Barrier islands in the northern Gulf were also oiled and impacted as a result of the BP Deepwater Horizon (DWH) oil disaster (NOAA, 2012a).

Despite uncertainty regarding the magnitude of the various effects of climate change, management and restoration plans for barrier islands should account for how increased storm activity and rates of sea level rise might impact the islands. Sand supply is the only factor contributing to barrier island land loss that can be managed directly. The most successful erosion control and restoration projects use sediment and vegetation engineered to work in concert with the natural processes that shape barrier islands (Penland et al., 2005). Human-made coastal structures such as seawalls and groins have limited success; by disrupting the natural redistribution of sands to create areas of gain, these structures also create large zones of accelerated erosion (Penland et al., 2005).

See related maps and narratives on Salt Marshes and Mangrove Forests, Brown Pelican, Least Tern, Projected Sea Level Rise, Land Area Change, and Tropical Cyclone Track Density.

Data Compilation and Mapping Methods

Barrier islands were delineated in the Gulf using an imagery service database of natural color imagery from years 2001 to 2011, provided by the Microsoft Corporation through Esri basemaps in ArcGIS (Microsoft Corporation, 2011). Due to the varied coastal geomorphologic conditions of barrier islands, several simple rules were followed in digitizing: islands must be separated from the mainland by natural waterways, excluding capes and spits; an island must be fronted by the Gulf and not by marshes or mangroves; only the primary island was included in the delineation, excluding landward-side small islands not directly adjacent to the open Gulf; and islands must be sedimentary in recent origin, excluding islands developed from exposed reef tracts or hard substrate separated by the mainland due to erosion.

An index of infrastructure and other human modifications was used to provide a Gulf-wide view of the status of these important ecological features. A simple three-level classification system was used to indicate the degree of development as determined by the true color imagery available in the image database. Islands were classified as “Less Than 25% Developed,” “25% to 50% Developed” or “Greater Than 50% Developed” as determined by visual estimation while delineating each island. Development here is generally defined as any human modification or feature, such as roads, buildings, campgrounds, agricultural fields or impoundments.

Data Quality

This map has good data quality due to the availability of recent imagery covering the entire Gulf Coast, allowing for complete delineation of all islands using the criteria listed above. The islands were mapped at a scale of one to thirty thousand. This scale was chosen to provide sufficient detail for mapping the general outline of each island but not for delineating the exact shoreline. In some cases small internal tidal lagoons were included in the island boundary. Relatively small marsh areas or sandy bars may have been excluded due to the general nature of the delineation at this scale. Using true color imagery presented limitations in determining the boundary between dry land and seagrass or shallow bars, which inevitably introduced delineation errors. This issue was especially problematic in areas of very shallow lagoons, as in Laguna Madre and a majority of the coast of the Mexican states of Tamaulipas and Veracruz. These data are useful for locating barrier islands but should not be used to calculate areal extent of an island. Island boundaries on the map are exaggerated to highlight the presence of these often very narrow features on this broad-scale map.

Summary and Synthesis

Barrier islands are ecologically and commercially important, protecting wildlife, vegetation and inland areas from storm surges, while also serving as popular vacation destinations. These important habitats are experiencing high rates of land loss due to storm activity, relative sea level rise, subsidence and low sediment input. Due to these threats and to other anthropogenic impacts such as dredging along the Mississippi and Alabama islands and the DWH oil disaster, long-term and comprehensive monitoring of barrier islands is vital for future conservation. Management and restoration plans for barrier islands in the Gulf need to consider how increased storm activity and rates of sea level rise might affect the islands over time.

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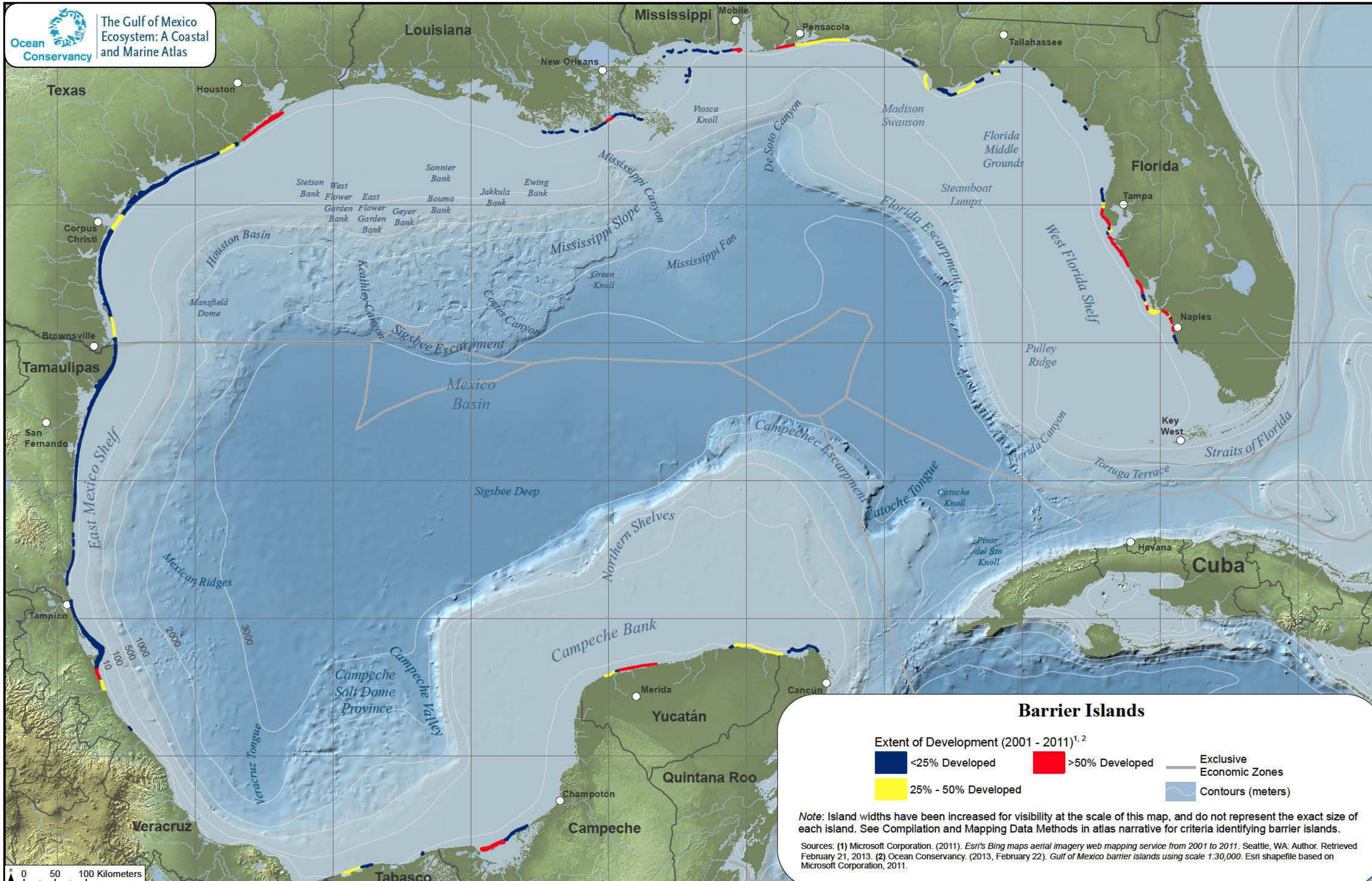
MAP 11 *(next page)*. **BARRIER ISLANDS**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
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94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Havana
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
West Florida Shelf
Pulley Ridge
Florida Escarpment
Florida Canyon
Tortuga Terrace
Straits of Florida
De Soto Canyon
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Green Knoll
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Mansfield Dome
Keathley Canyon
Coyotes Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Veracruz Tongue
Campeche Salt Dome Province
Campeche Valley
Campeche Bank
Northern Shelves
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
10
100
500
1000
2000
3000
0 50 100 Kilometers
Barrier Islands
Extent of Development (2001 - 2011)[1, 2]
<25% Developed
>50% Developed
25% - 50% Developed
Exclusive Economic Zones
Contours (meters)
Note: Island widths have been increased for visibility at the scale of this map, and do not represent the exact size of each island. See Compilation and Mapping Data Methods in atlas narrative for criteria identifying barrier islands.
Sources: (1) Microsoft Corporation. (2011). Esri's Bing maps aerial imagery web mapping service from 2001 to 2011. Seattle, WA: Author. Retrieved February 21, 2013. (2) Ocean Conservancy. (2013, February 22). Gulf of Mexico barrier islands using scale 1:30,000. Esri shapefile based on Microsoft Corporation, 2011.

3.4 Corals

Description

Shallow coral reef in Florida Keys. Credit: NOAA

Corals are widespread throughout the Gulf of Mexico. Along the U.S. Gulf coastline, Florida has extensive coral reef formations near its coast, with the most reef development occurring west of the Florida Keys (Map 12). Additional shallow and mesophotic coral communities are located in the Flower Garden Banks approximately 200 kilometers (124 miles) south of Galveston, Texas. In Mexico, corals occur mostly along the edge of the continental shelf near Campeche Banks and Veracruz. (Spalding et al., 2001). Corals also occur on the continental shelf of Cuba, encircling its entire coastline. Deep-water corals are commonly found on hard bottom substrates along the continental shelf or slope (e.g., rocky ledges, seamounts, ridges and pinnacles), in offshore canyons, or on oceanic islands, slopes or seamounts (NOAA, 2010). Corals create unique habitats in both shallow- and deep-water environments, which are important for fish and invertebrates. For purposes of this description, corals are classified by depth based on the following delineations: shallow-water corals occur in depths less than 30 meters (100 feet), mesophotic corals occur from 30 to 200 meters (100 to 655 feet) and deep-water corals occur at depths greater than 200 meters (655 feet) (CRTF, 2011).

Deep-water corals in the Gulf include stony corals, black corals, lace corals, gorgonians, sea pens and soft corals. These coral species generally inhabit cold oceanic waters and can be found as deep as six kilometers (3.73 miles) (NOAA, 2008). Their range extends from approximately 50 to 2,000 meters (165 to 6,560 feet). The polyps of deep-water corals are suspension feeders, capturing organic detritus and plankton from the strong, deep-sea currents. Some deep-water corals in the Gulf have extremely slow growth rates, living thousands of years (Prouty et al., 2011). Only a small percentage of the potential deep-water coral habitat has been explored, and there are significant knowledge gaps regarding their distribution, extent, biology and ecology (NOAA, 2010).

Common shallow-water corals in the Gulf include soft corals, sea whips, sea fans, star corals and boulder brain corals. Shallow-water coral reefs grow best in warm seawater between 21 and 29 degrees Celsius (70 to 85 degrees Fahrenheit). Reef-building corals grow in areas where sunlight can penetrate the water column to reach the coral's zooxanthellae. As a result, the depth of zooxanthellae-dependent coral growth is limited by sunlight penetration (Kleypas et al., 1999). Shallow-water corals absorb dissolved organic materials from surrounding waters and most have evolved to form a special symbiotic relationship with zooxanthellae. Zooxanthellae are a type of tiny marine algae that supplies the coral with needed glucose, glycerol and amino acids through photosynthesis, and in return, these algae rely on the coral for protection and other compounds needed for photosynthesis. Corals can reproduce sexually and asexually. Most reproduce during annual spawning events that are synchronized by seawater temperature changes, lunar cycle and time of day. Other corals form from broken fragments or buds produced by individual polyps. Shallow-water corals provide habitat and food for benthic organisms and a variety of commercially important invertebrates and fishes while also protecting coastlines from erosion and storms.

An orange brisingid basket star on a large deep-water coral reef, *Lophelia pertusa*, at 450 meters (1475 feet) depth in the Gulf of Mexico. Credit: Lophelia II 2010 Expedition, NOAA / BOEMRE

The National Marine Fisheries Service has designated areas of the Gulf as critical habitat for elkhorn and staghorn corals. The Federal Fishery Management Plan for corals (managed by the Gulf and South Atlantic fishery management councils) prohibits the harvest of stony corals, sea fans, coral reefs and live rock with the exception of harvesting for scientific or educational purposes. The Fishery Management Plan also establishes Habitat Areas of Particular Concern in the Gulf where the use of bottom anchors, trawling gear, bottom longlines, buoy gear, and all traps and pots near coral reefs are prohibited (GMFMC, 1982). Recognizing the importance of coral to fisheries, the Gulf of Mexico Fishery Management Council designated essential fish habitat for coral, which fully encompasses the total distribution of coral species and life stages throughout the Gulf (GMFMC, 2004). However, shallow and deep-sea corals are still threatened by a variety of human activities and other impacts such as water pollution, overfishing, destructive fishing practices, disease, global climate change, ship groundings and oil spills. For example, deep-sea corals were significantly damaged by the BP Deepwater Horizon (DWH) oil disaster (White et al., 2012).

See related maps and narratives on Bathymetry, Red Snapper, and Coastal and Marine Protected Areas.

Data Compilation and Mapping Methods

Data for this map were obtained from the NOAA Gulf of Mexico Data Atlas. These data were compiled for Map 12 using the Gulf of Mexico Deep-Sea Coral database, which includes 2,250 records of corals from the Smithsonian National Museum of Natural History, Texas Cooperative Wildlife Collection, Harbor Branch Oceanographic Institution, Yale Peabody Museum and other samples reported in the literature. These data illustrate known locations from these sampling records and do not indicate predicted areas of occurrence.

Data Quality

This map has fair data quality. It is comprehensive in the sense that it represents currently known coral locations, but sampling across possible coral habitats is still inadequate for complete knowledge of coral distribution in the Gulf. A majority of the sampling effort occurs along the continental margin of the U.S. By comparison, habitats in Mexican and Cuban waters are relatively under-sampled and data quality is poor.

Synthesis and Conclusions

Coral species (in all of their life stages) are distributed throughout the Gulf. Some of the more prominent occurrences of coral include the following areas: the East and West Flower Garden Banks, Florida Middle Grounds, southwest tip of the Florida reef tract, the predominant patchy hard bottom offshore of Florida from about Crystal River south to the Keys, and scattered pinnacles and banks from Texas to Mississippi at the shelf edge (GMFMC, 2004). Shallow and deep-sea corals are threatened by a variety of impacts such as water pollution, overfishing, destructive fishing practices, disease, global climate change, ship groundings and oil spills. Corals serve as critical habitats for fish and invertebrates. For deep-sea Gulf corals, there are significant knowledge gaps regarding their locations, biology and ecology. Our limited understanding of these organisms makes estimating environmental impacts and recovery quite difficult. Continued monitoring and research of these organisms is essential to understanding impacts from the DWH oil disaster and their role in creating and supporting habitats.

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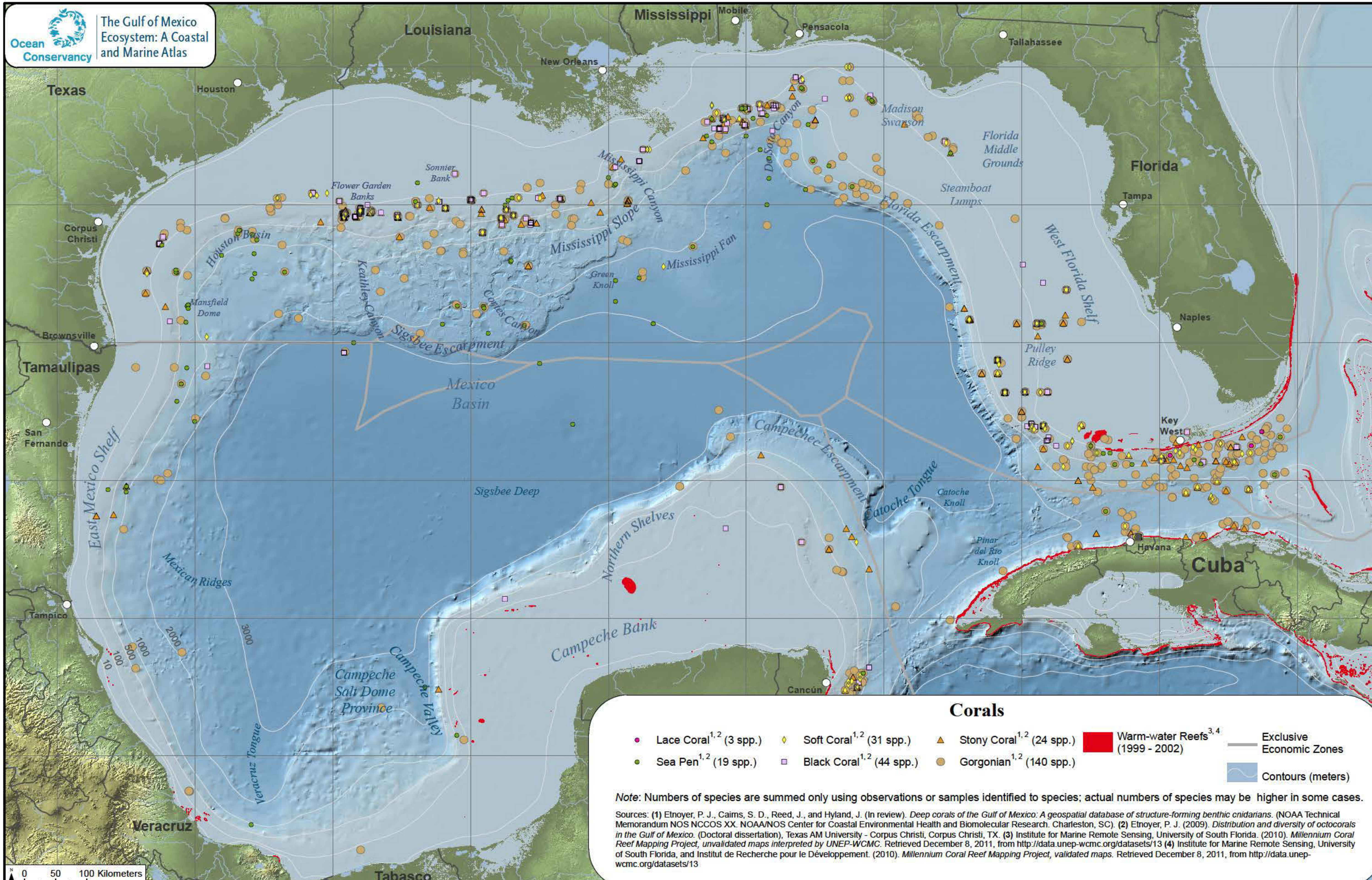
MAP 12 *(next page)*. **CORALS**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Louisiana
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Mobile
Pensacola
Tallahassee
New Orleans
Texas
Houston
Florida
Tampa
Naples
Key West
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Cancún
Havana
Cuba
Flower Garden Banks
Sonnier Bank
Mississippi Canyon
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Houston Basin
Mississippi Slope
Mississippi Fan
Green Knoll
Mansfield Dome
Keathley Canyon
Alaminos Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Corals
Lace Coral[1,2] (3 spp.)
Sea Pen[1,2] (19 spp.)
Soft Coral[1,2] (31 spp.)
Black Coral[1,2] (44 spp.)
Stony Coral[1,2] (24 spp.)
Gorgonian[1,2] (140 spp.)
Warm-water Reefs[3,4] (1999 - 2002)
Exclusive Economic Zones
Contours (meters)
Note: Numbers of species are summed only using observations or samples identified to species; actual numbers of species may be higher in some cases.
Sources: **(1)** Etnoyer, P. J., Caims, S. D., Reed, J., and Hyland, J. (In review). *Deep corals of the Gulf of Mexico: A geospatial database of structure-forming benthic cnidarians.* (NOAA Technical Memorandum NOS NCCOS XX. NOAA/NOS Center for Coastal Environmental Health and Biomolecular Research. Charleston, SC). **(2)** Etnoyer, P. J. (2009). *Distribution and diversity of octocorals in the Gulf of Mexico.* (Doctoral dissertation), Texas AM University - Corpus Christi, Corpus Christi, TX. **(3)** Institute for Marine Remote Sensing, University of South Florida. (2010). *Millennium Coral Reef Mapping Project, unvalidated maps interpreted by UNEP-WCMC.* Retrieved December 8, 2011, from http://data.unep-wcmc.org/datasets/13 **(4)** Institute for Marine Remote Sensing, University of South Florida, and Institut de Recherche pour le Développement. (2010). *Millennium Coral Reef Mapping Project, validated maps.* Retrieved December 8, 2011, from http://data.unep-wcmc.org/datasets/13

3.5 Pelagic Sargassum *Sargassum natans & Sargassum fluitans*

Description

A hatchling loggerhead sea turtle swims in pelagic sargassum. Credit: Blair Witherington

Sargassum is a genus of large brown algae. In the Gulf of Mexico, pelagic sargassum is found mostly between the latitudes 20 degrees north to 40 degrees north and from 30 degrees west longitude to the western edge of the Florida Current/Gulf Stream (SAFMC, 2002) (Map 13). Pelagic sargassum floats at the surface in island-like masses, and can also be found in widely dispersed clumps or long weed lines. Currents, gyres, eddies and winds dictate the circulation of sargassum. The two pelagic species in the Gulf are *Sargassum fluitans* and *Sargassum natans*. The latter is the more dominant floating algae in the open Gulf and makes up approximately 90 percent of the total drifting mats of macroalgae in the Sargasso Sea (SAFMC, 2002). Distinguishing between *Sargassum natans* and *Sargassum fluitans* from satellite imagery is nearly impossible, so for the purposes of Map 13, the two species are mapped together. *Sargassum natans* is the primary focus of this description narrative.

Sargassum natans has low nitrogen and phosphorus requirements and exhibits optimal growth in water with temperatures of 24 to 30 degrees Celsius (75 to 86 degrees Fahrenheit) and a salinity near 36 parts per thousand (SAFMC, 2002). This species has complex branching and numerous berry-like structures called pneumatocysts, which are small gas-filled bladders that keep the plant buoyant. It undergoes vegetative reproduction, a type of asexual reproduction by which new plants grow from vegetative parts (Calder, 1995).

The South Atlantic Fishery Management Council designated sargassum as an essential fish habitat due to its role as a nursery, a shelter from predators and a food source for various aquatic species (SAFMC, 2002). Some economically important or at-risk animals dependent on sargassum include larval and juvenile yellowfin tuna, gray triggerfish, Kemp's ridley sea turtles and blue crabs (Wells & Rooker, 2004). It is necessary to identify and evaluate existing and potential cumulative impacts of fishing and non-gear-related fishery activities on sargassum habitats, such as direct physical loss or alteration or impaired quality or function (SAFMC, 2002).

The highest concentrations of pelagic sargassum in the world are located in the Gulf and the Atlantic Ocean (Gower & King, 2008). Within the scientific community there is uncertainty about the regeneration time of sargassum and whether sargassum in the Gulf is self-renewing or comes from the larger Atlantic population. Using satellite imagery, researchers show an annual increase in sargassum in the northwest Gulf between March and June and theorize that it originates in the western Gulf and moves east through the Gulf and into the Atlantic in late summer (Gower & King, 2008). Based on their findings, Gower and King (2008) concluded that the northwest Gulf is a major nursery area for sargassum and that most sargassum plants have a lifespan of one year or less.

See related maps and narratives on Sea Surface Currents and Kemp's Ridley Sea Turtle.

Data Compilation and Mapping Methods

This map was developed from data provided by the Institute of Ocean Sciences at Fisheries and Oceans Canada (Gower & King, 2008). These data represent a simplified outline of the seasonal average extent of pelagic sargassum during the months of March, May, July and August averaged over the years 2002 through 2007. Pelagic sargassum was detected using the Medium Resolution Imaging Spectrometer aboard the European Space Agency's Envisat satellite as it orbited the earth, providing global coverage of ocean color every three days. A maximum chlorophyll index provides good data on the extent of floating vegetation in the ocean (Gower & King, 2008). The summarized data in Map 13 are based on the maximum chlorophyll index for the Gulf.

Data Quality

Data quality for this map is considered good because of the Gulf-wide data coverage at a constant resolution of 1,200 meters (3,937 feet). While interpretation of these satellite-based data, including the inferred seasonal movements of pelagic sargassum, is controversial in the scientific community, these data are the first time-series observations of this habitat type in the Gulf and Atlantic waters. As more studies are published using other satellite-based sensors, such as the Moderate Resolution Imaging Spectroradiometer and field-based genetic research, scientific understanding of the origins and seasonal movements of this pelagic species will continue to expand.

Synthesis and Conclusion

The Gulf has one of the highest concentrations of pelagic sargassum in the world. It floats at the surface in island-like masses and can also be found in widely dispersed clumps or along ocean convergence weed lines. Sargassum is an important habitat for sea turtles, larval and juvenile fish, and invertebrates. Research is needed to support a higher level of resolution to describe and identify the sargassum habitat. It is also necessary to identify and evaluate the existing and potential natural or human impacts on sargassum habitat, such as direct physical loss or alteration, impaired quality or function, cumulative effects from fishing, and non-gear-related fishery activities. Continued monitoring and research on the various effects of the BP Deepwater Horizon oil disaster concerning sargassum mats and associated biological communities will be essential to conservation and preservation efforts in the Gulf.

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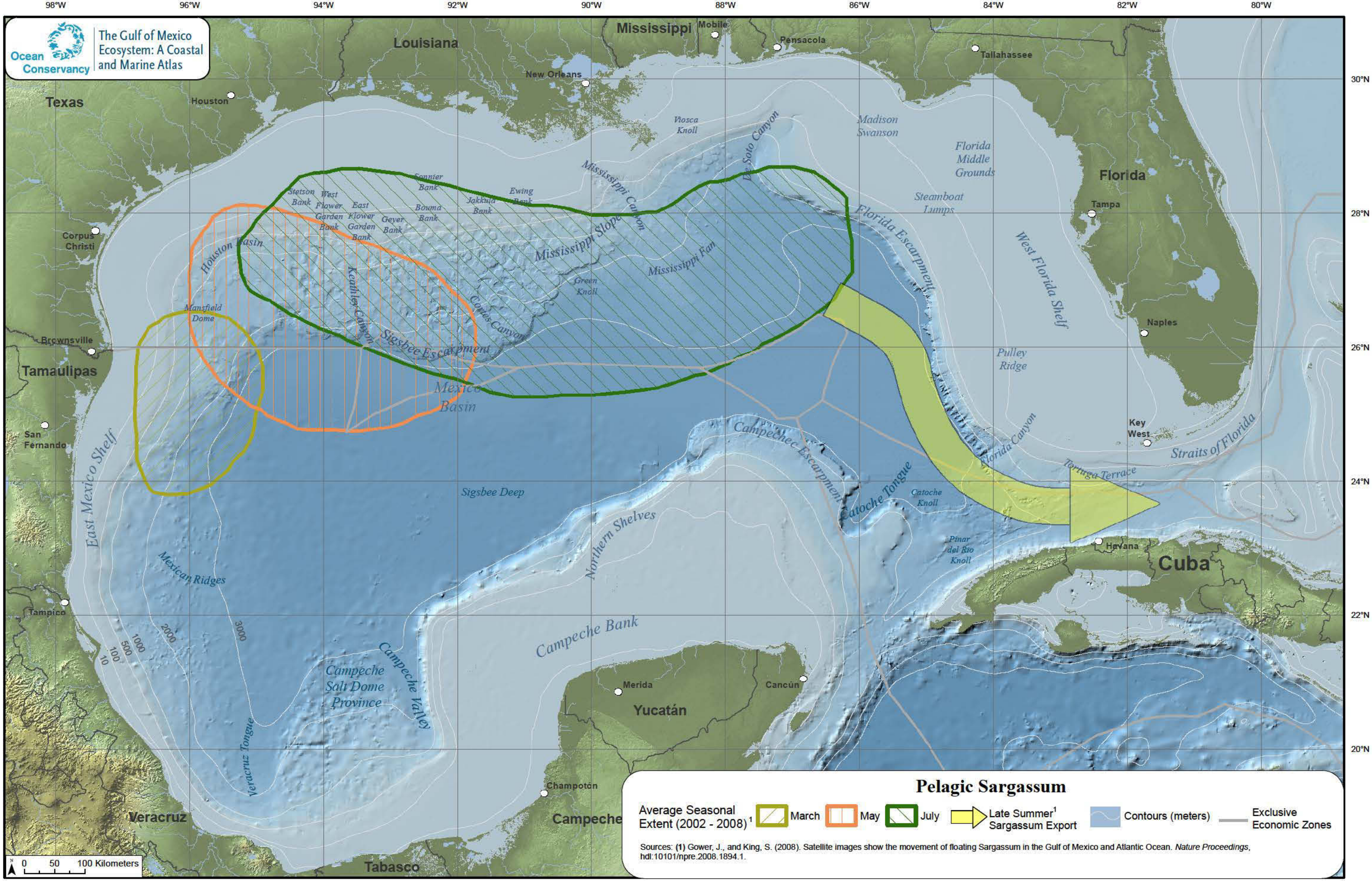
MAP 13 *(next page)***. PELAGIC SARGASSUM**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Pelagic Sargassum
Average Seasonal Extent (2002 - 2008)[1]
March
May
July
Late Summer[1] Sargassum Export
Contours (meters)
Exclusive Economic Zones
Sources: (1) Gower, J., and King, S. (2008). Satellite images show the movement of floating Sargassum in the Gulf of Mexico and Atlantic Ocean. Nature Proceedings, hdl:10101/npre.2008.1894.1.
0 50 100 Kilometers
98°W
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86°W
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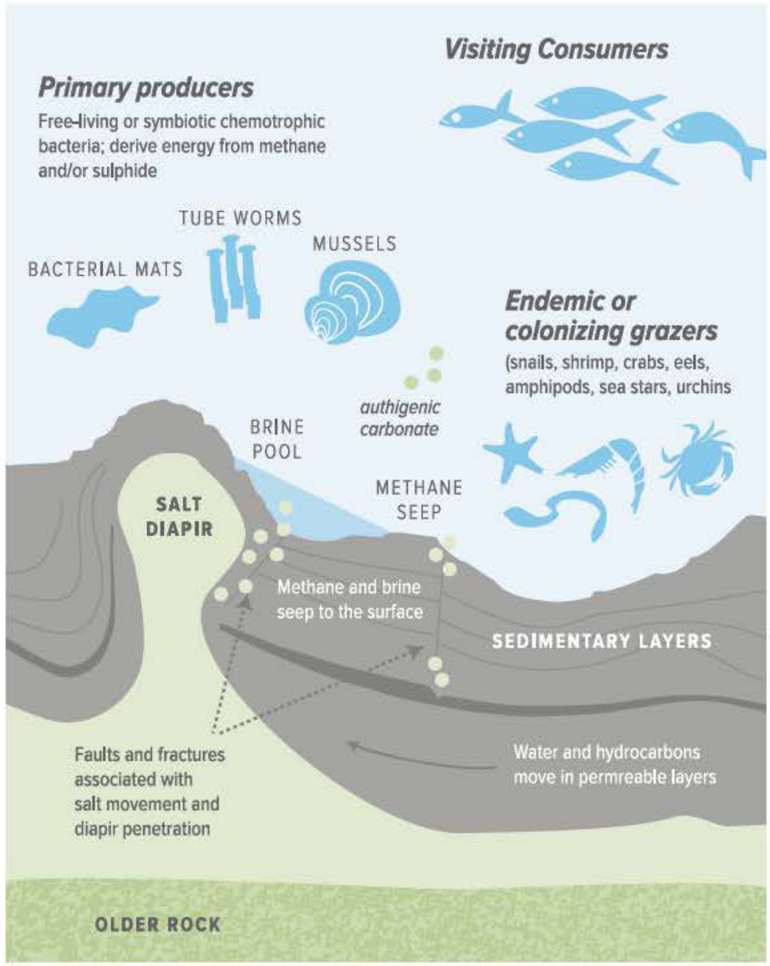
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Viosca Knoll
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Keathley Canyon
Green Knoll
Mansfield Dome
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
East Mexico Shelf
Mexican Ridges
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
500
1000
2000
3000

3.6 Hydrocarbon Seeps & Chemosynthetic Communities

Description

The Gulf of Mexico is the most active area in the world for natural submarine hydrocarbon and brine seepages. These are sometimes called cold seeps to distinguish them from submarine hydrothermal or hot seeps associated with mid-ocean ridges and other areas where magma comes up close to the sea bottom. Map 14 shows the numerous reported seepages in the Gulf. Hydrocarbon seeps (areas where oil and natural gas slowly leak out of the seafloor) are very common on the continental shelf and slope in the north-central Gulf, especially on the continental slope areas off of Texas and Louisiana, where intense seepage activity occurs. As much as 16 million gallons of oil per year seep naturally into the Gulf (I. MacDonald, personal communication, 2012). Brine seeps occur over salt-core diapirs (intrusions of ancient brine into the surface layers of the ocean sediment) and are scattered over the shelf break and continental slope of the northern Gulf.



A diagram of a cold-seep community on the continental slope associated with petroleum seepage from a salt diapir, or salt dome, showing fauna that utilize seepage and accompanying geochemical fluids. Credit: *Restoring the Gulf of Mexico* / Ocean Conservancy

The cold-seep chemosynthetic communities associated with oil and gas seepage and brine seepage stand out as areas of unusually high biological activity on the mostly homogeneous deep-sea muddy bottoms of the continental slope. Cold-seep chemosynthetic communities depend on methane and hydrogen sulfide for their energy rather than light and are largely independent of shallow-water photosynthetic-dependent communities near the ocean surface (Childress et al., 1986; Fisher et al., 1987). The dominant organisms in these slope communities are either mussels or vestimentiferan worms (pogonophorans). In one case, chemosynthetic-dependent mussels live at the edge of these hypersaline methane-rich pools at a depth of 650 meters (about 2100 feet) on the continental slope (MacDonald et al., 1990). Cold seeps support mussels and vestimentiferan worms that provide structure and habitats for diverse associations of benthic animals in an environment lacking much habitat diversity (Berquist et al., 2003). Similar biocenoses involving chemosynthetic bacterial mats in hydrocarbon seeps are apparently common on the upper continental shelf of the Gulf (Sassen et al., 1993).

Hard-bottom habitat is also scattered along the continental slope. It consists of authigenic (generated where found) carbonate deposits that form through the combined activities of sulfate-reducing and methane-oxidizing bacteria in areas of natural gas seepage. These elevated carbonate-based substrates allow large fixed animals to settle and grow, including ahermatypic (cold-water) corals, gorgonians, sponges, hydroids and anemones. These hard-bottom communities appear to be the climax in a biological succession of colonizing organisms near hydrocarbon seepages. The corals, gorgonians and anemones inhabiting these substrates are not nutritionally dependent on the chemosynthetic processes in the seeps that once supported the original colonizers (e.g., bacteria, tube worms, mussels, etc.) (Continental Shelf Associates International, Inc., 2007). The degree to which seep communities interact with one another and the rest of the Gulf ecosystem is unknown (Becker, 2012).

See related maps and narratives on Bathymetry, Corals, Oil and Gas Distribution, and Current U.S. Oil and Gas Leases and International Activity.

Data Compilation and Mapping Methods

Multiple datasets were used on this map to illustrate the distribution of hydrocarbon seeps and chemosynthetic communities. Hydrocarbon seep data were derived from seafloor seismic surveys and satellite-based detections of slicks on the surface of the Gulf. Seismic surveys conducted by the Bureau of Ocean Energy Management (BOEM) have resulted in the mapping of more than 25,000 seafloor seismic amplitude anomalies in the deep northern Gulf. More than 19,000 instances were detected from the presence of carbonate-hard grounds created by bacteria living off the hydrocarbon in the sediments at these seeps (BOEM, 2012). The satellite-based detections of seeps are from backscatter anomalies (surface slicks) observed using satellite synthetic aperture radar (SAR) images (Mitchell et al., 1999; MacDonald et al., 2004). These anomalies were judged to be floating oil, naturally released from seafloor sources based on the consistency of their shapes and locations on the sea surface (SarSea Ocean Imaging, 2012). Data for chemosynthetic communities were obtained from the NOAA Gulf of Mexico Data Atlas. These data represent known sites of chemosynthetic communities in the northern Gulf compiled by BOEM from a variety of reports and surveys.

Data Quality

This map has fair data quality for seafloor seismic detections of hydrocarbon seeps due to the limited geographic extent of these surveys, which are restricted to the north-central Gulf. No data are provided for areas outside of the north-central Gulf region. Data quality rating for SAR-detected slicks from natural seeps is good because data are provided for the full Gulf at a constant resolution. The data quality for the chemosynthetic communities is fair in U.S. waters. Data for Mexico and Cuba waters were not available.

Synthesis and Conclusions

Hydrocarbon seeps account for a small area of the seafloor compared to the flat mud bottom that characterizes the majority of the Gulf. They contain an astounding density of life due to their important role as sources of primary productivity for chemosynthetic communities. Studying the interactions among animals within seep ecosystems, especially food web interactions, is important for understanding the function of seep ecosystems (Becker, 2012). Our current understanding of seep ecosystems is fragmented, in part due to the relative inaccessibility of these ecosystems, as it requires advanced and expensive submarine technologies to study them.

Natural petroleum seeps also have economic significance in identifying potential oil reserves (Etiope, 2009). Historically, these seeps have been drivers of global petroleum exploration. Assessing remotely the origin of seeping gas is key for understanding subsurface hydrocarbon potential, genesis and quality (Etiope, 2009).

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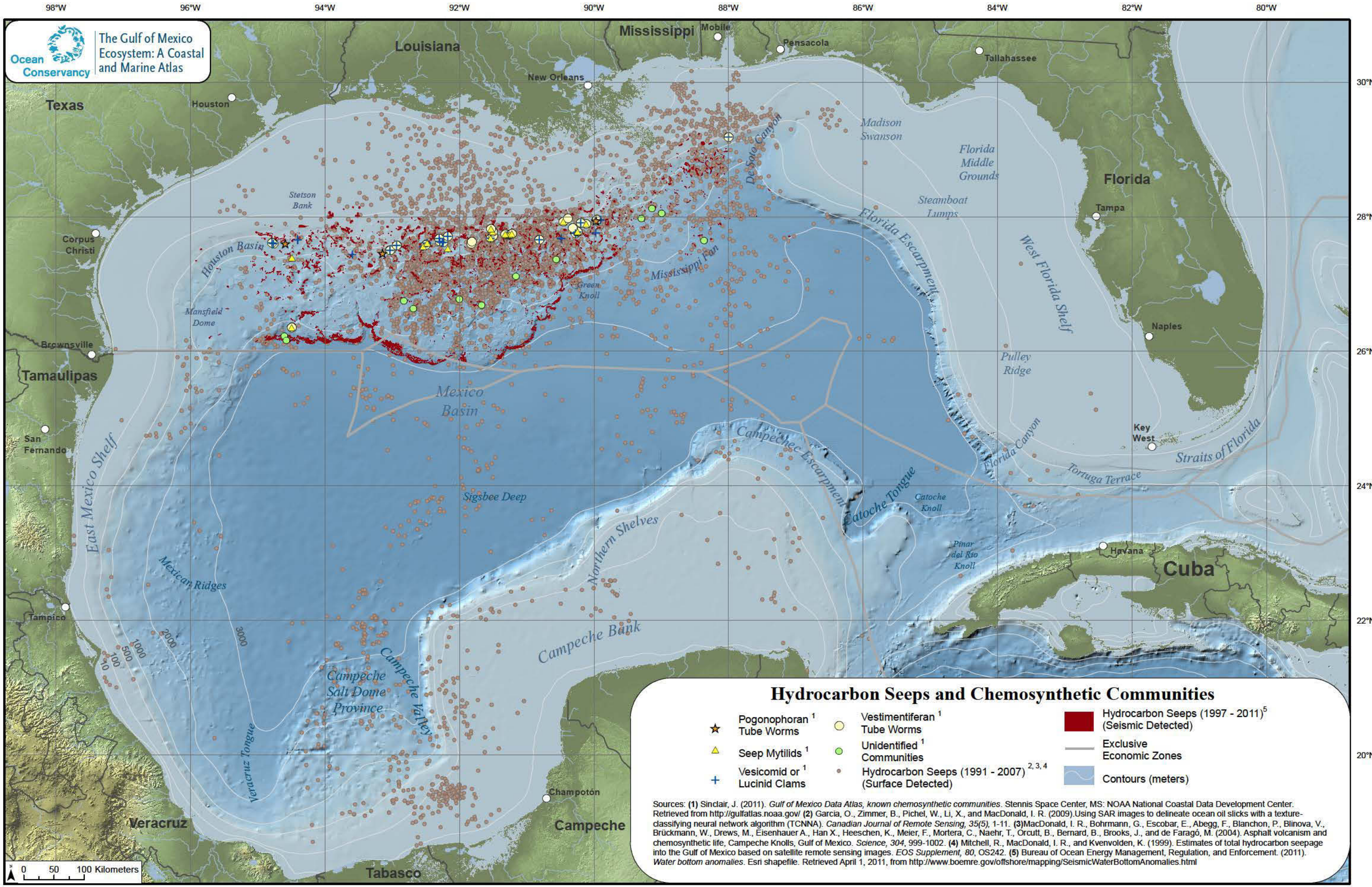
MAP 14 *(next page)*. **HYDROCARBON SEEPS AND CHEMOSYNTHETIC COMMUNITIES**


The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
Hydrocarbon Seeps and Chemosynthetic Communities
Pogonophoran [1] Tube Worms
Seep Mytilids [1]
Vesicomid or [1] Lucinid Clams
Vestimentiferan [1] Tube Worms
Unidentified [1] Communities
Hydrocarbon Seeps (1991 - 2007) [2, 3, 4] (Surface Detected)
Hydrocarbon Seeps (1997 - 2011) [5] (Seismic Detected)
Exclusive Economic Zones
Contours (meters)
Sources: **(1)** Sinclair, J. (2011). *Gulf of Mexico Data Atlas, known chemosynthetic communities*. Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retrieved from http://gulfatlas.noaa.gov/ **(2)** Garcia, O., Zimmer, B., Pichel, W., Li, X., and MacDonald, I. R. (2009).Using SAR images to delineate ocean oil slicks with a texture-classifying neural network algorithm (TCNNA). *Canadian Journal of Remote Sensing, 35(5)*, 1-11. **(3)**MacDonald, I. R., Bohrmann, G., Escobar, E., Abegg, F., Blanchon, P., Blinova, V., Brückmann, W., Drews, M., Eisenhauer A., Han X., Heeschen, K., Meier, F., Mortera, C., Naehr, T., Orcutt, B., Bernard, B., Brooks, J., and de Faragó, M. (2004). Asphalt volcanism and chemosynthetic life, Campeche Knolls, Gulf of Mexico. *Science, 304*, 999-1002. **(4)** Mitchell, R., MacDonald, I. R., and Kvenvolden, K. (1999). Estimates of total hydrocarbon seepage into the Gulf of Mexico based on satellite remote sensing images. *EOS Supplement, 80*, OS242. **(5)** Bureau of Ocean Energy Management, Regulation, and Enforcement. (2011). *Water bottom anomalies*. Esri shapefile. Retrieved April 1, 2011, from http://www.boemre.gov/offshore/mapping/SeismicWaterBottomAnomalies.html
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80°W
30°N
28°N
26°N
24°N
22°N
20°N
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
New Orleans
Texas
Houston
Florida
Tampa
Naples
Key West
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champotón
Havana
Cuba
Stetson Bank
Houston Basin
Mansfield Dome
Green Knoll
Mississippi Fan
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
East Mexico Shelf
Mexican Ridges
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
3000
2000
1000
500
100
10
0 50 100 Kilometers

Invertebrates

4.0 Brown Shrimp *Farfantepenaeus aztecus*

Description

Credit: Joel Sartore / National Geographic Stock

Brown shrimp occur off of the Atlantic Coast and the entire Gulf Coast. In the Gulf of Mexico, brown shrimp are present in coastal waters of the U.S. and extend into waters of Mexico as far as Campeche. In U.S. waters, brown shrimp are most abundant in the northern and northwestern Gulf off of the coasts of Louisiana and Texas (Map 15). Seagrasses, marshes, mangroves and other estuarine habitats are important feeding and nursery grounds for post-larval and juvenile brown shrimp. Adult brown shrimp are typically found offshore in marine habitats and favor soft bottoms of mud, sand and shell (NOAA, 2010). In offshore waters, brown shrimp travel primarily at night, especially near dusk, and burrow in the bottom substrate during the day (NOAA, 2010).

Brown shrimp have a reddish-brown shell and dark green and red tail-fan appendages. They generally grow to between 17 and 20 centimeters (6.5 to 7.5 inches) in length, with males being smaller than females. Brown shrimp typically have a life span of less than two years and reach sexual maturity when they are about 14 centimeters (5 inches) in length (Larson et al., 1989). A single female shrimp can release between 500,000 and 1 million eggs near the ocean floor and can reproduce more than once within a year (Pérez-Farfante, 1969). Wind-driven currents bring larval shrimp shoreward. During early spring, post-larval shrimp move into estuarine habitats where they feed and develop. Brown shrimp remain inshore until they are large enough to move offshore. Changing water temperatures and salinity trigger their return to deeper waters in May through August (Rogers et al., 1993; TPWD, 2002). Brown shrimp undergo the same development cycle as white shrimp, but migrate at slightly different times of the year.

Brown shrimp are omnivorous scavengers that consume algae, polychaetes, copepods, and various other invertebrates and organic debris. They are an important prey species for many finfish and crustaceans (Larson et al., 1989).

In federal waters, brown shrimp and three other shrimp species (white, pink and royal red) are managed by the Gulf of Mexico Fishery Management Council under a Shrimp Fishery Management Plan. In addition, each Gulf state manages brown shrimp in its respective jurisdiction by establishing seasons and gear requirements. Brown shrimp are the most valuable shrimp species caught in the Gulf (GMFMC, 2007). Currently, brown shrimp populations in the Gulf are not overfished or undergoing overfishing. The detection of the giant tiger prawn, a non-native species, in the Gulf could be a potential concern for native brown shrimp if competition or predation becomes an issue. Another concern is the area of seasonal low oxygen (or dead zone) in the northern Gulf that reduces available bottom habitats for this species (Craig et al., 2005).

See related maps and narratives on Salt Marshes and Mangrove Forests, White Shrimp, Low Oxygen Areas, Selected Non-Native Species of Concern, and Offshore Shrimp Trawl Fishery.

Data Compilation and Mapping Methods

Relative abundance data were obtained from the NOAA Gulf of Mexico Data Atlas. These data were compiled from the Southeast Area Monitoring and Assessment Program (SEAMAP), involving fishery-independent summer and fall shrimp and groundfish surveys administered by the Gulf States Marine Fisheries Commission and the National Marine Fisheries Service. These relative abundance data, represented as the number of shrimp caught per one-hour tow, were summarized from 11,637 40-foot (12-meter) shrimp trawls taken from 1987 through 2009.

Data Quality

The quality of these relative abundance data is good for U.S. waters due to the extent of sampling by the SEAMAP project and its consistent methods of data collection. Comparable data were not located for Mexico and Cuba.

Synthesis and Conclusions

Brown shrimp are an abundant species in estuarine habitats throughout most of the Gulf, and are also found offshore when spawning. Brown shrimp are an important part of the Gulf food web, serving as a food source for many animals. They support a valuable commercial fishery and are the most abundantly caught shrimp species in the Gulf. Further research is needed to evaluate the impacts of the giant tiger prawn and hypoxia on brown shrimp.

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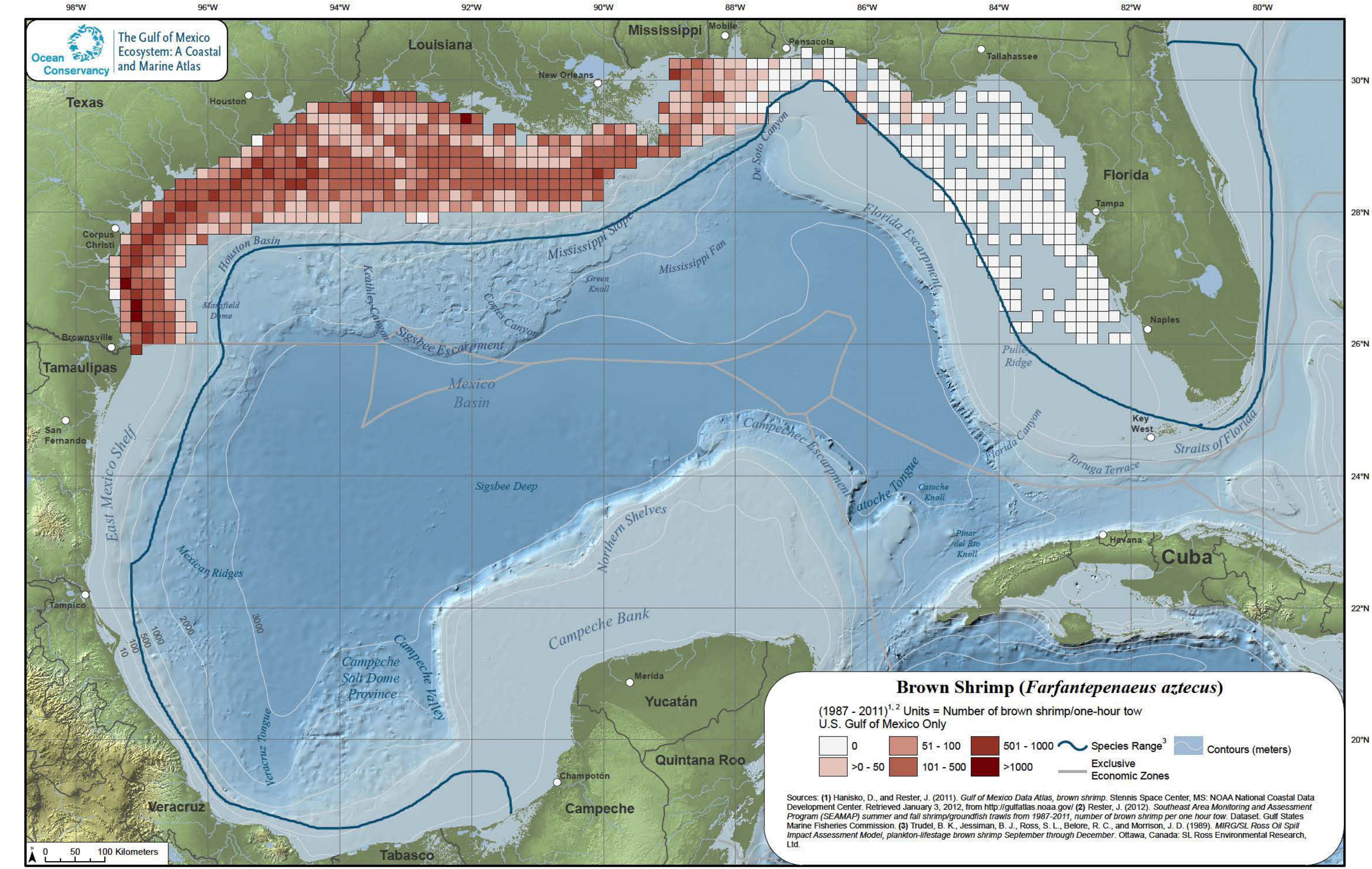
MAP 15 *(next page)*. **BROWN SHRIMP**


The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
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22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Houston Basin
Mississippi Slope
Mississippi Fan
De Soto Canyon
Florida Escarpment
Green Knoll
Keathley Canyon
Alaminos Canyon
Sigsbee Escarpment
Mansfield Dome
Mexico Basin
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Sigsbee Deep
East Mexico Shelf
Northern Shelves
Mexican Ridges
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Brown Shrimp (Farfantepenaeus aztecus)
(1987 - 2011)[1, 2] Units = Number of brown shrimp/one-hour tow
U.S. Gulf of Mexico Only
0
>0 - 50
51 - 100
101 - 500
501 - 1000
>1000
Species Range[3]
Exclusive Economic Zones
Contours (meters)
Sources: (1) Hanisko, D., and Rester, J. (2011). Gulf of Mexico Data Atlas, brown shrimp. Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retrieved January 3, 2012, from http://gulfatlas.noaa.gov/ (2) Rester, J. (2012). Southeast Area Monitoring and Assessment Program (SEAMAP) summer and fall shrimp/groundfish trawls from 1987-2011, number of brown shrimp per one hour tow. Dataset. Gulf States Marine Fisheries Commission. (3) Trudel, B. K., Jessiman, B. J., Ross, S. L., Belore, R. C., and Morrison, J. D. (1989). MIRG/SL Ross Oil Spill Impact Assessment Model, plankton-lifestage brown shrimp September through December. Ottawa, Canada: SL Ross Environmental Research, Ltd.

4.1 White Shrimp *Litopenaeus setiferus*

Description

White shrimp occur off of the Gulf Coast from the Ochlochonee River on the coast of Florida to Campeche, Mexico (Muncy, 1984). They can also be found on the U.S. Atlantic Coast. White shrimp are most abundant in areas with extensive estuarine marshes and are in great abundance in the Mississippi River Delta of Louisiana (Map 16). Seagrasses, marshes and mangroves are important feeding and nursery habitats for post-larval white shrimp. Adult white shrimp are typically found offshore in marine habitats and favor soft bottoms of mud, sand and shell (NOAA, 2010). White shrimp are most common in water less than roughly 30 meters (100 feet), and when compared to brown and pink shrimp, tend to occur higher in the water column (Muncy, 1984).

Their shell color ranges from white to greenish-gray, and they can be distinguished from other shrimp species by their long antennae and darker tail-fan appendages. White shrimp are generally between 17 and 20 centimeters (7 to 8 inches) in length. White shrimp have a life span of less than two years, and reach sexually maturity when they are between 10 and 14 centimeters (4 to 5.5 inches) in length (Muncy, 1984). A single female shrimp can release about 500,000 to 1 million eggs per spawn, and can spawn more than once a year (Pérez-Farfante, 1969). Therefore, a relatively small number of spawning adults have the potential to support a large-year class (Nance et al., 2010). Wind-driven currents during the summer bring larval shrimp shoreward. Post-larval shrimp settle into estuarine habitats with shallow muddy bottoms and low to moderate salinity (Muncy, 1984). Once mature, adult shrimp return to offshore waters to spawn, which peaks from May to August (Diop et al., 2007). White shrimp undergo the same development cycle as brown shrimp, but migrate at slightly different times of the year.

White shrimp are omnivorous scavengers. They consume algae, polychaetes, copepods, and various other invertebrates and organic debris. White shrimp are important prey for finfish and blue crabs (NOAA, 2010).

Credit: NOAA

In federal waters, white shrimp and three other shrimp species (brown, pink and royal red) are managed by the Gulf of Mexico Fishery Management Council under a Shrimp Fishery Management Plan. In addition, each Gulf state manages white shrimp in its respective jurisdiction by establishing seasons and gear requirements. White shrimp are the second-most valuable shrimp species harvested in the Gulf (GMFMC, 2007). Currently, white shrimp populations in the Gulf are not overfished or undergoing overfishing. The detection of the giant tiger prawn, a non-native species, in the Gulf could be a potential concern for native white shrimp if competition or predation becomes an issue. Another concern is the area of seasonal low oxygen (or dead zone) in the northern Gulf that reduces available bottom habitats for brown shrimp and possibly white shrimp as well (Craig et al., 2005).

See related maps and narratives on Salt Marshes and Mangrove Forests, Brown Shrimp, Low Oxygen Areas, Selected Non-Native Species of Concern, and Offshore Shrimp Trawl Fishery.

Data Compilation and Mapping Methods

Relative abundance data were obtained from the NOAA Gulf of Mexico Data Atlas. These data were compiled from the Southeast Area Monitoring and Assessment Program (SEAMAP) along with independent summer and fall shrimp and groundfish surveys by the Gulf States Marine Fisheries Commission and the National Marine Fisheries Service. These relative abundance data were summarized from 11,637 shrimp trawls (40-feet [12-meters] deep) taken from 1987 through 2009. Relative abundance is expressed in catch per unit effort, which represents the number of shrimp caught per one-hour tow.

Data Quality

The quality of these relative abundance data is good for U.S. waters due to the extent of sampling by the SEAMAP project and its consistent methodologies. Comparable data were not located for Mexico and Cuba.

Synthesis and Conclusions

White shrimp are an abundant species found in estuarine habitats throughout most of the Gulf as well as offshore when spawning. White shrimp are an important part of the Gulf food web, serving as a food source for many animals. Known as the second-most abundantly caught shrimp species in the Gulf, white shrimp support a valuable commercial fishery. Further research is needed to evaluate the impacts of the giant tiger prawn and hypoxia on white shrimp.

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Map Data Sources

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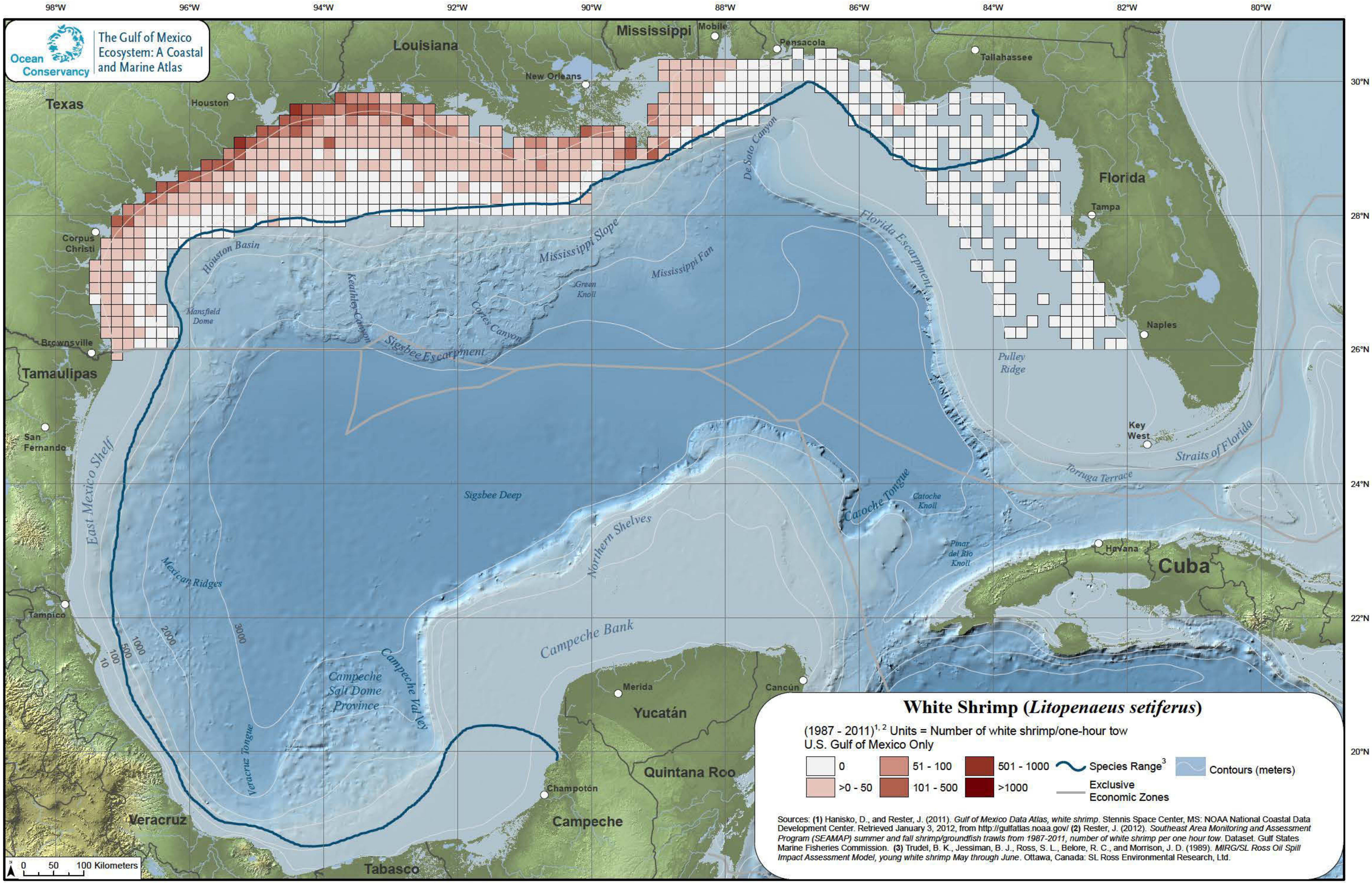
MAP 16 *(next page)***. WHITE SHRIMP**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
White Shrimp (Litopenaeus setiferus)
(1987 - 2011)[1, 2] Units = Number of white shrimp/one-hour tow
U.S. Gulf of Mexico Only
0
>0 - 50
51 - 100
101 - 500
501 - 1000
>1000
Species Range[3]
Exclusive Economic Zones
Contours (meters)
Sources: (1) Hanisko, D., and Rester, J. (2011). Gulf of Mexico Data Atlas, white shrimp. Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retrieved January 3, 2012, from http://gulfatlas.noaa.gov/ (2) Rester, J. (2012). Southeast Area Monitoring and Assessment Program (SEAMAP) summer and fall shrimp/groundfish trawls from 1987-2011, number of white shrimp per one hour tow. Dataset. Gulf States Marine Fisheries Commission. (3) Trudel, B. K., Jessiman, B. J., Ross, S. L., Belore, R. C., and Morrison, J. D. (1989). MIRG/SL Ross Oil Spill Impact Assessment Model, young white shrimp May through June. Ottawa, Canada: SL Ross Environmental Research, Ltd.
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Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Houston Basin
Mississippi Slope
Mississippi Fan
De Soto Canyon
Florida Escarpment
Green Knoll
Mansfield Dome
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Pulley Ridge
Straits of Florida
Tortuga Terrace
Sigsbee Deep
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
East Mexico Shelf
Mexican Ridges
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
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4.2 Royal Red Shrimp *Pleoticus robustus*

Credit: NOAA

Description

Royal red shrimp, also known as deep-sea shrimp, occur throughout the Gulf of Mexico and off of the Atlantic coast from Massachusetts to French Guiana in South America. Royal red shrimp are present in the Gulf at 180 to 600 meter depths (590 to 1,968 feet), and concentrations are found between 250 and 475 meters (820 to 1,558 feet) (Anderson and Linder, 1971) (Map 17). Royal red shrimp are often found in areas with blue-black mud, sand, muddy sand or white calcareous mud, and may be found among deep-sea corals. More specifically, concentrations occur off of the Dry Tortugas in the Florida Straits and off of the Mississippi River Delta (Anderson & Lindner, 1971). The Gulf Stream is important for dispersal of royal red shrimp larvae.

Royal red shrimp reach maturity at about 3 years and have a minimum lifespan of about 5 years (Anderson & Lindner, 1971). They reach a maximum length of about 18 to 23 centimeters (7 to 9 inches) (Klima, 1969).

Fishermen target royal red shrimp primarily off of the coasts of Louisiana, Mississippi, Alabama and Florida. Royal red shrimp occupy a niche market and represent a small proportion of the Gulf and Southeast U.S. shrimp industries. From 2000 through 2007, the number of vessels in this trawl fishery fluctuated between four and 15. In 1981, the Gulf of Mexico Fishery Management Council (GMFMC) included royal red shrimp in its Shrimp Fishery Management Plan. In 2002, the GMFMC required commercial vessels to have permits for royal red shrimp and prohibited the use of traps to harvest royal reds due to potential gear conflicts and the increased possibility of exceeding maximum sustainable yield. In 2005, the GMFMC reestablished overfishing criteria and total allowable catch levels for royal red shrimp (GMFMC, 2005). The National Marine Fisheries Service has not conducted a full stock assessment on royal red shrimp because biological and fisheries data have not been collected and are not available for such an assessment. As a result, neither the effects of fishing on royal red populations nor its overall population status is known. The scientific research needed to aid management of this fishery (e.g., age structure of the stock, critical habitats, migratory habits and mortality data) has been limited due to the small number of participants, niche market, seasonal nature and remote location of operations.

See related maps and narratives on Bathymetry, Corals and Offshore Shrimp Trawl Fishery.

Data Compilation and Mapping Methods

Map 17 is based on locations of commercial trawling for royal red shrimp and published species ranges. The published range data were obtained from the Gulf of Mexico Coastal and Ocean Zones Strategic Assessment: Data Atlas (1985) and defined by depth range for the entire Gulf. The published depth ranges for the two zones of royal red occurrence were extracted from the bathymetric dataset (Map 2). The first zone is the depth range of occurrence, and the second is the area of greatest abundance throughout its known distribution in the Gulf. Combined, the first and second zones represent its entire estimated habitat. Commercial trawling data represent a subsample of all federally permitted shrimp trawling vessels during the period 2004 to 2011. A trawl was identified as targeting royal red shrimp if it occurred at depths royal red shrimp inhabit and was considered too deep for other commercially viable shrimp species. These trawls were then aggregated and defined as commercial catch areas for royal red shrimp.

Data Quality

Data quality for this map is considered fair, due to an absence of relative abundance delineation for this species. Published depth ranges were the best source identified for defining primary habitat, but other ecological factors beyond depth likely define primary habitat and range for this species; however, information on these potential factors is sparse in the scientific literature.

Data quality for the commercial catch area is considered good in U.S. waters, but poor outside the U.S. exclusive economic zone in the Gulf. The electronic logbook (ELB) program monitors the location of a subsample of the commercial shrimp fishing fleet in U.S. federal waters. All royal red shrimp fishing in the U.S. occurs in federal waters. While not all vessels carry ELB recorders and the vessels that pursue royal red shrimp are relatively few, the percentage of the fleet that has ELB recorders is considered adequate by fisheries managers to produce statistically valid fishing effort and catch estimates for shrimp.

Synthesis and Conclusions

Royal red shrimp are distributed over a large geographic area but in poorly understood deep-sea habitats in the Gulf. Concentrations occur off of the Dry Tortugas in the Florida Straits and off of the Mississippi River Delta. The scientific research needed to aid management of this fishery (e.g., age structure of the stock, distribution, critical habitats, abundance, migratory habits and mortality rates) has been limited due to the small number of fishermen, the niche market, and the seasonal nature and remote location of fishing operations. This limitation highlights the need for marine habitat mapping and ecosystem-based management that encompasses deep-sea habitats, species and related human uses (Cogan et al., 2009).

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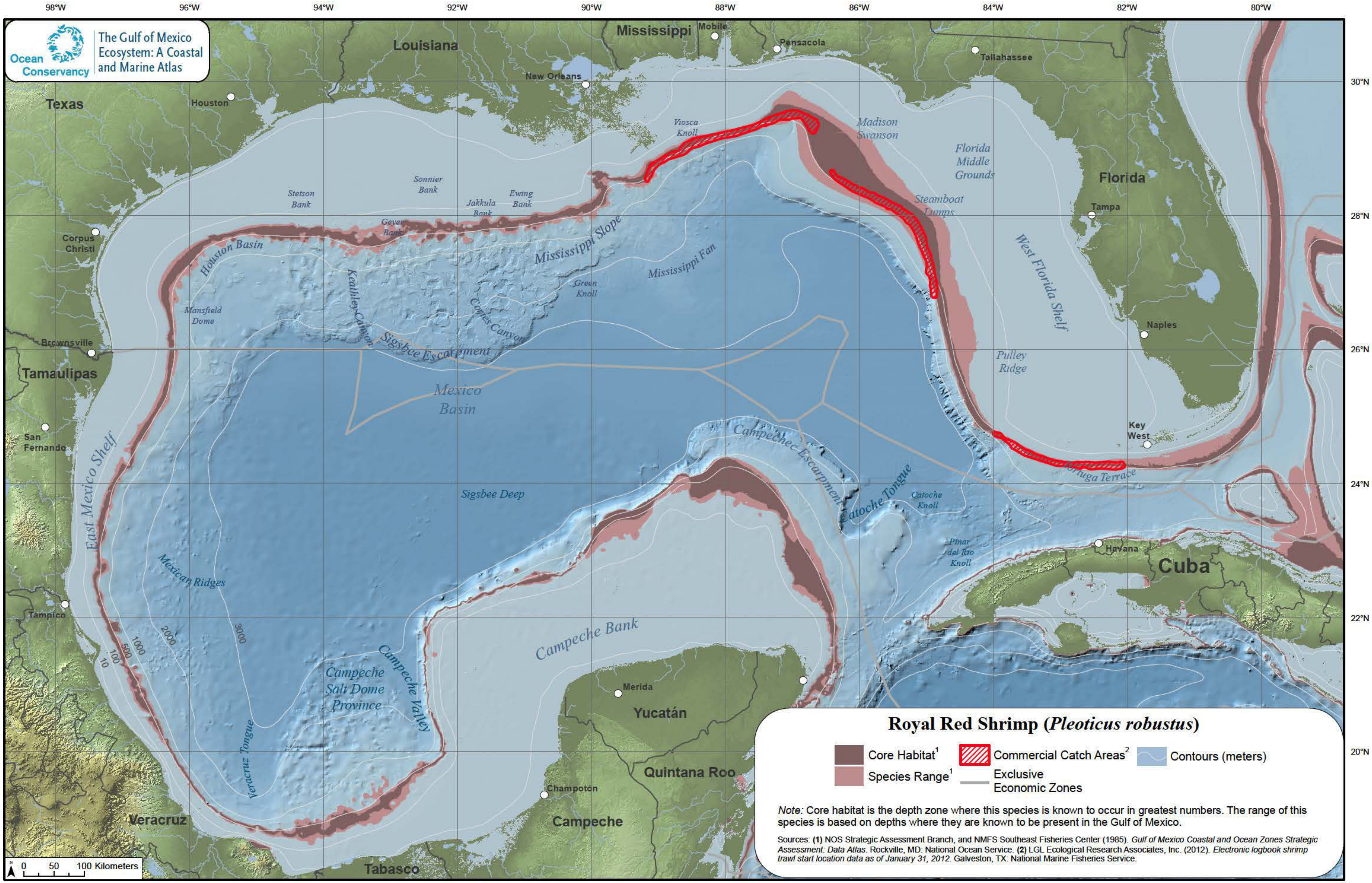
Map Data Sources

LGL Ecological Research Associates, Inc. (2012). *Electronic logbook shrimp trawl start location data as of January 31, 2012*. Galveston, TX: National Marine Fisheries Service.

NOS Strategic Assessment Branch, & NMFS Southeast Fisheries Center. (1985). *Gulf of Mexico Coastal and Ocean Zones Strategic Assessment: Data Atlas.* Rockville, MD: National Ocean Service.

MAP 17 *(next page)*. **ROYAL RED SHRIMP**


Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
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26°N
24°N
22°N
20°N
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
New Orleans
Texas
Houston
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champotón
Merida
Yucatán
Quintana Roo
Florida
Tampa
Naples
Key West
Havana
Cuba
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
West Florida Shelf
Pulley Ridge
Tortuga Terrace
Stetson Bank
Sonnier Bank
Jakkula Bank
Ewing Bank
Geyer Bank
Houston Basin
Mississippi Slope
Mississippi Fan
Green Knoll
Mansfield Dome
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
East Mexico Shelf
Mexican Ridges
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Royal Red Shrimp (Pleoticus robustus)
Core Habitat[1]
Species Range[1]
Commercial Catch Areas[2]
Exclusive Economic Zones
Contours (meters)
Note: Core habitat is the depth zone where this species is known to occur in greatest numbers. The range of this species is based on depths where they are known to be present in the Gulf of Mexico.
Sources: (1) NOS Strategic Assessment Branch, and NMFS Southeast Fisheries Center (1985). Gulf of Mexico Coastal and Ocean Zones Strategic Assessment: Data Atlas. Rockville, MD: National Ocean Service. (2) LGL Ecological Research Associates, Inc. (2012). Electronic logbook shrimp trawl start location data as of January 31, 2012. Galveston, TX: National Marine Fisheries Service.

4.3 Blue Crab *Callinectes sapidus*

Description

Blue crab on Dauphin Island, Alabama. Credit: Melissa Hanes / Shutterstock

Blue crabs are found from Nova Scotia to northern Argentina (GSMFC, 2001). In the Gulf of Mexico, they are present along the entire U.S. coastline and as far south as Campeche, Mexico (Map 18). Blue crabs depend on Gulf waters during all life stages. They are bottom dwellers found from nearshore marshes to offshore waters down to depths of about 40 meters (130 feet). Juveniles generally prefer shallow soft mud sediments where they can burrow into the substrate for protection from predators. Mature males generally inhabit lower-salinity habitats, such as creeks, rivers and upper estuaries while mature females generally move to higher salinity areas, such as lower estuaries and adjacent marine waters to spawn (Tankersley et al., 1998).

Mating typically occurs in brackish water and peaks in spring and summer. Males mate often, but female blue crabs mate only once in their lives during their final molt and store sperm for future spawning. Females spawn at least twice in their lifetime (GSMFC, 2001). Fertilized eggs are carried under the female's abdomen in a large, cohesive mass called a sponge. As the eggs develop, females travel to saltier water in search of offshore currents, which carry larval blue crabs into the open Gulf. After developing offshore into juvenile crabs, they will migrate back into brackish regions to grow and mature. Crabs in the Gulf may reach sexual maturity within a year (Perry & McIlwain, 1986).

Blue crabs are a keystone species that play critical roles as both prey and predator. They eat a wide variety of foods, captured alive or recently dead, including clams, snails, oysters, mussels, shrimp, crabs, fish and vegetation. Furthermore, blue crabs are important predators of oyster drills and mud crabs, both of which are oyster predators. At all life stages, blue crabs are key food sources for a variety of animals. Numerous fishes eat blue crab eggs. Fish, shellfish, jellyfish, juvenile blue crabs, shrimp and other organisms consume blue crab larvae. Drums, bass, croakers, sharks, trout, weakfish, gars, other blue crabs, turtles, seabirds and a number of other predators eat juvenile and adult blue crabs (GSMFC, 2001).

Blue crabs support one of the largest commercial and recreational fisheries in the Gulf, and coastal Louisiana is a major blue crab production area (GSMFC, 2001). Annual commercial landings in Louisiana average approximately 19,400 metric tons (over 42.8 million pounds), which is 24 percent of the total blue crab landings for the nation (NMFS, 2013). Although the blue crab population appears to be stable in the Gulf, there are no comprehensive and reliable Gulf-wide commercial or recreational catch and effort data with which to assess population health across each Gulf state (GSMFC, 2001). Furthermore, there are no Gulf-wide data on size and sex composition of commercial landings or on age structure for this species (GSMFC, 2001).

See related maps and narratives on Salinity and River Flow, Salt Marshes and Mangrove Forests, and Seagrasses.

Data Compilation and Mapping Methods

Abundance data were obtained from the Gulf States Marine Fisheries Commission's Southeast Area Monitoring and Assessment Program (SEAMAP), which conducts fishery-independent surveys in summer and fall for shrimp and groundfish. These abundance data were summarized from 40-foot trawls that sampled the Gulf from 1987 through 2009 and represent the offshore occurrence of blue crabs in the summer and fall, but do not include data from nearshore or estuarine waters. The blue crab data provided from this sampling were standardized to kilograms of blue crabs captured per one-hour tow time. To provide a better view of the distribution of blue crab abundance, these data were interpolated from point samples to a two-dimensional surface using ordinary kriging. This method provides a probabilistic estimation of unsampled locations using sample data to show a statistical representation of the area inclusive of all SEAMAP samples.

Data Quality

The quality of these abundance data is good for U.S. offshore waters due to the extent of sampling by the SEAMAP project and consistent methodologies used. Analogous data were not located for Mexico and Cuba. The quality of these data for nearshore and estuarine waters of all three countries is poor. While data for inshore and estuarine waters are available from fishery-independent monitoring programs or specific research projects in U.S. states, the lack of standardized sampling among states or projects limits the comparability of these data sets for Gulf-wide use.

Synthesis and Conclusions

Blue crabs are a widespread and abundant species in the Gulf. They fill important prey and predator roles in the food web. The blue crab population appears to be stable in the Gulf. However, due to the sampling differences among Gulf states' fishery-independent monitoring programs, comprehensive and consistently sampled Gulf-wide commercial or recreational catch and effort data for nearshore areas are not readily available for population assessments. Furthermore, Gulf-wide data on size and sex composition of commercial landings and information on age structure do not exist. More information is needed on the ecosystem role of blue crabs, their contribution to the food web, and the composition of commercial and recreational blue crab catch data. Continued monitoring and research on the acute and sublethal effects of the BP Deepwater Horizon oil disaster on blue crabs are essential to conservation and ecosystem preservation efforts.

Text Citations

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Map Data Sources

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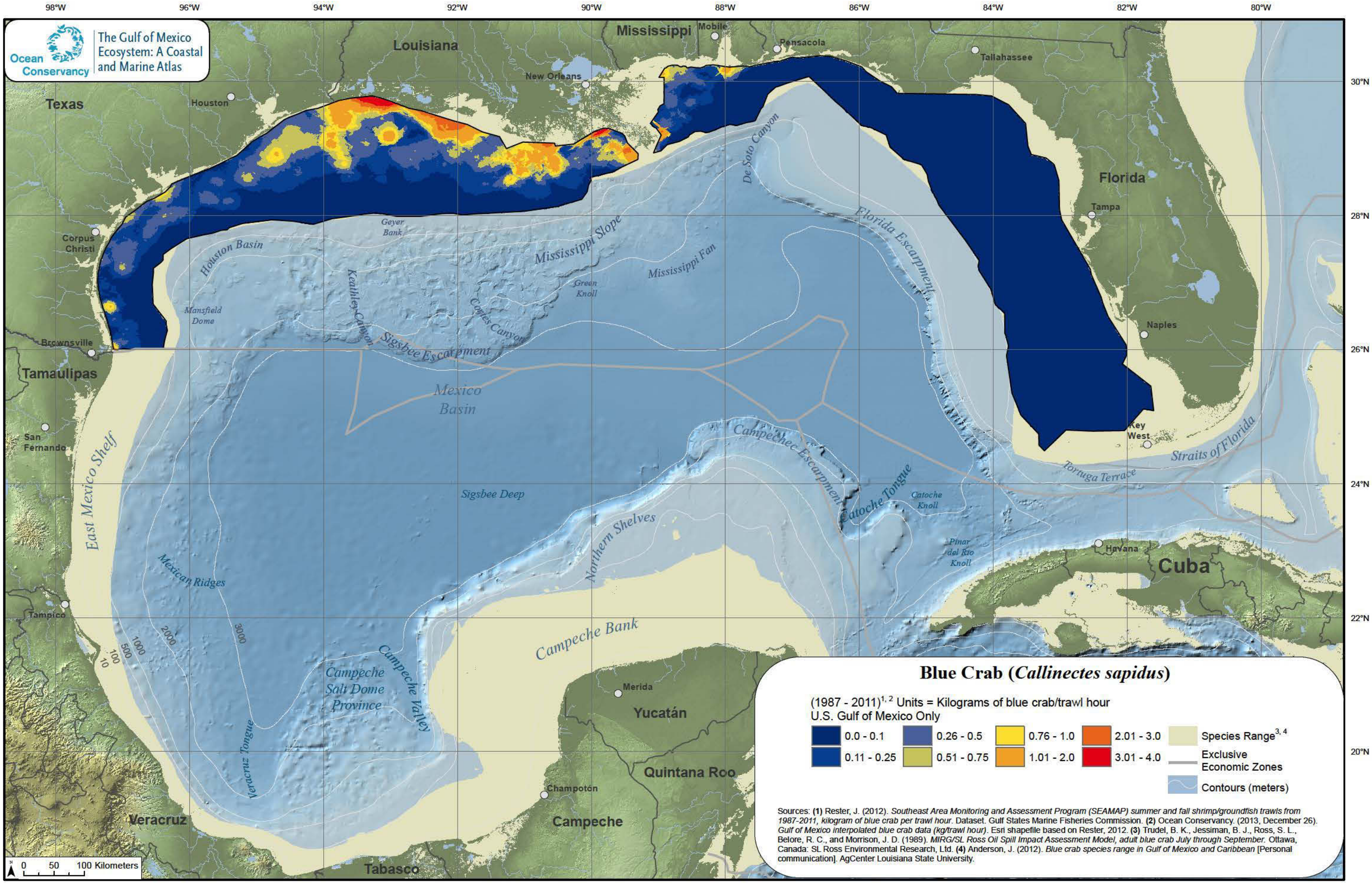
Rester, J. (2012). *Southeast Area Monitoring and Assessment Program (SEAMAP) summer and fall shrimp/ groundfish trawls from 1987-2011, kilogram of blue crab per trawl hour*. Dataset. Gulf States Marine Fisheries Commission.

Trudel, B. K., Jessiman, B. J., Ross, S. L., Belore, R. C., & Morrison, J. D. (1989). *MIRG/SL Ross Oil Spill Impact Assessment Model, adult blue crab July through September*. Ottawa, Canada: SL Ross Environmental Research, Ltd.

MAP 18 *(next page)***. BLUE CRAB**



The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
Blue Crab (*Callinectes sapidus*)
(1987 - 2011)[1, 2] Units = Kilograms of blue crab/trawl hour
U.S. Gulf of Mexico Only
0.0 - 0.1
0.11 - 0.25
0.26 - 0.5
0.51 - 0.75
0.76 - 1.0
1.01 - 2.0
2.01 - 3.0
3.01 - 4.0
Species Range[3, 4]
Exclusive Economic Zones
Contours (meters)
Sources: **(1)** Rester, J. (2012). *Southeast Area Monitoring and Assessment Program (SEAMAP) summer and fall shrimp/groundfish trawls from 1987-2011, kilogram of blue crab per trawl hour.* Dataset. Gulf States Marine Fisheries Commission. **(2)** Ocean Conservancy. (2013, December 26). *Gulf of Mexico interpolated blue crab data (kg/trawl hour).* Esri shapefile based on Rester, 2012. **(3)** Trudel, B. K., Jessiman, B. J., Ross, S. L., Belore, R. C., and Morrison, J. D. (1989). *MIRG/SL Ross Oil Spill Impact Assessment Model, adult blue crab July through September.* Ottawa, Canada: SL Ross Environmental Research, Ltd. **(4)** Anderson, J. (2012). *Blue crab species range in Gulf of Mexico and Caribbean* [Personal communication]. AgCenter Louisiana State University.
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20°N
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Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Houston Basin
Geyer Bank
Mississippi Slope
Mississippi Fan
De Soto Canyon
Florida Escarpment
Green Knoll
Mansfield Dome
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Tortuga Terrace
Straits of Florida
Northern Shelves
East Mexico Shelf
Mexican Ridges
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
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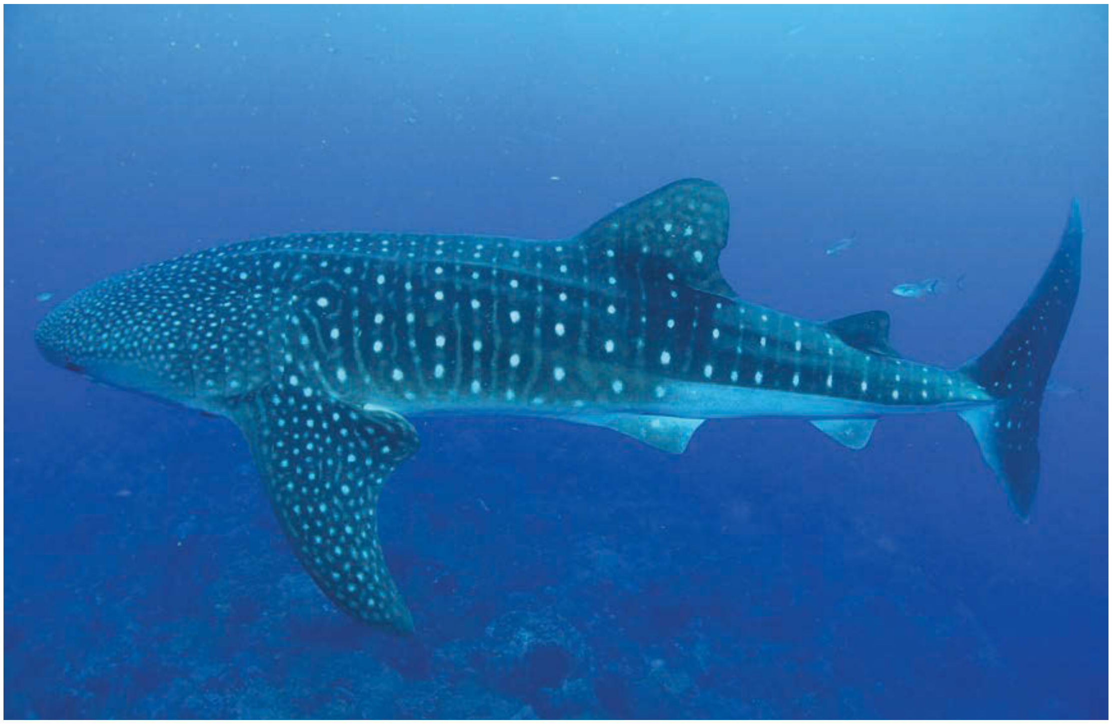
Fish

5.0 Whale Shark *Rhincodon typus*



A whale shark swims at the West Flower Garden Bank in the Gulf of Mexico. Credit: Ryan Eckert / Flower Garden Banks National Marine Sanctuary

Description

Whale sharks, the world's largest fish, occur throughout the Gulf of Mexico with the highest concentrations off of the Mississippi River Delta (McKinney et al., 2012) and the northern Yucatán Peninsula (de la Parra Venegas et al., 2011) (Map 19). This species is highly migratory and has a wide distribution, inhabiting all tropical and warm temperate seas with the exception of the Mediterranean Sea (Compagno, 1984). In the Gulf, as seen on Map 19, whale sharks occur in both coastal and offshore waters, but move into shallower waters, particularly near estuaries and river mouths, on a seasonal basis to feed (Hoffmayer et al., 2005). They are primarily surface swimmers, but can also be found in deep water far from shore (Graham et al., 2006).

Whale sharks, reaching lengths of 13.7 meters (45 feet), have streamlined bodies and broad, flattened heads. They have a unique spotted checkerboard color pattern, and each individual whale shark has a different pattern (Compagno, 1984). Researchers have found little genetic differentiation between whale shark populations from three different ocean basins and currently treat all as a single global population (Castro et al., 2007; Schmidt et al., 2009). Whale sharks have a long lifespan, living between 60 and 100 years (Pauly, 2002). Whale sharks consume a variety of planktonic prey, such as small crustaceans, fish eggs, and perhaps phytoplankton and macroalgae (Taylor, 2007). Whale sharks use a suction filter-feeding method, drawing water into their transverse, very large mouths at high velocities and capturing food using filtering pads that cover the entrance of their throats (Motta et al., 2010; Nelson & Eckert, 2007). Their suction filter-feeding method might cause whale sharks to be dependent on dense aggregations of prey due to the fact that their small teeth play no major role in feeding (Nelson & Eckert, 2007). Female whale sharks are ovoviviparous, bearing live young with a litter size of over 300 pups (Joung et al., 1996). Researchers estimate that whale sharks reach sexual maturity when they are about 8 to 9 meters (26 to 29.5 feet) in length, which occurs when they reach about 25 to 30 years of age (Wintner, 2000).

The 1982 United Nations Convention on the Law of the Sea classified whale sharks as a highly migratory species, emphasizing the need for "coordinated management and assessment to better understand cumulative impacts of fishing effort on the status of the shared populations" of these sharks. Fishermen are prohibited from keeping whale sharks in the Atlantic Ocean, Gulf of Mexico and the Caribbean Sea (NOAA, 2010). In 2003, whale sharks were listed in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora, strengthening regulations for trading in whale shark parts, such as fins, which are popular in Asian medicinal markets (CITES, 2003). The International Union for the Conservation of Nature and Natural Resources lists whale sharks as "vulnerable" due to their slow growth rate, late age of maturation, and low fecundity. Little is known about the migratory patterns and behavior of whale sharks in the Gulf, although interactions between northern Gulf populations and those in the Caribbean and southern Gulf have been documented (Gulf Coast Research Laboratory, 2012).

See related maps and narratives on Bathymetry and Net Primary Productivity.

Data Compilation and Mapping Methods

Data for this map represent minimum distributions of whale sharks from two sources: presence-only sightings through reports to the Northern Gulf of Mexico Whale Shark Sighting Survey (http://www.usm.edu/gcrl/whaleshark/index.php) and marine-mammal aerial surveys by the National Marine Fisheries Service (NMFS). The sighting network survey, based at the University of Southern Mississippi Gulf Coast Research Laboratory, documents sightings reported by the public in order to increase awareness and information about this species. These sightings are voluntary and are not part of a standardized monitoring program. As such, these data are not used to produce statistically sound population estimates. However, this network provides the most comprehensive documentation of whale shark presence in the Gulf to date. The NMFS marine-mammal aerial surveys are from the Upper Continental Slope survey and the Gulf of Mexico Cetacean Studies I & II, conducted from 1989 through 1998. Standard line-transect sampling methods for aerial surveys of cetaceans were used in these projects, with efforts concentrated between the 100 and 2,000 meter (330 to 6,560 foot) depth range.

Data Quality

Data quality for this map in U.S. waters is poor due to the low number of surveys conducted in the Gulf and the limited detection capability from voluntary reports provided by the public. As the sighting network reporting database becomes more recognized by this user community, volunteer-based sightings should increase. While whale shark aggregations are known to occur in Mexican waters, and some data exist for these areas, data quality for this map in Mexico and Cuba is poor due to the lack of available data.

Synthesis and Conclusions

In the Gulf, whale sharks concentrate in areas of high coastal productivity, with the highest concentrations off of the Mississippi River Delta and northern Yucatán Peninsula. The International Union for the Conservation of Nature and Natural Resources lists whale sharks as "vulnerable" due to their slow growth rate, late age of maturation and low fecundity. Little is known about the migratory patterns and behavior of whale sharks in the Gulf, although interactions between northern Gulf populations and those in the Caribbean Sea and southern Gulf have been documented. Additional research and systematic monitoring are needed to address gaps in whale shark life history, ecology, population estimates and seasonal distribution within the Gulf, as are long-term studies on the sublethal impacts of the BP Deepwater Horizon oil disaster on whale shark populations.

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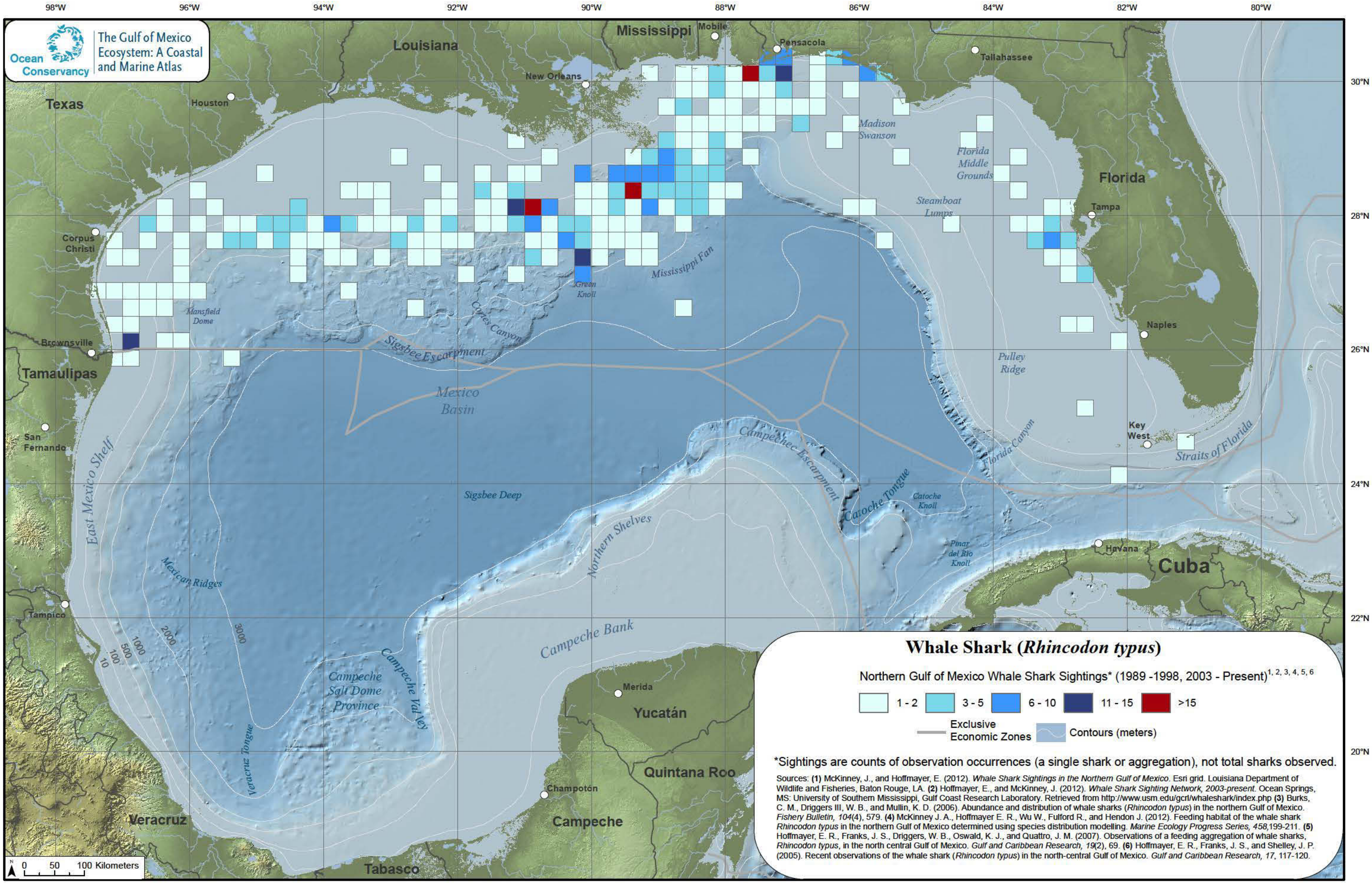
MAP 19 *(next page)*. **WHALE SHARK**



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Whale Shark (*Rhincodon typus*)
Northern Gulf of Mexico Whale Shark Sightings* (1989 -1998, 2003 - Present)[1, 2, 3, 4, 5, 6]
1 - 2
3 - 5
6 - 10
11 - 15
>15
Exclusive Economic Zones
Contours (meters)
*Sightings are counts of observation occurrences (a single shark or aggregation), not total sharks observed.
Sources: **(1)** McKinney, J., and Hoffmayer, E. (2012). *Whale Shark Sightings in the Northern Gulf of Mexico.* Esri grid. Louisiana Department of Wildlife and Fisheries, Baton Rouge, LA. **(2)** Hoffmayer, E., and McKinney, J. (2012). *Whale Shark Sighting Network, 2003-present.* Ocean Springs, MS: University of Southern Mississippi, Gulf Coast Research Laboratory. Retrieved from http://www.usm.edu/gcrl/whaleshark/index.php **(3)** Burks, C. M., Driggers III, W. B., and Mullin, K. D. (2006). Abundance and distribution of whale sharks (*Rhincodon typus*) in the northern Gulf of Mexico. *Fishery Bulletin, 104*(4), 579. **(4)** McKinney J. A., Hoffmayer E. R., Wu W., Fulford R., and Hendon J. (2012). Feeding habitat of the whale shark *Rhincodon typus* in the northern Gulf of Mexico determined using species distribution modelling. *Marine Ecology Progress Series, 458*,199-211. **(5)** Hoffmayer, E. R., Franks, J. S., Driggers, W. B., Oswald, K. J., and Quattro, J. M. (2007). Observations of a feeding aggregation of whale sharks, *Rhincodon typus*, in the north central Gulf of Mexico. *Gulf and Caribbean Research, 19*(2), 69. **(6)** Hoffmayer, E. R., Franks, J. S., and Shelley, J. P. (2005). Recent observations of the whale shark (*Rhincodon typus*) in the north-central Gulf of Mexico. *Gulf and Caribbean Research, 17*, 117-120.
98°W
96°W
94°W
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90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Pulley Ridge
Florida Canyon
Straits of Florida
Mississippi Fan
Green Knoll
Mansfield Dome
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers

5.1 Bull Shark *Carcharhinus leucas*

Description

Credit: NOAA

Bull sharks have a global distribution in tropical and subtropical waters, including those of the Gulf of Mexico (Compagno, 1984). They occur at depths of up to 150 meters (500 feet) over the continental shelf, but prefer shallow, coastal waters of less than 30 meters (100 feet) deep (Compagno, 1984). They are common in estuarine and freshwaters, such as lagoons, bays, and river mouths, and can survive in freshwater for a sustained duration, traveling long distances up rivers, such as the Mississippi (Snelson et al., 1984; Simpfendorfer & Burgess, 2009). Essential fish habitat for immature bull sharks in the Gulf is largely comprised of inshore and coastal waters, whereas adult essential fish habitat is predominately offshore (Map 20). Bull shark aggregations form in the northern Gulf, especially near the mouth of the Mississippi River (Springer, 1938; Branstetter, 1981), and a large nursery area for bull sharks is located in the coastal and inland waters of Louisiana (Blackburn et al., 2007).

Bull sharks are apex predators with no known natural predators of their own. The species has evolved to have one of the most powerful of all shark bites, likely giving bull sharks a competitive advantage (Habegger et al., 2012). The bull shark is an opportunistic feeder with a diverse diet that favors bony fishes (e.g., menhaden) and elasmobranches, but may also ingest turtles, birds, invertebrates and mammals (Compagno, 1984). Female bull sharks generally have a longer lifespan and are larger than males, averaging approximately 2.5 meters (8 feet) in length while males average just over 2 meters (7 feet) in length (Branstetter & Stiles, 1987). Female bull sharks are estimated to reach a maximum age of 24 to 28 years, and males are estimated to reach a maximum age of 21 to 23 years (Cruz-Martinez et al., 2005; Branstetter & Stiles, 1987). Bull sharks mature at different rates and ages depending on their gender and location within the Gulf. In the southern Gulf, for example, scientists believe that females reach maturity at 10 years of age and males at 9 to 10 years. In the northern Gulf, females reach maturity at about 18 years and males between 14 and 15 years (Branstetter & Stiles, 1987). This species gives birth to live, free-swimming offspring, and litter size ranges from 1 to 13 pups (NOAA, 2011).

Bull sharks are managed by the National Marine Fisheries Service (NMFS) in federal waters as part of the non-sandbar, large coastal shark complex in the Gulf and Atlantic longline and pelagic fisheries. States manage the species in their territorial waters. While the large coastal shark complex is not overfished, fishing limits are in place at federal and state levels because sharks are highly vulnerable to fishing pressure. Some species take a decade or more to mature, produce few offspring, have specific nursery habitat requirements and are indiscriminately caught in various types of fishing gear (NOAA, 2011).

See related maps and narratives on Bathymetry, Salinity and River Flow, and Gulf Menhaden.

Data Compilation and Mapping Methods

Data used to illustrate the various life stages of bull sharks in the Gulf (including neonate, juvenile and adult) encompass the areas designated as essential fish habitat by NMFS for each life stage. NMFS works with the Gulf of Mexico Fishery Management Council (GMFMC) to identify the essential habitats for these life stages and uses the best scientific information available (NMFS, 2009). Essential fish habitat delineations, by life stage, were obtained directly from NMFS using the Essential Fish Habitat Mapper version 3.0.

Data Quality

Data quality for Map 20 is fair for U.S. waters. While the best available research was used to make these delineations of essential fish habitat, discontinuous spatial and temporal coverage prevented a more thorough assessment of seasonality and spatial movement throughout the known range of this species. The delineation of essential fish habitat is available only for U.S. waters and does not extend outside the U.S. exclusive economic zone. Comparable data were not located for Mexican and Cuban waters.

Synthesis and Conclusions

Bull sharks are present throughout the Gulf, primarily in estuaries, and are especially common near the mouth of the Mississippi River. They are apex marine predators, adapted to live in a wide variety of environments, from offshore waters to freshwater rivers. While the large coastal shark complex, of which the bull shark is a member, is not overfished, fishing limits are in place at federal and state levels because sharks are highly vulnerable to fishing pressure.

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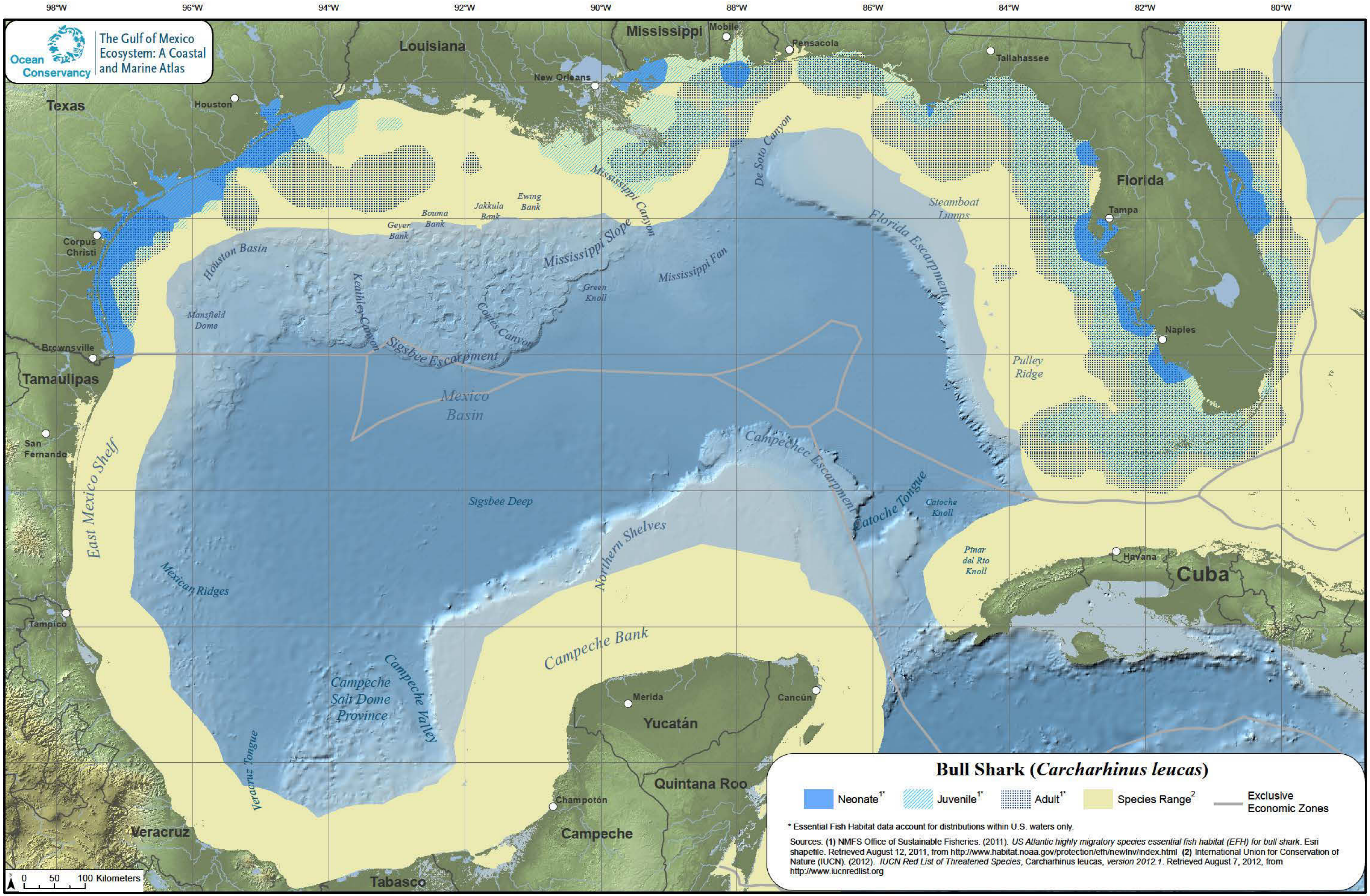
MAP 20 *(next page)*. **BULL SHARK**



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The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
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94°W
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30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Havana
Houston Basin
Mansfield Dome
Geyer Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Green Knoll
De Soto Canyon
Steamboat Lumps
Florida Escarpment
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Pulley Ridge
East Mexico Shelf
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Northern Shelves
Pinar del Rio Knoll
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
0 50 100 Kilometers
Bull Shark (Carcharhinus leucas)
Neonate 1*
Juvenile 1*
Adult 1*
Species Range 2
Exclusive Economic Zones
* Essential Fish Habitat data account for distributions within U.S. waters only.
Sources: (1) NMFS Office of Sustainable Fisheries. (2011). US Atlantic highly migratory species essential fish habitat (EFH) for bull shark. Esri shapefile. Retrieved August 12, 2011, from http://www.habitat.noaa.gov/protection/efh/newInv/index.html (2) International Union for Conservation of Nature (IUCN). (2012). IUCN Red List of Threatened Species, Carcharhinus leucas, version 2012.1. Retrieved August 7, 2012, from http://www.iucnredlist.org

5.2 Gulf Menhaden *Brevoortia patronus*

Description

Gulf menhaden occur throughout the Gulf of Mexico and range from the Yucatán Peninsula to Tampa Bay, Florida (GSMFC, 2010a). The distribution of menhaden is greatest in the northern Gulf from the mid-Texas coast to the extreme western end of the Florida Panhandle (Map 21).

Credit: Joel Sartore / National Geographic Stock

Gulf menhaden are members of the Clupeidae family, which include herrings, shads and sardines. Larval menhaden (3 to 5 weeks old) prefer low-energy, low-salinity waters in estuaries, rivers, bays and other nearshore habitats (VanderKooy & Smith, 2002). In nearshore waters, Gulf menhaden form dense, large schools near the surface, usually comprising same size and age-class fish (Lewis & Roithmayr, 1981). Following their first summer in nearshore waters, menhaden migrate offshore. Initial growth is rapid within the first year, and fish reach sexual maturity near the end of their second year (Vaughan et al., 2007). Gulf menhaden reach a maximum age of 5 to 6 years, but the fishery is dominated by young fish, especially 2-year-olds (Ahrenholz, 1991). Gulf menhaden have laterally compressed bodies and adults reach 13 to 17 centimeters (5 to 8 inches) in length. They are fast-swimming, omnivorous filter feeders, consuming phytoplankton, organic detritus and zooplankton (Ahrenholz, 1991; Castillo-Rivera et al., 1996). Menhaden are an important prey species for piscivorous fishes, seabirds and marine mammals (Ahrenholz, 1991).

Gulf menhaden fisheries are managed by individual Gulf states in cooperation with the Gulf States Marine Fisheries Commission (GSMFC). The latest stock assessment found that Gulf menhaden is neither overfished nor undergoing overfishing (Vaughan et al., 2011). Texas and Florida are the only Gulf states that set quotas or otherwise restrict the location of menhaden fishing (TPWD, 2011; Vaughan et al., 2011). Fishing effort and menhaden landings in the Gulf were highest in the 1980s when fleet size peaked (VanderKooy & Smith, 2002). The current menhaden reduction fishery is the second-most valuable fishery in the nation. It consists of about 40 vessels and four reduction plants and is the largest fishery by volume in the Gulf, with annual landings averaging approximately 493,000 metric tons (over 1 billion pounds) (GSMFC, 2010b; NMFS, 2013). As seen in Map 21, fishing intensity is highest off coastal Louisiana and Mississippi. Dry fishmeal and extracted oil are the main products of the Gulf menhaden fishery (GSMFC, 2010b). The BP Deepwater Horizon (DWH) oil disaster resulted in unprecedented large-scale closures of the menhaden fishery during the 2010 fishing season.

See related maps and narratives on Sea Surface Currents and Net Primary Productivity.

Data Compilation and Mapping Methods

Distribution data for Gulf menhaden were obtained from GIS data models, developed for the SL Ross Oil Spill Impact Assessment Model. This model and associated data were developed for hazard management in 2003 for the Marine Industry Group in the Gulf, which included Shell, Exxon, BP America, Petro Canada, Chevron, Amoco, Phillips 66, Conoco and Mobil (Trudel et al., 2003). Due to the overlap of the different life stages in areas of occurrence, only the egg/larvae and adult life stages were included for the seasons with the greatest range in geographic extent (summer and winter).

The National Marine Fisheries Service and the Gulf States Marine Fisheries Commission provided commercial fishery activity data. These data represent the density of set locations in the large purse seine nets for all commercial activity during the 2006 to 2009 fishing seasons.

Data Quality

Data quality for menhaden distribution in U.S. waters is fair because of the lack of supporting documentation providing information on the data used to build the life stage distribution models. While the fisheries management community generally accepts these distribution delineation models, the lack of supporting documentation to verify the models reduces the quality of data. While Gulf menhaden are concentrated in the north-central Gulf, no data were located for their distribution in the southern Gulf waters of Cuba and Mexico.

Data on the distribution of the menhaden commercial fleet effort are of good quality. These data were originally derived from the electronic logbooks of each commercial vessel denoting vessel location during the deployment of sets.

Synthesis and Conclusions

Gulf menhaden are widespread and abundant in estuarine environments and adjacent offshore waters. Both of these habitats are important to the life cycle and productivity of Gulf menhaden, particularly at the core of its range in the northern Gulf. The menhaden reduction fishery is the largest fishery by volume in the Gulf. Knowledge gaps regarding menhaden in the northern Gulf include: recruitment in the rivers and upper bays, reexamination of reproductive biology, predator-prey relations, stock structure (genetics), natural mortality rates, and the role of environmental factors in recruitment and catchability. Long-term monitoring and research are essential to detect and characterize sublethal effects of the DWH oil disaster on Gulf menhaden.

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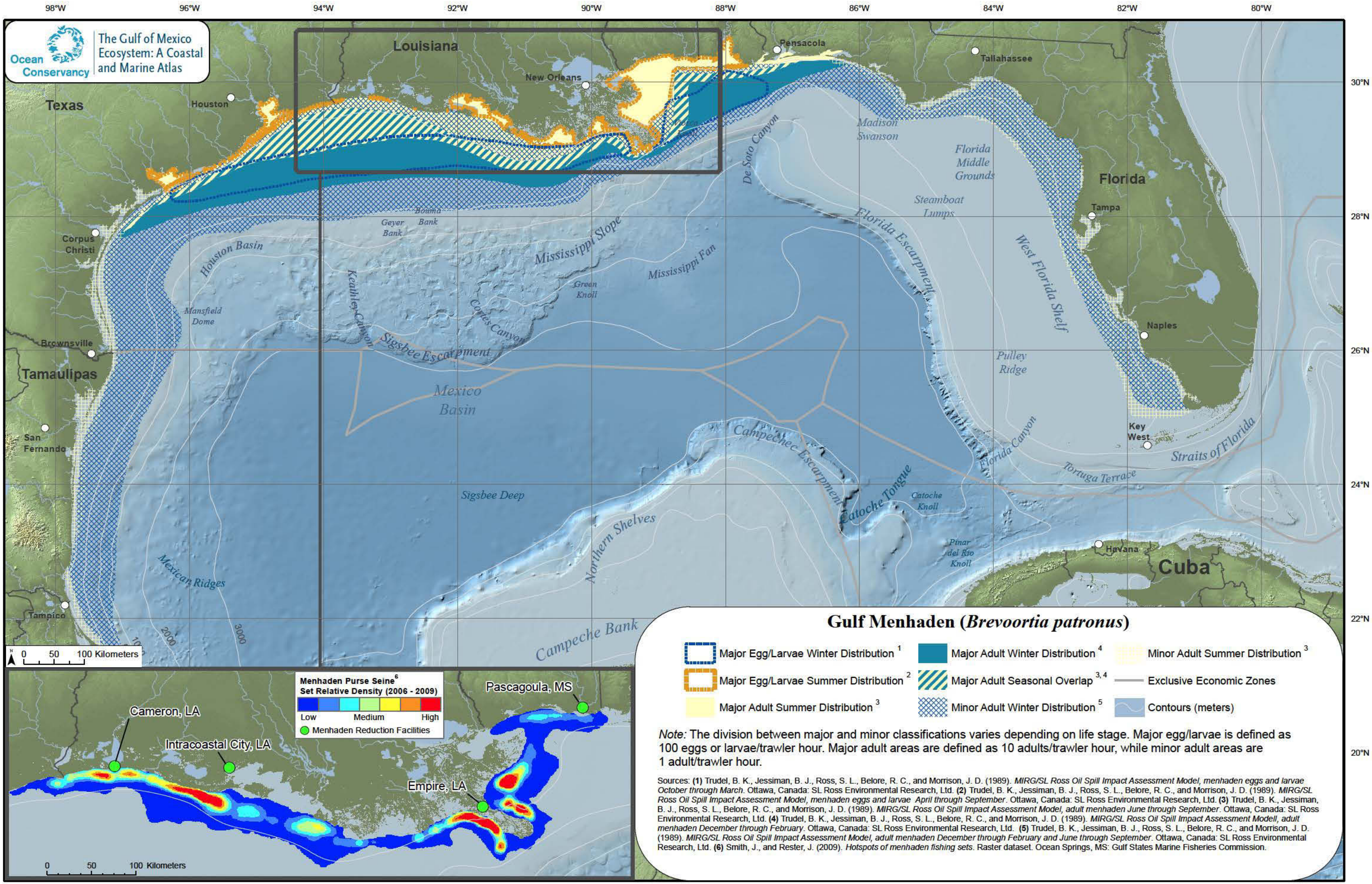
MAP 21 *(next page)*. **GULF MENHADEN**



Note: The division between major and minor classifications varies depending on life stage. Major egg/larvae is defined as 100 eggs or larvae/trawler hour. Major adult areas are defined as 10 adults/trawler hour, while minor adult areas are 1 adult/trawler hour.

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5.3 Red Snapper *Lutjanus campechanus*

Credit: David Doubilet / National Geographic Stock

Description

Red snapper, a member of the Lutjanidae family, occur in a variety of habitats throughout the Gulf of Mexico (Map 22), the Caribbean Sea and from the U.S. Atlantic Coast to northern South America (Moran, 1988; SEDAR, 2005). Larval red snapper are planktonic for the first two to three weeks after hatching and then settle on low-relief sand, mud and shell habitat. Older sub-adult and adult fish are bottom-dwellers and usually reside near natural and artificial structured habitats (e.g., ledges, rock outcroppings, artificial reefs, oil rigs) and are commonly found in water depths of 30 to 130 meters (100 to 425 feet) (Moran, 1988; SEDAR, 2005). Larger red snapper, approximately 8 years old, inhabit areas of open habitat where predators are less prevalent (Gallaway et al., 2009).

Individual Gulf red snapper start reaching sexual maturity at about age 2, when they are roughly 30 centimeters (12 inches) in total length. All fish in the population are mature by age 9 at about 75 centimeters (30 inches) in total length, although this varies by region and habitat (SEDAR, 2012). Gulf red snapper can live 40 to 50 years or more and can weigh up to 23 kilograms (50 pounds) (Wilson & Nieland, 2001; Woods et al., 2003). Spawning occurs from May through October, peaking from July through September (NOAA, 2010). Larval and young juvenile red snapper are planktivorous, consuming plankton and zooplankton. Older juveniles and adults are carnivorous, with a diet comprised of various prey species including shrimp, small reef fish, crabs and squid (Moran, 1988).

Red snapper support an active commercial and recreational fishery in Gulf waters of both the U.S. and Mexico (SEDAR, 2005). Commercial landings totaling millions of pounds and high dockside values make it an economically valuable finfish species. In the United States, red snapper is managed by the Gulf of Mexico Fishery Management Council (GMFMC) under a management plan first implemented in 1984 and last amended in 2012. Gulf red snapper have been heavily exploited for well over 100 years and are currently considered overfished. Historically, the bycatch of red snapper in the shrimp trawl fishery contributed to its overfished condition. In recent years, however, the population has produced some strong year classes and shows signs of recovery in response to the GMFMC rebuilding plan and improved shrimp fishing gear (NOAA, 2012; SEDAR, 2009). The BP Deepwater Horizon (DWH) oil disaster coincided with the location and timing of red snapper spawning in the northern Gulf.

See related maps and narratives on Offshore Shrimp Trawl Fishery and Artificial Reefs.

Data Compilation and Mapping Methods

Data for red snapper were obtained from the NOAA Gulf of Mexico Data Atlas and show the occurrence of adult, juvenile and larval red snapper. These data have been summarized to illustrate presence or absence of all life stages of red snapper at each sample location from 1986 through 2006.

Data Quality

Data quality for this map in U.S. waters is good because of the long-term monitoring dataset (more than 20 years) available. Standardized sampling protocols have been used by SEAMAP throughout the sampling period, generating reliable estimates of red snapper distribution. An analogous sampling program does not exist for Mexican and Cuban waters, and comparable red snapper data outside of U.S. waters were not obtained.

Synthesis and Conclusions

Red snapper is a long-lived species that occurs in a variety of habitats in the Gulf. Young red snapper often prefer lower-relief bottom environments, while older fish tend to occupy higher-relief structured areas or even open waters in the Gulf. This species supports important commercial and recreational fisheries. Areas for further study include: more accurate habitat estimates to refine fishery-independent surveys and stock assessments, demographics of different red snapper populations, discard mortality rates for different gear types, and better fishery-independent surveys. Long-term studies estimating the lethal and sublethal impacts of the DWH oil disaster on the Gulf red snapper population are also needed.

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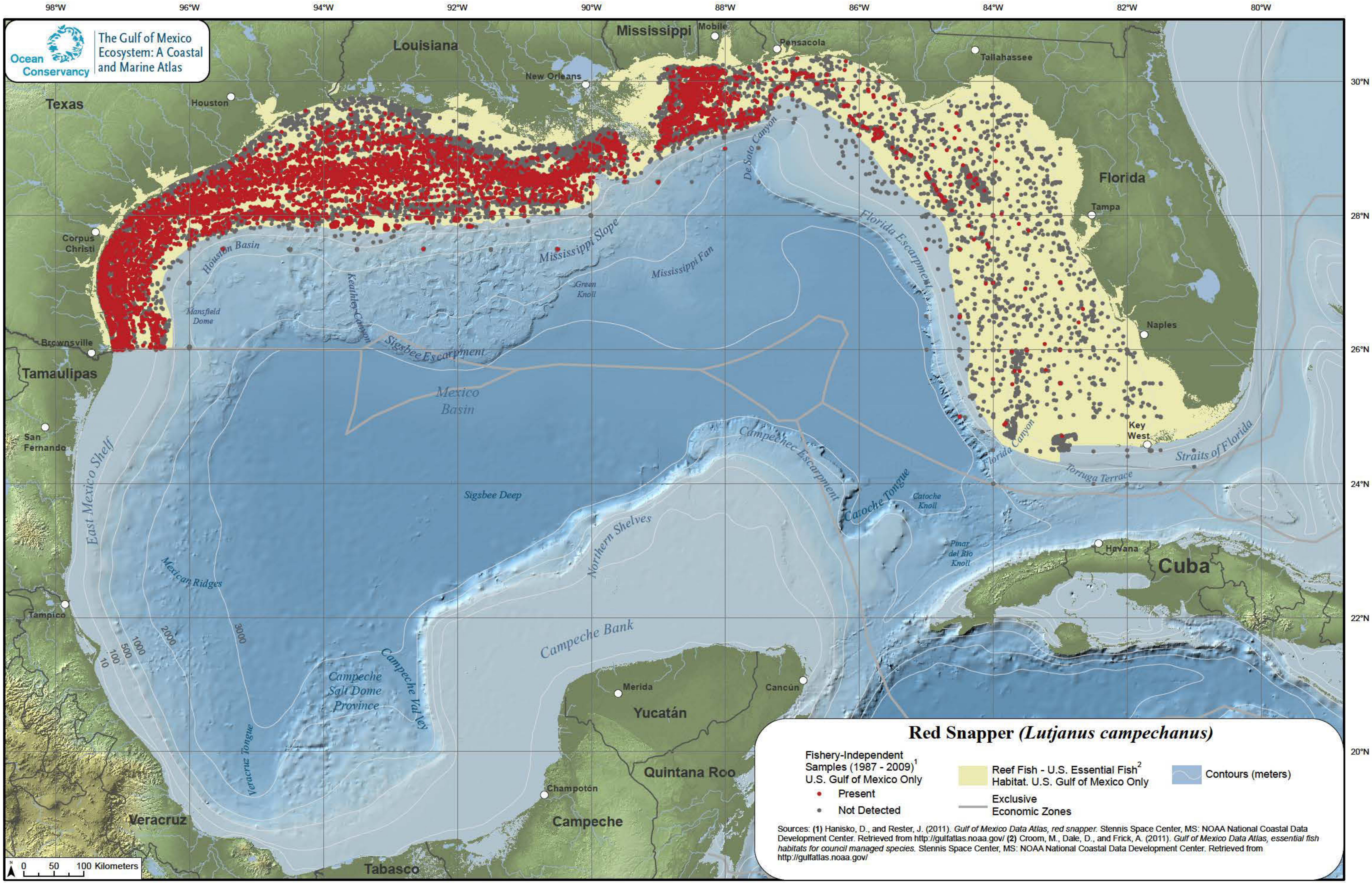
MAP 22 *(next page)*. **RED SNAPPER**


98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
New Orleans
Texas
Houston
Florida
Tampa
Corpus Christi
Brownsville
Naples
Key West
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champotón
Yucatán
Merida
Cancún
Quintana Roo
Havana
Cuba
De Soto Canyon
Houston Basin
Mississippi Slope
Mississippi Fan
Green Knoll
Mansfield Dome
Keathley Canyon
Sigsbee Escarpment
Florida Escarpment
Mexico Basin
Campeche Escarpment
Florida Canyon
Straits of Florida
Tortuga Terrace
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Sigsbee Deep
Northern Shelves
East Mexico Shelf
Mexican Ridges
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Red Snapper (Lutjanus campechanus)
Fishery-Independent Samples (1987 - 2009)[1] U.S. Gulf of Mexico Only
Present
Not Detected
Reef Fish - U.S. Essential Fish[2] Habitat. U.S. Gulf of Mexico Only
Exclusive Economic Zones
Contours (meters)
Sources: (1) Hanisko, D., and Rester, J. (2011). Gulf of Mexico Data Atlas, red snapper. Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retrieved from http://gulfatlas.noaa.gov/ (2) Croom, M., Dale, D., and Frick, A. (2011). Gulf of Mexico Data Atlas, essential fish habitats for council managed species. Stennis Space Center, MS: NOAA National Coastal Data Development Center. Retrieved from http://gulfatlas.noaa.gov/

5.4 Red Drum *Sciaenops ocellatus*

Description

Credit: Joel Sartore / National Geographic Stock

Red drum (or redfish) are found from Massachusetts to Key West, Florida and along the Gulf Coast from Western Florida to Tupxan, Mexico (TPWD, 2010). In the Gulf, red drum inhabit a variety of depths and habitats, ranging from 40 meters (132 feet) deep to shallow estuarine waters (GMFMC, 2004) (Map 23). Red drum spawn near the mouths of bays and inlets in relatively deep water and on the Gulf side of barrier islands from mid-August to mid-October (TPWD, 2010; GMFMC, 2004). Eggs hatch mainly in the Gulf, and larvae are transported by surface currents into estuaries where juvenile fish mature (GMFMC, 2004). Larval red drum are sensitive to water conditions, because temperature and salinity affect the rate of larval development and influence the movement of immature fish in estuaries (Davis, 1990). As they age, red drum move from the estuaries to offshore waters where they join schooling adult fish (GMFMC, 2004; Louisiana Sea Grant, 2010).

Red drum grow quickly, reaching 28 centimeters (11 inches) and 0.5 kilograms (1 pound) in the first year of life. By age 3, they can be roughly 60 centimeters (24 inches) in length and weigh up to 3.6 kilograms (8 pounds). Red drum can grow to lengths of 1.5 meters (5 feet) and weigh up to 45 kilograms (100 pounds) (SAFMC, 2010). Red drum bear a distinctive single large black spot on the upper part of their tail base. Red drum are named for their reddish hue and for the drumming sound males produce by vibrating a muscle in their swim bladders to attract females. Red drum reach sexual maturity at 3 to 4 years of age (TPWD, 2010) and live 20 to 30 years. Red drum are primarily bottom feeders. Juveniles eat small crabs, shrimp and marine worms, and adults eat larger crabs, shrimp and small fish (TPWD, 2010).

Heavy, unregulated fishing in the 1970s contributed to sharp declines in red drum populations, and the commercial fishery was closed in federal waters in the late 1980s (Louisiana Sea Grant, 2010). Today, red drum is a state-managed game fish caught recreationally and, on occasion, commercially in estuaries and nearshore waters (MDMR, 2012). Some Gulf states maintain hatchery programs for stock enhancement or for research purposes (TPWD, 2012; FWC, 2010). The location and timing of the BP Deepwater Horizon (DWH) oil disaster coincided with the spring-summer distribution of adult red drum in the northern Gulf and possibly with that year's red drum spawning season.

See related maps and narratives on Salinity and River Flow, Sea Surface Temperature, and Fish and Shellfish Hatcheries.

Data Compilation and Mapping Methods

Distribution data for red drum were obtained from GIS data models developed for the SL Ross Oil Spill Impact Assessment Model. This model and associated data were developed for hazard management in 2003 for the Marine Industry Group in the Gulf, which included Shell, Exxon, BP America, Petro Canada, Chevron, Amoco, Phillips 66, Conoco and Mobil (Trudel et al., 2003). Distribution data for this map were compiled from the biological database developed for the Oil Spill Impact Assessment model. Due to the overlap of the different life stages in areas of occupation, only select seasons are used to represent life stage distribution in the Gulf. The coastal and estuarine September and November delineations of egg and larvae distribution are used to show the importance of these habitats to the reproductive cycle of red drum. The greatest extent of adult distribution in the Gulf is during spring and summer, which are the seasons used here to show the maximum likely adult distribution. The primary spawning season of August to October is illustrated to show the areas important for adult red drum spawning (Wilson & Nieland, 1994).

Due to the lack of a Gulf-wide abundance database for this species, essential fish habitat designation extent is used to illustrate the use of coastal rivers for red drum for reproduction and development. Red drum essential fish habitat (EFH) includes all Gulf estuaries in U.S. waters, extending seaward to different depths depending on the location. Boundaries for EFH during the different life stages were derived using all available distribution data points or known samples and were generated using a 95 percent probability envelope surrounding all sample points.

Data Quality

Data quality for red drum distribution in U.S. waters is fair because of the lack of supporting documentation that provides information on the data used to build the life stage distribution models. While these distribution delineation models are generally accepted by the fisheries management community, lack of supporting documentation to verify the models reduces the quality of data. While the geographic range of this species extends from Cape Cod, Massachusetts to as far south as Tuxpan, Veracruz, no data were located for their distribution in Mexican waters.

Synthesis and Conclusions

In the U.S. portion of the Gulf, all estuaries are classified as EFH for red drum. Adult red drum can also occur offshore. Red drum fisheries in federal waters have been closed since the 1980s, when sharp declines in the spawning population were documented following years of heavy fishing. The only fisheries open today are in state waters. Impacts on red drum resulting from the DWH oil disaster are still not known, but continued long-term research and monitoring are essential to understand the related sublethal impacts on this species.

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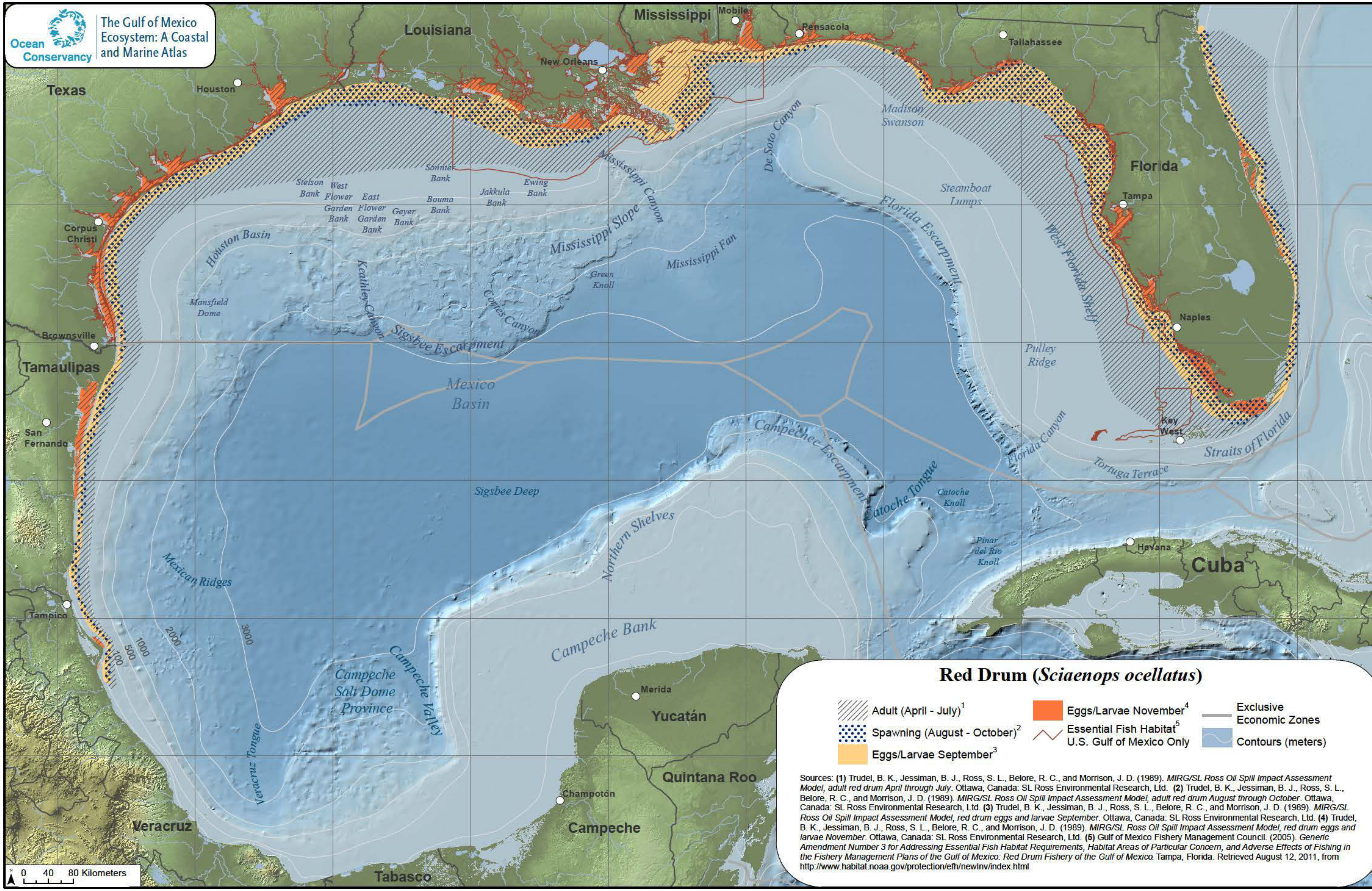
MAP 23 *(next page)***. RED DRUM**



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5.5 Atlantic Bluefin Tuna *Thunnus thynnus*

Description

Bluefin tuna occur in the temperate and tropical waters of the Pacific and Atlantic oceans. Atlantic bluefin tuna (*Thunnus thynnus*) are a distinct species from the other two bluefin tuna, the Pacific (*Thunnus orientalis*) and the Southern (*Thunnus maccoyii*). Atlantic bluefin tuna have at least two major spawning populations: a western population that spawns exclusively in the Gulf of Mexico (Map 24) and an eastern population that spawns in the Mediterranean Sea (Block et al., 2005). The western Atlantic bluefin tuna are fully mature at age 8 and spawn in Gulf surface waters from mid-April through June (Corriero et al., 2005; NOAA, 2006). The northern slope waters of the Gulf are important habitat for spawning bluefin tuna, which prefer the cooler, more productive and anti-cyclonic eddies associated with these areas of rapid depth change (Block et al., 2005; Teo & Block, 2010). The National Oceanic and Atmospheric Administration (NOAA) has established this area as a habitat area of particular concern for spawning bluefin tuna (Atlantic Bluefin Tuna Status Review Team, 2011).


A school of Atlantic bluefin tuna in the Gulf. Credit: Tom Puchner / USFWS

Atlantic bluefin tuna are the largest members of the family Scombridae, and are closely related to mackerels and other tunas. Atlantic bluefin tuna are one of the largest bony fishes in the ocean. They can grow to more than 3 meters (10 feet) in length and weigh more than 650 kilograms (1,433 pounds) (NOAA, 2006). This pelagic species, with its torpedo-shaped body, is adapted for continuous fast swimming in cold water. Tuna are highly mobile and transoceanic, and they migrate thousands of miles, diving to depths ranging from 500 to 1,000 meters (1,640 to 3,280 feet) (NOAA, 2011). Atlantic bluefin tuna have a long lifespan, living 20 years or possibly longer (NOAA, 2006). An adult bluefin tuna is a top pelagic predator and typically consumes fish, such as herring, anchovy, sand lance, sardine, sprat, bluefish and mackerel (ICCAT, 2012). Juvenile bluefin tuna feed on crustaceans, fish and cephalopods (ICCAT, 2012). Marine mammals, sharks and large predatory fishes are the main natural predators for the bluefin tuna. Juvenile bluefin are prey for bluefish and seabirds (NOAA, 2011).

Atlantic bluefin tuna populations have been in decline for decades and are now depleted due to chronic overfishing (NOAA, 2006). Total catch for the western Atlantic bluefin tuna stock peaked in the 1960s and 1970s in the Gulf and declined steadily thereafter. Since 1982, a harvest quota for the western stock of bluefin tuna has been in place. Directed fishing for Atlantic bluefin tuna is prohibited in the Gulf, although a limited number of incidental catches is allowed in the Gulf pelagic longline fishery (NOAA, 2011). The International Commission for the Conservation of Atlantic Tunas recommends an annual total allowable catch for the western stock, and the National Marine Fisheries Service (NMFS) implements this quota (NOAA, 2006). On a pound for pound basis, bluefin tuna is the world's most valuable fish. The BP Deepwater Horizon (DWH) oil disaster coincided with the location and timing of bluefin spawning in the northern Gulf, exposing adults and eggs or larval fish to hydrocarbons and chemical dispersants.

See related maps and narratives on Bathymetry, Salinity and River Flow, and Sea Surface Currents.

Data Compilation and Mapping Methods

Distributional data for Atlantic bluefin tuna in the Gulf were derived from two sources. The first data source was a combination of geospatial tracks of Atlantic bluefin tuna tagged with satellite-linked transmitters and U.S. pelagic longline observer and logbook catch data (Block et al., 2005). These data indicate presence or absence in 1-degree blocks of observed locations in the Gulf based on pop-up satellite tags, geolocation estimates from electronic tags and catch location statistics from pelagic longlines to show areas of highest activity. This dataset provides a synoptic view of hotspots for Atlantic bluefin tuna in the Gulf. The second data source was the 2009 essential fish habitat designation obtained directly from the NMFS using the Essential Fish Habitat Mapper version 3.0.

Data from Block et al. (2005) were digitized directly from an existing figure with the author's permission and used to recreate the figure for this atlas. Data from the NMFS U.S. pelagic longline observer and logbook programs (since 2005) were not available due to the proprietary nature of the data.

Data Quality

For the entire Gulf, the quality of mapped data is good due to the amount of available data. The number of observed geolocations of Atlantic bluefin tuna from electronic tags in the Gulf during the period 1996 through 2004 was 263, while the number of geolocations from catch statistics from the pelagic longline observer program was 3,207.

Synthesis and Conclusions

Atlantic bluefin tuna is a large, highly migratory species. The western stock of Atlantic bluefin tuna spawns exclusively in the northern Gulf. Atlantic bluefin tuna populations have been in decline for decades due to chronic overfishing, so more effective management measures are needed to recover their populations. Directed fishing for Atlantic bluefin tuna is prohibited in the Gulf, although a limited incidental catch is allowed in the Gulf pelagic longline fishery. Areas of further research for Atlantic bluefin tuna include: the location and timing of reproduction, mean age at maturity, spawning site fidelity, ontogeny of movement patterns, and the role of climate variability in movements. The resulting information will improve stock assessments and management in general. Long-term research and monitoring are essential to improve our understanding of the impacts of the DWH oil disaster on Atlantic bluefin tuna populations.

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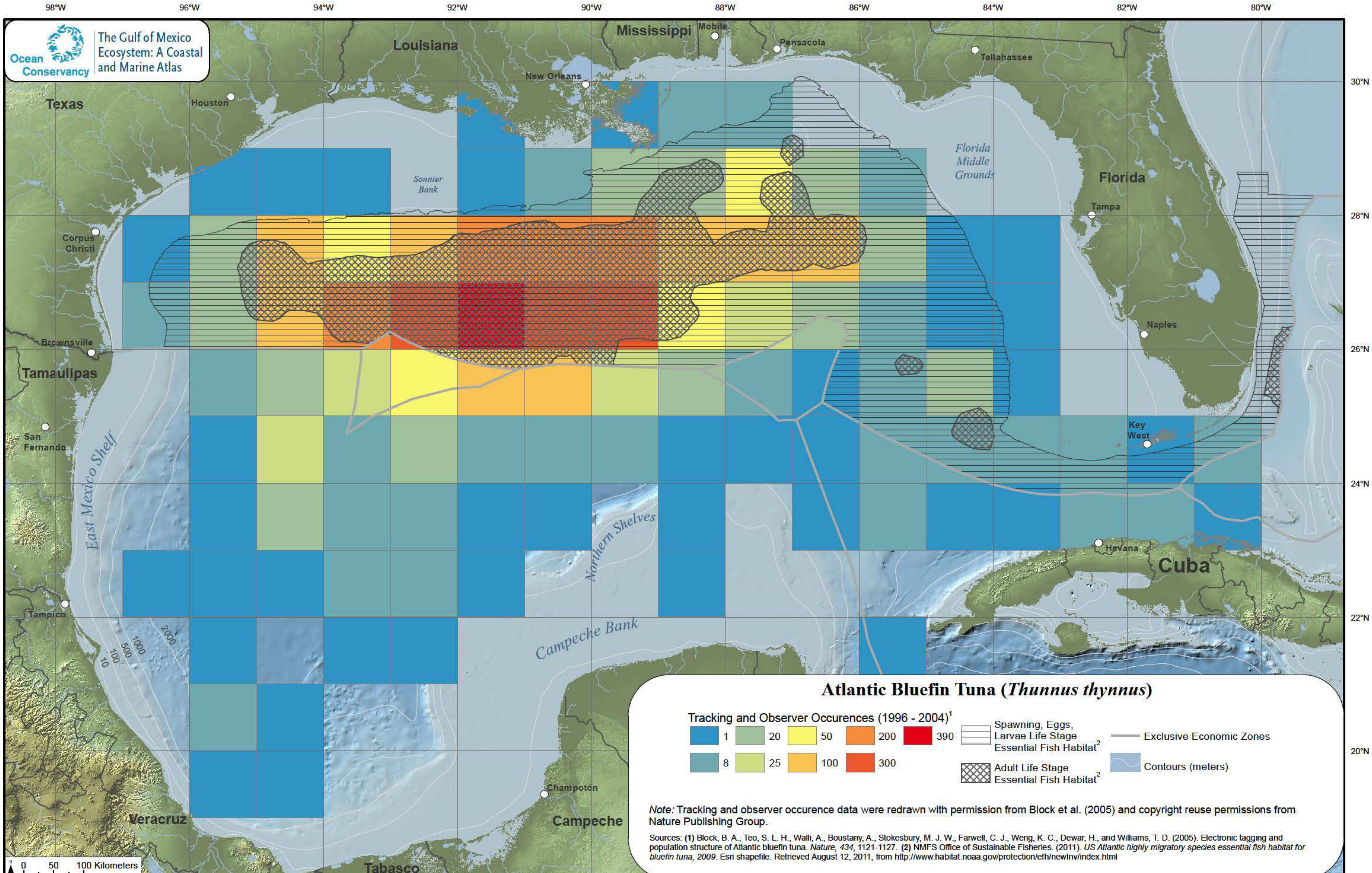
MAP 24 *(next page)*. **ATLANTIC BLUEFIN TUNA**



Note: Tracking and observer occurence data were redrawn with permission from Block et al. (2005) and copyright reuse permissions from Nature Publishing Group.

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Birds

6.0 Common Loon *Gavia immer*

Description


Common loon in nonbreeding plumage. Credit: Steve Byland / Shutterstock

Common loons are distributed throughout freshwater lakes in much of Canada, Alaska and the northern U.S. during the summer. In the fall, common loons from the Great Lakes region migrate to Gulf of Mexico estuaries and nearshore marine waters, where they remain until spring. Some of the highest common loon densities are found in coastal areas along the Florida Panhandle, the Alabama coastline, the Mississippi Sound, and the Barataria and Vermillion bays in Louisiana (Map 25) (Evers, 2004).

Breeding common loons use clear, freshwater lakes, and wintering loons in the Gulf use coastal waterways, such as bays, channels, coves and inlets (Evers et al., 2010). Common loons are long-lived, have delayed maturity and first breed at 6 years of age on average. They typically come to land only to mate and incubate eggs (Cornell University, 2011). Juvenile common loons remain in the Gulf until they are ready to migrate north to reproduce.

Common loons are medium-distance migratory birds known for their distinct nocturnal wailing. They have solid bones and large, powerful webbed feet, which are attributes that help them dive and swim efficiently underwater. Adult common loons weigh between roughly 3.5 to 5.5 kilograms (8 to 12 pounds), range from about 70 to 90 centimeters (28 to 36 inches) in length, and have a wingspan of about 130 to 150 centimeters (52 to 58 inches) wide. Loons have a long body relative to wing size, so they require long distances, up to 200 meters (656 feet), to take off (Evers et al., 2010). Common loons dive to depths near 70 meters (230 feet). Their diet in the Gulf consists mainly of fish such as Atlantic croaker and Gulf silversides, but they also occasionally consume invertebrates such as crabs (Evers et al., 2010).

In the U.S., common loon populations are generally stable and healthy, although declines have occurred along the southern edge of their distribution (Cornell University, 2011). Loons are protected in the U.S. under the federal Migratory Bird Treaty Act (USFWS, 2011).

Internationally, the species receives some protection under treaties between the U.S. and Canada, Mexico, Japan and Russia (USFWS, 2011). The BP Deepwater Horizon (DWH) oil disaster resulted in the oiling of common loons, but information on the full extent of impacts is not yet available.

See related narratives and maps on Bathymetry and Seagrasses.

Data Compilation and Mapping Methods

Data for common loons were obtained from the National Audubon Society's Christmas Bird Count (CBC) using only counts conducted in coastal areas containing marine or estuarine habitats within the 15-mile-diameter count circle. Land cover data were used for the habitat-based selection process from the coastal change and analysis program produced by NOAA. Only count circles that were active for at least 7 out of the past 10 years (2001-2010) were used to compile these data. The mean number of loons observed per party hour for active survey years was then calculated and used to represent the number of common loons present in each circle. Party hours were used to standardize the counts by effort. A party hour equals one group of observers in the field for one hour.

Data Quality

Data quality for this map is fair in U.S. waters. There are 64 CBC circles along the Gulf Coast that intersect marine and estuarine habitats, but CBCs are typically, though not always, land-based. Therefore, a complete count of all birds present within count circles is not likely. Few or no relevant CBCs exist for Mexico and Cuba.

Synthesis and Conclusions

Common loons are migratory water birds inhabiting the freshwater lakes of Alaska, Canada and the northern U.S. in the summer. In the fall, common loons from the Great Lakes region migrate to Gulf wintering waters, where they remain until spring. Common loon populations are stable, and the International Union for Conservation of Nature classifies common loon as a species of Least Concern. Long-term research and monitoring are essential to assess the effects of the DWH oil disaster on this long-lived species and inform restoration strategies.

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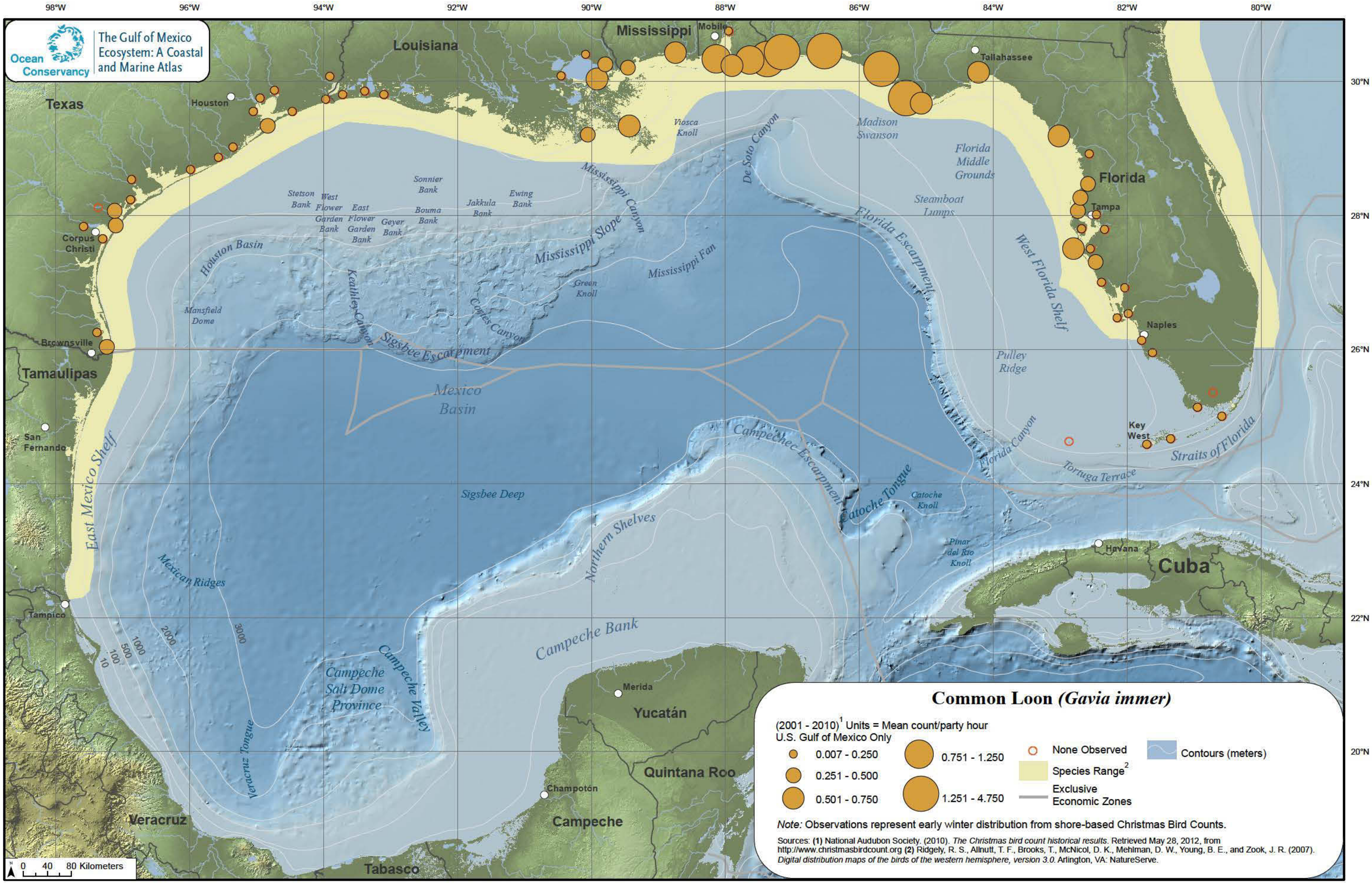
MAP 25 *(next page)*. **COMMON LOON**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
Corpus Christi
Brownsville
San Fernando
Tampico
Mobile
Tallahassee
Tampa
Naples
Key West
Havana
Merida
Champotón
Houston Basin
Mansfield Dome
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Keathley Canyon
Sigsbee Escarpment
Mississippi Slope
Mississippi Canyon
Mississippi Fan
Green Knoll
Viosca Knoll
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Mexican Ridges
East Mexico Shelf
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
Common Loon (Gavia immer)
(2001 - 2010)[1] Units = Mean count/party hour
U.S. Gulf of Mexico Only
0.007 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.250
1.251 - 4.750
None Observed
Species Range[2]
Exclusive Economic Zones
Contours (meters)
Note: Observations represent early winter distribution from shore-based Christmas Bird Counts.
Sources: (1) National Audubon Society. (2010). The Christmas bird count historical results. Retrieved May 28, 2012, from http://www.christmasbirdcount.org (2) Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). Digital distribution maps of the birds of the western hemisphere, version 3.0. Arlington, VA: NatureServe.
0 40 80 Kilometers

6.1 Northern Gannet *Morus bassanus*

Description

Northern gannets are large seabirds that breed in colonies located in the North Atlantic, primarily in the maritime provinces of Canada and in northern Europe. Adult gannets form large concentrations in waters over the continental slope from Massachusetts to North Carolina in winter (Mowbray, 2002). During the fall, all age classes from the North American breeding colonies migrate southward along the Atlantic Coast, and immature birds continue their migration to the Gulf of Mexico (Map 26). Subadult northern gannets are common in the eastern Gulf during winter, but less common in the spring and rare in the summer (Mowbray, 2002).

A northern gannet in flight.
Credit: Colin Carter / Shutterstock

Male and female northern gannets reach average lengths of nearly 100 centimeters (39 inches), with wingspans around 510 centimeters (201 inches) (Mowbray, 2002). For their first 3 to 4 years, juveniles have black and brown or brown and white plumage. Adult plumage (white with black-tipped wings) is achieved at 4 to 5 years of age. Adult crowns and napes are yellowish, becoming more intensely colored in breeding males.

Northern gannets typically remain continuously at sea until about the age of 3 (USFWS, 2010), then, for several years, they attend colonies as nonbreeders. At 5 to 6 years of age, they begin to breed (Mowbray, 2002). During the breeding season, northern gannets form loud, dense colonies on remote and inaccessible coastal cliffs, stacks, steep slopes and islands where males select a nest site and then pair with females (Mowbray, 2002). Male and female pairs typically bond and remain together for life, and both participate in parental care. A pair generally reoccupies the same nest year after year (Mowbray, 2002).

Northern gannets are among the deepest-diving birds, plunge diving from heights of 10 to 40 meters (33 to 130 feet) and to depths of 22 meters (72 feet). Northern gannets consume a variety of schooling fishes, such as menhaden and mackerel, and some squid (Mowbray, 2002).

North American breeding populations have increased in recent decades, due in part to the successful ban on toxic chemicals, such as DDT and PCBs, and to the protection of nesting habitats (Mowbray, 2002). In the U.S., the northern gannet is protected under the Migratory Bird Treaty Act of 1918. The BP Deepwater Horizon (DWH) oil disaster in the Gulf resulted in the oiling and deaths of many northern gannets. Montevecchi et al. (2011) estimated that 25 percent of the North American northern gannet population migrated to the DWH oil disaster pollution area. Information on the full extent of impacts on the population is currently not available.

See related maps and narratives on Bathymetry and Gulf Menhaden.

Data Compilation and Mapping Methods

Data for northern gannets were obtained from the National Audubon Society Christmas Bird Count (CBC) using only counts conducted in areas containing marine or estuarine habitats within the 15-mile diameter count circle. Land cover data were used for the habitat-based selection process from the coastal change and analysis program produced by NOAA. Only circles with counts in at least 7 of the past 10 years (2001-2010) were used to compile these data. The mean number of northern gannets per party hour was calculated for the active years of each survey to represent the number of northern gannets present in each count circle. Party hours are used to standardize the counts by effort. A party hour equals one group of observers in the field for one hour.

Data Quality

Data quality for this map is poor in U.S. waters. While there are 64 CBC circles along the Gulf Coast that intersect marine and estuarine habitats, most CBCs are land-based. Since northern gannets are marine birds occupying coastal and offshore waters during the winter, complete counts of all of the birds present within the count circle is unlikely. Few or no relevant CBCs exist in Mexico and Cuba.

Synthesis and Conclusions

Northern gannets are migratory seabirds that breed in eastern Canada. Young birds leave their north Atlantic Coast nests to migrate to the Gulf, where they remain until adulthood. Because of habitat protections and bans on pesticides, the North American population has steadily increased and populations continue to expand today. The DWH oil disaster impacted northern gannets, and continued research and monitoring will be necessary to track the long-term trends and impacts to this species as well as to identify restoration opportunities.

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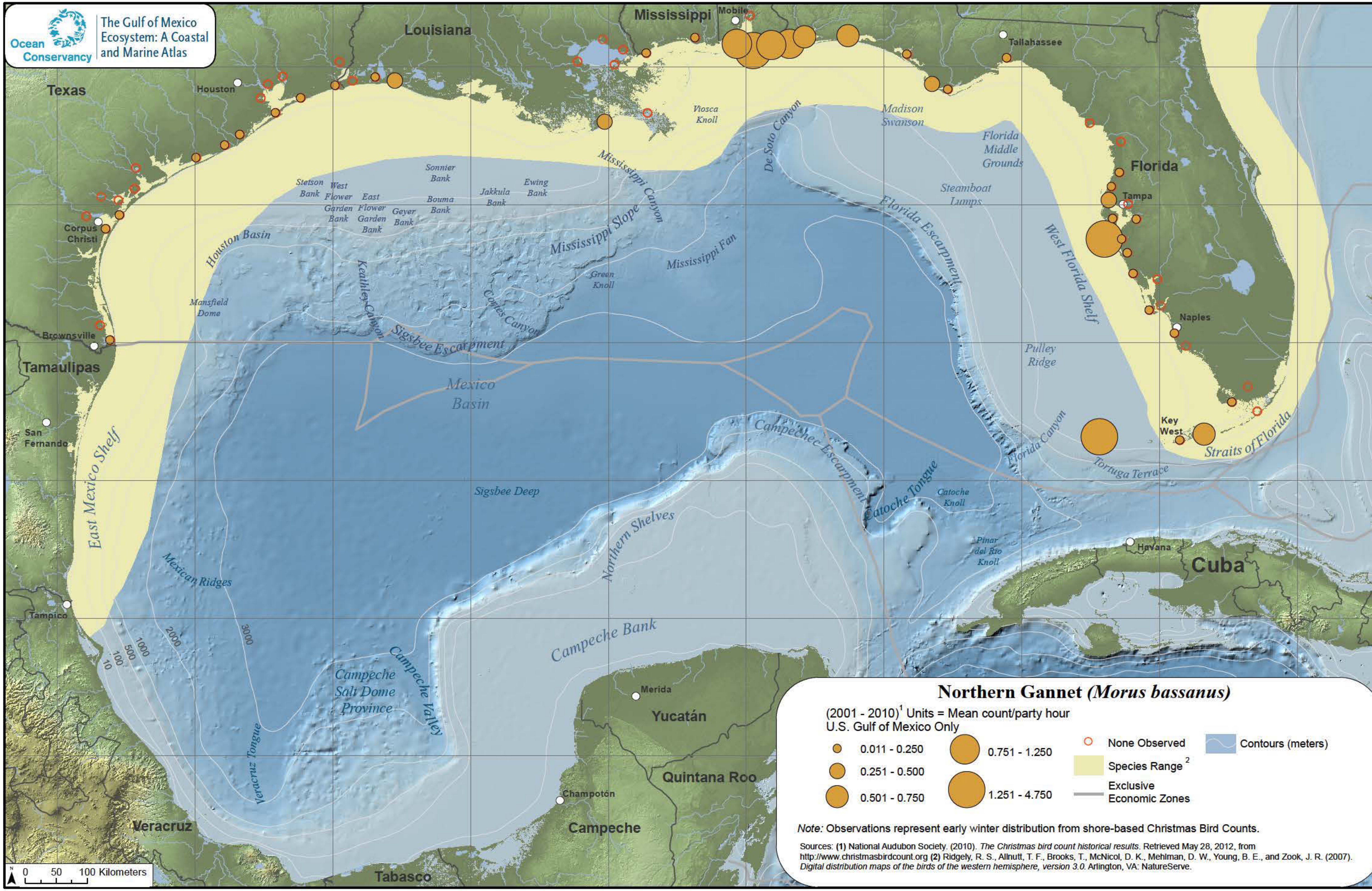
MAP 26 *(next page)***. NORTHNER GANNET**


Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
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86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Mississippi
Louisiana
Texas
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Mobile
Tallahassee
Houston
Corpus Christi
Brownsville
San Fernando
Tampico
Tampa
Naples
Key West
Havana
Merida
Champotón
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
De Soto Canyon
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Sonnier Bank
Bouma Bank
Geyer Bank
Jakkula Bank
Ewing Bank
Houston Basin
Green Knoll
Keathley Canyon
Cortes Canyon
Mansfield Dome
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
Mexican Ridges
East Mexico Shelf
10
100
500
1000
2000
3000
0 50 100 Kilometers
Northern Gannet (Morus bassanus)
(2001 - 2010)1 Units = Mean count/party hour
U.S. Gulf of Mexico Only
0.011 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.250
1.251 - 4.750
None Observed
Species Range 2
Exclusive Economic Zones
Contours (meters)
Note: Observations represent early winter distribution from shore-based Christmas Bird Counts.
Sources: (1) National Audubon Society. (2010). The Christmas bird count historical results. Retrieved May 28, 2012, from http://www.christmasbirdcount.org (2) Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). Digital distribution maps of the birds of the western hemisphere, version 3.0. Arlington, VA: NatureServe.

6.2 Brown Pelican *Pelecanus occidentalis*

Description

Brown pelicans and laughing gulls gather at the water's edge near Grand Isle, Louisiana. Credit: Cheryl Gerber

Brown pelicans occur along the Atlantic, Pacific and Gulf coasts of North and South America as well as throughout the Gulf of Mexico. They inhabit marine and estuarine environments ranging from sandy beaches to water fronts and marinas (Map 27) (Shields, 2002). The species breeds primarily on barrier islands, natural estuarine islands and dredge-spoil islands removed from human disturbance and predators. They also breed on mangrove islets in Florida. Important roosting sites are sandbars, pilings, jetties, breakwaters, mangrove islets, and offshore rocks and islands where ground or tree nests are constructed (Briggs et al., 1983). During the breeding season, brown pelicans tend to nest within 12 to 19 kilometers (20 to 30 miles) of a consistent food supply. Outside of the breeding season, brown pelicans expand their foraging range up to 30 kilometers (45 miles) from land (Shields, 2002).

Brown pelicans are the smallest of seven pelican species worldwide (Shields, 2002). Adults can reach 37 centimeters (15 inches) in length and typically have a wingspan of 2 to 2.3 meters (6.5 to 7.5 feet) (USFWS, 2009). Adults weigh between about 3.5 and 4.5 kilograms (8 to 10 pounds). They have white heads with pale yellow crowns, brownish bodies, and black legs and feet. Pelicans live up to 30 years or more and reach maturity between 3 and 5 years of age (USFWS, 2009). They are social birds and congregate in large flocks throughout the year. The Gulf breeding season is from winter through spring, with peak egg-laying between March and May (Shields, 2002; USFWS, 2009). Both males and females share the responsibility of incubating eggs and raising hatchlings. Since brown pelicans cannot remain on the water for more than an hour at a time without becoming water logged, they require secure, dry sites for roosting, and a place to perch and rest.

Brown pelicans are strong swimmers and plunge divers, plunging into the water to catch prey in their expandable pouches, which is a feeding strategy unique to brown pelicans. Pelicans are primarily fish-eaters and consume roughly 4 pounds of fish a day (USFWS, 2009). Finfish, such as menhaden, herring, and minnows, and, to a lesser degree, crustaceans are important food items for this species.

The brown pelican population declined sharply due to the widespread use of pesticides, especially Endrin and DDT, before the U.S. government banned DDT in 1972 (EPA, 37 Fed. Reg. 13369-13376). Pelicans ate fish contaminated with DDT and, as a result, laid eggs with thin shells susceptible to cracking during incubation. By the 1960s, breeding pelicans were extirpated from Louisiana and nearly so in Texas. Although brown pelicans were listed nationally as an endangered species under the U.S. Endangered Species Act, they have made a strong recovery in the Gulf (USFWS, 74 Fed. Reg. 59444). The successful recovery of brown pelicans resulted in their removal from the U.S. Endangered Species list in 2009, but recovery monitoring continues. The species is no longer on the state lists of endangered species in Texas, Alabama or Florida, but it remains endangered at the state level in Louisiana and Mississippi. The BP Deepwater Horizon (DWH) oil disaster in the Gulf resulted in the oiling and deaths of brown pelicans, but information on the full extent of impacts on the population is not currently available. The size of the global brown pelican population is about 650,000, and about half of the southeastern population nests along the Gulf Coast (EPA, 37 Fed. Reg. 13369-13376; USFWS, 2010).

See related maps and narratives on Barrier Islands and Gulf Menhaden.

Data Compilation and Mapping Methods

Data for brown pelican nesting colonies along the U.S. Gulf Coast were obtained from various surveys and monitoring programs conducted by state or federal wildlife agencies or nonprofit conservation organizations. Maximum nest counts were used for locations that have been active in the past 25 years and only sites with more than 10 nests were included on Map 27. When direct nest counts were not available, the nesting population data obtained from each state were divided by 2 to generate a rough estimate of nesting pairs within a nesting colony as a proxy for nest numbers. For sites with multiple nesting years, an average was calculated for the active nesting years. In addition, we used the following nesting season datasets: U.S. Geological Survey Patuxent Wildlife Research Center (2012) for years 1987-2003 in several states; Florida Shorebird Alliance (2010, 2011) for years 2005-2012 in Florida; National Audubon Society (2012) for years 1998-2012 in Florida; Michot et al. (2003) for the 2001 nesting season in Louisiana; Texas Colonial Waterbird Society (2012) for years 1987-2011 in Texas; Elisa Peresebarbosa Rojas of Pronatura Veracruz (2012) for the 2012 nesting season in Veracruz; and Barbara MacKinnon de Montes of Amigos de Sian Ka'an A.C. (2012) for Campeche, Yucatán and Quintana Roo.

Data Quality

Data quality for this map in U.S. waters is fair, primarily because brown pelican nesting data are unavailable for recent years in many parts of the Gulf. Different survey methods, the variable age of the data, and limited geographic coverage are additional limitations. The data used for Map 27 were the most current available for each area at the time of map production. Very few data were obtained for nesting colonies in Mexico, and no data were obtained for Cuba.

Synthesis and Conclusions

Brown pelicans are widespread in coastal areas throughout the Gulf. The successful recovery of brown pelicans resulted in their removal in 2009 from the U.S. Endangered Species list, although recovery monitoring continues. The brown pelican is listed as endangered in Louisiana and Mississippi, in Texas as threatened, and in Florida as a Species of Special Concern (FWC, 2012). The DWH oil disaster affected brown pelicans, and continued research and monitoring is needed to determine the full extent of these effects and to track the long-term trends and other related environmental impacts on this species.

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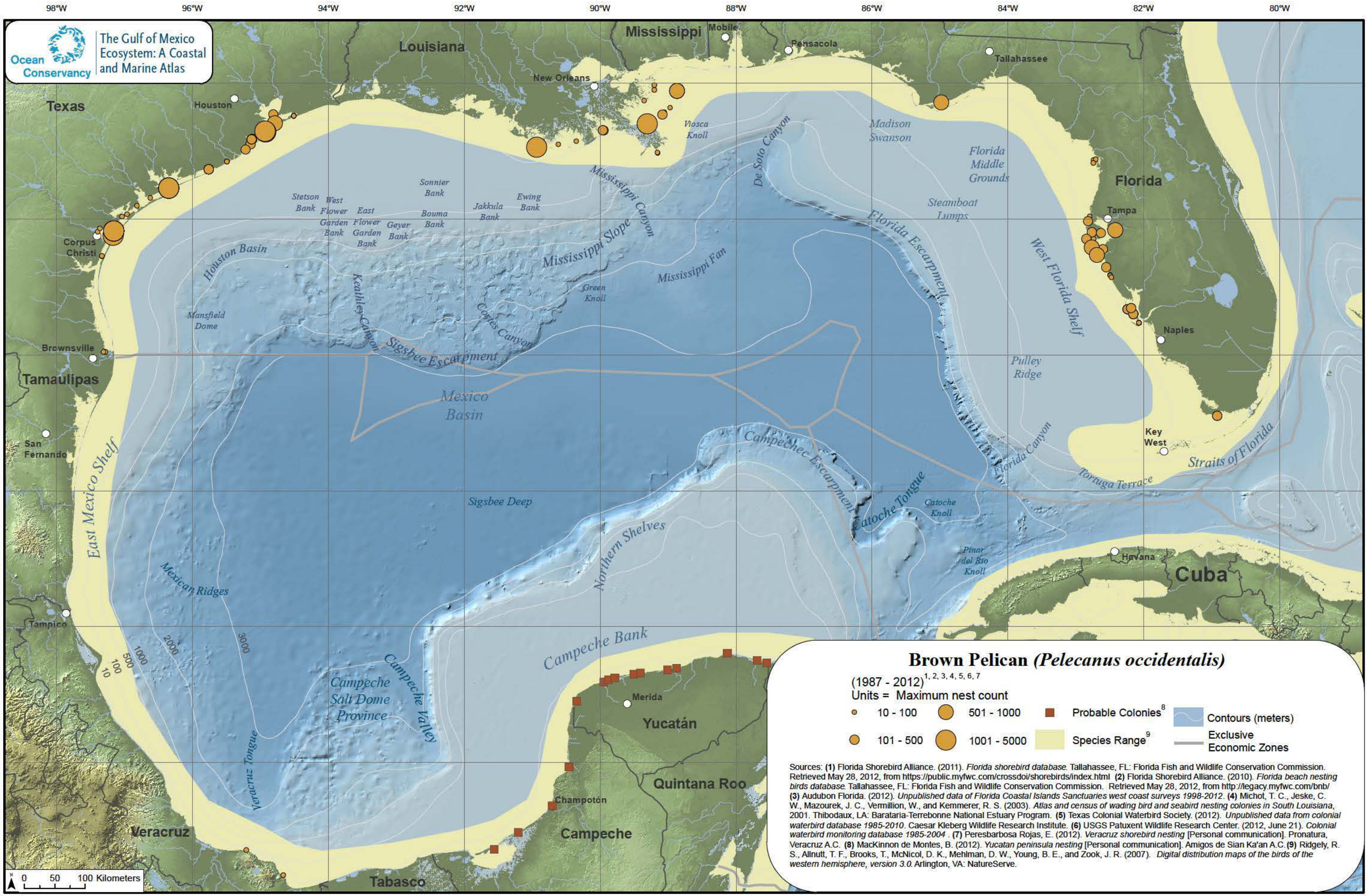
MAP 27 *(next page)*. **BROWN PELICAN**


Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Brown Pelican (Pelecanus occidentalis)
(1987 - 2012)1, 2, 3, 4, 5, 6, 7
Units = Maximum nest count
10 - 100
101 - 500
501 - 1000
1001 - 5000
Probable Colonies8
Species Range9
Contours (meters)
Exclusive Economic Zones
Sources: (1) Florida Shorebird Alliance. (2011). Florida shorebird database. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from https://public.myfwc.com/crossdoi/shorebirds/index.html (2) Florida Shorebird Alliance. (2010). Florida beach nesting birds database. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from http://legacy.myfwc.com/bnb/ (3) Audubon Florida. (2012). Unpublished data of Florida Coastal Islands Sanctuaries west coast surveys 1998-2012. (4) Michot, T. C., Jeske, C. W., Mazourek, J. C., Vermillion, W., and Kemmerer, R. S. (2003). Atlas and census of wading bird and seabird nesting colonies in South Louisiana, 2001. Thibodaux, LA: Barataria-Terrebonne National Estuary Program. (5) Texas Colonial Waterbird Society. (2012). Unpublished data from colonial waterbird database 1985-2010. Caesar Kleberg Wildlife Research Institute. (6) USGS Patuxent Wildlife Research Center. (2012, June 21). Colonial waterbird monitoring database 1985-2004 . (7) Peresbarbosa Rojas, E. (2012). Veracruz shorebird nesting [Personal communication]. Pronatura, Veracruz A.C. (8) MacKinnon de Montes, B. (2012). Yucatan peninsula nesting [Personal communication]. Amigos de Sian Ka'an A.C. (9) Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). Digital distribution maps of the birds of the western hemisphere, version 3.0. Arlington, VA: NatureServe.
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
Corpus Christi
Brownsville
San Fernando
Tampico
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Merida
Champotón
Houston Basin
Mississippi Slope
Mississippi Canyon
Mississippi Fan
De Soto Canyon
Florida Escarpment
West Florida Shelf
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Northern Shelves
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Mexican Ridges
East Mexico Shelf
Veracruz Tongue
Straits of Florida
Tortuga Terrace
Florida Canyon
Pulley Ridge
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Viosca Knoll
Green Knoll
Catoche Knoll
Pinar del Rio Knoll
Mansfield Dome
Keathley Canyon
Cortes Canyon
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
10
100
500
1000
2000
3000
0 50 100 Kilometers

6.3 Clapper Rail *Rallus longirostris*

Description

Clapper rails (or marsh hens) are distributed throughout the Americas and the Caribbean, ranging from the northern U.S. to Peru and Brazil (Rush et al., 2012). In the Gulf of Mexico, year-round populations occur from Cape Sable, Florida west to Tamaulipas, Mexico and to Cuba (Map 28) (Garrido & Kirkconnell, 1993; Rush et al., 2012). During the summer, clapper rails inhabit salt and brackish marshes typically dominated by cordgrass, pickleweed, needlerush or mangroves near open water. In the winter, clapper rails tend to prefer heavier cover and favor denser, more mature vegetation and higher elevation marsh. Clapper rails are considered an indicator of marsh condition because they rely exclusively on this habitat for nesting and foraging (Novack et al., 2006).

A clapper rail in a coastal marsh.
Credit: Gerald A. DeBoer / Shutterstock

Clapper rails are good swimmers and have laterally flattened bodies, enabling them to slip between the reeds and tall grasses of marshes (Rush et al., 2012). Adults range in length from roughly 30 to 40 centimeters (12 to 16 inches), weighing approximately 160 to 400 grams (6 to 14 ounces), and males are generally 20 percent larger than females (Rush et al., 2012). Their bills are approximately 5 centimeters (2 inches) long, their wings are short and rounded, and they have large feet and long legs in proportion to their bodies (Lewis & Garrison, 1983). Across the species' range, adult coloration varies considerably between grayish and cinnamon brown, with white and black barred flanks, but both sexes have similar coloration (Rush et al., 2012). While clapper rails are slightly smaller than king rails and prefer a more saline environment, they closely resemble king rails and frequently hybridize in habitats of intermediate salinity. As a result, clapper and king rails are often difficult to distinguish from one another (Rush et al., 2012).

Clapper rails eat primarily crustaceans (e.g., fiddler crabs and shrimp), but also clams, mussels, marine worms, insects, seeds, bird eggs and slugs (Rush et al., 2012). Male clapper rails are territorial, displaying more aggression during the breeding season (National Audubon Society, 2010). Males and females are monogamous for the breeding season, mating once or twice. Females lay five to eight eggs, which the pair incubates for approximately 20 days. Clapper rails are secretive and fly infrequently, which makes them difficult to observe and study.

Globally, populations are decreasing, but the species is generally not considered vulnerable due to its very wide range (BirdLife International, 2012). Eastern U.S. populations of the clapper rail appear stable, and the International Union for Conservation of Nature classifies this species as Least Concern (Rush et al., 2012). Habitat loss, pollutants, urbanization and predation are the most significant threats to the clapper rail (Rush et al., 2012). The BP Deepwater Horizon (DWH) oil disaster in the Gulf resulted in the oiling and deaths of clapper rails, but information on the full extent of impacts on population status is not yet available.

See related map and narrative on Salt Marshes and Mangrove Forests

Data Compilation and Mapping Methods

Data for clapper rails were obtained from the National Audubon Society's Christmas Bird Count (CBC) using only counts conducted in marine or estuarine habitats within the 15-mile diameter count circle. Land cover data were used for the habitat-based selection process from the coastal change and analysis program produced by NOAA. Only counts that were active in at least 7 out of the past 10 years (2001-2010) were used to compile these data. The mean number of rails per party hour were calculated for the active years of each survey to represent the number of rails present in each count circle. Party hours were used to standardize the counts by effort. A party hour equals one group of observers in the field for one hour.

Data Quality

Data quality for Map 28 is fair in U.S. waters. While there are 64 CBCs along the Gulf Coast that intersect the marine and estuarine environment, clapper rails are estuarine birds occupying coastal salt marshes and are very difficult to locate during the winter in this region. Clapper rails are typically counted by response vocalizations to broadcast calls during the breeding season using standardized North American marsh bird monitoring methodology (Conway, 2011). Broadcast calls may be used on a CBC, but their use outside of the breeding season is less effective. Hence, clapper rails are almost certainly undercounted on CBCs. Few or no relevant CBCs exist in Mexico and Cuba, so data quality for this portion of the map is poor.

Synthesis and Conclusions

Clapper rails are medium-size marsh birds found throughout the Americas and the Caribbean. Gulf clapper rails are a resident population, nesting and foraging in coastal wetlands, such as salt and brackish marshes and mangroves. Populations are considered stable, but knowledge gaps in clapper rail biology need attention through additional research and monitoring, particularly in light of potential impacts from the DWH oil disaster on this species and its prey and habitats.

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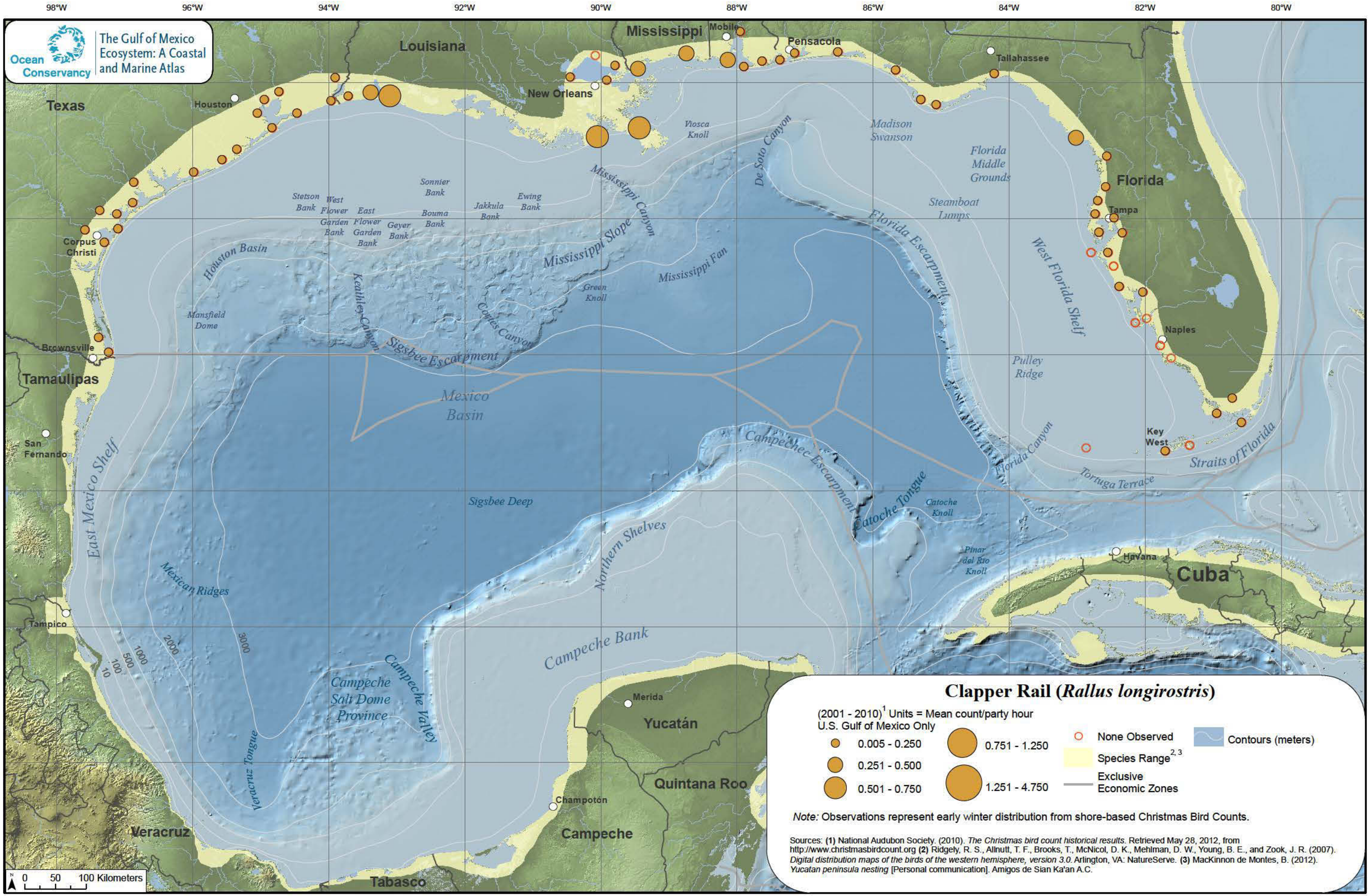
MAP 28 *(next page)*. **CLAPPER RAIL**


Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Clapper Rail (Rallus longirostris)
(2001 - 2010)[1] Units = Mean count/party hour
U.S. Gulf of Mexico Only
0.005 - 0.250
0.251 - 0.500
0.501 - 0.750
0.751 - 1.250
1.251 - 4.750
None Observed
Species Range[2, 3]
Exclusive Economic Zones
Contours (meters)
Note: Observations represent early winter distribution from shore-based Christmas Bird Counts.
Sources: (1) National Audubon Society. (2010). The Christmas bird count historical results. Retrieved May 28, 2012, from http://www.christmasbirdcount.org (2) Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). Digital distribution maps of the birds of the western hemisphere, version 3.0. Arlington, VA: NatureServe. (3) MacKinnon de Montes, B. (2012). Yucatan peninsula nesting [Personal communication]. Amigos de Sian Ka'an A.C.
98°W
96°W
94°W
92°W
90°W
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86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Houston Basin
Mansfield Dome
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Keathley Canyon
Sigsbee Escarpment
Mississippi Slope
Mississippi Canyon
Mississippi Fan
Green Knoll
Viosca Knoll
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
East Mexico Shelf
Mexican Ridges
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers

6.4 Least Tern *Sternula antillarum*

Least tern on a beach. Credit: Dennis Donohue / Shutterstock

Description

The least tern is widely distributed in coastal areas and major inland waterways throughout much of the Americas and the Caribbean (Thompson et al., 1997). This species has three breeding populations and their distributions within those populations are localized and not continuous. The California least tern breeds along the Pacific Coast from California to western Mexico, the eastern (or coastal) least tern breeds along the Atlantic and Gulf coasts from New England to the Caribbean and Central America, and the interior least tern breeds along major rivers and watersheds in the central U.S. (e.g., Mississippi, Arkansas and Red River watersheds) (Robertson & Woolfenden, 1992; Lott, 2006). All populations are migratory, moving to more tropical coastal waters in the Western Hemisphere from Central America south to the west coast of Peru and to southern Brazil. Least terns from two of the three populations are seasonally present on the Gulf Coast (Map 29). Eastern least terns breed in colonies along the coast in each of the U.S. Gulf states and in Mexico and Cuba, whereas interior least terns pass through the region during migration and occasionally winter on the Gulf Coast.

The preferred nesting habitats of least terns are sandy beaches, yet riverine sandbars, mudflats and even gravel roofs are also suitable nesting areas. The species is a plunge diver, feeding on small fish, but also crustaceans and insects in shallow-water habitats, such as bays, lagoons, estuaries, river and creek mouths, tidal marshes, and ponds (Thompson et al., 1997).

Least terns are 20 to 23 centimeters (8 to 9 inches) in length and weigh approximately 28 grams (1 ounce). Their wingspan is about 51 centimeters (20 inches).

Least terns arrive at their breeding grounds from late April to mid-May, forming colonies that can have well over 1,000 pairs of birds. Peak nesting is from mid-May through July. By late August and early September, least terns leave their breeding grounds and migrate to wintering areas. The minimum estimate for the least tern population from Texas to the Florida panhandle is about 11,400 to 12,200 (Lott, 2006).

Any interior (>50 km from the coast) nesting least tern is listed as endangered under the federal Endangered Species Act (USFWS, 50 Fed. Reg. 21792). Although the eastern least tern population is not federally listed, they are listed as a Species of Concern in Mississippi and Threatened in Florida, and are considered a Species Requiring Management Attention by the Southeast United States Regional Waterbird Conservation Plan (Hunter et al., 2006). Continued habitat loss, due to human activities, as well as sea level rise and erosion, especially on barrier islands, are threats to least terns. Human activities, such as beach grooming and recreation in nesting and adjacent feeding areas, are additional sources of stress and threat to the species along the Gulf Coast (Thompson et al., 1997). The BP Deepwater Horizon (DWH) oil disaster in the Gulf resulted in the oiling and deaths of least terns, and clean-up efforts caused additional disturbance to nesting colonies, but information on the full extent of impacts on the population is not currently available.

See related maps and narratives on Barrier Islands, Gulf Menhaden and Projected Sea Level Rise.

Data Compilation and Mapping Methods

Government agencies and nonprofit organizations that conduct surveys or oversee monitoring programs provided data on eastern least tern nesting colonies along the U.S. Gulf Coast, but nesting locations of interior least terns were not included. Maximum nest counts were used for locations known to be active at any time during the past 25 years, and only sites with more than 50 nests were included on Map 29. For sites with multiple years of nesting data, maximum counts during the range of available data were used to represent the entire data period. When direct nest counts were not available, but estimates of the nesting population were available, we used the estimated nesting population divided by 2 as a proxy for nest numbers. Least tern nests are ephemeral, so these nest counts represent a maximum total over a 25-year record and may not represent the current nesting population numbers.

The U.S. Geological Survey (2012) provided data on least tern nests for the years 1987 through 2003 in Texas, Louisiana, Mississippi and Florida. In addition, we used the following nesting season datasets: Florida Shorebird Alliance (2010, 2011) for years 2005-2011 in Florida; Dinsmore (2005) for the 2005 nesting season in Mississippi; Michot et al. (2003) and Zdravkovic (2006b) for the 2001 and 2005 nesting seasons in Louisiana; Texas Colonial Waterbird Society (2012) for years 1987 through 2011 in Texas; and Zdravkovic (2006a), Elisa Peresebarbosa Rojas of Pronatura Veracruz (2012), Barbara MacKinnon de Montes of Amigos de Sian Ka'an A.C. (2012), and Adriana Vallarino Moncada of Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México (2012) for Mexico.

Data Quality

Data quality for Map 29 is fair for the U.S. coast, primarily because least tern nesting data are unavailable for recent years in many parts of the Gulf Coast and none are available in Alabama. Many U.S. data sources represent single season snapshots taken from single survey years, while others are now several years old. Very few data were obtained for nesting colonies in Mexico, and no data were obtained for Cuba.

Synthesis and Conclusions

The least tern is native to the Americas and distributed throughout North, Central and South America as well as the Caribbean. Two populations use the Gulf Coast: 1) interior least terns breeding along rivers in the continental U.S. are present as migrants and occasionally during the winter in the Gulf, and 2) eastern least terns breed on the Gulf Coast from Florida to Mexico and sporadically in Central America. The preferred nesting habitat of this species is along beaches on the mainland as well as on barrier islands. Least tern populations appear stable in the Gulf, but continuing habitat loss and incompatible human activities, such as sand grooming near beach nesting sites, are concerns and raise questions about the status of the species. Loss of nesting habitat due to sea level rise and coastal erosion is also a major concern. Continued research and monitoring are essential to track the long-term trends and impacts of the DWH oil disaster, environmental change due to global warming, and increasing pressure due to human activities on the coast.

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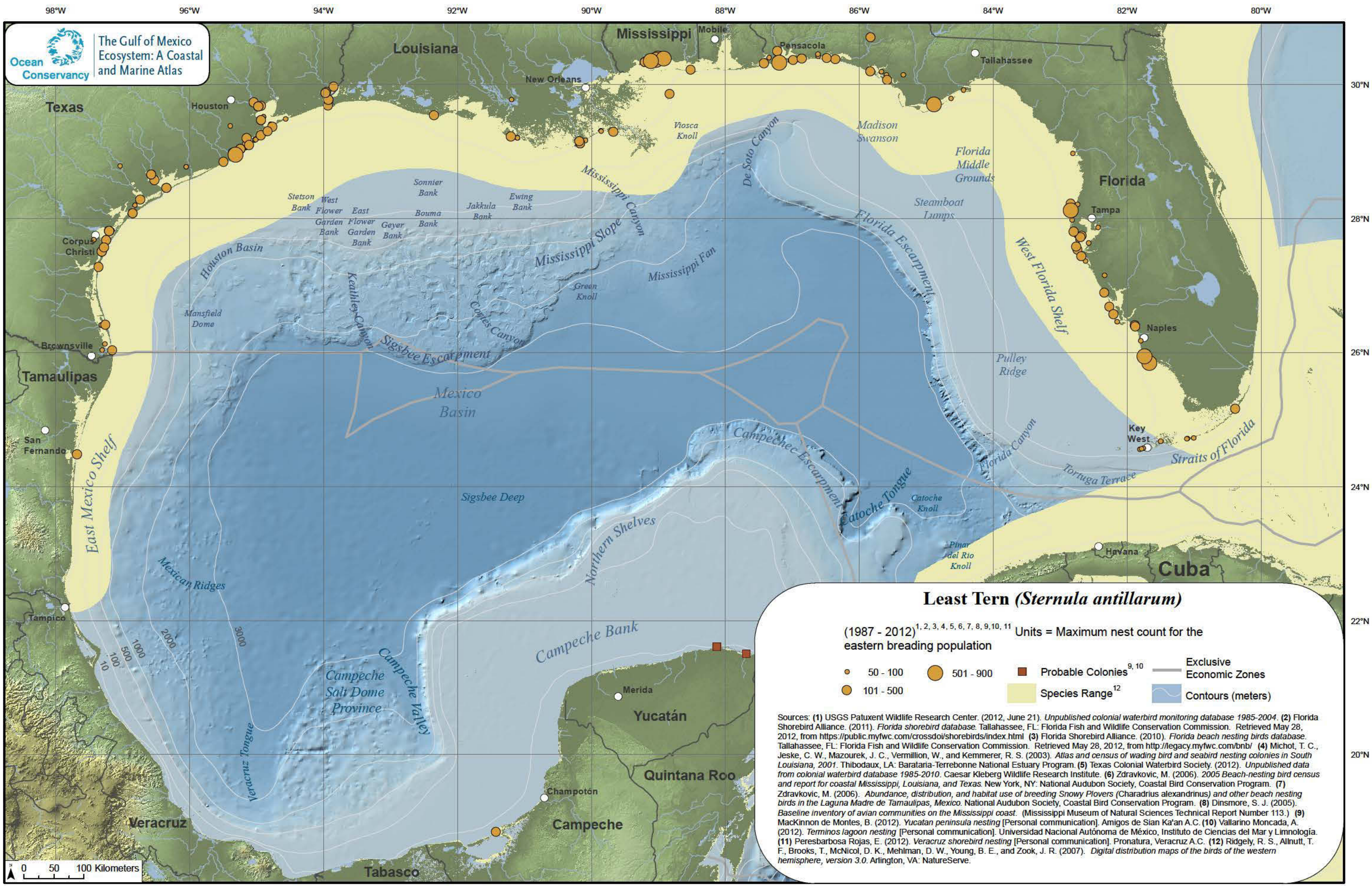
MAP 29 *(next page)***. LEAST TERN**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
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82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Viosca Knoll
Madison Swanson
Florida Middle Grounds
De Soto Canyon
Mississippi Canyon
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Sonnier Bank
Bouma Bank
Geyer Bank
Jakkula Bank
Ewing Bank
Steamboat Lumps
Houston Basin
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Green Knoll
Mansfield Dome
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Pulley Ridge
Mexico Basin
Campeche Escarpment
Florida Canyon
Tortuga Terrace
Straits of Florida
East Mexico Shelf
Sigsbee Deep
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Least Tern (Sternula antillarum)
(1987 - 2012)[1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11] Units = Maximum nest count for the eastern breading population
50 - 100
101 - 500
501 - 900
Probable Colonies[9, 10]
Species Range[12]
Exclusive Economic Zones
Contours (meters)
Sources: (1) USGS Patuxent Wildlife Research Center. (2012, June 21). Unpublished colonial waterbird monitoring database 1985-2004. (2) Florida Shorebird Alliance. (2011). Florida shorebird database. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from https://public.myfwc.com/crossdoi/shorebirds/index.html (3) Florida Shorebird Alliance. (2010). Florida beach nesting birds database. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from http://legacy.myfwc.com/bnb/ (4) Michot, T. C., Jeske, C. W., Mazourek, J. C., Vermillion, W., and Kemmerer, R. S. (2003). Atlas and census of wading bird and seabird nesting colonies in South Louisiana, 2001. Thibodaux, LA: Barataria-Terrebonne National Estuary Program. (5) Texas Colonial Waterbird Society. (2012). Unpublished data from colonial waterbird database 1985-2010. Caesar Kleberg Wildlife Research Institute. (6) Zdravkovic, M. (2006). 2005 Beach-nesting bird census and report for coastal Mississippi, Louisiana, and Texas. New York, NY: National Audubon Society, Coastal Bird Conservation Program. (7) Zdravkovic, M. (2006). Abundance, distribution, and habitat use of breeding Snowy Plovers (Charadrius alexandrinus) and other beach nesting birds in the Laguna Madre de Tamaulipas, Mexico. National Audubon Society, Coastal Bird Conservation Program. (8) Dinsmore, S. J. (2005). Baseline inventory of avian communities on the Mississippi coast. (Mississippi Museum of Natural Sciences Technical Report Number 113.) (9) MacKinnon de Montes, B. (2012). Yucatan peninsula nesting [Personal communication]. Amigos de Sian Ka'an A.C. (10) Vallarino Moncada, A. (2012). Terminos lagoon nesting [Personal communication]. Universidad Nacional Autónoma de México, Instituto de Ciencias del Mar y Limnología. (11) Peresbarbosa Rojas, E. (2012). Veracruz shorebird nesting [Personal communication]. Pronatura, Veracruz A.C. (12) Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). Digital distribution maps of the birds of the western hemisphere, version 3.0. Arlington, VA: NatureServe.

6.5 Royal Tern *Thalasseus maximus*

Description

Royal terns on a Florida beach. Credit: Dennis Donohue / Shutterstock

Royal terns occur year-round in the Gulf of Mexico. They breed in large, dense colonies (sometimes numbering in the thousands), on isolated barrier islands and beaches from April to July and then disperse throughout the region (Map 30). The New World subspecies, *T. m. maxima*, breeds as far north as Virginia on the U.S. Atlantic Coast (Clay, 2006), on the Pacific Coast from northern Mexico to southern California, on the Gulf Coast of Mexico near Campeche Bank and less regularly in the Caribbean (Buckley & Buckley, 2002). Royal terns move to their wintering grounds in October, which overlap breeding areas and extend south to northeastern South America and Peru.

This species is associated with warm, marine waters, inhabiting sandy coasts, coastal bays and nearshore islands close to foraging areas, such as surf zones, inlets and back bays (Clay, 2006). Breeding sites tend to be surrounded by shallow water near the mouths of bays with high visibility and little vegetation that are inaccessible to mammalian predators. Nests are simple shallow depressions in the ground, also known as scrapes, but eggs can be laid directly on the ground with no scrape. Royal terns begin nesting at 4 years of age and are generally believed to be a long-lived species, with the oldest known individual living 28 years (Buckley & Buckley, 2002; Clay, 2006).

Royal terns have an average length of about 40 to 50 centimeters (16 to 20 inches), a wingspan just over 1 meter (4 feet), and a weight of approximately 0.5 kilograms (1 pound) (Buckley & Buckley, 2002). This species is a plunge diver, eating mainly fish (e.g., menhaden) and crustaceans (e.g., blue crab and shrimp). They generally forage close to shore in marine waters, but can travel from 80 to 120 kilometers (50 to 75 miles) away from shore (Buckley & Buckley, 2002).

Royal tern populations are generally stable, with the estimated number of nesting pairs totaling more than 50,000 in the Gulf region (Hunter et al., 2006; E. Johnson, personal communication, 2013). Most nesting royal terns are concentrated in Texas and in the Mississippi Sound, off of the coasts of Louisiana and Mississippi (Map 30). Degradation of nesting habitat due to development and human activity near nesting sites are sources of stress, but the species has adapted to rely on alternative habitats, such as dredge-spoil islands. The BP Deepwater Horizon (DWH) oil disaster in the Gulf resulted in the oiling and deaths of adult royal terns and their chicks, but information on the full extent of impacts on their population is not available.

See related maps and narratives on Barrier Islands, Blue Crab and Gulf Menhaden.

Data Compilation and Mapping Methods

Data for royal tern nesting colonies along the U.S. Gulf Coast came from various survey and monitoring programs conducted by either state or federal wildlife agencies or nonprofit organizations. Maximum nest counts were used for locations known to be active at any time during the past 25 years. Only nesting sites with at least 10 nests were included on Map 30. When direct nest counts were not available, the estimated nesting population was divided by 2 to generate a proxy for nest numbers.

The U.S. Geological Survey (2012) provided colonial water bird data, including royal tern nests, for the years 1987 through 2003 in Texas, Louisiana, Mississippi and Florida. In addition, we used the following nesting season datasets: Florida Shorebird Alliance (2010, 2011) for years 2005-2011 in Florida; Dinsmore (2005) for the 2005 nesting season in Mississippi; Michot et al. (2003) and Audubon (2005), respectively, for the 2001 and 2005 nesting seasons in Louisiana; Texas Colonial Waterbird Society (2012) for years 1987-2011 in Texas; and Audubon (2006), Adriana Vallarino Moncada of Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México (2012), Barbara MacKinnon de Montes of Amigos de Sian Ka'an A.C. (2012), and Tunnell and Chapman (2000) for Mexico.

Data Quality

The data quality for this map in U.S. waters is fair, primarily because royal tern nesting data are unavailable for recent years in many parts of the Gulf. Many source datasets are from single survey years and are now several years old. Use of different survey methods in different locations is an additional limitation. Very few data were obtained for nesting colonies in Mexico, and no data were obtained for Cuba.

Synthesis and Conclusions

Royal terns are present year-round in warm, nearshore waters of the Gulf. They favor barrier islands and other isolated environments for nesting and feed in waters close to shore. The species is not listed as endangered or threatened at the federal level or in any of the Gulf states. Continued research and monitoring are essential to track the long-term trends and specific impacts of the DWH oil disaster and other stressors on this species.

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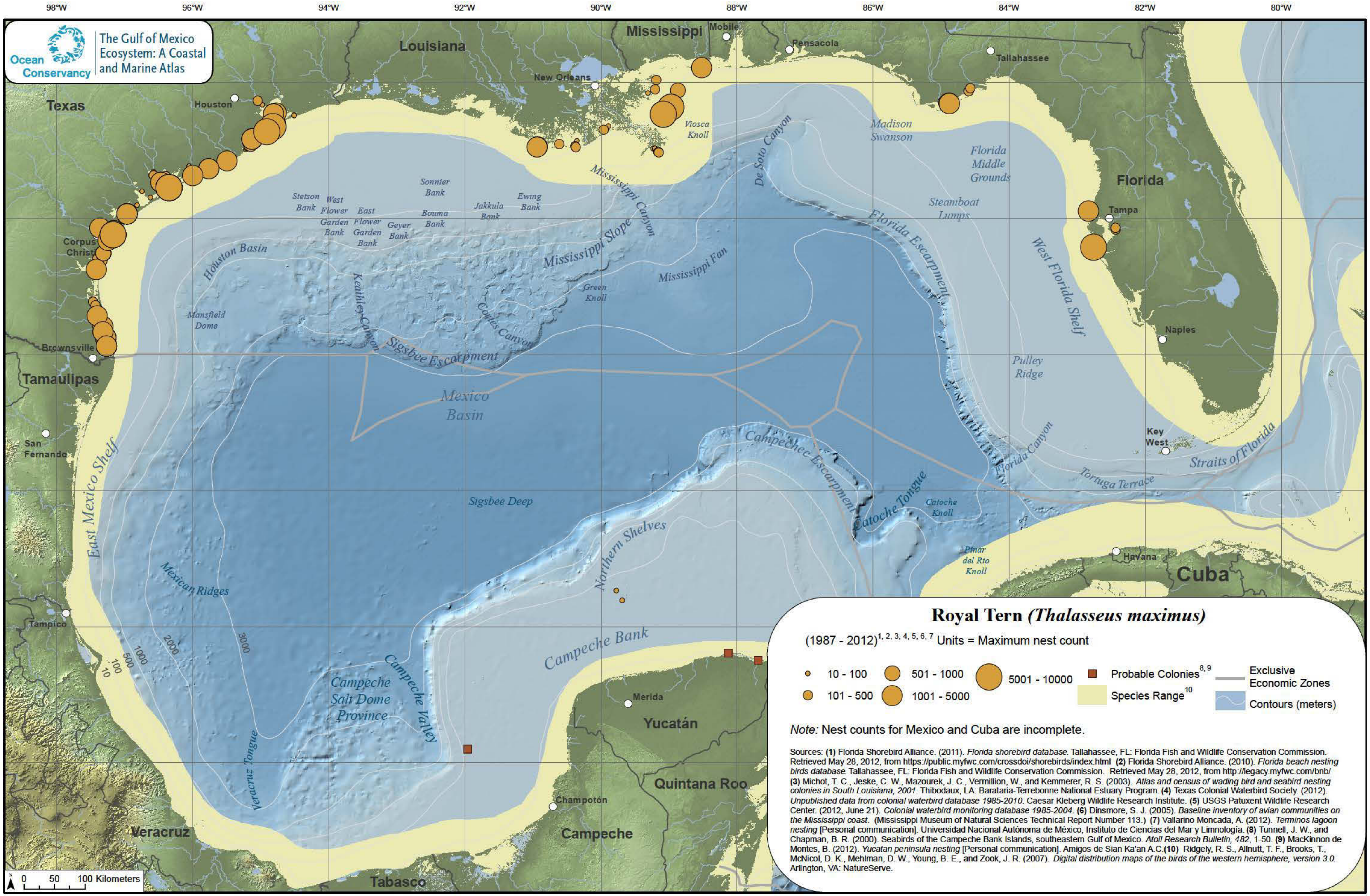
MAP 30 *(next page)*. **ROYAL TERN**



Royal Tern *(Thalasseus maximus)*

(1987 - 2012)[1, 2, 3, 4, 5, 6, 7] Units = Maximum nest count

10 - 100; 101 - 500; 501 - 1000; 1001 - 5000; 5001 - 10000; Probable Colonies[8, 9]; Species Range[10]; Exclusive Economic Zones; Contours (meters)

Note: Nest counts for Mexico and Cuba are incomplete.

Sources: **(1)** Florida Shorebird Alliance. (2011). *Florida shorebird database.* Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from https://public.myfwc.com/crossdoi/shorebirds/index.html **(2)** Florida Shorebird Alliance. (2010). *Florida beach nesting birds database.* Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from http://legacy.myfwc.com/bnb/ **(3)** Michot, T. C., Jeske, C. W., Mazourek, J. C., Vermillion, W., and Kemmerer, R. S. (2003). *Atlas and census of wading bird and seabird nesting colonies in South Louisiana, 2001.* Thibodaux, LA: Barataria-Terrebonne National Estuary Program. **(4)** Texas Colonial Waterbird Society. (2012). *Unpublished data from colonial waterbird database 1985-2010.* Caesar Kleberg Wildlife Research Institute. **(5)** USGS Patuxent Wildlife Research Center. (2012, June 21). *Colonial waterbird monitoring database 1985-2004.* **(6)** Dinsmore, S. J. (2005). *Baseline inventory of avian communities on the Mississippi coast.* (Mississippi Museum of Natural Sciences Technical Report Number 113.) **(7)** Vallarino Moncada, A. (2012). *Terminos lagoon nesting* [Personal communication]. Universidad Nacional Autónoma de México, Instituto de Ciencias del Mar y Limnología. **(8)** Tunnell, J. W., and Chapman, B. R. (2000). Seabirds of the Campeche Bank Islands, southeastern Gulf of Mexico. *Atoll Research Bulletin, 482,* 1-50. **(9)** MacKinnon de Montes, B. (2012). *Yucatan peninsula nesting* [Personal communication]. Amigos de Sian Ka'an A.C. **(10)** Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). *Digital distribution maps of the birds of the western hemisphere, version 3.0.* Arlington, VA: NatureServe.

6.6 Black Skimmer *Rynchops niger*

Description

A black skimmer flies above a beach. Credit: Steve Hillebrand / USFWS

Black skimmers are coastal waterbirds that breed locally in colonies along the Atlantic Coast, south from Massachusetts, and on the Gulf Coast from Florida to Texas and south to the Yucatán Peninsula (Map 31). On the Pacific Coast, black skimmers occur in southern California and on the coast of Mexico south to Oaxaca. Black skimmers nest in colonies on beaches, dredge spoil islands, salt marshes and other coastal habitats, often sharing these areas with other species, such as laughing gulls and common, least or gull-billed terns (Cornell University, 2011). Other subspecies of black skimmers are also found on both coasts of South America, as far south as Ecuador in the west and northern Argentina in the east. These subspecies nest along major waterways in South America, including the Amazon River. In winter, black skimmers are more widely distributed, including irregularly on the coast of Cuba (Gochfeld & Burger, 1994). Birds in the northern U.S. migrate south, whereas birds in the Gulf Coast appear to be more resident, but also may wander or migrate south to the Caribbean and northern South America.

Adult black skimmers are black on the backs of their heads and white from below their foreheads and chests (Gochfeld & Burger, 1994). Their legs and feet are reddish-orange, and the basal portion of the bill is orange or red with the distal remainder being black. Males are slightly larger than females, weighing approximately 349 grams (0.8 pounds) compared to females at 254 grams (0.6 pounds), and are an average 46 centimeters (18 inches) in length (USGS, 2011). Unique among birds, their lower mandible is longer than the maxilla. As hatchlings, the lower and upper bills are the same length, but by the time fledglings are 4 weeks old, the lower bill has outgrown the upper (Cornell University, 2011). The longer lower bill is an adaptation essential to foraging, which is performed by flying over open water while skimming the surface with the lower mandible until prey is detected, triggering the upper bill to snap shut (Gochfeld & Burger, 1994). Skimmers consume small fish, such as herring, killifish, mullet and pipefish, as well as crustaceans (Cornell University, 2011). Black skimmer pupils can constrict to a narrow vertical slit, an unusual trait in birds that may help reduce glare from water and sand (Gochfeld & Burger, 1994).

Black skimmers are social birds. Large colonies often occur at the same site year after year, while smaller colonies tend to relocate each year. They nest in simple surface scrapes and females lay two to five eggs each year (Gochfeld & Berger, 1994). During the nonbreeding season, black skimmers also form large flocks, but may be more flexible in their use of habitat for foraging, including both estuarine and marine environments for feeding (Mariano-Jelicich et al., 2003).

Black skimmers are classified by the International Union for Conservation of Nature as a species of Least Concern, by the federal government as a Species of Conservation Concern (USFWS, 2008), and in several Gulf Coast states, including Louisiana, Mississippi and Florida, as a Species of Conservation Concern. Black skimmers are considered a species requiring Management Attention by the Southeast U.S. Regional Waterbird Conservation Plan because of the loss of beach-nesting habitats to development and intrusions by humans and their pets (Hunter et al., 2006). This species nests just above the high tide line on sandy and shelled islands, so habitat loss, erosion and long-term sea level rise are serious continuing threats to nesting. The black skimmer was a species of concern during the BP Deepwater Horizon (DWH) oil disaster due to their close proximity to oiled nearshore waters and shorelines. Visibly oiled black skimmers were recovered, although information on the effects on local populations is not currently available.

See related maps and narratives on Salt Marshes and Mangrove Forests, Barrier Islands, Gulf Menhaden, and Projected Sea Level Rise.

Data Compilation and Mapping Methods

Data for black skimmer nesting colonies along the U.S. Gulf Coast came from various survey and monitoring programs conducted by either state or federal wildlife agencies or nonprofit organizations. Maximum nest counts were used for locations that have been active within the past 25 years. Only nesting sites with more than a maximum count of at least 10 nests were included on Map 31. When direct nest counts were not available, the estimated nesting population was divided by 2 to generate a proxy for nest numbers.

The U.S. Geological Survey (2012) provided colonial waterbird data, including information on black skimmer nests, for the years 1987 through 2003 in Texas, Louisiana, Mississippi and Florida. In addition, we used the following nesting season datasets: Florida Shorebird Alliance (2010, 2011) for years 2005-2011 in Florida; Dinsmore (2005) for the 2005 nesting season in Mississippi; Michot et al. (2003) and Audubon (2005) for the 2001 and 2005 nesting seasons, respectively, in Louisiana; Texas Colonial Waterbird Society (2012) for years 1987- 2011 in Texas; and Audubon (2006), Barbara MacKinnon de Montes of Amigos de Sian Ka'an A.C. (2012), Elisa Peresebarbosa Rojas of Pronatura Veracruz (2012), and Adriana Vallarino Moncada of Instituto de Ciencias del Mar y Limnología, Universidad Nacional Autónoma de México (2012) for Mexico.

Data Quality

Data quality for Map 31 on the U.S. Gulf Coast is fair, primarily because black skimmer nesting data are unavailable for recent years in many parts of the Gulf. Differences in survey methods are an additional limitation on the quality of these data. Very few data were obtained for nesting colonies in Mexico, and no data were obtained for Cuba.

Synthesis and Conclusion

In the Gulf, black skimmers are present year-round and rely on beaches, dredge spoil islands, salt marshes and similar coastal habitats for nesting and foraging. The black skimmer is a species of concern in the region, due to habitat loss and disturbance from humans. Continued research and monitoring are essential to track the long-term trends and impacts on this species from the DWH oil disaster, as well as sea level rise and increasing human activities along the Gulf Coast. Coordinated surveys are needed at nesting sites documenting colony size and productivity to assess long-term regional population trends as well as local management needs.

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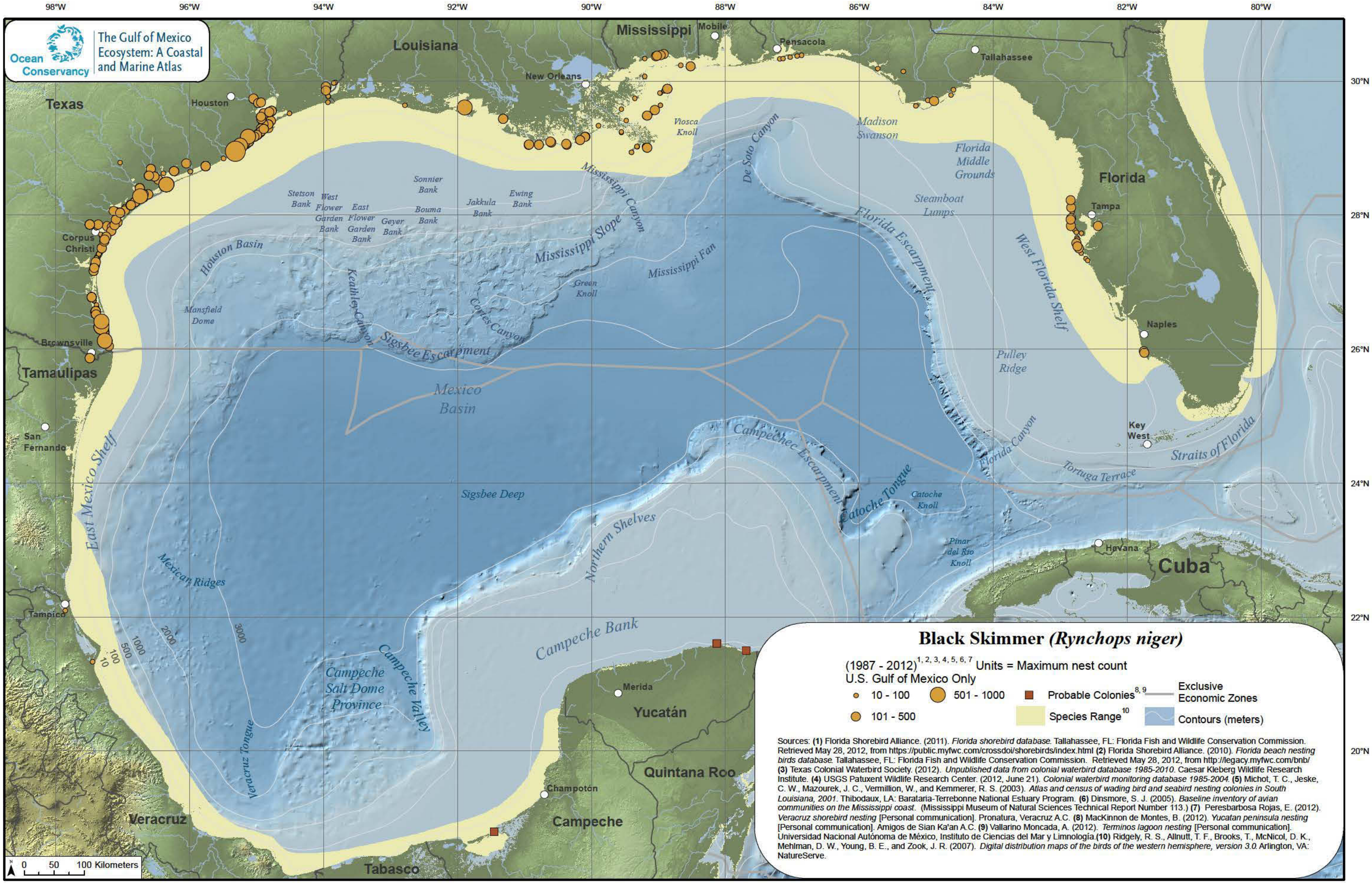
MAP 31 *(next page)*. **BLACK SKIMMER**



The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
Black Skimmer (Rynchops niger)
(1987 - 2012)[1, 2, 3, 4, 5, 6, 7] Units = Maximum nest count
U.S. Gulf of Mexico Only
10 - 100
101 - 500
501 - 1000
Probable Colonies[8, 9]
Species Range[10]
Exclusive Economic Zones
Contours (meters)
Sources: (1) Florida Shorebird Alliance. (2011). Florida shorebird database. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from https://public.myfwc.com/crossdoi/shorebirds/index.html (2) Florida Shorebird Alliance. (2010). Florida beach nesting birds database. Tallahassee, FL: Florida Fish and Wildlife Conservation Commission. Retrieved May 28, 2012, from http://legacy.myfwc.com/bnb/ (3) Texas Colonial Waterbird Society. (2012). Unpublished data from colonial waterbird database 1985-2010. Caesar Kleberg Wildlife Research Institute. (4) USGS Patuxent Wildlife Research Center. (2012, June 21). Colonial waterbird monitoring database 1985-2004. (5) Michot, T. C., Jeske, C. W., Mazourek, J. C., Vermillion, W., and Kemmerer, R. S. (2003). Atlas and census of wading bird and seabird nesting colonies in South Louisiana, 2001. Thibodaux, LA: Barataria-Terrebonne National Estuary Program. (6) Dinsmore, S. J. (2005). Baseline inventory of avian communities on the Mississippi coast. (Mississippi Museum of Natural Sciences Technical Report Number 113.) (7) Peresbarbosa Rojas, E. (2012). Veracruz shorebird nesting [Personal communication]. Pronatura, Veracruz A.C. (8) MacKinnon de Montes, B. (2012). Yucatan peninsula nesting [Personal communication]. Amigos de Sian Ka'an A.C. (9) Vallarino Moncada, A. (2012). Terminos lagoon nesting [Personal communication]. Universidad Nacional Autónoma de México, Instituto de Ciencias del Mar y Limnología.(10) Ridgely, R. S., Allnutt, T. F., Brooks, T., McNicol, D. K., Mehlman, D. W., Young, B. E., and Zook, J. R. (2007). Digital distribution maps of the birds of the western hemisphere, version 3.0. Arlington, VA: NatureServe.
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Houston Basin
Mississippi Slope
Mississippi Canyon
Mississippi Fan
De Soto Canyon
Florida Escarpment
West Florida Shelf
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Northern Shelves
Mexican Ridges
East Mexico Shelf
Veracruz Tongue
Catoche Tongue
Catoche Knoll
Florida Canyon
Tortuga Terrace
Straits of Florida
Pulley Ridge
Steamboat Lumps
Florida Middle Grounds
Madison Swanson
Viosca Knoll
Green Knoll
Mansfield Dome
Keathley Canyon
Cortes Canyon
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Pinar del Rio Knoll
10
100
500
1000
2000
3000
0 50 100 Kilometers

Sea Turtles & Marine Mammals

7.0 Kemp's Ridley Sea Turtle *Lepidochelys kempii*

Description

Kemp's ridley sea turtle hatchling heading for the ocean on Padre Island, Texas.
Credit: Laronna Doggett

Kemp's ridley sea turtles (Kemp's ridleys) are present throughout the Gulf of Mexico. Their range also includes the U.S. Atlantic Coast from Massachusetts to Florida, and juveniles are occasionally found as far from the Gulf as Europe and northern Africa (Zug et al., 1997). The largest Kemp's ridley nesting site is on the coast of Tamaulipas, Mexico. Nesting also occurs on sandy beaches in Veracruz and Campeche, Mexico, Padre Island National Seashore in Texas, and, infrequently, in other U.S. Gulf states (Shaver et al., 2005; NMFS et al., 2011) (Map 32).

The nearshore and inshore waters of the northern Gulf are important foraging grounds for Kemp's ridleys (Zug, 2009). Adult male Kemp's ridleys are thought to reside offshore near nesting beaches year-round (Shaver et al., 2005). During the first two years of life, Kemp's ridleys are pelagic and dependent on floating mats of sargassum seaweed for feeding and habitat as well as for protection from predators (TPWD, 2010). As adults, they feed mainly on a diet of crustaceans and larger mollusks (Zug, 2009).

Adult Kemp's ridleys are one of the smallest marine turtles, weighing between 32 and 49 kilograms (71 to 108 pounds), and with carapaces between 60 and 65 centimeters (24 to 26 inches) in length (Heppell et al., 2005). Kemp's ridleys are long-lived and reach maturity at 10 to 20 years of age (Shaver et al., 2005). Between May and July, waves of female Kemp's ridleys come ashore in large numbers and lay eggs in events called "arribadas" (NOAA, 2010). Unlike other sea turtle species, Kemp's ridleys come ashore to lay eggs during the day (NOAA, 2010). Females nest every one to three years, laying one to four clutches containing about 100 eggs each during the nesting season. Upon emergence from nests, hatchlings enter the Gulf where they are likely dispersed by eddies or swept into the Atlantic Ocean by sea surface currents (USFWS, 2010).

Kemp's ridley sea turtles are listed as endangered under the U.S. Endangered Species Act, and all five Gulf states classify the species as endangered (U.S. Department of the Interior, 35 Fed. Reg. 18319). Reduced population size is a result of historical egg harvest for food, loss of nesting beach habitat and incidental capture in fishing gear. Populations appear to be recovering, due in part to successful conservation measures (e.g., turtle excluder devices, habitat protection and reduced harvest) (NMFS, 2011). Kemp's ridleys were oiled and some died as a result of the BP Deepwater Horizon (DWH) oil disaster, though information on the full extent of the impact at the population level is not currently available.

See related maps and narratives on Sea Surface Currents and Pelagic Sargassum.

Data Compilation and Mapping Methods

A Kemp's ridley sea turtle nesting on a beach. Credit: National Park Service

Data for general Kemp's ridley habitat utilization (e.g., for nesting areas, migratory pathways and species range) and fishery restrictions were obtained from the following sources: NMFS et al. (2011) for nesting data and core adult habitat range; Halpin et al. (2009), Wallace et al. (2010), Marquez (1990), Wibbels (2007), Witt et al. (2007) and Status of the World's Turtles (2010) for the range of this species in and around the Gulf; Shaver and Rubio (2007) and Shaver (2012a, 2012b) for satellite-tagged Kemp's ridley tracks; and Texas Administrative Code for delineation of the seasonal south Texas shrimp fishery closure.

Data Quality

Data quality for Map 32 on the U.S. and Mexico Gulf coasts is fair. While there is good documentation of nesting activities in the U.S. and nesting arribadas in Mexico, the available tracking data for in-water distributions and habitat use are severely limited on this map. More recent data exist for Kemp's ridley nesting in Texas and Mexico, such as extensive satellite tracking data, primarily from nesting females in Texas. However, those data were not available, either because of concerns about nesting area security (i.e., revealing nest locations) or because researchers had not yet published the information.

Synthesis and Conclusions

Kemp's ridley sea turtles are dependent on the Gulf during all life stages. This species nests on beaches in south Texas and along the Mexico coast, forages in shallow nearshore waters and uses pelagic sargassum for food and habitat while young. Populations have been in decline for several decades, but appear to have stabilized due, in part, to successful conservation measures. Information on the full extent of impacts on Kemp's ridleys resulting from the DWH oil disaster is not currently available. Kemp's ridley sea turtles are listed as endangered under the U.S. Endangered Species Act, and all five Gulf states classify the species as endangered. Additional research is needed to better understand Kemp's ridleys' biology, movement and ecology (Shaver et al., 2005) as well as the long-term impacts of the DWH oil disaster on this species.

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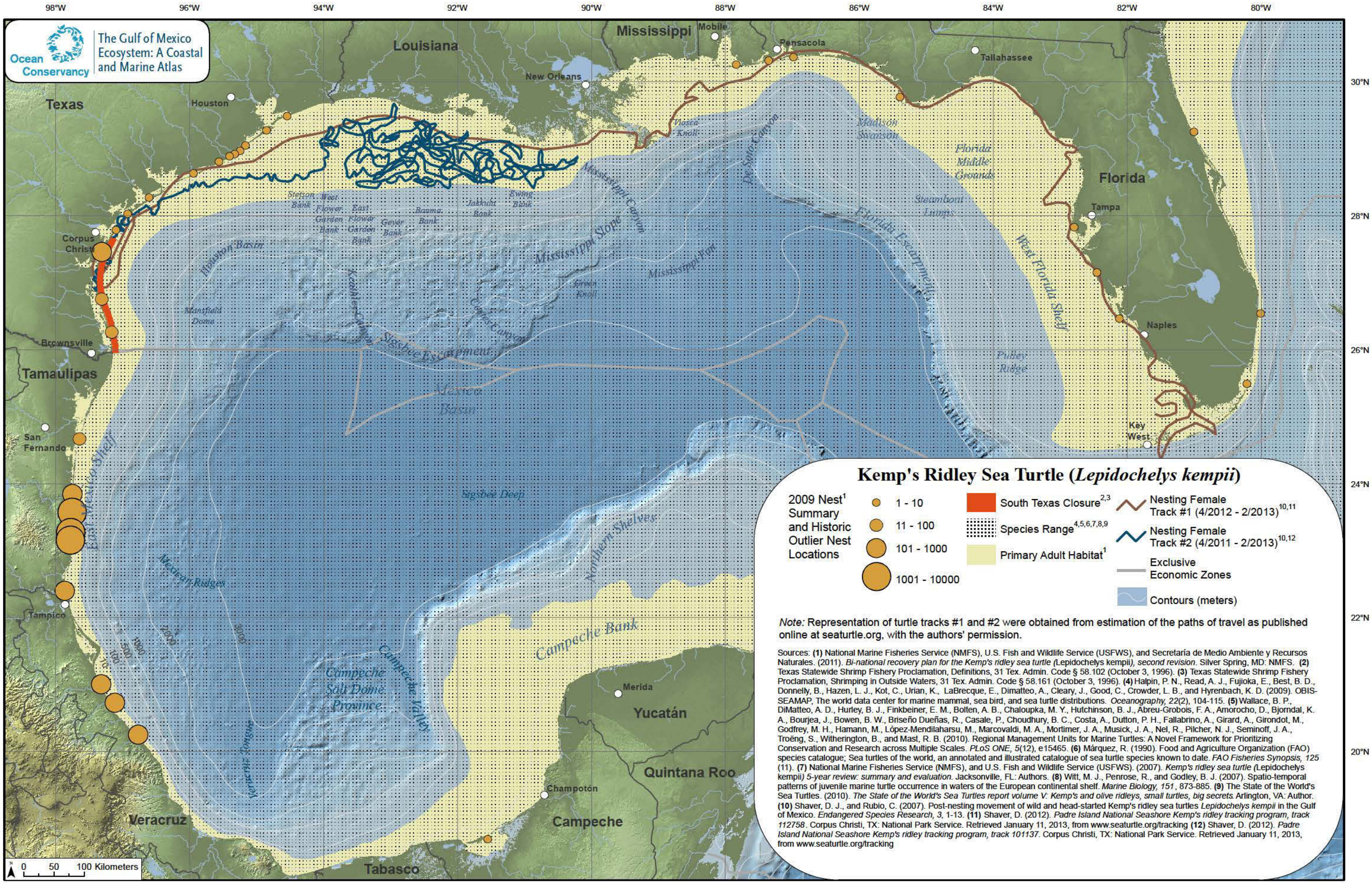
MAP 32 *(next page)*. **KEMP'S RIDLEY SEA TURTLE**


98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
New Orleans
Texas
Houston
Florida
Tampa
Naples
Key West
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champoton
Merida
Yucatán
Quintana Roo
Viosca Knoll
Madison Swanson
Florida Middle Grounds
De Soto Canyon
Mississippi Canyon
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Steamboat Lumps
Houston Basin
Mississippi Slope
Mississippi Fan
Green Knoll
Florida Escarpment
West Florida Shelf
Mansfield Dome
Sigsbee Escarpment
Mexico Basin
Pulley Ridge
East Mexico Shelf
Sigsbee Deep
Mexican Ridges
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
0 50 100 Kilometers
Kemp's Ridley Sea Turtle (*Lepidochelys kempii*)
2009 Nest[1] Summary and Historic Outlier Nest Locations
1 - 10
11 - 100
101 - 1000
1001 - 10000
South Texas Closure[2,3]
Species Range[4,5,6,7,8,9]
Primary Adult Habitat[1]
Nesting Female Track #1 (4/2012 - 2/2013)[10,11]
Nesting Female Track #2 (4/2011 - 2/2013)[10,12]
Exclusive Economic Zones
Contours (meters)
Note: Representation of turtle tracks #1 and #2 were obtained from estimation of the paths of travel as published online at seaturtle.org, with the authors' permission.
Sources: **(1)** National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), and Secretaría de Medio Ambiente y Recursos Naturales. (2011). *Bi-national recovery plan for the Kemp's ridley sea turtle (*Lepidochelys kempii*), second revision*. Silver Spring, MD: NMFS. **(2)** Texas Statewide Shrimp Fishery Proclamation, Definitions, 31 Tex. Admin. Code § 58.102 (October 3, 1996). **(3)** Texas Statewide Shrimp Fishery Proclamation, Shrimping in Outside Waters, 31 Tex. Admin. Code § 58.161 (October 3, 1996). **(4)** Halpin, P. N., Read, A. J., Fujioka, E., Best, B. D., Donnelly, B., Hazen, L. J., Kot, C., Urian, K., LaBrecque, E., Dimatteo, A., Cleary, J., Good, C., Crowder, L. B., and Hyrenbach, K. D. (2009). OBIS-SEAMAP, The world data center for marine mammal, sea bird, and sea turtle distributions. *Oceanography, 22*(2), 104-115. **(5)** Wallace, B. P., DiMatteo, A. D., Hurley, B. J., Finkbeiner, E. M., Bolten, A. B., Chaloupka, M. Y., Hutchinson, B. J., Abreu-Grobois, F. A., Amorocho, D., Bjorndal, K. A., Bourjea, J., Bowen, B. W., Briseño Dueñas, R., Casale, P., Choudhury, B. C., Costa, A., Dutton, P. H., Fallabrino, A., Girard, A., Girondot, M., Godfrey, M. H., Hamann, M., López-Mendilaharsu, M., Marcovaldi, M. A., Mortimer, J. A., Musick, J. A., Nel, R., Pilcher, N. J., Seminoff, J. A., Troëng, S., Witherington, B., and Mast, R. B. (2010). Regional Management Units for Marine Turtles: A Novel Framework for Prioritizing Conservation and Research across Multiple Scales. *PLoS ONE, 5*(12), e15465. **(6)** Márquez, R. (1990). Food and Agriculture Organization (FAO) species catalogue; Sea turtles of the world, an annotated and illustrated catalogue of sea turtle species known to date. *FAO Fisheries Synopsis, 125* (11). **(7)** National Marine Fisheries Service (NMFS), and U.S. Fish and Wildlife Service (USFWS). (2007). *Kemp's ridley sea turtle (*Lepidochelys kempii*) 5-year review: summary and evaluation.* Jacksonville, FL: Authors. **(8)** Witt, M. J., Penrose, R., and Godley, B. J. (2007). Spatio-temporal patterns of juvenile marine turtle occurrence in waters of the European continental shelf. *Marine Biology, 151*, 873-885. **(9)** The State of the World's Sea Turtles. (2010). *The State of the World's Sea Turtles report volume V: Kemp's and olive ridleys, small turtles, big secrets.* Arlington, VA: Author. **(10)** Shaver, D. J., and Rubio, C. (2007). Post-nesting movement of wild and head-started Kemp's ridley sea turtles *Lepidochelys kempii* in the Gulf of Mexico. *Endangered Species Research, 3*, 1-13. **(11)** Shaver, D. (2012). *Padre Island National Seashore Kemp's ridley tracking program, track 112758*. Corpus Christi, TX: National Park Service. Retrieved January 11, 2013, from www.seaturtle.org/tracking **(12)** Shaver, D. (2012). *Padre Island National Seashore Kemp's ridley tracking program, track 101137*. Corpus Christi, TX: National Park Service. Retrieved January 11, 2013, from www.seaturtle.org/tracking

7.1 Sperm Whale *Physeter macrocephalus*

Credit: Douglas Kahle

Description

The range of the sperm whale includes all oceans. Sperm whales are present throughout the year in the northern Gulf of Mexico (Mullin & Fulling, 2004). They are especially common near the Mississippi Canyon where there is a resident breeding population (Davis et al., 2002; Mullin, 2007) and near the DeSoto Canyon (Map 33). Within the northern Gulf, sightings are more common in the summer. Aggregations of whales are consistently sighted off of the Mississippi River Delta and are thought to be associated with the Mississippi River plume and a narrow continental shelf that enhances primary productivity. Additionally, this area often has a cyclone/anti-cyclone eddy pair from the Loop Current that may entrain nutrients and transport them beyond the continental shelf, enhancing primary productivity offshore of this area (Davis et al., 2002). In the southern Gulf, sperm whales are widely distributed in continental slope waters of the western Bay of Campeche (NMFS, 2010).

The distribution of sperm whales is linked to their social structure, which includes nursery schools, harem or mixed schools, juvenile or immature schools, bachelor schools, bull schools or pairs, and solitary bulls (SAFMC, 2010). Adult males are more widely distributed than females, and range from equatorial to polar regions. Females and juveniles generally remain in tropical, subtropical and temperate regions.

Sperm whales are the largest of all odontocetes (or toothed whales). Adult males can grow to between 15 and 18 meters (49 to 59 feet) in length and weigh as much as 45 tons. Adult females can grow up to 11 meters (36 feet) and weigh as much as 13 to 14 tons. Sperm whales are deep divers, with the average dive lasting about 35 minutes and reaching depths near 400 meters (1,300 feet). They are capable of dives lasting more than an hour and reaching depths near 975 meters (3,200 feet) (NOAA, 2010). Sperm whales are long-lived, reaching 70 years of age or more. Females reach their maximum size around 30 years of age and sexual maturity around 9 years of age. Males often do not actively participate in breeding until their late twenties, and reach physical maturity around 50 years of age (NOAA, 2010).

Sperm whales forage mainly on or near the ocean bottom (Whitehead et al., 1992). They consume squid, demersal and mesopelagic sharks, skates, octopus, shrimp, crab and fish (NOAA, 2010). Giant squid comprise the majority of the sperm whale diet.

In the United States, sperm whales are listed as endangered under the federal Endangered Species Act. The best estimate for the number of sperm whales in the northern Gulf is slightly over 1,600 (NOAA, 2009). The Marine Mammal Protection Act and the Endangered Species Act protect them under federal law, which make it illegal to harass, hunt, capture or kill any sperm whale. Commercial whaling was a past threat to sperm whales, but ceased when the International Whaling Commission implemented a moratorium in 1988 (NOAA, 2010).

See related maps and narratives on Bathymetry, Sea Surface Currents and Net Primary Productivity.

Data Compilation and Mapping Methods

Data for sperm whales in the Gulf were obtained from the NOAA Cetacean Density and Distribution Mapping Working Group (Read et al., 2010). Model products were developed from the best available survey data and from models estimating density using predictive environmental factors (Best et al., 2007; Best et al., 2012). The NOAA Cetacean Density and Distribution Mapping Working Group categorized the model products in an information hierarchy, establishing a tiered level rating depending on source data and model processes used. At the time this atlas was developed, the level of model data available for this species in the Gulf was rated as probability of occurrence, which was tier three in a five-level hierarchy: tier 1) Habitat Based Density, tier 2) Stratified Density, tier 3) Probability of Occurrence, tier 4) Records Exist, and tier 5) Expert Based Presence or Likely Absence. Probability of occurrence products are spatially heterogeneous predictions of the probability of encountering the species, population, or guild across a grid covering the Gulf, based on environmental covariates. Only the summer season of the occurrence model is available for this species in the U.S. Gulf.

Data Quality

Data quality for this map is fair for U.S. waters because the probability of occurrence distribution depicted on Map 33 is only provided for the summer season. Data quality will remain fair until information on all four seasons is available. No analogous data were identified for waters of Cuba and Mexico or for the high seas area outside of the exclusive economic zones of the U.S., Mexico and Cuba.

Synthesis and Conclusions

Sperm whales are present year-round in the northern Gulf and have a resident breeding population near the Mississippi Canyon. Sperm whale populations have declined in the past, primarily due to commercial whaling, but have been rebounding since the 1980s. Known sperm whale distributions overlapped the trajectory of oil following the BP Deepwater Horizon oil disaster, so continued monitoring and research are essential to track the impacts of this event on sperm whales. More research, particularly tagging studies, is also needed to better understand sperm whale distribution, biology, population trends and ecosystem interactions in the Gulf. A specific need is to fill data gaps with respect to the distribution of this species throughout the year and the entire Gulf.

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Map Data Sources

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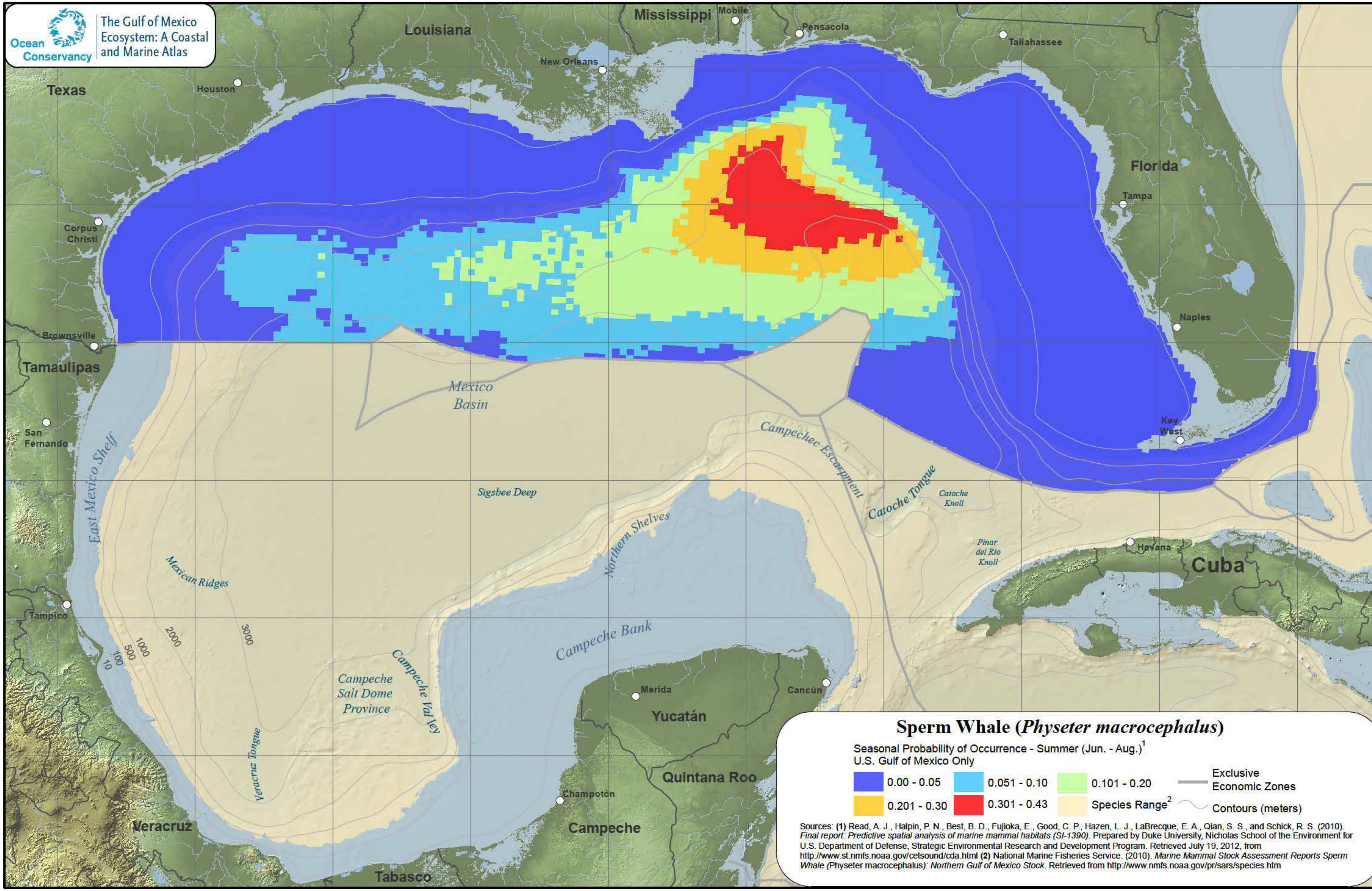
MAP 33 *(next page)*. **SPERM WHALE**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
Sperm Whale (*Physeter macrocephalus*)
Seasonal Probability of Occurrence - Summer (Jun. - Aug.)[1]
U.S. Gulf of Mexico Only
0.00 - 0.05
0.051 - 0.10
0.101 - 0.20
0.201 - 0.30
0.301 - 0.43
Species Range[2]
Exclusive Economic Zones
Contours (meters)
Sources: (1) Read, A. J., Halpin, P. N., Best, B. D., Fujioka, E., Good, C. P., Hazen, L. J., LaBrecque, E. A., Qian, S. S., and Schick, R. S. (2010). *Final report: Predictive spatial analysis of marine mammal habitats (SI-1390)*. Prepared by Duke University, Nicholas School of the Environment for U.S. Department of Defense, Strategic Environmental Research and Development Program. Retrieved July 19, 2012, from http://www.st.nmfs.noaa.gov/cetsound/cda.html (2) National Marine Fisheries Service. (2010). *Marine Mammal Stock Assessment Reports Sperm Whale* (Physeter macrocephalus)*: Northern Gulf of Mexico Stock*. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm

7.2 Atlantic Bottlenose Dolphin *Tursiops truncatus*

Credit: Wayne Hoggard / NOAA

Description

Atlantic bottlenose dolphins occur worldwide in tropical and temperate ocean waters, including throughout the entire Gulf of Mexico. They utilize a wide range of habitats including inshore environments, such as bays and sounds, and offshore habitats, such as the deep waters of the continental shelf and inner continental slope (NOAA, 2010a) (Map 34). Unlike other cetaceans that tend to concentrate over the continental slope or near cold-core eddies, bottlenose dolphins prefer the relatively shallow waters of the continental shelf and upper slope (McKay et al., 1999). During the summer, there is a relatively high concentration of bottlenose dolphins off of the southwest Florida coast (Map 34).

Adult bottlenose dolphins range from about 2 to 4 meters (6.5 to 13 feet) in length and weigh up to 635 kilograms (1,400 pounds). They have a lifespan of approximately 50 years. Female bottlenose dolphins generally reach sexual maturity between the ages of 5 and 13 years and then give birth every 3 to 6 years. Males generally reach maturity between 9 and 14 years of age (NOAA, 2010a).

Bottlenose dolphins often travel in groups of 2 to 15 individuals, but can be found offshore in groups of several hundred. Bottlenose dolphins use echolocation to locate and feed on a variety of prey, such as fish, squid and crustaceans (NOAA, 2010a). They forage individually or hunt cooperatively by herding schools of fish, taking turns charging the schools to feed.

An estimated 30 percent of the total bottlenose dolphin population in U.S. waters lives in the Gulf (NOAA, 2010a). The total population size of bottlenose dolphins in the Gulf is unknown. Bottlenose dolphins are divided into two ecotypes: inshore/nearshore and offshore. Dolphins from both of these ecotypes can be found in coastal waters (NOAA, 2010b). For management purposes, the dolphins in the Gulf are also grouped into six major stocks (Map 34) and some of these major stocks can be subdivided into many smaller stocks.

The Marine Mammal Protection Act prohibits exploitation and harassment of dolphins and other marine mammals. Current threats to the bottlenose dolphin are incidental capture in fisheries, exposure to contaminants and viral outbreaks. Some of the estuaries and bays in the northern Gulf inhabited by bottlenose dolphins received heavy and prolonged exposure to oil resulting from the BP Deepwater Horizon (DWH) oil disaster (NOAA, 2012). An unusual number of dolphin strandings occurred in the northern Gulf during 2010 through 2012. The combination of the DWH oil disaster and large volumes of cold freshwater entering the Gulf may have contributed to this unusual mortality event (Carmichael et al., 2012).

See related maps and narratives on Bathymetry, Salinity and River Flow, Sea Surface Temperature, Gulf Menhaden, and Pantropical Spotted Dolphin.

Data Compilation and Mapping Methods

The main source of data for Map 34 was the NOAA Cetacean Density and Distribution Mapping Working Group (Read et al., 2010). Model products were developed from the best available survey data and models to estimate density using predictive environmental factors (Best et al., 2007; Best et al., 2012). The NOAA Cetacean Density and Distribution Mapping Working Group categorized the model products in an information hierarchy, establishing a tiered level rating depending on source data and model processes employed. At the time this atlas was developed, the level of model data available for this species in the Gulf was rated as probability of occurrence, which was tier three in a five-level hierarchy (starting with the highest degree of data reliability): tier 1) Habitat Based Density, tier 2) Stratified Density, tier 3) Probability of Occurrence, tier 4) Records Exist, and tier 5) Expert Based Presence or Likely Absence.

Probability of occurrence products are spatially heterogeneous predictions of the probability of encountering the species, population or guild across a grid covering the Gulf, based on environmental covariates. Two seasons of occurrence models are available: summer and fall (Map 34). Data for the fall season were used to show the U.S. Gulf-wide distribution, while the summer distribution data are provided as an inset map to illustrate the difference in seasonal abundance in the Gulf. Delineations of each of the six management stocks were developed from the area descriptions in the most recent stock assessment reports.

Data Quality

Data quality for Map 34 is fair for U.S. waters because the probability of occurrence distributions are only available for fall and summer. Data quality will remain fair until all four seasons, not just two, are represented. No analogous data were identified for waters outside of Cuba and Mexico or for the high seas area outside the exclusive economic zones of the U.S., Mexico and Canada.

Synthesis and Conclusions

The bottlenose dolphin is a wide-ranging marine mammal that occurs in both coastal and offshore waters of the Gulf. While the species is very common in the Gulf, the population size and status of bottlenose dolphin in the northern Gulf are not known. Continued long-term research and monitoring are essential to clarify stock structure, distribution, population size and trends (MMC, 2011), as well as impacts from the DWH oil disaster and other environmental stressors.

Text Citations

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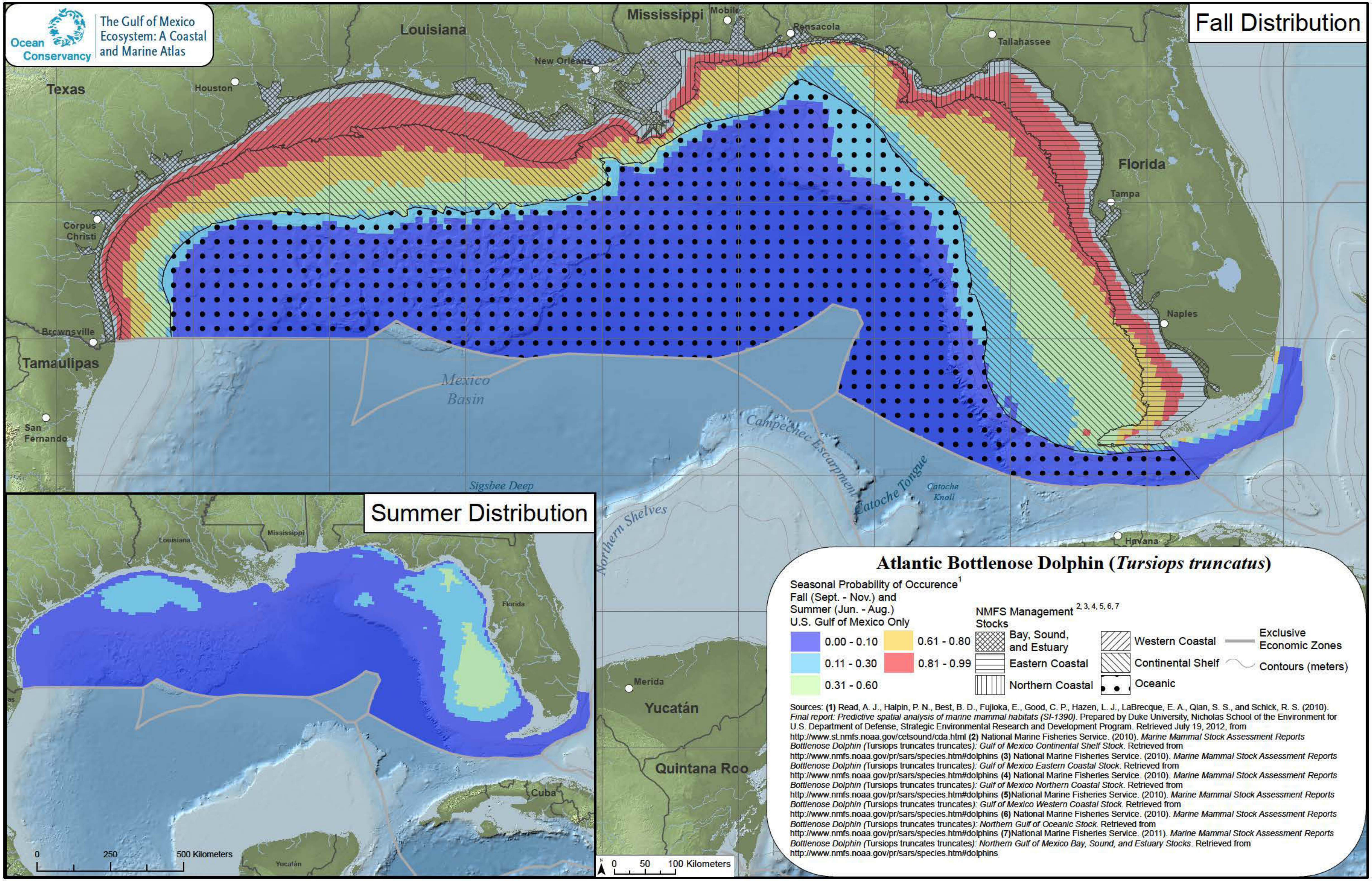
MAP 34 *(next page)*. **ATLANTIC BOTTLENOSE DOLPHIN**



Fall Distribution
Summer Distribution
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
Atlantic Bottlenose Dolphin (Tursiops truncatus)
Seasonal Probability of Occurence[1]
Fall (Sept. - Nov.) and
Summer (Jun. - Aug.)
U.S. Gulf of Mexico Only
0.00 - 0.10
0.11 - 0.30
0.31 - 0.60
0.61 - 0.80
0.81 - 0.99
NMFS Management Stocks [2, 3, 4, 5, 6, 7]
Bay, Sound, and Estuary
Eastern Coastal
Northern Coastal
Western Coastal
Continental Shelf
Oceanic
Exclusive Economic Zones
Contours (meters)
Sources: (1) Read, A. J., Halpin, P. N., Best, B. D., Fujioka, E., Good, C. P., Hazen, L. J., LaBrecque, E. A., Qian, S. S., and Schick, R. S. (2010). Final report: Predictive spatial analysis of marine mammal habitats (SI-1390). Prepared by Duke University, Nicholas School of the Environment for U.S. Department of Defense, Strategic Environmental Research and Development Program. Retrieved July 19, 2012, from http://www.st.nmfs.noaa.gov/cetsound/cda.html (2) National Marine Fisheries Service. (2010). Marine Mammal Stock Assessment Reports Bottlenose Dolphin (Tursiops truncates truncates): Gulf of Mexico Continental Shelf Stock. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm#dolphins (3) National Marine Fisheries Service. (2010). Marine Mammal Stock Assessment Reports Bottlenose Dolphin (Tursiops truncates truncates): Gulf of Mexico Eastern Coastal Stock. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm#dolphins (4) National Marine Fisheries Service. (2010). Marine Mammal Stock Assessment Reports Bottlenose Dolphin (Tursiops truncates truncates): Gulf of Mexico Northern Coastal Stock. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm#dolphins (5)National Marine Fisheries Service. (2010). Marine Mammal Stock Assessment Reports Bottlenose Dolphin (Tursiops truncates truncates): Gulf of Mexico Western Coastal Stock. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm#dolphins (6) National Marine Fisheries Service. (2010). Marine Mammal Stock Assessment Reports Bottlenose Dolphin (Tursiops truncates truncates): Northern Gulf of Oceanic Stock. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm#dolphins (7)National Marine Fisheries Service. (2011). Marine Mammal Stock Assessment Reports Bottlenose Dolphin (Tursiops truncates truncates): Northern Gulf of Mexico Bay, Sound, and Estuary Stocks. Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm#dolphins
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Yucatán
Quintana Roo
Houston
Corpus Christi
Brownsville
San Fernando
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Havana
Merida
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Northern Shelves
Cuba
0 50 100 Kilometers
0 250 500 Kilometers

7.3 Pantropical Spotted Dolphin *Stenella attenuata*

Description

The pantropical spotted dolphin is a relatively small, oceanic dolphin inhabiting tropical, subtropical or warm-temperate waters (Perrin, 2001). In the northern Gulf of Mexico, they occur primarily in the open ocean beyond the continental shelf (Davis et al., 1998) (Map 35). Pantropical spotted dolphins likely occur Gulf-wide, but little information is available on abundance and distribution in the waters of Mexico and Cuba (Perrin, 2001).

A pod of pantropical spotted dolphins breaching. Credit: NOAA

Pantropical spotted dolphins are physically similar to the Atlantic spotted dolphin, but have a pronounced cape above the eye, a narrower beak, a light lower trunk and darker coloration (Perrin, 2001; Davis & Schmidly, 1997). They reach about 2 meters (6 to 7 feet) in length and weigh about 114 kilograms (250 pounds) when mature. Pantropical spotted dolphin females reach sexual maturity between 9 and 11 years of age and males around 3 years (Kasuya, 1976; Kasuya et al., 1974; Myrick et al., 1986). The species breaches frequently and is a fast swimmer, reaching speeds of roughly 11 meters (36 feet) per second (Perrin, 2001).

The pantropical spotted dolphin's diet includes fish, cephalopods and decapod crustaceans. Flying fish are particularly important prey for this species in terms of total biomass consumed (Fitch & Brownell, 1968; Perrin & Hohn, 1994; Perrin et al., 1973; Robertson & Chivers, 1997; Perrin, 2001). Research suggests that cyclonic (cold-core) eddy confluence areas and the mouth of the Mississippi River may be important foraging areas for pantropical spotted dolphins and other cetaceans (Davis et al., 2002). These dolphins travel in schools ranging in size from a few individuals to several thousand. Schools may be divided into groups based on age or gender (Perrin, 2001).

The pantropical spotted dolphin is the most abundant cetacean in the Gulf. Its estimated population size is 91,300 in the northern Gulf (NOAA, 2012). While there is insufficient information to differentiate Gulf and Atlantic stocks, the Gulf stock is treated separately for management purposes (NOAA, 2012). The species is protected under the U.S. Marine Mammal Protection Act and its take or trade is prohibited in the U.S. Commercial fisheries were a historical cause of mortality for the pantropical spotted dolphin worldwide. The stock in the Gulf interacts with a pelagic longline fishery, but bycatch in the fishery today is infrequent; an estimated three animals die annually as a result of incidental capture in the fishery (NOAA, 2012). While several strandings were reported for the pantropical spotted dolphin between 2006 and 2010, the stock was not considered a part of the unusual morality event declared for cetaceans in the northern Gulf in February 2010 (NOAA, 2012). Aerial surveys conducted at the time of the BP Deepwater Horizon (DWH) oil disaster recorded sightings of pantropical spotted dolphins swimming in oiled waters (NOAA, 2010).

See related maps and narratives on Bathymetry, Sea Surface Currents and Atlantic Bottlenose Dolphin.

Data Compilation and Mapping Methods

The main source of data for Map 35 was the NOAA Cetacean Density and Distribution Mapping Working Group (Read et al., 2010). Model products were developed from the best available survey data and from models estimating density using predictive environmental factors (Best et al., 2007; Best et al., 2012). The NOAA Cetacean Density and Distribution Mapping Working Group categorized the model products in an information hierarchy, establishing a tiered level rating depending on source data and model processes employed. At the time this atlas was developed, the level of model data available for this species in the Gulf was rated as probability of occurrence, which was tier three in a five-level hierarchy (starting with the highest degree of data reliability): tier 1) Habitat Based Density, tier 2) Stratified Density, tier 3) Probability of Occurrence, tier 4) Records Exist, and tier 5) Expert Based Presence or Likely Absence.

Probability of occurrence products are spatially heterogeneous predictions of the probability of encountering the species, population or guild across a grid covering the Gulf, based on environmental covariates. Two seasons of occurrence models are available: spring and summer. The spring season of the occurrence models available for this species in the U.S. Gulf was used to illustrate the U.S. Gulf-wide distribution.

Data Quality

Data quality for Map 35 is fair for the U.S. because, at present, these data describe distributions for only two of the four seasons. No analogous data were identified for waters of Cuba and Mexico or waters outside of the exclusive economic zones for the U.S., Mexico and Cuba. Hence, geographic and seasonal data gaps exist for this species in the Gulf.

Synthesis and Conclusions

Pantropical spotted dolphins are small oceanic dolphins that are likely present throughout the Gulf. The status of pantropical spotted dolphins in the Gulf is mostly unknown despite numerous confirmed sightings in U.S. waters. Studies are needed in the waters of Mexico and Cuba to assess abundance and distribution, which in combination with data from U.S. waters, will provide a more complete assessment of population size, dynamics and trends in the Gulf. Continued research, assessment and long-term monitoring are critical to determine any sublethal effects of the DWH oil disaster on pantropical spotted dolphins.

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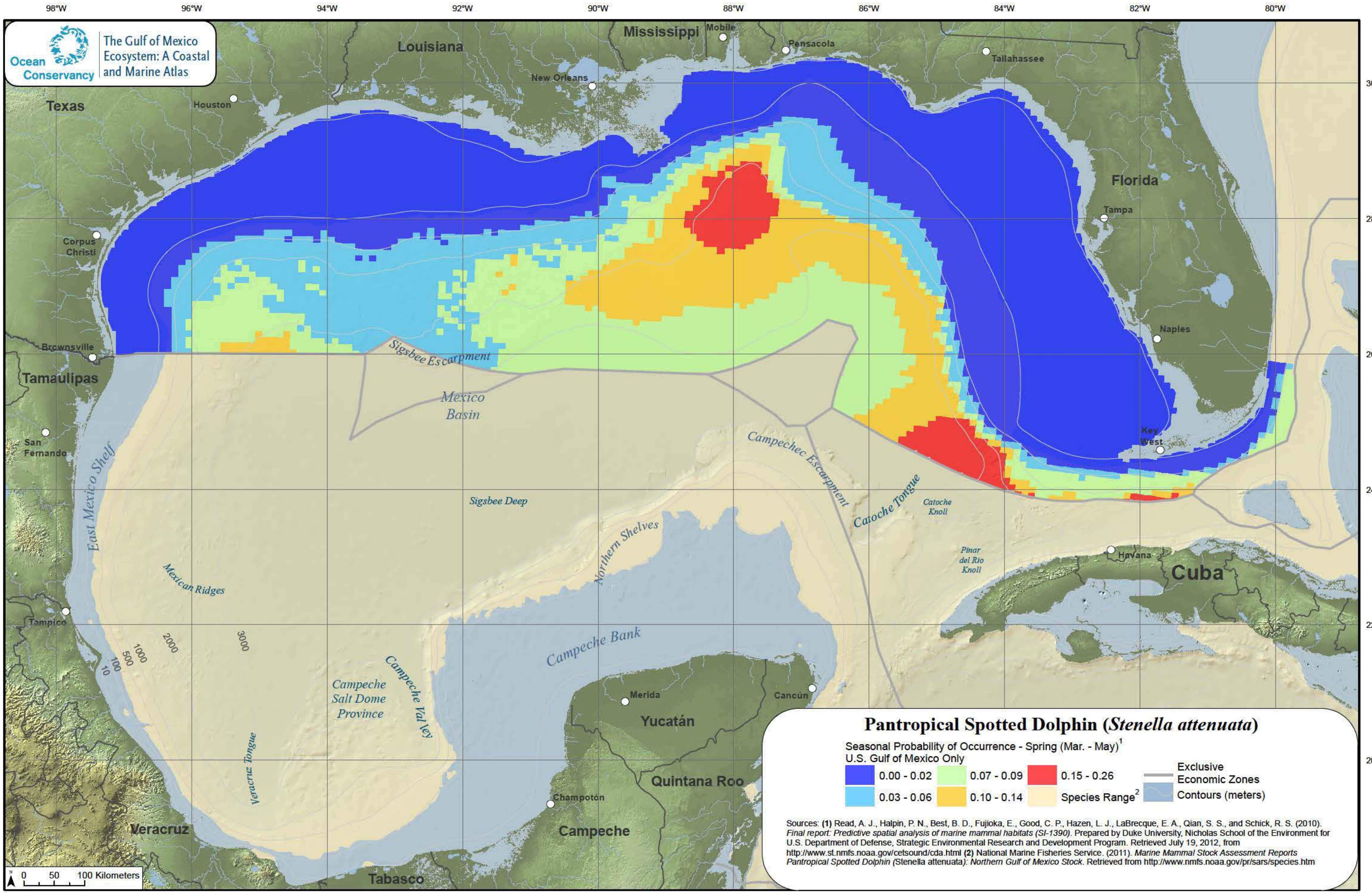
MAP 35 *(next page)*. **PANTROPICAL SPOTTED DOLPHIN**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Havana
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Val ley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Pantropical Spotted Dolphin (*Stenella attenuata*)
Seasonal Probability of Occurrence - Spring (Mar. - May)[1]
U.S. Gulf of Mexico Only
0.00 - 0.02
0.03 - 0.06
0.07 - 0.09
0.10 - 0.14
0.15 - 0.26
Species Range[2]
Exclusive Economic Zones
Contours (meters)
Sources: **(1)** Read, A. J., Halpin, P. N., Best, B. D., Fujioka, E., Good, C. P., Hazen, L. J., LaBrecque, E. A., Qian, S. S., and Schick, R. S. (2010). *Final report: Predictive spatial analysis of marine mammal habitats (SI-1390).* Prepared by Duke University, Nicholas School of the Environment for U.S. Department of Defense, Strategic Environmental Research and Development Program. Retrieved July 19, 2012, from http://www.st.nmfs.noaa.gov/cetsound/cda.html **(2)** National Marine Fisheries Service. (2011). *Marine Mammal Stock Assessment Reports Pantropical Spotted Dolphin* (Stenella attenuata)*: Northern Gulf of Mexico Stock.* Retrieved from http://www.nmfs.noaa.gov/pr/sars/species.htm

7.4 West Indian Manatee *Trichechus manatus*

A West Indian manatee in Florida's Crystal River National Wildlife Refuge. Credit: Amanda Cotton / iStockphoto

Description

West Indian manatees are mammals that occur in fresh, brackish and marine waters throughout Florida, the Greater Antilles, Central America and South America (USFWS, 1999). The West Indian manatee, *Trichechus manatus*, is divided into two distinct subspecies: the Florida manatee, *Trichechus manatus latirostris*, and the Antillean manatee, *Trichechus manatus manatus*. Both subspecies can be found in the Gulf and are grouped together on Map 36. Florida manatees are found almost exclusively in the coastal and inland waterways of Florida, while the Antillean subspecies may be found in the remaining range (UNEP, 2010). West Indian manatees are occasionally sighted in Alabama, Mississippi, Louisiana and, occasionally, in Texas (USFWS, 2010). There are no statistically-based abundance estimates for manatees in the Gulf. The best estimate is a minimum of 3,300 manatees in Florida's Atlantic and Gulf coastal waters (Haubold et al., 2006).

Manatees often use secluded canals, creeks, embayments and lagoons near the mouths of coastal rivers for feeding, resting, mating and calving (Trudel et al., 2003). As water temperatures rise from April to September, manatees may travel more along the Gulf Coast, using coastal areas as migration corridors between river systems (Deutsch et al., 2008; Trudel et al., 2003). They have a high salinity tolerance, but prefer habitats where freshwater is periodically available to reduce osmotic stress (O'Shea & Kochman, 1990). Most manatees return to the same warm-water location each year, but some manatees move to other areas on a permanent or temporary basis (Trudel et al., 2003).

Adult West Indian manatees reach lengths of about 3 meters (9 feet) and weights of approximately 454 kilograms (1,000 pounds) (USFWS, 2010). They reach maturity at 3 to 5 years of age and live as long as 60 years or older (USFWS, 2010). Calving peaks in the spring, but calves may be born at any time of the year. Manatees are herbivores that feed opportunistically on a wide variety of marine, estuarine and freshwater plants, including submerged, floating and emergent vegetation. Seagrasses are the staple of the manatee diet in coastal areas (Lefebvre et al., 2000).

The West Indian manatee is listed as endangered under the U.S. Endangered Species Act, and each of the Gulf states designates the species as endangered. The species is also protected under the Marine Mammal Protection Act and Florida's Manatee Sanctuary Act of 1978. Main threats to manatees are watercraft strikes, warm-water habitat loss through channelization and land development, trash ingestion, and fishing gear entanglement (Deutsch et al., 2008).

See related maps and narratives on Seagrasses, Coastal Population Density and Recreational Fishing Effort.

Data Compilation and Mapping Methods

Map 36 was based on annual statewide winter census counts, starting in 1991, at known areas of concentration, such as natural springs and power plant outfalls, which are a subset of habitats used by manatees (FWRI, 2011). The uncorrected counts reflect minimum numbers of animals present at surveyed sites in winter, when most of the Florida manatees (*Trichechus manatus latirostris*) are in Florida due to warmer waters.

Data Quality

Data quality for Map 36 is fair. The winter distribution, derived from the synoptic survey is shown only for Florida and represents unknown fractions of animals in the larger population. The proportion of animals observed varies from year to year and can be influenced by factors that are independent of changes in the population (e.g., visibility during surveys). Similar data for this species outside of the winter season and distribution data based on broad-scale surveys for the Antillean manatee are not available or were not identified. Hence, data gaps exist for the Florida and Antillean subspecies of the West Indian manatee.

Synthesis and Conclusions

Manatees are marine mammals with a preference for warm, shallow estuarine waters near a source of freshwater, such as rivers, creeks or canals. The Florida manatee, a subspecies of the West Indian manatee, is native to the Gulf and occurs primarily in Florida, although it migrates seasonally north and west along the Gulf Coast. The West Indian manatee is threatened by habitat loss, boat strikes and other human activities. It is listed as endangered under the U.S. Endangered Species Act and by each of the Gulf states. Broad-scale surveys are needed to better establish the year-round distributions of both subspecies of manatees.

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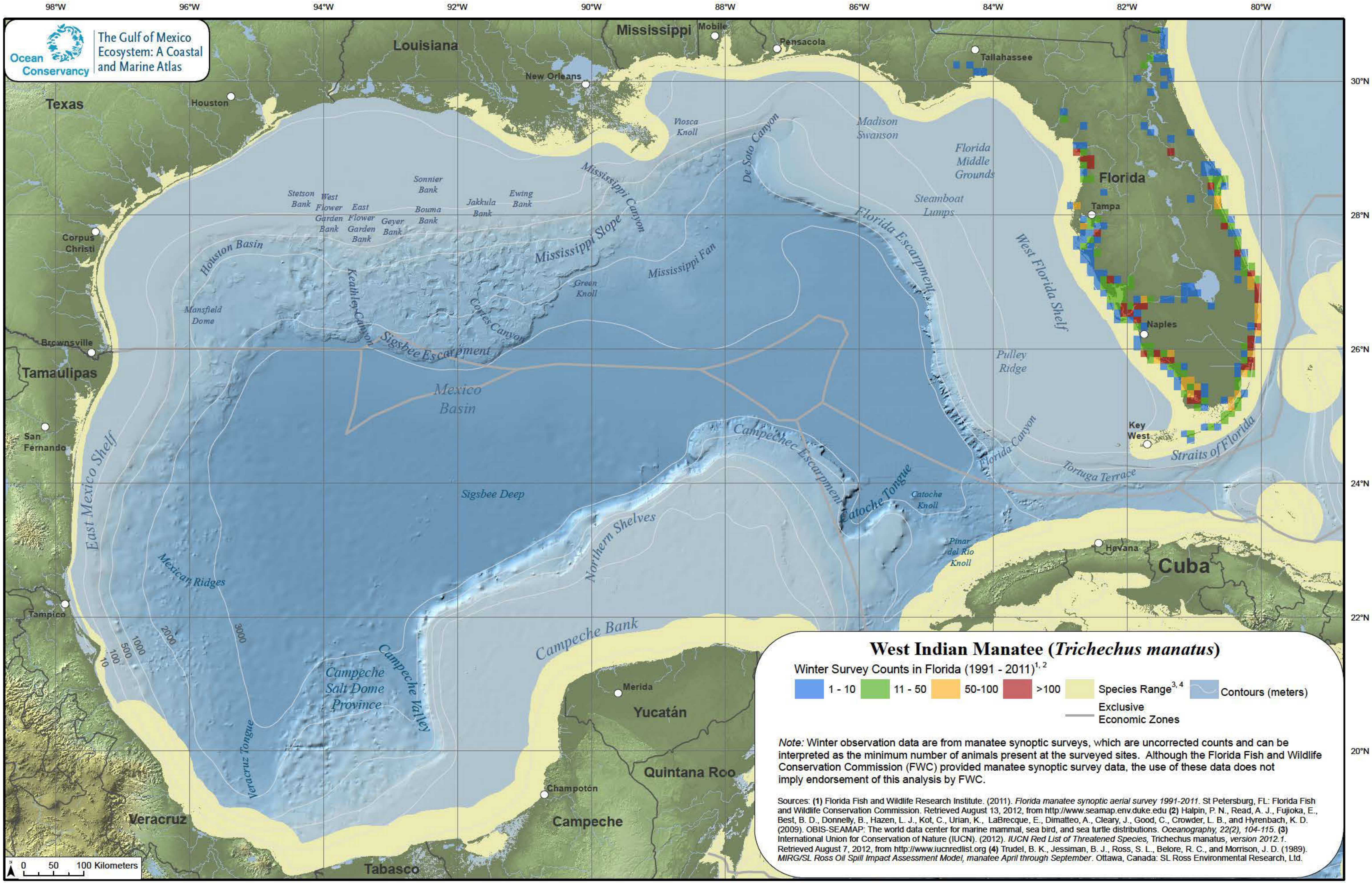
MAP 36 *(next page)*. **WEST INDIAN MANATEE**



West Indian Manatee (*Trichechus manatus*)

Winter Survey Counts in Florida (1991 - 2011)[1, 2]

1 - 10 | 11 - 50 | 50-100 | >100 | Species Range[3, 4] | Contours (meters) | Exclusive Economic Zones

Note: Winter observation data are from manatee synoptic surveys, which are uncorrected counts and can be interpreted as the minimum number of animals present at the surveyed sites. Although the Florida Fish and Wildlife Conservation Commission (FWC) provided manatee synoptic survey data, the use of these data does not imply endorsement of this analysis by FWC.

Sources: **(1)** Florida Fish and Wildlife Research Institute. (2011). *Florida manatee synoptic aerial survey 1991-2011*. St Petersburg, FL: Florida Fish and Wildlife Conservation Commission. Retrieved August 13, 2012, from http://www.seamap.env.duke.edu **(2)** Halpin, P. N., Read, A. J., Fujioka, E., Best, B. D., Donnelly, B., Hazen, L. J., Kot, C., Urian, K., LaBrecque, E., Dimatteo, A., Cleary, J., Good, C., Crowder, L. B., and Hyrenbach, K. D. (2009). OBIS-SEAMAP: The world data center for marine mammal, sea bird, and sea turtle distributions. *Oceanography, 22(2), 104-115.* **(3)** International Union for Conservation of Nature (IUCN). (2012). *IUCN Red List of Threatened Species,* Trichechus manatus, *version 2012.1.* Retrieved August 7, 2012, from http://www.iucnredlist.org **(4)** Trudel, B. K., Jessiman, B. J., Ross, S. L., Belore, R. C., and Morrison, J. D. (1989). *MIRG/SL Ross Oil Spill Impact Assessment Model, manatee April through September*. Ottawa, Canada: SL Ross Environmental Research, Ltd.

Environmental Stressors

8.0 Coastal Population Density

Description

Coastlines are among the areas most densely populated by human beings, and long-term projections suggest that coastal populations will continue to grow. Some of the fastest growing populations in the U.S. are located in the Gulf Coast region. Gulf Coast populations in Mexico and Cuba are smaller and growing less rapidly than the U.S. Gulf Coast population, but each has densely populated pockets. Growth in coastal populations is expected to put additional pressure on coastal and marine environments, wildlife, and ecosystem services, such as fisheries and storm mitigation. In addition, rising sea levels, land subsidence and episodic storm events will also challenge human communities along the Gulf Coast.

The population size in the U.S. Gulf states of Alabama, Florida, Mississippi, Louisiana and Texas is approximately 56 million, accounting for nearly 20 percent of the total U.S. population (NOAA, 2011). Since 2000, Texas has experienced a population increase of nearly 21 percent, one of the largest increases in the U.S., and during the same period Florida grew at 18 percent, the third-largest increase in the country (Mackun & Wilson, 2011) (Map 37). The population of Louisiana grew at one of the slowest rates in the country, with a 1.4 percent increase (Mackun & Wilson, 2011). Not only is the human population growing in the Gulf Coast region, but housing development expanded 20 percent from 2000 to 2010. Housing growth, based on the number of building permits, is particularly high in south Texas, the greater Houston area, and central and south Florida (NOAA, 2011).

The portion of the human population in each of the U.S. Gulf states living along the coast varies considerably. In Texas and Florida, 39 and 37 percent of people in those states are concentrated in the coastal region, respectively, followed by 17 percent in Louisiana, 4 percent in Alabama and 3 percent in Mississippi. The U.S. Gulf Coast population is expected to increase 15 percent by 2020, a rate that is 4 percent higher than the national average (NOAA, 2011). More than a quarter of all people along the U.S. Gulf Coast live within areas classified as flood hazard zones (NOAA, 2011).

The Gulf Coast of Mexico, which comprises of the six states of Tamaulipas, Veracruz, Tabasco, Campeche, Yucatán and Quintana Roo, accounts for about 15 percent of the country's population (INEGI, 2012). As of 2010, Veracruz, with a population of 7,643,194, was the most populous state along Mexico's Gulf Coast, followed by Tamaulipas (3,268,554), Tabasco (2,238,603), Yucatán (1,955,577), Quintana Roo (1,325,578) and Campeche (822,441) (INEGI, 2012). The population of the Gulf Coast of Mexico is expanding just above its national average of 1.4 percent per year. The fastest growing Gulf Coast state, Quintana Roo, is expanding at nearly three times the national average (INEGI, 2012).

The population and growth rate of Cuba have been declining since the early 1960s, but appear to have stabilized in recent years. In 2011, the population of Cuba was approximately 11.25 million (World Bank, 2012). Havana, located on the northwest corner of the island, and Santiago de Cuba, facing the Caribbean, are the country's most populous cities. About 75 percent of the population of Cuba is concentrated in coastal and inland urban areas. The country has 278 coastal settlements distributed throughout 14 provinces and 88 municipalities. Ten percent of the population of Cuba lives within 1 kilometer of the coast (Mitrani Arenal et al., 2001).

See related maps and narratives on Projected Sea Level Rise, Land Area Change and Tropical Cyclone Track Density.

Data Compilation and Mapping Methods

Data for Map 37 were provided by the Center for International Earth Science Information Network (2005). This dataset consists of future human population estimates across the globe at the resolution of 2.5 arc-minute grid cells (about 5 kilometers) for years 2005, 2010 and 2015. These data were released in 2004, and the 2010 projected population estimate was used in this atlas to represent coastal population density. Population grids are developed using a proportional allocation algorithm on the highest spatial resolution census or survey data available. The future estimated population values are extrapolated based on a combination of subnational growth rates from census dates and national growth rates from United Nations statistics.

Data Quality

Data quality for Map 37 is fair. While these data are provided at consistent time scales, they were constructed from national administrative units across the three countries bordering the Gulf. The population projections from growth-rate calculations between previous census counts may not be correct. Data accuracy for each country depends on the accuracy of the original census counts.

Synthesis and Conclusions

Human populations on the U.S., Mexico and Cuba coasts are continuing to expand. Coastal communities and the natural resources and ecosystems of the Gulf can coexist if measures are implemented that reduce conflicts and strengthen resiliency by restoring coastal habitats in the face of climate change. (Boesch, 2006; Leichenko, 2011).

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Map Data Sources

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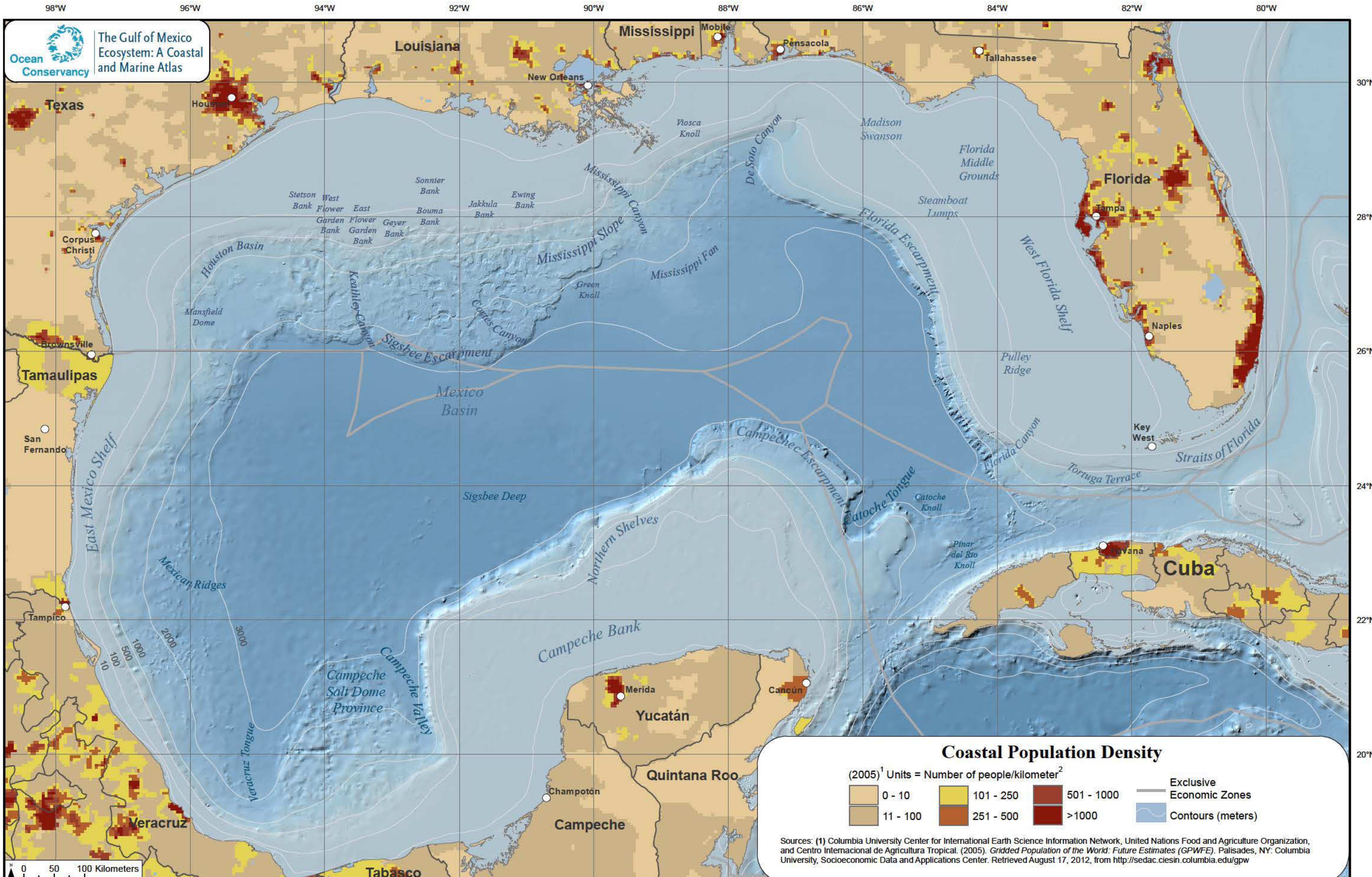
MAP 37 *(next page)*. **COASTAL POPULATION DENSITY**



98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
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28°N
26°N
24°N
22°N
20°N
Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
New Orleans
Texas
Houston
Florida
Tampa
Naples
Key West
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Campeche
Champotón
Yucatán
Merida
Cancún
Quintana Roo
Cuba
Havana
Viosca Knoll
Madison Swanson
Florida Middle Grounds
De Soto Canyon
Mississippi Canyon
Steamboat Lumps
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Keathley Canyon
Green Knoll
Mansfield Dome
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Pulley Ridge
Florida Canyon
Straits of Florida
Tortuga Terrace
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
East Mexico Shelf
Sigsbee Deep
Northern Shelves
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Coastal Population Density
(2005)¹ Units = Number of people/kilometer²
0 - 10
11 - 100
101 - 250
251 - 500
501 - 1000
>1000
Exclusive Economic Zones
Contours (meters)
Sources: (1) Columbia University Center for International Earth Science Information Network, United Nations Food and Agriculture Organization, and Centro Internacional de Agricultura Tropical. (2005). Gridded Population of the World: Future Estimates (GPWFE). Palisades, NY: Columbia University, Socioeconomic Data and Applications Center. Retrieved August 17, 2012, from http://sedac.ciesin.columbia.edu/gpw

8.1 Climate Change

Description

Climate change is a statistically significant variation in the mean state of the climate, persisting for an extended period, typically decades or longer, due to natural or anthropogenic processes (IPCC, 2001). Contemporary climate change already has had observable effects on the environment, including increased sea surface temperature and reduced amounts of seawater aragonite available to marine organisms. In the Gulf of Mexico, sea surface temperature rose as much as 0.8 degrees Celsius (1.44 degrees Fahrenheit) between 1985 and 2005 (Halpern et al., 2008) as aragonite availability decreased (Maps 38 and 39, respectively).

The water temperature at the ocean surface has increased over the course of the 20th century. From 1901 through 2009, sea surface temperatures rose at an average rate of 0.07 degrees Celsius (0.12 degrees Fahrenheit) per decade (EPA, 2012). Over the last 30 years, sea surface temperatures have risen more quickly, at a rate of 0.12 degrees Celsius (0.21 degrees Fahrenheit) per decade (EPA, 2012). Increased sea surface temperature alters the marine ecosystem by changing the composition of plants and animals (Grebmeier et al., 2006), threatening fragile ocean organisms, such as corals (Ostrander et al., 2000), and increasing sea levels (IPCC, 2007). Since the ocean constantly interacts with the atmosphere, sea surface temperature has profound effects on global climates, such as changing precipitation patterns (IPCC, 2007) and possibly influencing tropical cyclone intensity (Saunders & Lea, 2008).

The ocean naturally takes in atmospheric carbon dioxide (CO_2) on an enormous scale of approximately 7 billion metric tons of CO_2 per year (Ocean Acidification Network, 2012). Prior to the industrial revolution, ocean and atmospheric CO_2 concentrations were in balance. Now, excess atmospheric CO_2 from anthropogenic sources dissolves in sea water and, through a series of complex chemical reactions, increases the acidity of the water (lowering the pH), which reduces the amount of calcium carbonate in sea water. There are three different mineral forms of calcium carbonate ($CaCO_3$), aragonite being one of them. One method for measuring the change in ocean acidity is through the aragonite saturation state. The saturation state (Ω) measures the solubility (tendency to dissolve) rate of different forms of calcium carbonate in seawater. The solubility rate depends on the concentration of calcium and carbonate and the depth (or pressure). Waters with progressively lower saturation states tend to have less carbonate available, which is an indication of increasing acidity.

With less available carbonate, some marine organisms form thinner or weaker shells, which are then prone to shell solubility (i.e., they dissolve more easily) (Orr et al., 2005; Ries et al., 2009). Ocean acidification can also reduce zooplankton abundance and, in combination with other stressors, may have synergistic effects on the marine ecosystem (Thomas et al., 2007; Doney et al., 2009). The potential consequences for the ecosystem are not fully understood and are difficult to predict. In the northern Gulf, ocean acidification is further exacerbated by acidity from CO_2 released through algal decay due to eutrophication (Sunda & Cai, 2012).

See related maps and narratives on Eastern Oyster Reefs, Brown Shrimp, White Shrimp, Blue Crab, Projected Sea Level Rise and Tropical Cyclone Track Density.

Data Compilation and Mapping Methods

Observed Change in Sea Surface Temperature
Observed change in sea surface temperature data were obtained from Halpern et al. (2008), who employed Advanced Very High Resolution Radiometer Pathfinder Version 5.0 sea surface temperature (SST) data to create a global database of temperature anomalies. This database was then used to calculate the number of times the SST anomaly exceeded the standard deviation of SSTs for that location and week of the year between two time

periods: 1985-1990 and 2000-2005. The metric for measuring SST change was then developed by subtracting the number of non-zero positive anomalies in the early period (1985-1990) from the number in the more recent period (2000-2005). This calculation provided an estimate for observed climate change reflected in sea surface temperature.

Ocean Acidification
Observed changes in ocean acidification were obtained from Halpern et al. (2008), who employed the use of global distribution of aragonite saturation state values modeled at 1-degree resolution for pre-industrial (approximately 1870) and modern times (between 2000 and 2009), following the methodology in Kleypas et al. (1999). The difference between these modeled values from the two time periods provides the estimated change in ocean acidification (Halpern et al., 2008). This differential, used on this map, serves as the observed change in ocean acidification.

Data Quality

Observed Change in Sea Surface Temperature
Data quality for Map 38 is good because these data are derived from a stable and well-documented satellite observation platform and cover the entire Gulf at a consistent resolution. No data gaps exist with this dataset for the Gulf.

Ocean Acidification
Data quality for Map 39 is good because these data are derived from scientifically valid models (Kleypas et al., 1999) that cover the entire Gulf at a consistent, albeit coarse, resolution. No data gaps exist with this dataset for the Gulf.

Synthesis and Conclusions

Climate change, which is causing increased sea surface temperature and ocean acidification, is having, and will continue to have, significant effects on marine ecosystems, coastal communities and economies. To help coastal and ocean managers adapt to and mitigate these impacts, long-term studies monitoring changes in coastal and marine ecosystems caused by climate change are needed, especially to address possible ecosystem impacts due to increased sea surface temperature and ocean acidification.

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Map Data Sources

Observed Change in Sea Surface Temperature

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Ocean Acidification

Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C .V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., & Watson, R. (2008). *A global map of human impact on marine ecosystems* [Supplemental materials]. Raster dataset. Santa Barbara, CA: National Center for Ecological Analysis and Synthesis. Retrieved August 17, 2011, from http://www.nceas.ucsb.edu/globalmarine/models

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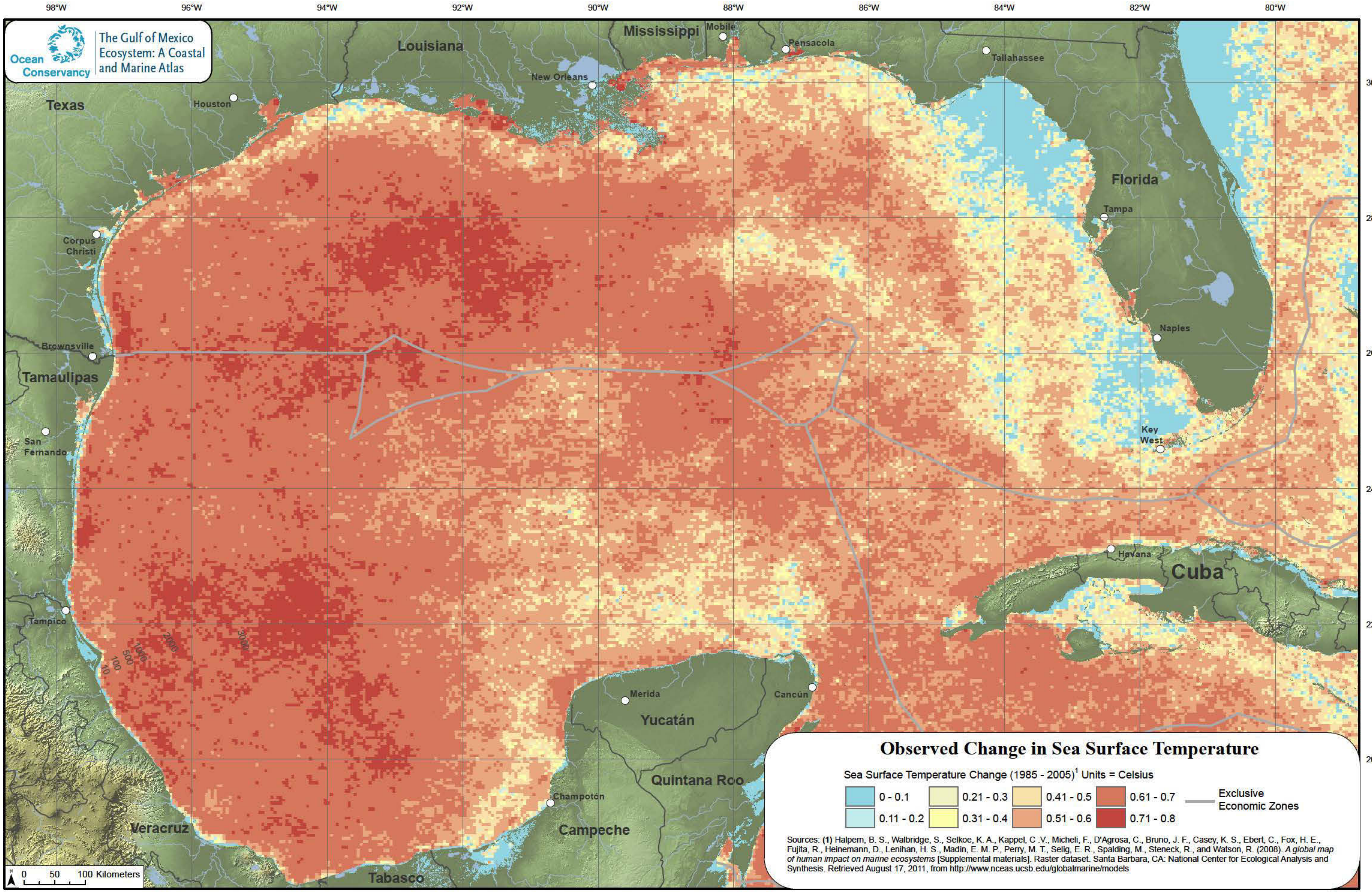
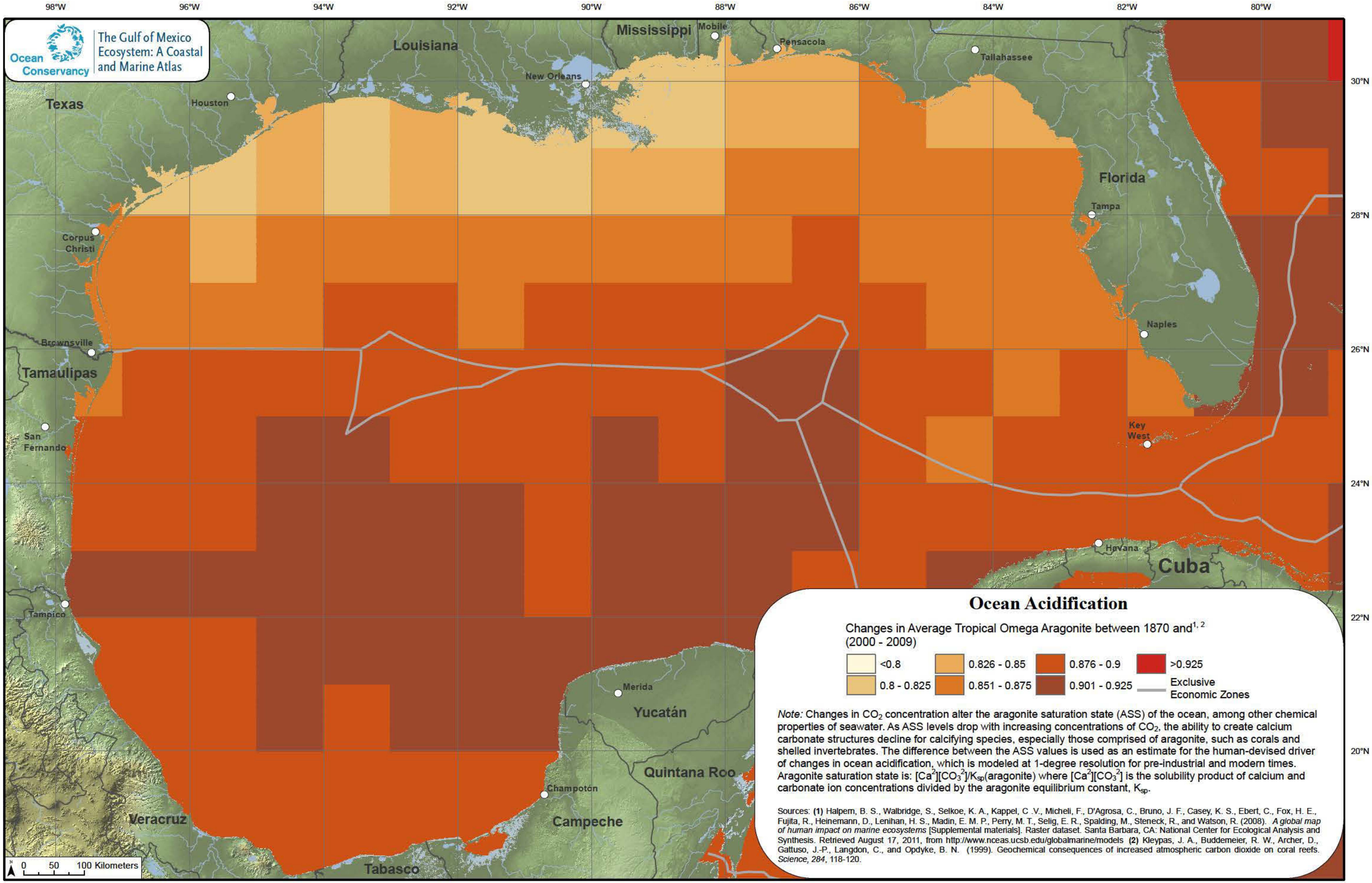
MAP 38 *(next page)*. **OBSERVED CHANGE IN SEA SURFACE TEMPERATURE**
MAP 39. OCEAN ACIDIFICATION



Sources: **(1)** Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C .V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., and Watson, R. (2008). *A global map of human impact on marine ecosystems* [Supplemental materials]. Raster dataset. Santa Barbara, CA: National Center for Ecological Analysis and Synthesis. Retrieved August 17, 2011, from http://www.nceas.ucsb.edu/globalmarine/models



Note: Changes in CO_2 concentration alter the aragonite saturation state (ASS) of the ocean, among other chemical properties of seawater. As ASS levels drop with increasing concentrations of CO_2, the ability to create calcium carbonate structures decline for calcifying species, especially those comprised of aragonite, such as corals and shelled invertebrates. The difference between the ASS values is used as an estimate for the human-devised driver of changes in ocean acidification, which is modeled at 1-degree resolution for pre-industrial and modern times. Aragonite saturation state is: $[Ca^2][CO_3^2]/K_{sp}$(aragonite) where $[Ca^2][CO_3^2]$ is the solubility product of calcium and carbonate ion concentrations divided by the aragonite equilibrium constant, K_{sp}.

Sources: **(1)** Halpern, B. S., Walbridge, S., Selkoe, K. A., Kappel, C .V., Micheli, F., D'Agrosa, C., Bruno, J. F., Casey, K. S., Ebert, C., Fox, H. E., Fujita, R., Heinemann, D., Lenihan, H. S., Madin, E. M. P., Perry, M. T., Selig, E. R., Spalding, M., Steneck, R., and Watson, R. (2008). *A global map of human impact on marine ecosystems* [Supplemental materials]. Raster dataset. Santa Barbara, CA: National Center for Ecological Analysis and Synthesis. Retrieved August 17, 2011, from http://www.nceas.ucsb.edu/globalmarine/models **(2)** Kleypas, J. A., Buddemeier, R. W., Archer, D., Gattuso, J.-P., Langdon, C., and Opdyke, B. N. (1999). Geochemical consequences of increased atmospheric carbon dioxide on coral reefs. *Science*, *284*, 118-120.

8.2 Projected Sea Level Rise

Description

Global warming, caused by increasing greenhouse gas emissions, raises sea level through two processes: thermal expansion of the ocean and the addition of water to the ocean from melting land ice (IPCC, 2007). The Intergovernmental Panel on Climate Change (IPCC) estimates that the global average sea level will rise between 20 and 60 centimeters (8 to 24 inches) in the next century (IPCC, 2007). However, this IPCC range is now considered an underestimation of sea level rise due to the accelerated decline of polar ice sheet mass (Allison et al., 2009), which raises the possibility of future sea level rise by about 1 meter (3 feet) or more by 2100 (Pfeffer et al., 2008). Sea level rise in the northern Gulf of Mexico will be dramatic (Map 40). Along the northern Gulf Coast, an estimated 3,860 kilometers (2,400 miles) of major roadway and 395 kilometers (246 miles) of freight rail lines are at risk of permanent flooding given the anticipated sea level rise within 50 to 100 years (NOAA, 2012c).

Climate models, satellite data and hydrographic observations demonstrate that sea level is not rising uniformly around the world (NOAA, 2012b). Depending on the region, sea level might be projected to rise or fall several times the mean rise globally (NOAA, 2012b). Local sea level change depends on both rise in sea level and the change in land elevation (NOAA, 2012a). Areas along the Gulf Coast are experiencing land subsidence at varying rates, which accelerates the effective rate of sea level rise. Studies show that the Mississippi Delta is sinking, but not as fast as previously predicted (Yu et al., 2012).

Impacts of sea level rise include accelerated erosion, loss of wetlands and low-lying terrestrial ecosystems, increased flooding of low-lying coastal areas such as barrier islands, and seawater intrusion into freshwater sources (Hagen et al., 2011). Sea level rise would also have economic impacts, including the loss of critical habitats (e.g., wetlands) for many commercially important fisheries, loss of storm-mitigation capacity, and loss of coastal development and commercial transportation activity.

Several different adaptation strategies are available for developed low-lying coastal areas: 1) move buildings and infrastructure inland and away from the sea, 2) design buildings and use construction practices that accommodate rising water levels (e.g., elevating buildings on stilts) and 3) protect existing development using flood control structures (U.S. Global Change Research Program, 2009). Each of these options has different associated costs, degrees of protection and risks. Coastal wetlands provide numerous ecosystem services, such as coastal buffering, and these habitats are also in danger of inundation as sea level rises. The resiliency of these habitats depends on their ability to adapt to changing environmental conditions, which humans can assist by protecting barrier islands, enhancing or maintaining natural sediment supplies, and creating landward buffer zones so marshes can retreat inland as sea level rises (Titus, 1988).

See related maps and narratives on Coastal Population Density and Land Area Change.

Data Compilation and Mapping Methods

Data used to illustrate an approximately 1-meter rise in sea level by 2100 were derived from NOAA Coastal Services Center (2012d) and the Coastal Protection and Restoration Authority of Louisiana (2012). The NOAA source, developed for the “sea level rise viewer” tool, was developed to illustrate the degree of inundation using the best available digital elevation data. The process to generate this inundation data set is generally considered a modified bathtub approach, which attempts to account for local/regional tidal variability and hydrological connectivity. This mapping methodology incorporates high resolution Light Detection and Ranging (or LIDAR) data and data from tide gauges within the study area. These inundation data are available for Texas, Mississippi, Alabama and Florida. The second source, the 2010 Elevation Model for Coastal

Louisiana (LCPRA, 2012a), at 30-meter resolution, is used for elevations in Louisiana. A second dataset, the Land Water Area (LCPRA, 2012b) was used for Louisiana to correct any elevation conflicts between the digital elevation model used for the general land topography on the map and the more current Louisiana digital elevation model used for inundation representation. These data were developed as part of the wetland morphology model to estimate the impacts of coastal restoration and sea level rise in the 2012 Louisiana Comprehensive Master Plan for a Sustainable Coast. The methodology for mapping Louisiana data was a simple bathtub approach, shading the elevation data equivalent to the projected rise in sea level. Tidal variation was not taken into account within Louisiana.

Data Quality

Data quality for Map 40 is fair. While Texas, Mississippi, Alabama and Florida are represented by high quality digital elevation models and the mapping methods incorporate local variability, these data are for screening impacts only. Many factors that can exacerbate sea level rise by enhancing inundation, such as engineered drainage networks (e.g., culverts, pipes and ditches) along with future changes in coastal geomorphology and coastal subsidence, all increase the uncertainty related to the mapping process. Digital elevation data covering Louisiana have relatively high uncertainty in vertical control compared to those data covering the other four U.S. states that do not have subsidence rates as high as Louisiana. In other words, the Louisiana model is a general representation of inundation with a much higher degree of uncertainty. Analogous data for Mexico and Cuba were not identified.

Synthesis and Conclusions

While scientific uncertainties regarding the extent of future sea level rise remain, experts predict that sea level rise and its impacts in the northern Gulf will be dramatic. Research is needed to better understand how the climate system, including sea level, will change in the future and whether human efforts to reduce greenhouse gas emissions are sufficient to slow future sea level rise (Lausche, 2009). There are also questions about the melting rate of ice sheets, especially polar caps, and the regional variability of sea level rise.

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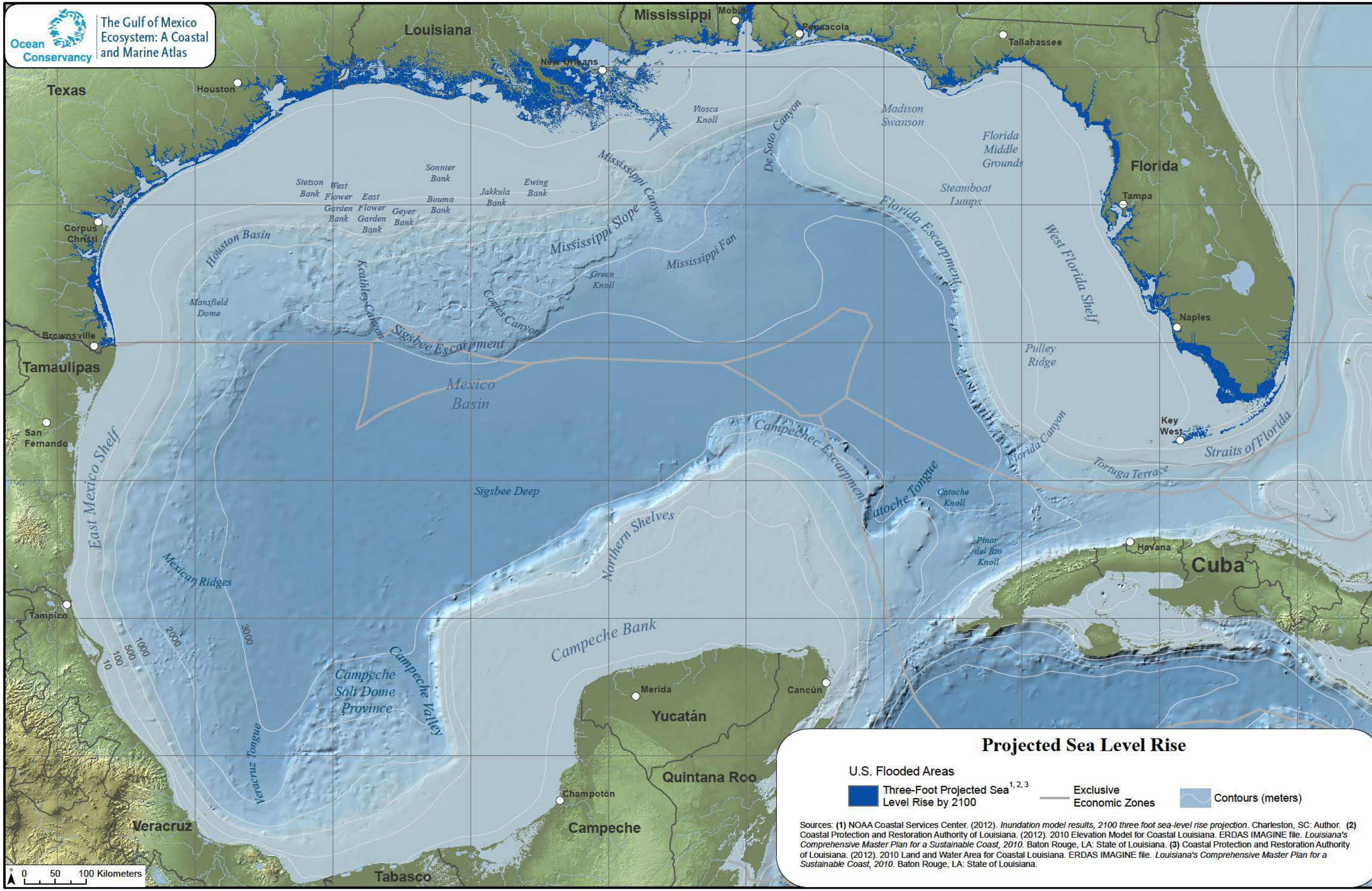
MAP 40 *(next page)*. **PROJECTED SEA LEVEL RISE**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Projected Sea Level Rise
U.S. Flooded Areas
Three-Foot Projected Sea Level Rise by 2100 [1, 2, 3]
Exclusive Economic Zones
Contours (meters)
Sources: (1) NOAA Coastal Services Center. (2012). Inundation model results, 2100 three foot sea-level rise projection. Charleston, SC: Author. (2) Coastal Protection and Restoration Authority of Louisiana. (2012). 2010 Elevation Model for Coastal Louisiana. ERDAS IMAGINE file. Louisiana's Comprehensive Master Plan for a Sustainable Coast, 2010. Baton Rouge, LA: State of Louisiana. (3) Coastal Protection and Restoration Authority of Louisiana. (2012). 2010 Land and Water Area for Coastal Louisiana. ERDAS IMAGINE file. Louisiana's Comprehensive Master Plan for a Sustainable Coast, 2010. Baton Rouge, LA: State of Louisiana.
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Havana
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
West Florida Shelf
Pulley Ridge
Florida Escarpment
De Soto Canyon
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Green Knoll
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Mansfield Dome
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Florida Canyon
Tortuga Terrace
Straits of Florida
Northern Shelves
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Veracruz Tongue
10
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500
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8.3 Land Area Change

Description

Gulf wetlands are in a state of continuous, natural flux due to the dynamic nature of the Gulf and its river systems, particularly the Mississippi and Atchafalaya rivers. For example, when the lower Mississippi changes course, which it has done about every 1,000 years, water and sediment shift from one delta to another, creating disparities in sedimentation. Historically, the river would top its banks, creating either a uniform sheet of water over the landscape or several more concentrated flows called splays, both of which redistributed sediment from the channel to the broader delta (Viosca, 1927).

The role of wetlands in ecosystem function and fisheries productivity cannot be overstated. For example, researchers have found that shrimp yields are directly related to marsh acreage in Louisiana's estuaries (Turner, 1977). Unfortunately, Gulf wetlands are in an accelerated state of decline because of an expanding human footprint and decades of disruption of key hydrological processes. Each state in the Gulf is experiencing some level of land change, especially where river impoundments have occurred, severing the flow and accumulation of sediment responsible for land accretion (White et al., 2002).

Louisiana had the highest statewide rate of land change in the Gulf, with a long-term average loss of 8.2 plus or minus 4.4 meters (26.9 plus or minus 14.4 feet) per year and a short-term average loss of 12 meters (39.4 feet) per year (Morton et al., 2005). The rates of loss in Louisiana vary among hydrologic basins, with a range of 0.2 kilometers per year (0.1 miles per year) in the Atchafalaya Basin to 17.9 kilometers per year (11.1 miles per year) in the Barataria Basin (Louisiana Coastal Wetlands Conservation and Restoration Task Force, 1997). Between 1932 and 2010, coastal Louisiana had a net loss of over 4,800 square kilometers (1,883 square miles) of land (Couvillion et al., 2011), an area larger than the state of Rhode Island. From 1985 to 2010, coastal Louisiana had a wetland loss rate of about 43 square kilometers (16.6 square miles) per year (Couvillion et al., 2011). Natural processes, such as geologic compaction and sea level rise, and anthropogenic activities, such as dredging, levees, sediment reduction in the Mississippi River Delta and salinity changes, all influence land area change in Louisiana (Turner, 1997). Converting marsh habitat to open water (canals) for navigation and for access to oil and gas fields has exacerbated the deterioration of coastal wetlands (Steyer et al., 2008). The geophysical side effects of the removal of hydrocarbons are also a contributing factor, as land sinks faster in oil and gas fields where the extraction of hydrocarbons from subsurface pockets creates down-faulting or subsidence (Ko & Day, 2004).

The Mississippi River Delta is the primary area of land loss in the state of Louisiana (Map 41), and the barrier islands and headlands are especially susceptible to land loss. The Mississippi Delta is the result of a dynamic equilibrium between sediment deposition and subsidence. Historically, sediment deposits from the Mississippi River replenished the delta, providing a countermechanism to the geologic compaction that occurs naturally in the delta. However, as sediment input has declined and compaction has continued, areas of the Louisiana coast have become submerged and experienced land loss. Anthropogenic changes have reduced the amount of sediment available for Mississippi River Delta deposition by about 50 percent (Kessel, 1989; Louisiana Coastal Wetlands Conservation and Restoration Task Force, 1997; Blum & Roberts, 2009). Prior to construction of dams and diversions, the Mississippi River had a suspended sediment load of more than 400 million tons per year. In 2006, the sediment load of the river was less than 200 million tons (Blum & Roberts, 2009). During the past 200 years, 25 percent of the delta's wetlands have been inundated by the sea (Blum & Roberts, 2009), and without additional sediment loads of 18-24 billion tons, the current delta will not be rebuilt on a sustained basis. The Coastal Protection and Restoration Authority of Louisiana (2012) predicts that without further restoration action, an additional 4,532 square kilometers (1,750 square miles) will be lost by the year 2062.

See related maps and narratives on Salt Marshes and Mangrove Forests, Barrier Islands, Brown Shrimp, White Shrimp, Projected Sea Level Rise, and Tropical Cyclone Track Density.

Data Compilation and Mapping Methods

Land area change data for Louisiana were obtained from Couvillion et al. (2011) at the U.S. Geological Survey (USGS) National Wetlands Research Center. The methods used to develop this dataset build on earlier efforts to document the loss of emergent land and vegetation in Louisiana. The source report uses historical surveys from 1932, National Wetland Inventory data based on aerial photography for 1956, Landsat Multi-Spectral Scanner satellite imagery covering the period 1973-1979, and Landsat Thematic Mapper satellite imagery for the period 1985-2010. These data were used to track land loss and accumulation in delta-building regions of the state from 1932 through 2010 (Couvillion et al., 2011).

Data Quality

Data quality for this map is good because of the consistent resolution of data for Louisiana, the remote sensing methodologies used and the broad temporal coverage of datasets available for the analysis. Data gaps exist in areas of the map in the 1932 and 1956 datasets, but assuming no land area change in those gap areas during that time span, the overall data quality is unchanged. The gaps in question are forested wetlands, whose distribution has been historically stable, making this assumption reasonable (Couvillion et al., 2011). Analogous data of sufficient resolution for other U.S. states, Cuba and Mexico were not identified.

Synthesis and Conclusions

The Gulf shoreline is actively eroding and the highest rates of land loss are occurring in coastal Louisiana. Due to subsidence and submergence, the coastal population and coastline of Louisiana are increasingly vulnerable to tropical storms, while productive habitats for fish and wildlife are disappearing. Although the exact rates of subsidence are uncertain, the consensus in the scientific community is that inundation of coastal areas will occur. Mitigation strategies will need to be employed to reduce risks to communities and infrastructure, enhance environmental resiliency, and sustain economic development.

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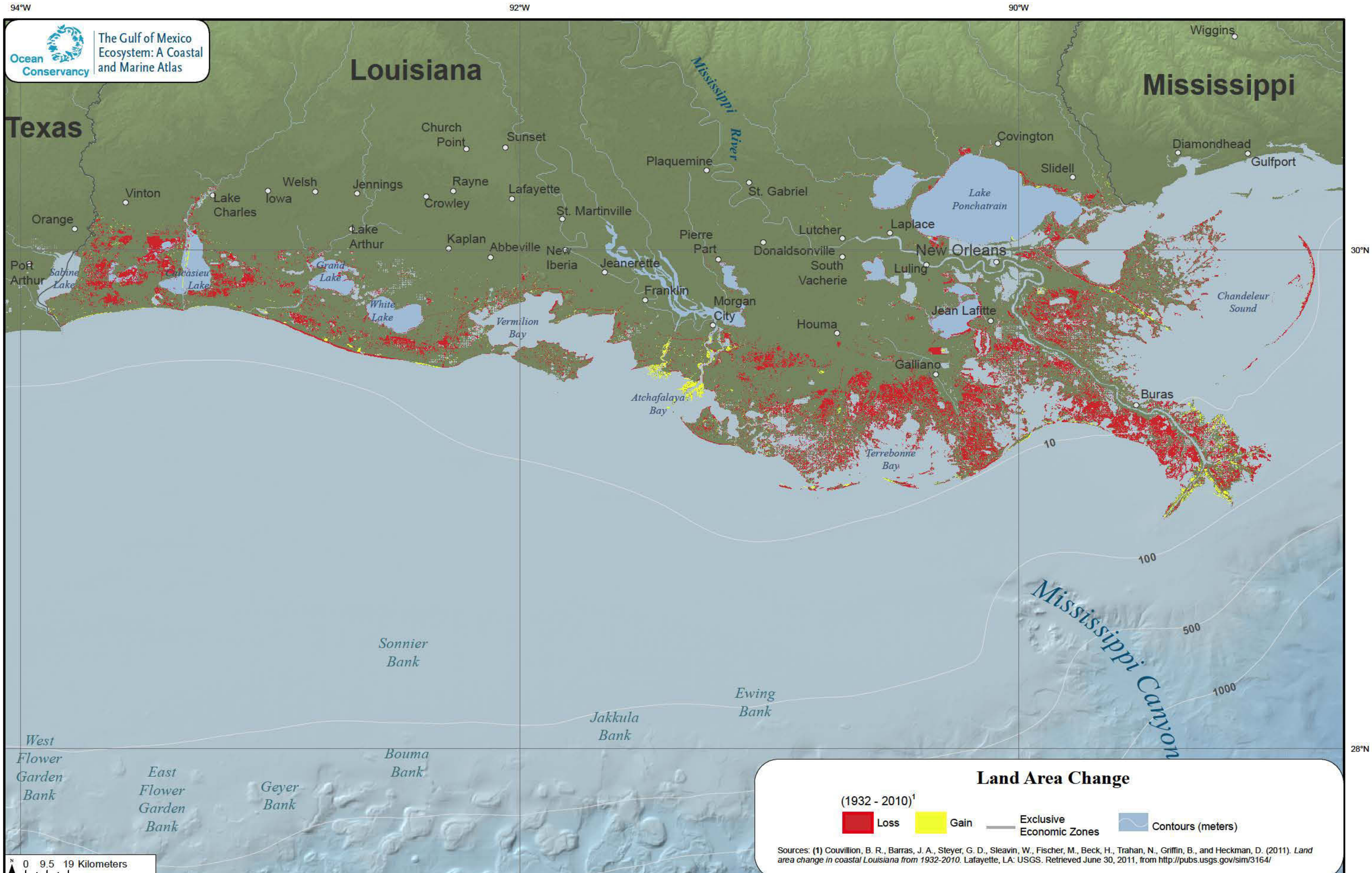
MAP 41 *(next page)*. **LAND AREA CHANGE**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
94°W
92°W
90°W
30°N
28°N
Louisiana
Mississippi
Texas
Mississippi River
Wiggins
Church Point
Sunset
Plaquemine
Covington
Diamondhead
Gulfport
Slidell
Vinton
Lake Charles
Welsh
Iowa
Jennings
Rayne
Crowley
Lafayette
St. Gabriel
Lake Ponchatrain
Orange
Lake Arthur
Kaplan
Abbeville
St. Martinville
Pierre Part
Lutcher
Laplace
New Orleans
Port Arthur
Sabine Lake
Calcasieu Lake
Grand Lake
New Iberia
Jeanerette
Donaldsonville
South Vacherie
Luling
White Lake
Vermilion Bay
Franklin
Morgan City
Houma
Jean Lafitte
Chandeleur Sound
Galliano
Atchafalaya Bay
Buras
Terrebonne Bay
10
100
500
1000
Mississippi Canyon
Sonnier Bank
Ewing Bank
Jakkula Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Bouma Bank
0 9.5 19 Kilometers
Land Area Change
(1932 - 2010)[1]
Loss
Gain
Exclusive Economic Zones
Contours (meters)
Sources: (1) Couvillion, B. R., Barras, J. A., Steyer, G. D., Sleavin, W., Fischer, M., Beck, H., Trahan, N., Griffin, B., and Heckman, D. (2011). Land area change in coastal Louisiana from 1932-2010. Lafayette, LA: USGS. Retrieved June 30, 2011, from http://pubs.usgs.gov/sim/3164/

8.4 Tropical Cyclone Track Density

Description

The Gulf of Mexico has experienced some of the strongest storms that have impacted the coast of the U.S. Among them are Hurricane Katrina (2005), Hurricane Charley (2004), Hurricane Andrew (1992), Hurricane Camille (1969), the Labor Day Hurricane (1935) and the Galveston Hurricane of September 1900 (NOAA, 2012b). During landfall, Hurricane Katrina had sustained winds of 201 kilometers (125 miles) per hour and caused widespread destruction along the central Gulf Coast, especially in New Orleans, Louisiana, Mobile, Alabama and Gulfport, Mississippi (NOAA, 2012b). Map 42 includes all listed categories of cyclones that are tropical in nature. From 1851 to 2010, there have been 1,589 tropical cyclones in the Gulf, 644 of which were hurricanes.

Tropical cyclones are classified into four categories: 1) tropical depression with persistent clouds and thunderstorms with closed low-level circulation and maximum sustained winds of up to 61 kilometers (38 miles) per hour; 2) tropical storm, having an organized system of strong thunderstorms with a well-defined circulation and maximum sustained wind speeds from 63 kilometers (39 miles) to 117 kilometers (73 miles) per hour; 3) hurricane, an intense tropical weather system with well-defined circulation and maximum sustained winds of 119 kilometers (74 miles) per hour or higher; and 4) major hurricane with maximum sustained winds of 179 kilometers (111 miles) per hour or higher, which corresponds to category three, four or five on the Saffir-Simpson Hurricane Wind Scale (NOAA, 2012a).

Tropical cyclones can cause flooding from torrential rains, storm surges and storm tides, as well as tornadoes and substantial winds (NOAA, 2012a). These events result in loss of life, extensive damage to coastal development and infrastructure (e.g., homes, industries and roads), altered sediment distribution, and saltwater intrusion (Stone et al., 2004). Damage from Hurricane Katrina alone is estimated at $125 billion (NOAA, 2012c).

Researchers have examined the impacts of global warming on tropical cyclone frequency and intensity (Landsea et al., 2006; Gualdi et al., 2008; Yu et al., 2009). The detection of long-term trends of tropical cyclones is complicated by the large fluctuations in frequency and intensity of tropical cyclones and the limited global historical records of tropical cyclones (Knutson et al., 2010). As a result, there is uncertainty about whether the characteristics of tropical cyclones have changed or will change in a warming climate. Since human influence on future tropical cyclone activity is not empirically detectable, modeling is needed to predict and assess the future impact of climate changes on tropical cyclone activity (Knutson et al., 2010).

See related maps and narrative on Salt Marshes and Mangrove Forests, Barrier Islands, Observed Change in Sea Surface Temperature, and Ocean Acidification.

Data Compilation and Mapping Methods

Data for Map 42 on the density of tropical cyclone tracks in the Gulf were obtained from Knapp et al. (2010). This database was derived from data provided by many Regional Specialized Meteorological Centers, other international centers, and individuals to create a global best-track dataset, followed by merging storm information from multiple centers into one product and archiving the data for public use. To construct the track density dataset used on this map, the Environmental Systems Research Institute Line Density tool was used with a neighborhood radius of 50 kilometers (31 miles) to calculate the number of tracks around each 10-square-kilometer (3.8-square-mile) cell that collectively comprises the entire Gulf of Mexico and Atlantic Ocean within the map extent. Cyclone landfall per U.S. county was developed by adding the total number of tracks that intersect the boundary of each county.

Data Quality

Data quality for Map 42 is good because the map was developed from the most complete global set of historical tropical cyclone data available, and these data were subjected to quality assurance and control provided by the World Data Center for Meteorology before release to the public. These data are the most comprehensive inventory of tropical cyclones with standardized wind speeds across all meteorological centers. No data gaps exist in the Gulf within the time frame of this dataset.

Synthesis and Conclusions

The Gulf has experienced some of the strongest storms to have ever impacted the coastal U.S. During the last 160 years, 1,589 tropical cyclones have been reported in the Gulf and 644 were hurricanes. More studies are needed to better understand future intensity and frequency of tropical cyclones, especially in relation to climate change. By understanding the spatial patterns and temporal trends of tropical cyclone tracks and landfalls in the Gulf, environmental planners and risk assessors will be able to increase storm preparedness and minimize the loss of lives and property.

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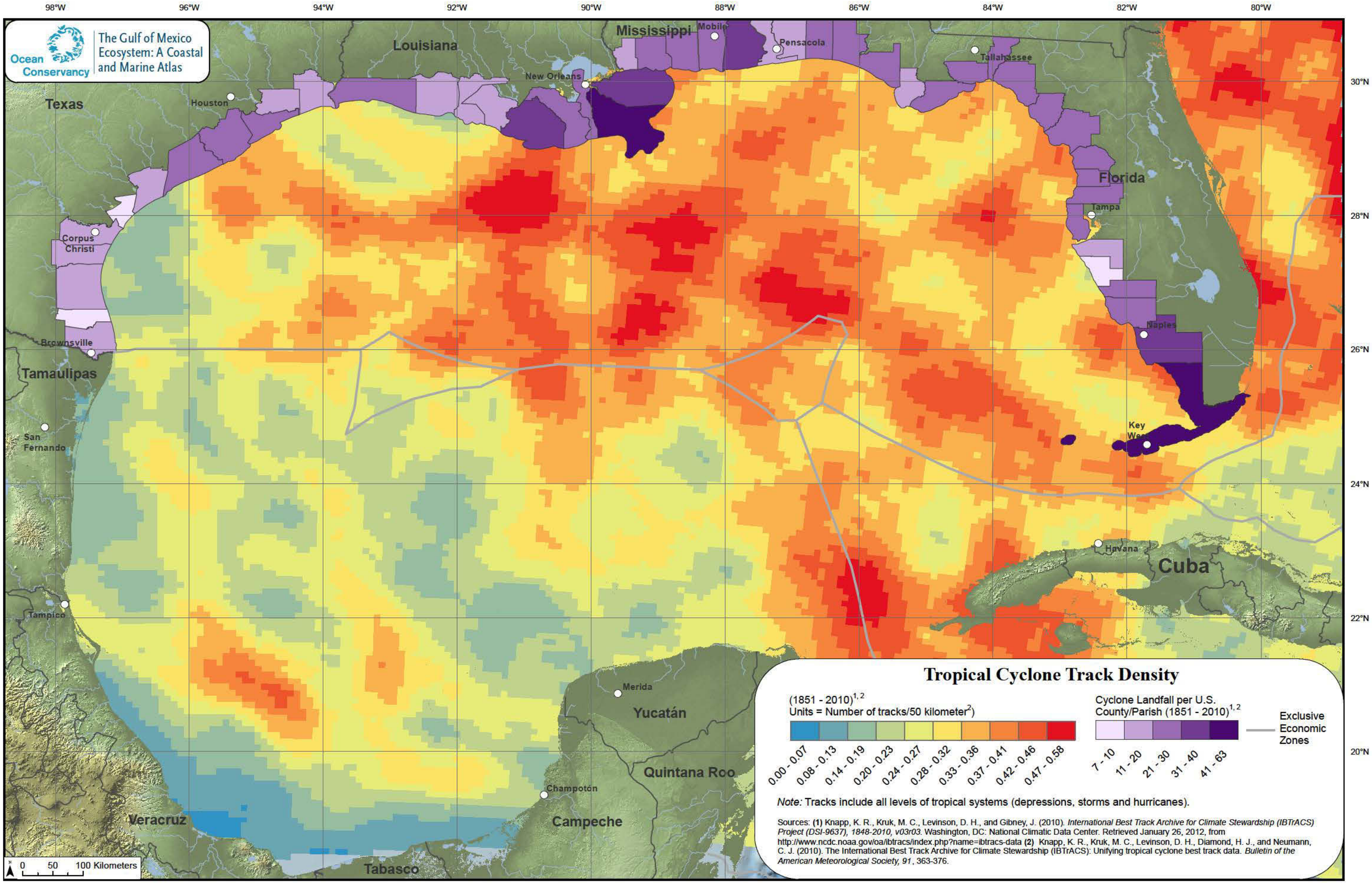
MAP 42 *(next page)*. **TROPICAL CYCLONE TRACK DENSITY**


Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
98°W
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84°W
82°W
80°W
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28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
New Orleans
Houston
Florida
Tampa
Corpus Christi
Naples
Brownsville
Tamaulipas
San Fernando
Key West
Havana
Cuba
Tampico
Merida
Yucatán
Quintana Roo
Champotón
Campeche
Veracruz
Tabasco
0 50 100 Kilometers
Tropical Cyclone Track Density
(1851 - 2010)[1, 2]
Units = Number of tracks/50 kilometer²)
0.00 - 0.07
0.08 - 0.13
0.14 - 0.19
0.20 - 0.23
0.24 - 0.27
0.28 - 0.32
0.33 - 0.36
0.37 - 0.41
0.42 - 0.46
0.47 - 0.58
Cyclone Landfall per U.S. County/Parish (1851 - 2010)[1, 2]
7 - 10
11 - 20
21 - 30
31 - 40
41 - 63
Exclusive Economic Zones
Note: Tracks include all levels of tropical systems (depressions, storms and hurricanes).
Sources: **(1)** Knapp, K. R., Kruk, M. C., Levinson, D. H., and Gibney, J. (2010). *International Best Track Archive for Climate Stewardship (IBTrACS) Project (DSI-9637), 1848-2010, v03r03.* Washington, DC: National Climatic Data Center. Retrieved January 26, 2012, from http://www.ncdc.noaa.gov/oa/ibtracs/index.php?name=ibtracs-data **(2)** Knapp, K. R., Kruk, M. C., Levinson, D. H., Diamond, H. J., and Neumann, C. J. (2010). The International Best Track Archive for Climate Stewardship (IBTrACS): Unifying tropical cyclone best track data. *Bulletin of the American Meteorological Society, 91*, 363-376.

8.5 Low Oxygen Areas

Description

The dead zone, which is an area of low oxygen or hypoxia, develops in the Gulf of Mexico every summer on the continental shelf, west of the Mississippi River Delta (Map 43). It has averaged 17,350 square kilometers (6,700 square miles) from 2007 to 2011 (Rabalais & Turner, 2011). The largest dead zone documented to date in the Gulf was nearly as large as the state of New Jersey when it was measured in 2002 at roughly 22,000 square kilometers (8,481 square miles) (LUMCON, 2010). The hypoxic area can extend from nearshore to 125 kilometers (78 miles) off the coasts of Louisiana and Texas. It has been expanding west into Texas waters, and new areas of hypoxia were documented east of the Mississippi River outflow in 2011 (Rabalais & Turner, 2011; LUMCON, 2010). The Mississippi River dead zone persists from late spring to late summer and is usually largest in mid-July to early August.

Hypoxic conditions occur when dissolved oxygen concentrations are less than 2 to 3 milligrams of oxygen per liter of water. These low oxygen areas often do not have sufficient dissolved oxygen concentrations to support animal life, so animals will flee or die; hence, the name "dead zone." In the Gulf, dead zones are found in coastal, estuarine and offshore waters. As of 2008, 105 out of 205 (51 percent) estuarine and coastal water bodies around the U.S. Gulf had at least one report of hypoxia (Committee on Environment and Natural Resources, 2010) (Map 43). There is limited information on the occurrence of hypoxia in Mexico and Cuba, with only one documented site along the Yucatán Peninsula. In addition to the coastal low oxygen areas, which are largely caused by human activities, the Gulf also has a natural area of low oxygen (an oxygen minimum zone) in the pelagic environment between 200 and 1,000 meters (656 to 3,280 feet) deep (Levin, 2003).

Eutrophication is an elevated supply of nutrients in a body of water, resulting in increased algal growth and low oxygen conditions, including hypoxia. Human-generated nutrients enrich coastal ecosystems beyond the threshold where ecological processes are able to assimilate nutrients back into the ecosystem, causing the formation of pollution-generated hypoxic zones that increase the frequency, duration and intensity of naturally occurring hypoxia (Committee on Environment and Natural Resources, 2010). These pollution-driven hypoxic zones tend to occur in coastal areas and have adverse effects on organisms, because they are not adapted to survive under low oxygen conditions.

The main sources of nutrient pollution in the Gulf are runoff from agricultural and urban sources, effluent, wastewater treatment plants, and atmospheric deposition from the burning of fossil fuels (Committee on Environment and Natural Resources, 2010; EPA, 2007; Diaz & Rosenberg, 2008). The increased occurrences of coastal eutrophication and hypoxia are closely related to the increased application of fertilizers that began in the late 1950s (Rabalais et al., 2010). Coastal hypoxic events are an increasingly common problem around the world, with the occurrence of hypoxic events rising at an exponential rate since the 1960s (Diaz & Rosenberg, 2008; Rabalais et al., 2010). As of 2008, more than 245,000 square kilometers (94,595 square miles) in more than 400 aquatic systems around the world have at some time reported hypoxic events (Diaz & Rosenberg, 2008), and an additional 115 sites have been identified since then (Conley et al., 2011). Scientists predict that coastal eutrophication will worsen as the world's population grows and food and energy demands rise, making it one of the planet's most important conservation issues (Diaz & Rosenberg, 2008).

See related maps and narratives on Net Primary Productivity, Brown Shrimp, White Shrimp, Blue Crab and Offshore Shrimp Trawl Fishery.

Data Compilation and Mapping Methods

Mid-summer shelfwide monitoring administered by researchers at the Louisiana Universities Marine

Consortium was the original source of data on the extent of the Louisiana-Texas dead zone in Map 43 (Rabalais et al., 2011). However, Map 43 is based on representations of the annual hypoxia footprint maps from 1985 through 2001 compiled by the Gulf States Marine Fisheries Commission. These annual hypoxia extents were combined to show the cumulative annual extent of areas that experienced hypoxia at any point during that 15-year period. Diaz et al. (2011) was the source of data for isolated dead zones along the remainder of the Gulf Coast.

Data Quality

Data quality for Map 43 is fair, primarily because the mid-summer hypoxia cruise data for oxygen concentrations in the north-central Gulf were derived from map representations and not directly from the original data. The rating is also lower because oxygen concentration monitoring is infrequent in most areas of the U.S. Gulf, and many sites that experience low oxygen may be missed by the sampling programs. One location of hypoxia is documented in Mexico but no comprehensive data were identified for Mexico and Cuba.

Synthesis and Conclusions

The Gulf dead zone is of particular concern to Gulf ecosystem services, such as valuable commercial and recreational Gulf fisheries. The EPA Science Advisory Board (2007) recommends a significant reduction of nutrients. Targeted nutrient reduction measures have been identified as a viable hypoxia abatement strategy (Graham et al., 2011; EPA, 2008). Continued support is needed for studies that evaluate and monitor the causes of hypoxia and investigate this stressor's effects on living resources and coastal economies. Studies are also needed to better understand the cumulative effects of multiple stressors, such as climate change, hypoxia and the BP Deepwater Horizon oil disaster on the Gulf marine ecosystem.

Text Citations

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Map Data Sources

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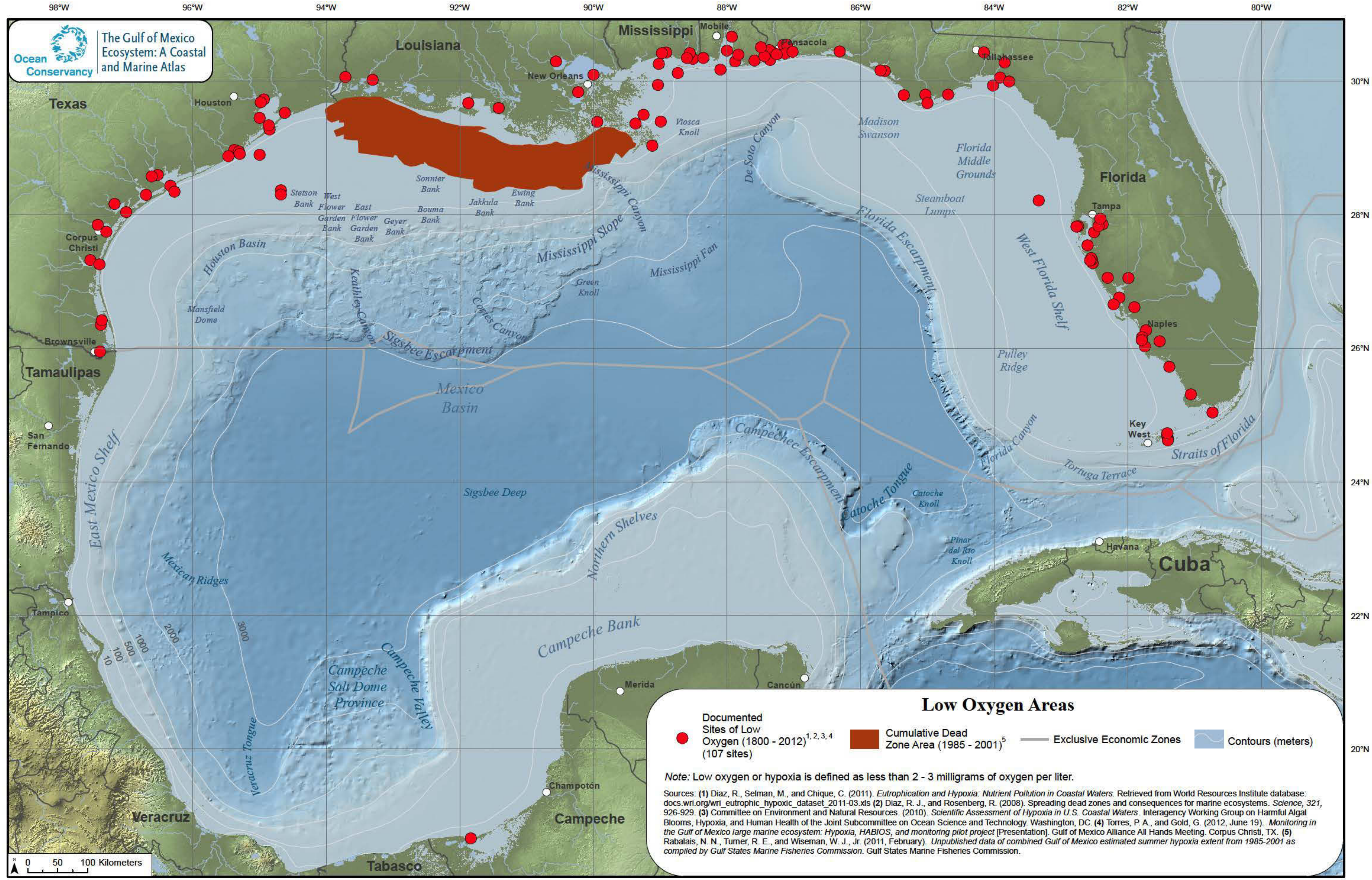
MAP 43 *(next page)*. **LOW OXYGEN AREAS**



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Low Oxygen Areas
Documented Sites of Low Oxygen (1800 - 2012)[1, 2, 3, 4] (107 sites)
Cumulative Dead Zone Area (1985 - 2001)[5]
Exclusive Economic Zones
Contours (meters)
Note: Low oxygen or hypoxia is defined as less than 2 - 3 milligrams of oxygen per liter.
Sources: (1) Diaz, R., Selman, M., and Chique, C. (2011). Eutrophication and Hypoxia: Nutrient Pollution in Coastal Waters. Retrieved from World Resources Institute database: docs.wri.org/wri_eutrophic_hypoxic_dataset_2011-03.xls (2) Diaz, R. J., and Rosenberg, R. (2008). Spreading dead zones and consequences for marine ecosystems. Science, 321, 926-929. (3) Committee on Environment and Natural Resources. (2010). Scientific Assessment of Hypoxia in U.S. Coastal Waters. Interagency Working Group on Harmful Algal Blooms, Hypoxia, and Human Health of the Joint Subcommittee on Ocean Science and Technology. Washington, DC. (4) Torres, P. A., and Gold, G. (2012, June 19). Monitoring in the Gulf of Mexico large marine ecosystem: Hypoxia, HABIOS, and monitoring pilot project [Presentation]. Gulf of Mexico Alliance All Hands Meeting. Corpus Christi, TX. (5) Rabalais, N. N., Turner, R. E., and Wiseman, W. J., Jr. (2011, February). Unpublished data of combined Gulf of Mexico estimated summer hypoxia extent from 1985-2001 as compiled by Gulf States Marine Fisheries Commission. Gulf States Marine Fisheries Commission.
0 50 100 Kilometers
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Cancún
Champotón
Houston Basin
Mansfield Dome
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Bouma Bank
Sonnier Bank
Jakkula Bank
Ewing Bank
Keathley Canyon
Sigsbee Escarpment
Mississippi Slope
Mississippi Canyon
Mississippi Fan
Green Knoll
Viosca Knoll
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Mexico Basin
Sigsbee Deep
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Mexican Ridges
East Mexico Shelf
Veracruz Tongue
10
100
500
1000
2000
3000

8.6 Hazardous Materials Spills

Description

Materials commonly produced or used by industry are often hazardous when leaked into the environment. The largest sources of accidental releases in the Gulf of Mexico are the oil and gas and chemical industries (Map 44). The Gulf Coast houses numerous petroleum refineries and chemical production facilities, as well as other infrastructure, such as pipelines, which produce, store, transport and occasionally leak harmful materials into the environment. These substances are given the broad category "hazardous materials" and can damage ecosystems (e.g., kill wildlife and foul habitats), cause harm to people, disrupt marine transportation and negatively impact coastal economies (e.g., fishery closures and cleanup costs) (NOAA, 2012b; NOAA, 2012d). Since 1957, there have been at least 1,089 hazardous materials spills in the marine and coastal environments of the Gulf (NOAA Emergency Response Division, 2012). Of the total spills in the Gulf, 80 percent were oil or petroleum products, 13 percent were chemical or biological agents, 4 percent were other types of substances, and 3 percent were spills of unknown substances (NOAA Emergency Response Division, 2012). Spills reported as chemical or biological agents vary widely and include such substances as sulfuric acid, zinc bromide and hydrochloric acid. Spills classified as "other" or "unknown" often have little or no information on the type of substance released.

Hurricanes and other storms can destroy coastal infrastructure and, in the process, cause the leakage of hazardous materials. For example, hurricanes Katrina and Rita caused 146 oil, condensate or chemical spills that were one barrel or greater (six spills were greater than 1,000 barrels), damaged 457 pipelines and destroyed 113 platforms (MMS, 2006).

The two largest oil spills documented in the Gulf were the BP Deepwater Horizon (DWH) oil disaster and the Ixtoc I oil spill. The DWH oil disaster leaked an estimated 4.9 million barrels of oil into the northern Gulf over the course of nearly three months, starting April 20, 2010. The full ecological and economic impacts of this disaster are still unfolding, and the results of most of the formal Natural Resources Damage Assessment studies are not publically available. Early impacts included a fishery closure that covered 229,270 square kilometers (88,522 square miles) of federal fishing grounds at its peak (NOAA, 2012c), thousands of oiled and dead birds and other wildlife, and dead or damaged deep-sea corals (White et al., 2012; NOAA, 2012a). The DWH oil disaster contaminated 400 to 435 square kilometers (1,036 to 1,127 square miles) of Louisiana's already stressed coastal marshes (Mishra et al., 2012). Heavily oiled marshes had weakened resiliency and increased rates of erosion (Silliman et al., 2012).

The Ixtoc I oil spill occurred in 1979 and leaked 3.5 million barrels of oil into the southwestern Gulf over the course of 290 days (Federal Interagency Solutions Group, 2010). The lack of long-term research and monitoring following the Ixtoc I spill impairs our ability to understand the impacts of this event.

The methods used to clean up hazardous materials spills depend largely on the type and location of the spill. Choosing the proper cleanup method is also a process of balancing the potential damage from cleanup measures versus the short-term and long-term negative effects of oil or other hazardous materials in the ecosystem (Pezeshki et al., 2000). Common cleanup measures for oil spill response include on-water recovery (skimming), dispersant application, in-situ burning, shoreline cleanups and bioremediation. In some cases where response and cleanup activities would be greatly damaging, the best alternative may be no action or natural attenuation (Pezeshki et al., 2000).

See related maps and narratives on Sea Surface Currents, Tropical Cyclone Track Density, Oil and Gas Distribution, Current U.S. Oil and Gas Leases and International Activity, Oil and Gas Drilling Platforms and Boreholes, and Selected Oil and Gas Pipelines.

Data Compilation and Mapping Methods

Data for hazardous material spills illustrated in Map 44 were obtained from two separate data sources. Incident data from the Emergency Response Division (2012) reflect oil spills in U.S. coastal waters and other incidents for which the Office of Response and Restoration provided scientific support on spill response. Data on the earliest recorded spills, from the late 1950s, were provided by third-party records. The U.S. Department of Homeland Security (2010) provided the second dataset, which includes details on marine casualty and pollution incidents investigated by the U.S. Coast Guard in U.S. waters between 2002 and 2010. Spills occurring within the Gulf were isolated from both databases.

Data Quality

Data quality for Map 44 is fair. This rating reflects the unknown quantity of hazardous materials discharged and the relatively high number of unknown substances in each spill. These databases do not represent an exhaustive record of all spills that have occurred in U.S. waters during this time period. The information provided in Map 44 should be considered an approximation because hazardous materials spills in the Gulf are neither easily quantified nor differentiated by non-experts from natural substances (e.g., seeps). Moreover, a publicly accessible database of all historical spills is not available. The U.S. Coast Guard National Response Center is the point of contact for all marine and aquatic spills reported in U.S. waters, but one cannot differentiate false reports, minor spills and major incidents within those data. While a few large international incidents are documented in these databases (e.g., Ixtoc I oil spill), comparable data sources for Mexico and Cuba were not located.

Synthesis and Conclusions

Hazardous materials spills can have widespread environmental, ecological, human health and economic impacts. Studies are needed to better understand the cumulative impacts of small, chronic spills on marine ecosystems. Long-term studies on the lethal and sublethal effects on key species and habitats from the DWH oil disaster are also needed. The absence of long-term studies following the Ixtoc I oil spill prevented scientists from understanding the full extent of impacts from that event, which might have helped shape studies following the DWH oil disaster. Monitoring systems and environmental data are essential to study the synergistic effects of hazardous materials spills and other environmental stressors on animals and habitats in the Gulf.

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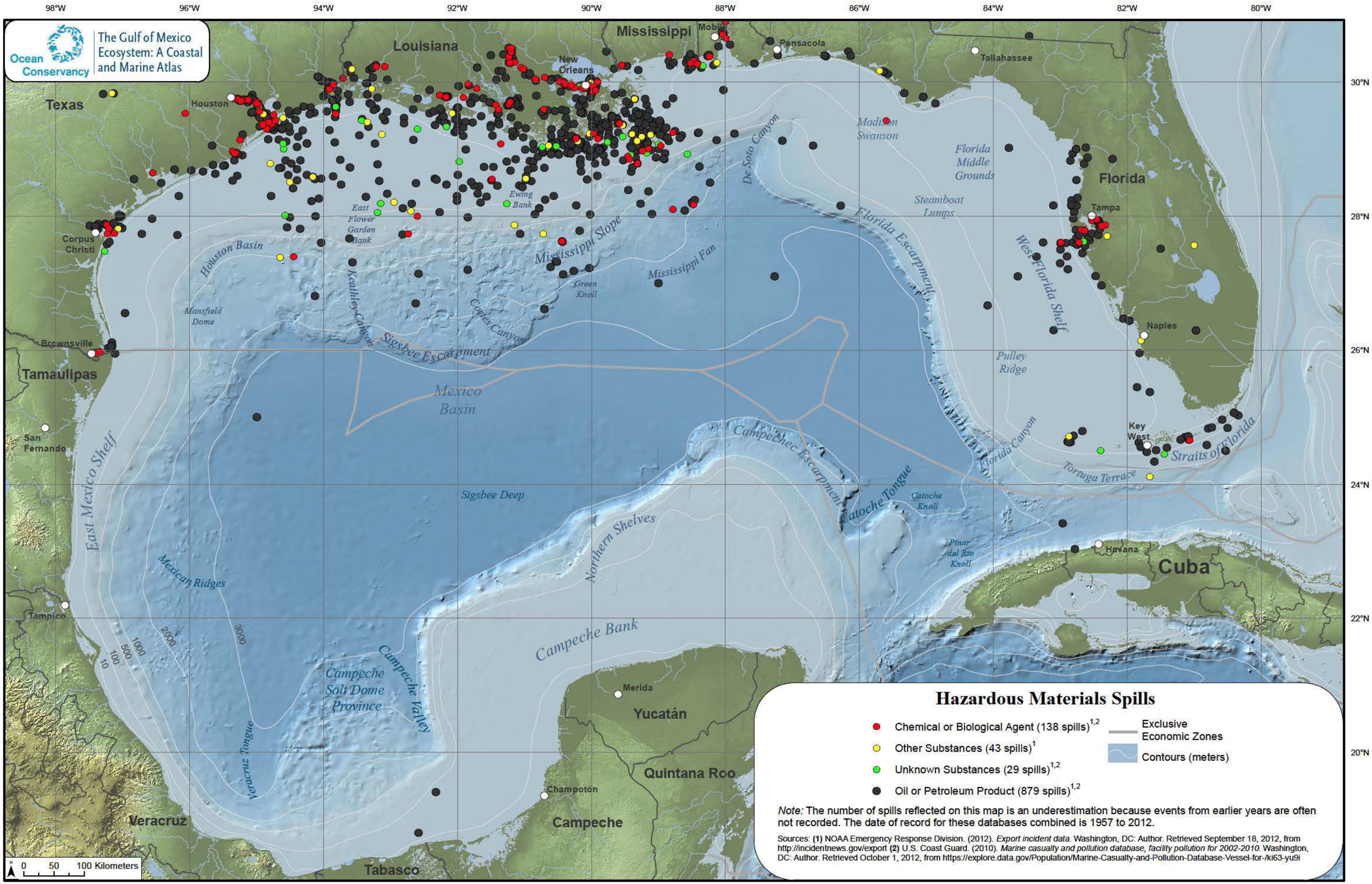
MAP 44 *(next page)***. HAZARDOUS MATERIALS SPILLS**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Hazardous Materials Spills
Chemical or Biological Agent (138 spills)[1,2]
Other Substances (43 spills)[1]
Unknown Substances (29 spills)[1,2]
Oil or Petroleum Product (879 spills)[1,2]
Exclusive Economic Zones
Contours (meters)
Note: The number of spills reflected on this map is an underestimation because events from earlier years are often not recorded. The date of record for these databases combined is 1957 to 2012.
Sources: **(1)** NOAA Emergency Response Division. (2012). *Export incident data.* Washington, DC: Author. Retrieved September 18, 2012, from http://incidentnews.gov/export **(2)** U.S. Coast Guard. (2010). *Marine casualty and pollution database, facility pollution for 2002-2010.* Washington, DC: Author. Retrieved October 1, 2012, from https://explore.data.gov/Population/Marine-Casualty-and-Pollution-Database-Vessel-for-/ki63-yu9i
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Houston Basin
Mansfield Dome
Keathley Canyon
East Flower Garden Bank
Ewing Bank
Mississippi Slope
Mississippi Fan
Green Knoll
Alaminos Canyon
Sigsbee Escarpment
Mexico Basin
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Sigsbee Deep
Northern Shelves
East Mexico Shelf
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers

8.7 Selected Non-Native Species of Concern

Description

The spread of non-native, invasive species is increasing due to human activities and has become a worldwide environmental and economic challenge, including in the Gulf of Mexico (Map 45). An invasive species is defined as "an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health" (Exec. Order No. 13112, 64 Fed. Reg. 6183). Map 45 shows the distribution of documented observations of four high profile, non-native species in Gulf coastal and marine waters: Asian green mussel (*Perna viridis*), red lionfish (*Pterois volitans*), Australian spotted jellyfish (*Phyllorhiza punctata*) and giant tiger prawn (*Penaeus monodon*). These species illustrate the types of invasions by non-native marine organisms that pose an economic and ecological threat to the Gulf ecosystem. More than 540 nonindigenous aquatic species have been documented in the five Gulf states (Benson, 2000).

Asian green mussels were first observed in the Gulf in 1999 in Tampa Bay (McGuire & Stevely, 2009). Asian green mussels are susceptible to cold temperatures, so they are not predicted to spread much farther north, although global warming may expand their range (University of Florida, 2012). The red lionfish has rapidly increased in distribution and reported observations since it was first recorded along the U.S. Atlantic Coast in 2007 and in the Gulf two years later (Schofield et al., 2012). The lionfish was likely introduced through the aquarium trade (Whitfield et al., 2002; Semmens et al., 2004). Giant tiger shrimp, first observed in Gulf waters off of the coast of Mississippi in 2006, were also likely introduced after escaping from aquaculture facilities or possibly by migrating from previously established populations in the wild (Knott et al., 2012). Ballast water and shipping traffic were the likely pathways of introduction for the Australian spotted jellyfish, first recorded in the Gulf in 2000. Roughly, ten million jellies were present in a huge jellyfish bloom in 2000 that clogged shrimp nets and temporarily caused fishing to stop in the affected area (Graham et al., 2003; BTNEP, n.d.).

Some non-native species (e.g., honeybees) are not considered invasive or harmful because they provide benefits that far outweigh their costs. Invasive species can cause environmental harm by feeding on or displacing native species, outcompeting native species for resources, altering ecosystem processes, transporting disease to native species or causing human illness (National Invasive Species Council, 2008). Climate change may cause shifts in species distributions, which may exacerbate the problem of invasive species spread by other anthropogenic means. The total nationwide economic impact of invasive species is estimated to be approximately $123 billion annually (USDA, 1999).

See related maps and narratives on Observed Change in Sea Surface Temperature, Ocean Acidification, Navigation Network and Port Facilities, and Artificial Reefs.

Data Compilation and Mapping Methods

Data on the occurrence of selected non-native aquatic species were obtained from the Nonindigenous Aquatic Species database (USGS, 2012). This database is a central repository for spatially referenced biogeographic accounts of introduced aquatic species in the U.S.

Data Quality

Data quality for Map 45 is only fair due to the lack of comprehensive surveys to fully assess the extent of these species in the Gulf. This database is populated by data obtained through different methods ranging from scientifically designed sampling surveys to casual sightings of nonindigenous species by the public. Sightings tend to be concentrated where potential human observers are more numerous, such as popular dive sites, constructed marine infrastructure and high-use fishing areas. No comparable data for Mexico and Cuba were identified.

Synthesis and Conclusions

More than 40 non-native species have been documented in the Gulf, and four of the most notorious are the Asian green mussel, red lionfish, Australian spotted jellyfish and giant tiger prawn. The full ecological and economic impacts of these non-native species in the Gulf may not yet be manifested and are certainly not well understood. International commerce, tourism and global climate change are expected to exacerbate the problem. Prevention is the best strategy against species invasions, but control measures, such as targeted fisheries for non-native marine species, may help limit or mitigate impacts. The National Invasive Species Council has outlined steps to prevent invasive species introduction and spread in its *National Invasive Species Management Plan* (2008).

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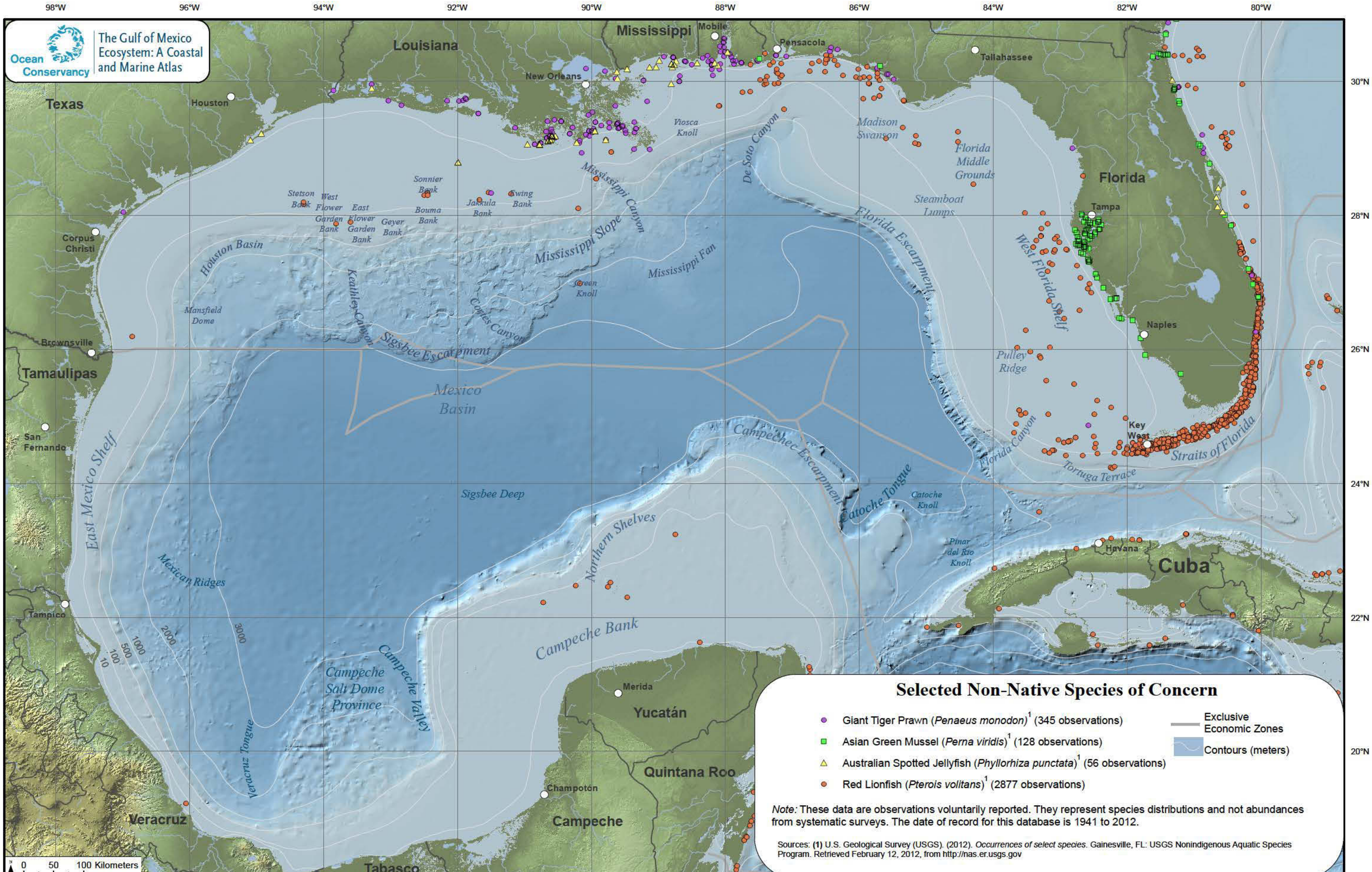
MAP 45 *(next page)*. **SELECTED NON-NATIVE SPECIES OF CONCERN**


The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Louisiana
Mississippi
Texas
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Mobile
Pensacola
Tallahassee
New Orleans
Houston
Corpus Christi
Brownsville
San Fernando
Tampico
Tampa
Naples
Key West
Havana
Merida
Champotón
Viosca Knoll
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Green Knoll
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Sonnier Bank
Bouma Bank
Geyer Bank
Jakkula Bank
Ewing Bank
Houston Basin
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mansfield Dome
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Selected Non-Native Species of Concern
Giant Tiger Prawn (Penaeus monodon)[1] (345 observations)
Asian Green Mussel (Perna viridis)[1] (128 observations)
Australian Spotted Jellyfish (Phyllorhiza punctata)[1] (56 observations)
Red Lionfish (Pterois volitans)[1] (2877 observations)
Exclusive Economic Zones
Contours (meters)
Note: These data are observations voluntarily reported. They represent species distributions and not abundances from systematic surveys. The date of record for this database is 1941 to 2012.
Sources: (1) U.S. Geological Survey (USGS). (2012). Occurrences of select species. Gainesville, FL: USGS Nonindigenous Aquatic Species Program. Retrieved February 12, 2012, from http://nas.er.usgs.gov

Human Uses

9.0 Oil & Gas

Description

The Gulf of Mexico is a significant producer of oil and gas for the U.S. The Gulf accounts for more than one-quarter of the total U.S domestic oil production and 7 percent of the total U.S. natural gas production (U.S. Energy Information Administration, 2012; BOEM, 2012b). In addition, more than 40 percent of the total U.S. petroleum refining capacity and about 30 percent of the total U.S. natural gas processing plant capacity are located on the Gulf Coast (U.S. Energy Information Administration, 2012). Four maps depicting the offshore oil and gas resources in the Gulf are described in this narrative: Oil and Gas Distribution (Map 46), Current U.S. Oil and Gas Leases and International Activity (Map 47), Oil and Gas Drilling Platforms and Boreholes (Map 48), and Selected Oil and Gas Pipelines (Map 49). Significant oil and gas infrastructure and production capacity are also located within each of the Gulf state's waters, but are not described here or shown on these maps.

The outer continental shelf of the U.S. Gulf is divided into three planning areas: Western, Central and Eastern (Map 47). The Central and Western planning areas have extensive oil and gas infrastructure (Maps 48 and 49) and production capacity (Map 46). The Eastern Planning Area is much less developed, and a moratorium prohibits oil and gas leasing activities until 2022. The moratorium in the Eastern Planning Area specifically covers all areas within 125 miles of the Florida shoreline, all areas east of the Military Mission Line (86 degrees, 41 minutes West), and all areas in the Central Planning Area within 100 miles of the Florida shoreline (Gulf of Mexico Energy Security Act, 43 U.S.C. § 1331).

Boreholes are drilled into the seafloor during exploratory phases of oil, gas and mineral exploration and are a necessary step to confirm the presence and composition of suspected oil and gas deposits. Approximately 52,000 known boreholes have been drilled in the Gulf seafloor in U.S. waters alone (BOEM, 2011b) (Map 48). Lease blocks are the individual lease units sold by the federal government to companies for exclusive oil and gas exploration and production rights. There are more than 29,000 leases, covering nearly 160 million acres, in the Gulf. The number of active leases in the Gulf is roughly 5,800 (covering >126,670 square kilometers). Of the active leases about 1,150 (>22,662 square kilometers) are producing leases, and about 4,665 (>103,600 square kilometers) are non-producing leases (BOEM, 2012a) (Map 47). There are approximately 3,700 oil and gas platforms in federal waters of the Gulf. In addition, roughly 3,320 oil and gas platforms have been removed from this same area (Map 48). The status of lease blocks changes frequently, so the numbers presented in this narrative and corresponding four maps are estimates.

Since the 1980s and 1990s, oil and gas technology has advanced rapidly and development in the Gulf has been moving farther offshore into deep water (>305 meters [1,000 feet]) and ultradeep water (>1,524 meters [5,000 feet]). Deep-water drilling faces additional challenges and risks when compared to drilling in shallow water, such as drilling through more porous materials and working at extreme depths, temperatures and subsea pressures (Graham et al., 2011). In 2008, deep-water production accounted for 70 percent of oil production in the Gulf (Johnson, 2011). The number of producing deep-water projects (hydrocarbon subsea and surface systems) increased eightfold from 1997 to 2008. The number of producing projects totaled 17 in 1997 and 141 at the end of 2008 (U.S. Department of the Interior, 2009). The U.S. government estimates that there are 82.72 billion barrels of oil and 460.35 trillion cubic feet of natural gas, or a total of 164.63 billion barrels of oil equivalent, in the total oil and gas planning areas of the Gulf (BOEM, 2011a) (Map 46). By definition, a barrel of oil equivalent is the sum of gas resources, expressed in terms of their energy equivalence to oil, plus the oil volume. The total endowment includes all conventionally recoverable hydrocarbon resources, which includes both removed and in-place hydrocarbon resources.

No offshore oil production has occurred in Cuba to date, but leases have been sold and exploration has begun in deep-water areas off its northwest coast. The offshore oil reserves of Cuba are estimated to be as high as 4.6 billion barrels (National Geographic Society, 2010). Three-quarters of oil production in Mexico comes from the Gulf. Offshore oil and gas reserves in Mexico are estimated to be as high as 13.81 billion barrels of oil equivalent (Petroleos Mexicanos, 2012).

Oil and gas exploration and production activities in the Gulf contribute substantially to the regional economy and national energy supplies, but also can impact coastal and marine environments. Potential impacts include noise from seismic surveys, marsh erosion and loss from exploration canals and land subsidence, direct physical impacts of drilling, including placement of structures on the seafloor (e.g., platforms, anchors, cables or pipelines), and hazardous materials spills (e.g., drilling fluids and oil). Oil discharges also can harm the Gulf ecosystem and the goods and services it provides to local communities.

See related maps and narratives on Land Area Change, Hazardous Materials Spills, and Navigation Network and Port Facilities.

Data Compilation and Mapping Methods

Oil and Gas Distribution

Data on the distribution of oil and gas plays in the northern Gulf were obtained from the Minerals Management Service (2000). This report provided the volume of oil and gas for each designated play in a tabular data file that was joined with the associated play delineations on a data CD provided with the report. A play is a group of known or postulated pools (hydrocarbon) that share common geologic, geographic and temporal properties, such as a history of hydrocarbon generation, migration, reservoir development and entrapment. To develop a surface view of the cumulative underlying petroleum volumes that occur in the geological strata on the Gulf floor, each play was converted to raster files representing barrel of oil equivalent estimates per square kilometer (BOE/km^2). All play raster files were then summed using Esri's cell statistics in the local toolset of the spatial analyst tools.

Current U.S. Oil and Gas Leases and International Activity

Data delineating the U.S. Gulf planning areas and the active oil and gas leases in the U.S. Gulf were obtained from the Bureau of Ocean Energy Management (BOEM) (2010). Depth designations were assigned by depth class to each lease block using the bathymetric dataset found in the bathymetry map of this atlas. Due to the prohibitive cost of purchasing original datasets from industry service companies, the leasing and exploration area delineation for Cuba and production areas for Mexico were approximations based on interpretations of maps published by the National Geographic Society (2010). Mobile offshore drilling units located in Mexico were obtained from the National Geospatial-Intelligence Agency (2012). Mobile offshore drilling units are facilities designed or modified to engage in drilling and exploration activities. They include drilling vessels, semi-submersibles, submersibles, jack-ups and similar facilities that can be moved without substantial effort.

Oil and Gas Drilling Platforms and Boreholes

Data for oil and gas platforms and drilling boreholes in the U.S. Gulf were obtained from BOEM (2011). These data include all releasable boreholes from drilling activity along with existing and removed oil and gas platforms in U.S. federal waters. The states of Alabama, Louisiana and Texas have platforms within state waters, but they are not represented on this map. Mississippi and Florida prohibit oil and gas platforms within their state waters.

Selected Oil and Gas Pipelines

Data representing the submerged oil and gas pipelines and submarine cables in U.S. federal waters were obtained from BOEM (2010). These oil and gas pipeline data represent structures used to transport petroleum products from offshore terminals or platforms to inshore or onshore facilities. Source geometry and attributes of submarine cables were originally derived from 2010 NOAA Electronic Navigation Charts and 2009 NOAA Raster Nautical Charts. Polyline features explicitly defined as cables were compiled from the original sources and are denoted as "cable areas." The scales of the source material were highly variable and discontinuous among the original multiple sources. BOEM resolved these differences with the least possible spatial adjustments.

Data Quality

Oil and Gas Distribution

Data quality for Map 46 within the U.S. exclusive economic zone is good due to the extensive effort involved in defining the plays, delineating their geographic limits, and compiling data on critical geologic and reservoir-engineering parameters (Hunt & Burgess, 1995; Seni et al., 1997; Hentz et al., 1997). Play delineations and petroleum volume estimates were calculated consistently for all plays within the jurisdiction of BOEM in federal waters of the Gulf. However, no comparable data were available for Cuba and Mexico.

Current U.S. Oil and Gas Leases and International Activity

Data quality for Map 47 in U.S. waters is good. These data came directly from the managing agency that delineates the lease blocks and planning areas. Data quality for this map is fair in the waters of Mexico and Cuba. While the source map from which these areas were delineated is expected to be accurate based on correct geographic data available, the original data could not be directly obtained, nor could the data used for the map be verified for accuracy. Some drilling facilities in the waters of Mexico are shown, but the substantial infrastructure in place off of the coasts of the states of Tabasco and Veracruz is not represented on this map.

Oil and Gas Drilling Platforms and Boreholes

Data quality for Map 48 in U.S. waters is good because the geographic coordinates for platforms and boreholes are considered to be accurate and represent the true location of infrastructure or activity. No infrastructure from activity in Mexico or Cuba is displayed on this map; therefore, data quality is poor for the waters of Mexico and Cuba.

Selected Oil and Gas Pipelines

Data quality for Map 49 in U.S. waters is good. These data come directly from the agency responsible for managing these resources (BOEM), and the agency charged with mapping marine infrastructure, such as marine cables (NOAA). Pipeline data were not available for state waters or terrestrial areas due to non-disclosure requirements associated with national security concerns. No reasonably available, non-proprietary data were identified for Cuba and Mexico.

Synthesis and Conclusions

Oil and gas exploration and production activities in the Gulf contribute substantially to the regional economy and national energy supplies, but also can impact the marine environment. Over 40 percent of the total U.S. petroleum refining capacity and about 30 percent of the total U.S. natural gas processing plant capacity are located on the Gulf Coast. There are also significant oil and gas reserves in Mexico and Cuba. As the oil and gas industry moves farther offshore, more unknowns about the interactions between industry and the marine environment will be encountered. More research and monitoring are essential to understand these interactions and the cumulative impacts of oil and gas activities on offshore marine environments.

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Oil and Gas Distribution
Minerals Management Service (MMS). (2000). *2000 Assessment of Conventionally Recoverable Hydrocarbon Resources of the Gulf of Mexico and Atlantic Outer Continental Shelf as of January 1, 1999.* New Orleans, LA: Author.

Ocean Conservancy. (2012, February 29). *Cumulative underlying petroleum volumes*. Raster dataset based on Minerals Management Service, 2000.

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Bureau of Ocean Energy Management (BOEM). (2010). *Gulf of Mexico BOEM active oil and gas leases*. Washington, DC: Author. Retrieved February 08, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

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Bureau of Ocean Energy Management (BOEM). (2010). *Gulf of Mexico platforms*. Washington, DC: Author. Retrieved January 18, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

Bureau of Ocean Energy Management (BOEM). (2011). *Gulf of Mexico oil and natural gas wells*. Washington, DC: Author. Retrieved February 29, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

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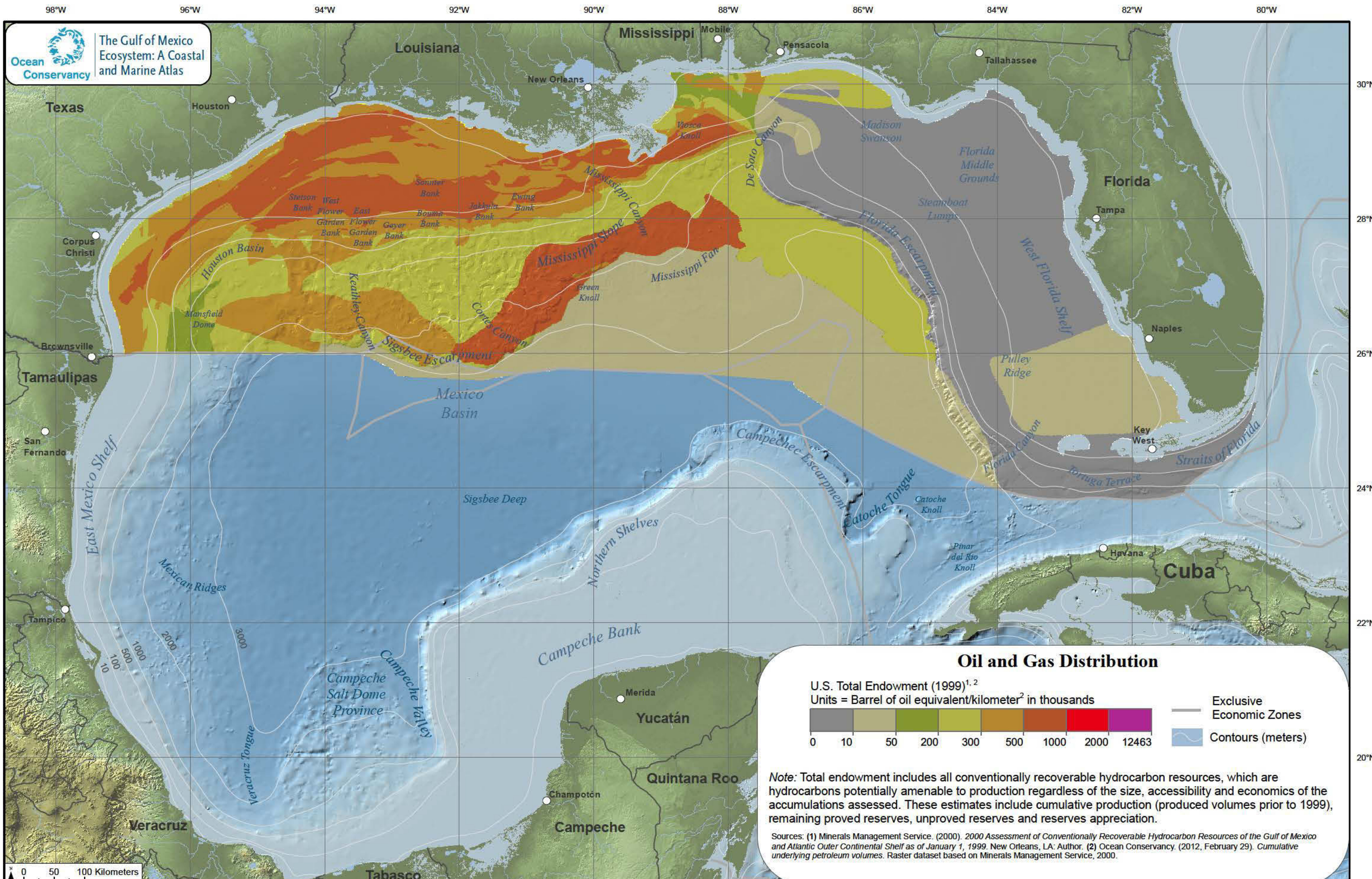
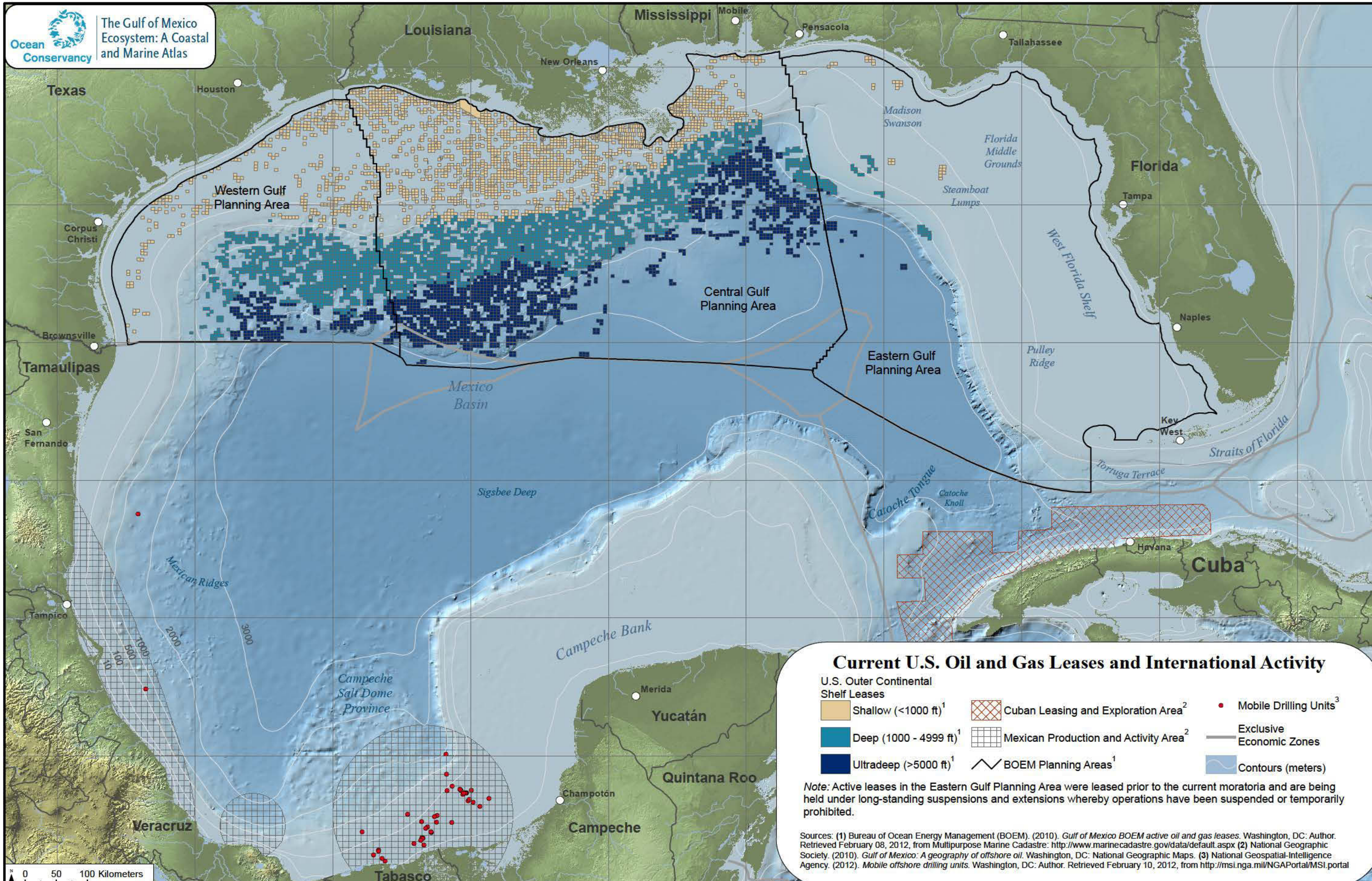
Bureau of Ocean Energy Management (BOEM). (2010). *Gulf of Mexico selected pipelines*. Washington, DC: Author. Retrieved January 18, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

MAP 46 *(next page)*. **OIL AND GAS DISTRIBUTION**
MAP 47. CURRENT U.S. OIL AND GAS LEASES AND INTERNATIONAL ACTIVITY
MAP 48. OIL AND GAS DRILLING PLATFORMS AND BOREHOLES
MAP 49. SELECTED OIL AND GAS PIPELINES



Note: Total endowment includes all conventionally recoverable hydrocarbon resources, which are hydrocarbons potentially amenable to production regardless of the size, accessibility and economics of the accumulations assessed. These estimates include cumulative production (produced volumes prior to 1999), remaining proved reserves, unproved reserves and reserves appreciation.

Sources: **(1)** Minerals Management Service. (2000). *2000 Assessment of Conventionally Recoverable Hydrocarbon Resources of the Gulf of Mexico and Atlantic Outer Continental Shelf as of January 1, 1999*. New Orleans, LA: Author. **(2)** Ocean Conservancy. (2012, February 29). *Cumulative underlying petroleum volumes*. Raster dataset based on Minerals Management Service, 2000.



The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Ocean Conservancy
Current U.S. Oil and Gas Leases and International Activity
U.S. Outer Continental Shelf Leases
Shallow (<1000 ft)[1]
Deep (1000 - 4999 ft)[1]
Ultradeep (>5000 ft)[1]
Cuban Leasing and Exploration Area[2]
Mexican Production and Activity Area[2]
BOEM Planning Areas[1]
Mobile Drilling Units[3]
Exclusive Economic Zones
Contours (meters)
Note: Active leases in the Eastern Gulf Planning Area were leased prior to the current moratoria and are being held under long-standing suspensions and extensions whereby operations have been suspended or temporarily prohibited.
Sources: (1) Bureau of Ocean Energy Management (BOEM). (2010). Gulf of Mexico BOEM active oil and gas leases. Washington, DC: Author. Retrieved February 08, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx (2) National Geographic Society. (2010). Gulf of Mexico: A geography of offshore oil. Washington, DC: National Geographic Maps. (3) National Geospatial-Intelligence Agency. (2012). Mobile offshore drilling units. Washington, DC: Author. Retrieved February 10, 2012, from http://msi.nga.mil/NGAPortal/MSI.portal
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Tallahassee
Tampa
Naples
Key West
Havana
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
Western Gulf Planning Area
Central Gulf Planning Area
Eastern Gulf Planning Area
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
West Florida Shelf
Pulley Ridge
Tortuga Terrace
Straits of Florida
Catoche Tongue
Catoche Knoll
Mexico Basin
Sigsbee Deep
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
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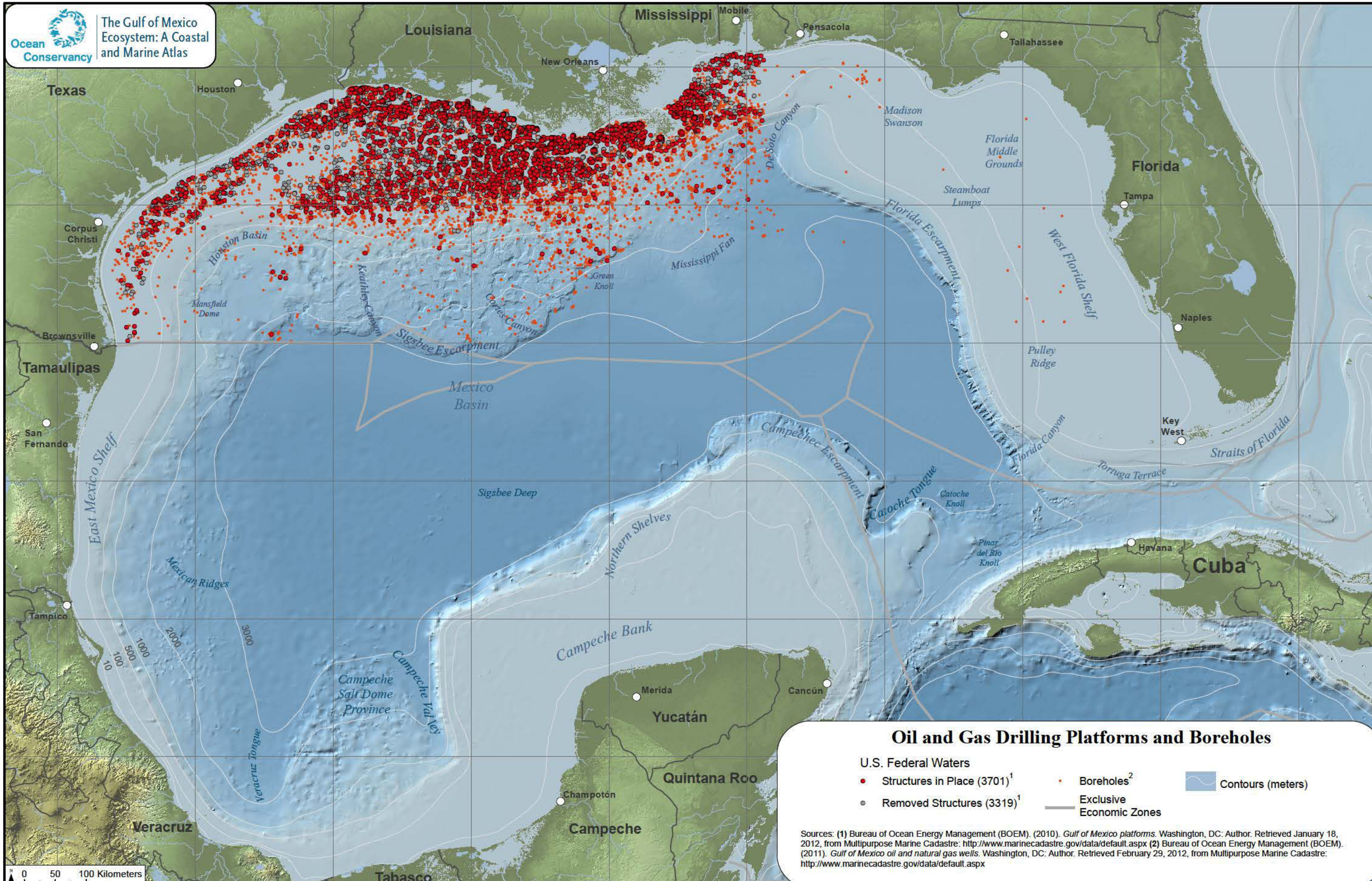
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Green Knoll
Mississippi Fan
De Soto Canyon
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
Florida Escarpment
West Florida Shelf
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Sigsbee Escarpment
Mexico Basin
Sigsbee Deep
Campeche Escarpment
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Catoche Knoll
Pinar del Rio Knoll
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Campeche Bank
Campeche Salt Dome Province
Campeche Valley
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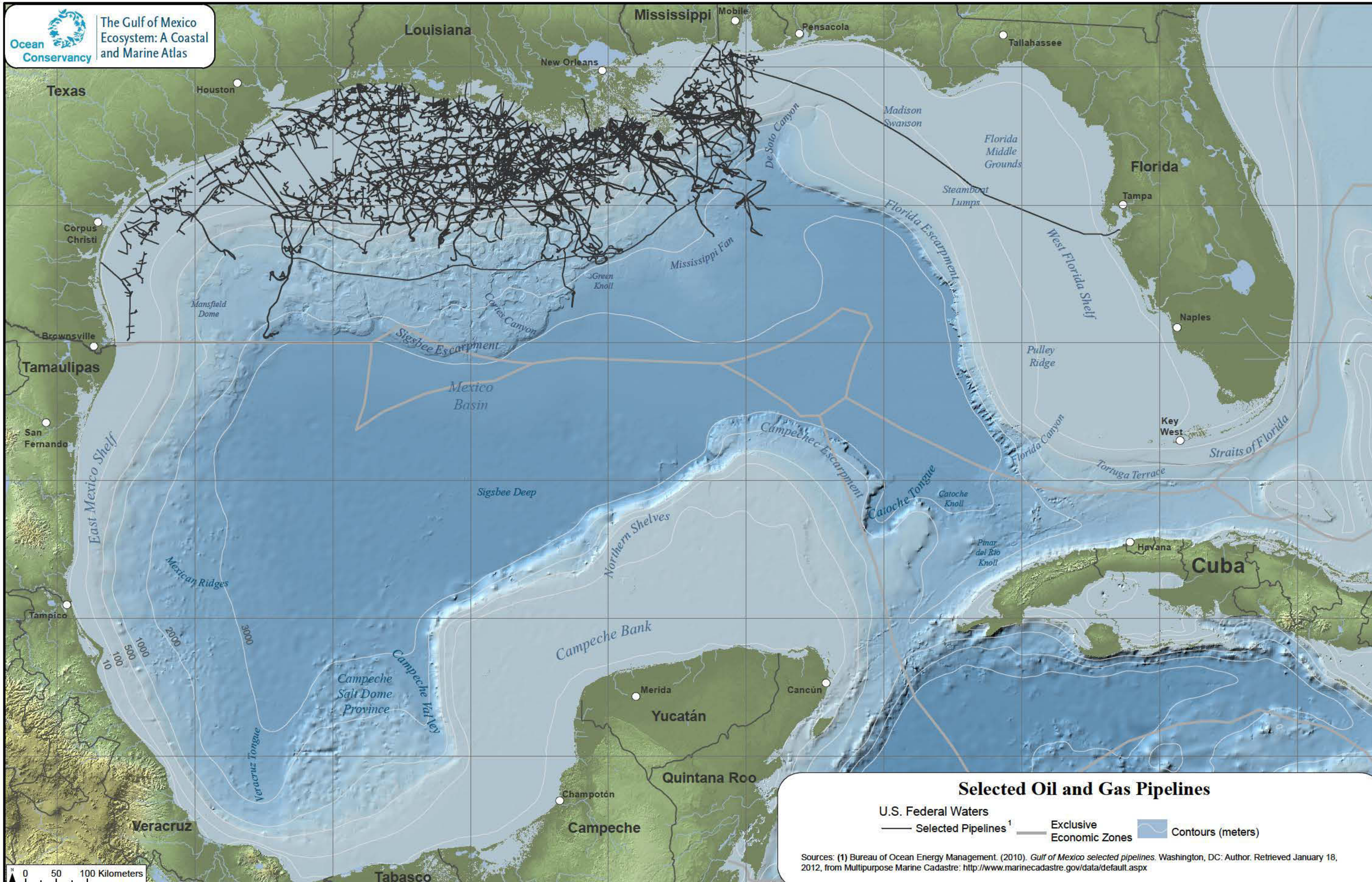
Oil and Gas Drilling Platforms and Boreholes
U.S. Federal Waters
Structures in Place (3701)[1]
Removed Structures (3319)[1]
Boreholes[2]
Exclusive Economic Zones
Contours (meters)
Sources: (1) Bureau of Ocean Energy Management (BOEM). (2010). Gulf of Mexico platforms. Washington, DC: Author. Retrieved January 18, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx (2) Bureau of Ocean Energy Management (BOEM). (2011). Gulf of Mexico oil and natural gas wells. Washington, DC: Author. Retrieved February 29, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx



Selected Oil and Gas Pipelines

U.S. Federal Waters

Selected Pipelines[1] — Exclusive Economic Zones — Contours (meters)

Sources: **(1)** Bureau of Ocean Energy Management. (2010). *Gulf of Mexico selected pipelines*. Washington, DC: Author. Retrieved January 18, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

9.1 Navigation Network & Port Facilities

Description

Map 50 shows a total of 80 ports of all types in the Gulf of Mexico and roughly 4,800 kilometers (about 3,000 miles) of shipping lanes. In 2010, the Gulf of Mexico had six of the top 10 U.S. shipping ports by cargo volume: South Louisiana (236,262,069 tons); Houston, Texas (227,133,231 tons); Beaumont, Texas (76,958,592 tons); Corpus Christi, Texas (73,663,432 tons); New Orleans, Louisiana (72,410,730 tons); and Texas City, Texas (56,590,856 tons) (NOAA, 2012). Primary commodities moving through these Gulf ports included coal, crude petroleum, petroleum products, fertilizers, chemicals, sand, iron, other metals, metal products, food and manufactured goods (NOAA, 2011). This region also includes an operational deep-water port, defined as a nonvessel, which is a fixed or floating man-made structure that is used as a port or terminal for the loading, unloading, or handling of oil and liquefied natural gas for transportation to a state. Located 26 kilometers (16 miles) southeast of Port Fourchon, Louisiana, the Louisiana Offshore Oil Port serves as an unloading and distribution deep-water port for incoming oil tankers (U.S. Department of Transportation, 2012). One additional deep-water port, Port Dolphin, has been approved and scheduled for future construction 45 kilometers (28 miles) offshore of Tampa, Florida (U.S. Department of Transportation, 2012).

The entire U.S. marine transportation industry supports nearly $1.16 trillion in commerce (NOAA, 2012) and creates employment for more than 13 million people (American Association of Port Authorities, 2008). U.S. seaports are responsible for moving more than 99 percent of the country's overseas cargo by volume and 65 percent by value (American Association of Port Authorities, 2008). Ports, waterway networks and fairways contribute to local and regional economies and are important gateways to domestic and international trade. A fairway is defined in federal law as a lane or navigation corridor in which no artificial island or fixed structure, whether temporary or permanent, will be permitted (Definition of Shipping Safety Fairway, 33 C.F.R. Part 166.105).

Vessel traffic can introduce invasive species via ballast water, cause sound pollution, strike, injure or kill marine mammals, pollute the air, and spill oil and other hazardous materials. As maritime commerce increases, the U.S. will need to accommodate more and larger ships with appropriate infrastructure and regulations, such as deeper channel depths and improved navigational safety measures. The threats to the environment will increase along with increasing vessel traffic. As ocean uses (e.g., shipping, oil and gas activity, and fishing) increase, haphazard development and overlapping coastal and ocean uses may result in conflicts. Coastal and marine spatial planning provides a framework that can help manage these activities so as to reduce or avoid conflicts and help sustain the continued health, productivity and function of a marine ecosystem (Ehler & Douvere, 2010). Coastal and marine spatial planning is a process designed to decrease user conflict, improve planning and regulatory efficiencies, decrease associated costs and delays, engage affected communities and stakeholders, and preserve critical ecosystem functions and services (NOAA, n.d.).

See related maps and narratives on Sperm Whale, Tropical Cyclone Track Density, Hazardous Materials Spills, Selected Non-Native Species of Concern, Oil and Gas Distribution, Current U.S. Oil and Gas Leases and International Activity, Oil and Gas Drilling Platforms and Boreholes, and Selected Oil and Gas Pipelines.

Data Compilation and Mapping Methods

Data on navigation, shipping and port-related infrastructure in the Gulf were obtained from the U.S. National Geospatial Intelligence Agency (2000), U.S. Army Corps of Engineers (2010) and National Oceanic and Atmospheric Administration (2010). Port locations were obtained for the wider Caribbean region from the World Port Index. Shipping fairways are defined and managed by the U.S. Coast Guard and were obtained from the Multipurpose Marine Cadastre (NOAA, 2010). The U.S. National Waterway Network was obtained from the 2011 National Transportation Atlas Databases. The line features of this waterway network represent either actual shipping lanes (e.g., channels, intracoastal waterways, sea lanes and rivers) or common shipping paths in open water where no defined shipping paths exist.

Data Quality

Data quality for U.S. waters is good. At the 1:5,575,680 scale of this map, the shipping and navigation features represent the true location of the ports, navigation networks and shipping lanes. Data quality for Mexico and Cuba are fair. While the port facilities are represented in the database for these countries, no analogous shipping lanes or navigation networks were identified.

Synthesis and Conclusions

The Gulf is an important body of water for maritime commerce. As maritime commerce increases, the U.S. will need to accommodate more and larger ships with appropriate infrastructure and regulations, and environmental protections. Challenges may arise as the Gulf region works to balance the potential improvements in economic efficiency and competitiveness of maritime commerce with the risks to life, property and the coastal environment. Real-time oceanographic information is vital to the prevention of maritime accidents and protection of coastal ecosystems. Coastal and marine spatial planning may help reduce or avoid conflicts among users of the ocean, as well as reduce impacts on the marine environment.

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NOAA Coastal Services Center. (2010). *Shipping fairways*. Charleston, SC: Author. Retrieved January 18, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

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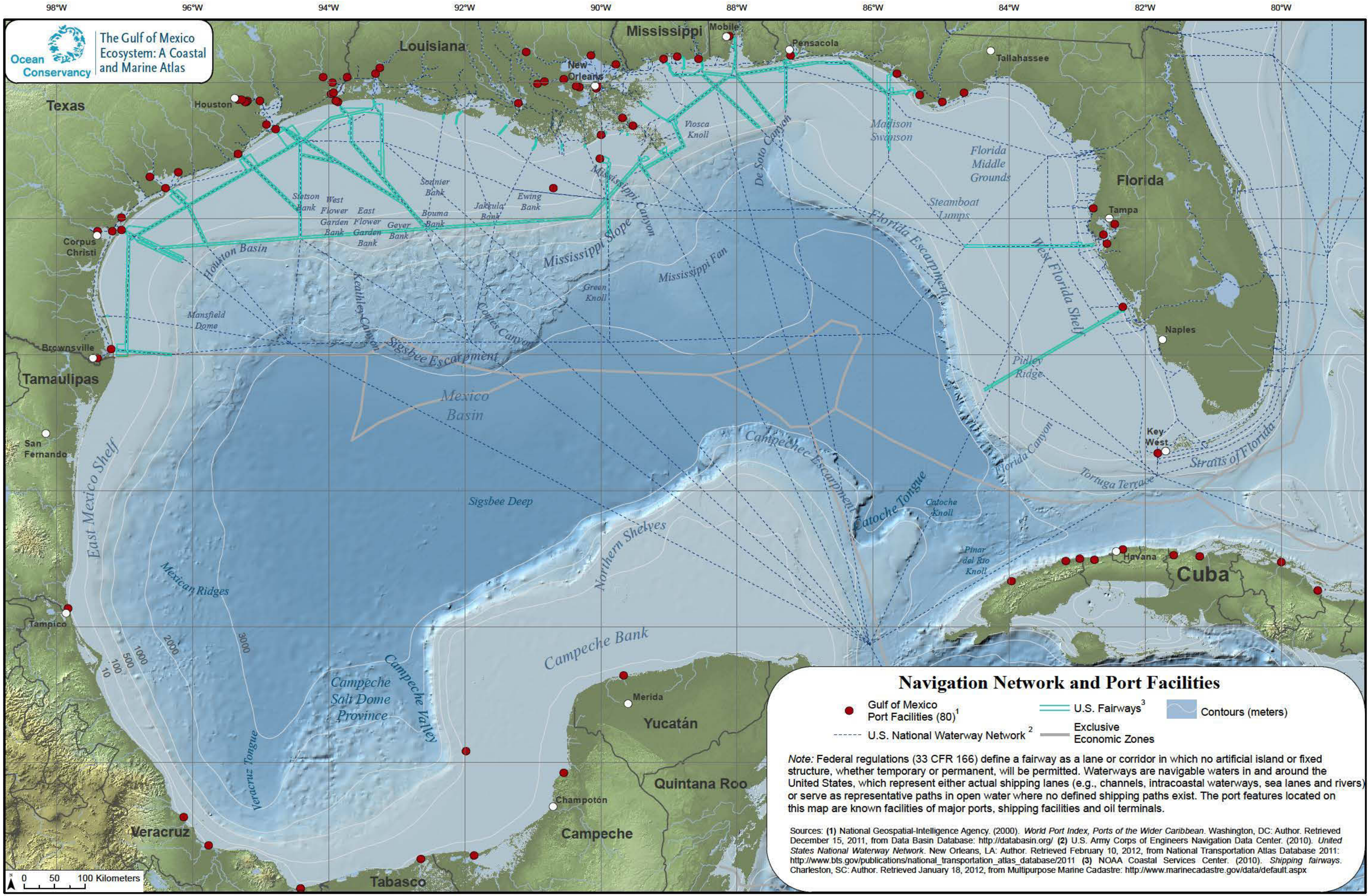
MAP 50 *(next page)*. **NAVIGATION NETWORK AND PORT FACILITIES**



Navigation Network and Port Facilities

- Gulf of Mexico Port Facilities (80)[1]
- U.S. National Waterway Network[2]
- U.S. Fairways[3]
- Exclusive Economic Zones
- Contours (meters)

Note: Federal regulations (33 CFR 166) define a fairway as a lane or corridor in which no artificial island or fixed structure, whether temporary or permanent, will be permitted. Waterways are navigable waters in and around the United States, which represent either actual shipping lanes (e.g., channels, intracoastal waterways, sea lanes and rivers) or serve as representative paths in open water where no defined shipping paths exist. The port features located on this map are known facilities of major ports, shipping facilities and oil terminals.

Sources: **(1)** National Geospatial-Intelligence Agency. (2000). *World Port Index, Ports of the Wider Caribbean*. Washington, DC: Author. Retrieved December 15, 2011, from Data Basin Database: http://databasin.org/ **(2)** U.S. Army Corps of Engineers Navigation Data Center. (2010). *United States National Waterway Network*. New Orleans, LA: Author. Retrieved February 10, 2012, from National Transportation Atlas Database 2011: http://www.bts.gov/publications/national_transportation_atlas_database/2011 **(3)** NOAA Coastal Services Center. (2010). *Shipping fairways*. Charleston, SC: Author. Retrieved January 18, 2012, from Multipurpose Marine Cadastre: http://www.marinecadastre.gov/data/default.aspx

9.2 Offshore Shrimp Trawl Fishery

Description

Fishery managers are able to track shrimp fishing efforts via electronic logbooks (ELBs), which record the location and duration of fishing activity in offshore waters (Gallaway et al., 2003*)*. Map 51 shows the shrimp trawling density for every 10-square-kilometer (4-square-mile) block as derived from all ELB trawl start locations from 2004 through 2011. The waters off Louisiana and Texas are historically known for the highest shrimp fishing effort in the Gulf of Mexico. The offshore shrimp trawl fishery in the Gulf primarily targets three species: pink shrimp, white shrimp and brown shrimp. Royal red shrimp, a fourth species, supports a small deepwater fishery off of Alabama and western Florida and is delineated in Map 17.

Shrimp are considered an annual crop, since most do not have a lifespan longer than two years (NOAA, 2010b). Brown shrimp are primarily caught in May, June and July off of the coasts of Texas and Louisiana; white shrimp from August through October primarily in Louisiana state waters; and pink shrimp from October through May off of the southeastern Gulf Coast of Florida, particularly near the Florida Keys (GMFMC, 2007; Louisiana Sea Grant, 2010; NOAA, 2010a). The Gulf is the largest regional producer of shrimp in the U.S. (NOAA, 2010d), landing 73 percent of the U.S. total for a dockside value of roughly $363 million. Gulf fishermen land about 85.3 million kilograms (188 million pounds) of shrimp annually (NOAA, 2010c), with Louisiana accounting for the highest landings, followed by Texas, Alabama, the West Coast of Florida and Mississippi (NOAA, 2010d). Although still productive, fewer fishing vessels are active in the Gulf federally-managed shrimp fishery today than ten or twenty years ago. Natural disasters, low shrimp prices, high fuel costs and competition with imported products have contributed to a dramatically reduced fishing fleet (GMFMC, 2007). Overall, the industry is struggling to recover from these recent setbacks. Due to fewer competing boats, however, some of the remaining vessels have been catching more shrimp per unit of effort (GMFMC, 2007).

Offshore shrimp fishing is managed by the National Marine Fisheries Service (NMFS) in coordination with the five Gulf states. While there are no concerns about the health of the shrimp populations themselves, the unintended catch of nontarget species, such as finfish and sea turtles, known as bycatch, remains a persistent management challenge. As a result, fishery managers have implemented measures to help reduce sea turtle interactions and finfish bycatch in the offshore otter trawl shrimp fishery. Otter trawl vessels operating under a federal permit must use Turtle Excluder Devices (TEDs) and Bycatch Reduction Devices (BRDs). The TEDs are designed to allow sea turtles to escape from otter trawl nets (Raborn et al., 2012). The purpose of BRDs is to reduce the accidental capture and mortality of finfish species, such as red snapper, while maximizing shrimp retention. The ELB data, as shown on Map 51, help fishery managers estimate where and how much fishing effort is occurring.

See related maps and narratives on White Shrimp, Brown Shrimp, Red Snapper, Kemp's Ridley Sea Turtle, Low Oxygen Areas and Selected Non-Native Species of Concern.

Data Compilation and Mapping Methods

Data on shrimp trawl density for federally permitted trawling activity were obtained from the ELB vessel-monitoring program maintained by LGL Ecological Research Associates, Inc. (2012). Vessels with electronic logbooks document their trawling path while actively fishing. NMFS then later uses the path of travel and trawl duration to calculate shrimp fishing effort for management purposes. Data used in this map represent the density of all trawl start locations between July 2004 and January 2012. The top commercial fishing ports were provided by the Center for the Blue Economy (2010), which provides summarized data on port landings collected by NMFS. These ports were categorized as top fishing ports by weight or value of landings during the 2000 to 2010 time frame.

Data Quality

Data quality for Map 51 in U.S. waters is good. The ELB program provides precise geographic location data of a statistically valid subsample of federally permitted shrimp vessels. The number of vessels with ELB data recorders increased from 50 in 2004, the first year of the program, to 656 by 2011. The top fishing ports are derived from the NMFS annual commercial landings database, the primary data source for U.S. port landings data. Analogous data for shrimping activity and fishing ports in Cuba and Mexico were not identified.

Synthesis and Conclusions

Fewer fishing vessels are active in the Gulf federally-managed shrimp fishery today than ten or twenty years ago. Natural disasters, unfavorable market forces, high fuel costs and the BP Deepwater Horizon oil disaster have contributed to a dramatically reduced fishing fleet. While there are no concerns about the health of the shrimp populations themselves, the unintended catch of nontarget species (or bycatch), such as finfish and sea turtles, remains a persistent management challenge. The environmental and economic impacts of low oxygen zones, invasive species and other environmental stressors on shrimp fisheries should be studied carefully.

Text Citations

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Raborn, S. W., Gallaway, B. J., Cole, J. G., Gezey, W. J., & Andrews, K. I. (2012). Effects of turtle excluder devices (TEDs) on the bycatch of small coastal sharks in the Gulf of Mexico penaeid shrimp fishery. *North American Journal of Fisheries Management*, *32*(2), 333-345.

Map Data Sources

Center for the Blue Economy. (2010). *Top commercial fishing ports*. Monterey, CA: Author. Retrieved July 16, 2012, from National Ocean Economics Program: http://www.oceaneconomics.org/LMR/topPorts.asp

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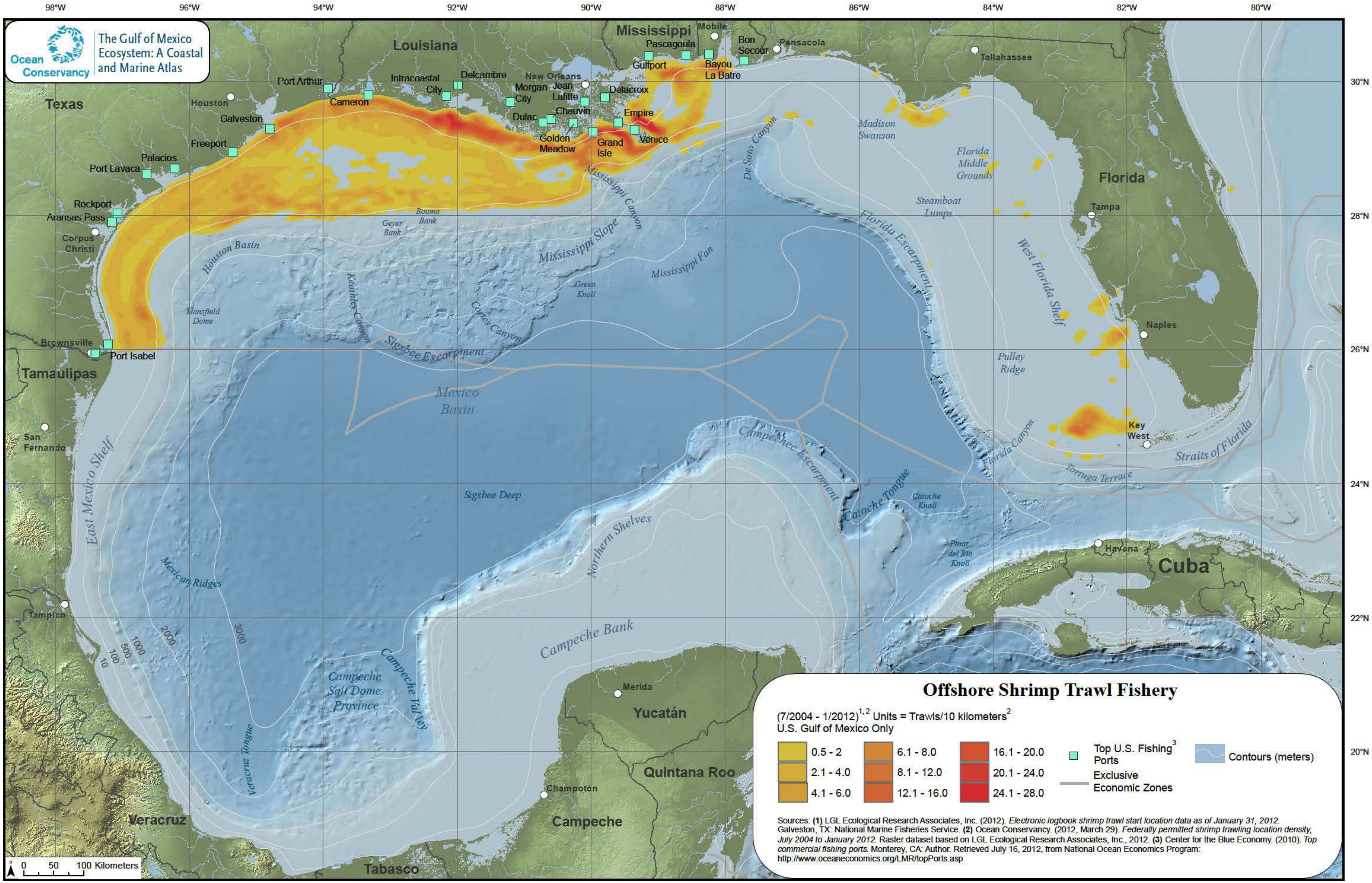
Ocean Conservancy. (2012, March 29). *Federally permitted shrimp trawling location density, July 2004 to January 2012*. Raster dataset based on LGL Ecological Research Associates, Inc., 2012.

MAP 51 *(next page)*. **OFFSHORE SHRIMP TRAWL FISHERY**


Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Offshore Shrimp Trawl Fishery
(7/2004 - 1/2012)1,2 Units = Trawls/10 kilometers2
U.S. Gulf of Mexico Only
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16.1 - 20.0
20.1 - 24.0
24.1 - 28.0
Top U.S. Fishing3 Ports
Exclusive Economic Zones
Contours (meters)
Sources: (1) LGL Ecological Research Associates, Inc. (2012). Electronic logbook shrimp trawl start location data as of January 31, 2012. Galveston, TX: National Marine Fisheries Service. (2) Ocean Conservancy. (2012, March 29). Federally permitted shrimp trawling location density, July 2004 to January 2012. Raster dataset based on LGL Ecological Research Associates, Inc., 2012. (3) Center for the Blue Economy. (2010). Top commercial fishing ports. Monterey, CA: Author. Retrieved July 16, 2012, from National Ocean Economics Program: http://www.oceaneconomics.org/LMR/topPorts.asp
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Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
Galveston
Freeport
Palacios
Port Lavaca
Rockport
Aransas Pass
Corpus Christi
Brownsville
Port Isabel
Port Arthur
Cameron
Intracoastal City
Delcambre
Morgan City
Dulac
Golden Meadow
Chauvin
Jean Lafitte
New Orleans
Grand Isle
Empire
Venice
Delacroix
Gulfport
Pascagoula
Mobile
Bayou La Batre
Bon Secour
Pensacola
Tallahassee
Tampa
Naples
Key West
Havana
San Fernando
Tampico
Merida
Champotón
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
West Florida Shelf
Pulley Ridge
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Straits of Florida
De Soto Canyon
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Mississippi Slope
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Geyer Bank
Bouma Bank
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Keathley Canyon
Cortes Canyon
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Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
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9.3 Recreational Fishing Effort

Description

The U.S. portion of the Gulf of Mexico is a popular fishing destination for resident and visiting recreational fishermen (Map 52). With over three million anglers taking an estimated 24 million trips annually, it is intensively fished (NOAA, 2012b). Recreational fishermen fish both nearshore, typically from beaches, piers or jetties, and offshore. Recreational fishermen accessing the offshore fishery use boats that they own or rent, hire charter boats or pay a head fee to join dozens of other anglers aboard party boats (headboats). The primary method of fishing in the Gulf is from private boats, accounting for 60 percent of the total fishing effort (NOAA, 2010). The private recreational boat fleet, in terms of total catch and effort, is the largest component of the Gulf recreational fishery. The majority of private boat-based catch and effort is within state territorial waters, whereas the for-hire component primarily targets offshore waters (Figueira & Coleman, 2010).

Recreational fishing effort is measured by the number of angler trips taken in private or for-hire recreational boats and is a proxy for fishing pressure. In 2011, private boat fishing effort in the Gulf was estimated at more than 12.9 million angler trips, with nearly 80 percent of this effort occurring in bay and estuarine waters. By comparison, the charter-for-hire fishing effort was estimated to be greater than 750,000 angler trips. The Gulf Coast accounted for more than 34 percent of total angler trips and nearly 43 percent of the recreational fishery's total catch in the U.S. in 2011 (NOAA, 2012a). Almost 59 percent of the trips originated in west Florida, followed by Louisiana, Alabama, Mississippi and Texas (NOAA, 2012a).

The marine recreational fishery in the Gulf is a very important component of the regional economy and lifestyle, contributing nearly $10 billion to local economies and supporting an estimated 92,000 jobs annually (NOAA, 2010). Recreational anglers in the Gulf seek a variety of finfish, including popular inshore species, such as red drum, spotted seatrout and Gulf flounder, as well as offshore reef fish species, such as red snapper, gag grouper and greater amberjack.

See related maps and narratives on Red Snapper, Red Drum, Artificial Reefs, and Fish and Shellfish Hatcheries.

Data Compilation and Mapping Methods

Data from wave three of the Access Point Angler Intercept Survey (NMFS, 2011) of the Marine Recreational Information Program (MRIP) at the National Marine Fisheries Service Office of Science and Technology were used to illustrate the distribution of recreational fishing activity by private boat and charter boat in Florida, Alabama, Mississippi and Louisiana. Similar data were obtained from the Texas Parks and Wildlife Department 2011 Texas Marine Sport-Harvest Monitoring program surveys. MRIP data were provided as the number of anglers expected at each interview site on a typical day, segregated into weekend day and weekday, for each month. Angler estimates were provided as an estimated range of anglers present. To obtain a single angler estimate value for each interview site, the mean value of each range was calculated and used to develop fishing effort estimates for private boat and charter boat fishing modes. Texas Parks and Wildlife data were provided as direct angler counts for each date sampled.

A subset of each dataset was used to illustrate angler activity during the peak, high-use season. For MRIP data, July weekend days were determined to be the period of highest angler activity. The mean July weekend-day angler count was used for the states covered by MRIP data. Many of the interview sites in Texas were not sampled during the month of July, so data from June were also included to develop the mean number of anglers present at each interview site during the high-use period. Texas data did not segregate angler numbers by weekend day or weekday, so weekdays are included in the Texas estimates.

To better visualize angler activity from these datasets, all interview sites were aggregated at the county/parish level by summing the mean angler counts for each site within each county/parish.

Data Quality

Data quality for Map 52 in the U.S. is good due to the availability of fishing activity estimates from fishery management agencies. The selection of a single high-use month (two months for Texas) prevents a complete assessment of the seasonality of fishing activity at the lower latitude sites during other months of the year. However, selection of the highest-use month is expected to serve as an adequate proxy for the general annual distribution of fishing activity. Interview sites are public access points, such as boat ramps and marinas, and do not include low-use boat ramps, private marinas, or private docks; therefore, these estimates should be treated as the minimum fishing activity for each county/parish. Analogous data for waters off of Cuba and Mexico were not identified.

Synthesis and Conclusions

The Gulf supports an active and economically important recreational fishery and ranks among the top angling destinations in the country. Most anglers fishing offshore use their own boats, rent boats for individual use and also hire charter boats or party boats. Some of the heaviest offshore recreational fishing occurs off of the Florida panhandle, central and southwestern Florida, and southern Texas. Important fish species for the recreational fishery include red drum, spotted seatrout, Gulf flounder, red snapper, gag grouper and greater amberjack.

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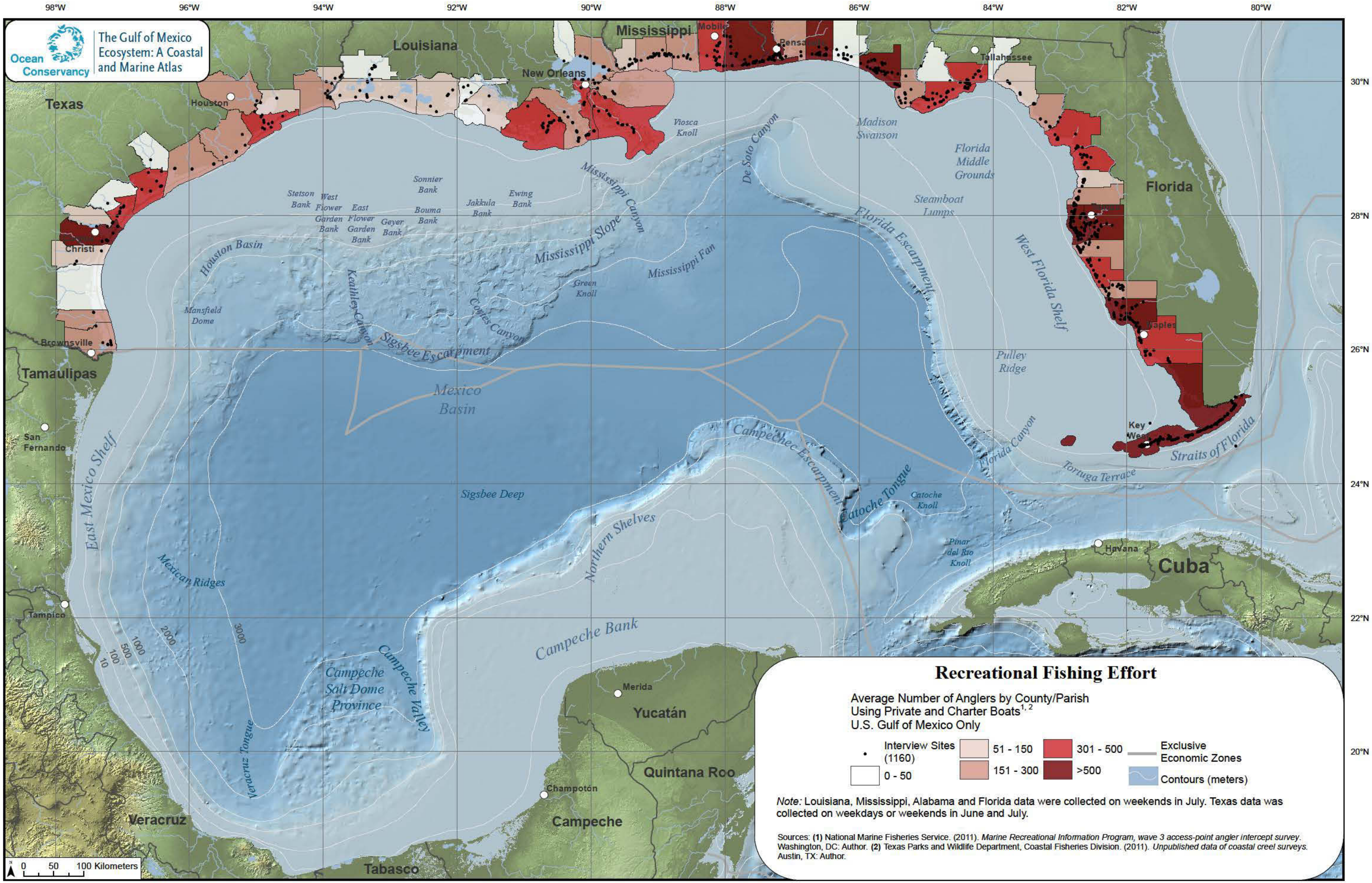
MAP 52 *(next page)*. **RECREATIONAL FISHING EFFORT**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Recreational Fishing Effort
Average Number of Anglers by County/Parish Using Private and Charter Boats[1, 2]
U.S. Gulf of Mexico Only
Interview Sites (1160)
0 - 50
51 - 150
151 - 300
301 - 500
>500
Exclusive Economic Zones
Contours (meters)
Note: Louisiana, Mississippi, Alabama and Florida data were collected on weekends in July. Texas data was collected on weekdays or weekends in June and July.
Sources: (1) National Marine Fisheries Service. (2011). Marine Recreational Information Program, wave 3 access-point angler intercept survey. Washington, DC: Author. (2) Texas Parks and Wildlife Department, Coastal Fisheries Division. (2011). Unpublished data of coastal creel surveys. Austin, TX: Author.
98°W
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86°W
84°W
82°W
80°W
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28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Cuba
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Christi
Brownsville
Naples
Key West
Havana
Merida
Champotón
Tampico
San Fernando
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
De Soto Canyon
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Green Knoll
Mansfield Dome
Keathley Canyon
Gomes Canyon
Sigsbee Escarpment
Mexico Basin
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Sigsbee Deep
Northern Shelves
East Mexico Shelf
Mexican Ridges
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers

9.4 Artificial Reefs

Description

Thousands of artificial reefs are distributed across the United States portion of the Gulf of Mexico (Map 53). Artificial reefs are structures or materials deployed on the sea bottom to enhance fisheries and fishing opportunity, promote aquaculture, or mitigate loss of natural habitat (Seaman & Jensen, 2000). In most cases, artificial reefs are intentionally deployed (e.g., oyster reef cultch material) to enhance fisheries or recreational fishing opportunity. Artificial reefs also may be structures that are unintentionally submerged, such as shipwrecks.

Interest in artificial reefs as a form of marine habitat or fisheries restoration in the Gulf is growing, but whether these structures simply attract fish or increase productivity remains uncertain and controversial in the scientific community (Powers et al., 2003). In addition to fishing and aquaculture, artificial reefs provide recreational benefits to scuba divers and snorkelers (Whitmore, 2006). Made from manmade or natural materials, artificial reefs are designed to mimic natural habitat and are deposited in areas of the seafloor that are flat, homogenous, or lacking hard substrate and structure (ASMFC & GSMFC, 2004; NOAA, 2007). A significant portion of the northern Gulf continental shelf has a low-relief mud and sand bottom, which provides characteristics suitable for artificial reef placement. Some Gulf states maintain active “rigs to reefs” programs that promote the partial removal and conversion of decommissioned oil and gas platforms to artificial reefs. For example, the state of Louisiana has created 69 offshore reefs using obsolete oil platforms since the creation of its artificial reef program in 1986 (LDWF, 2012).

A common type of artificial reef found in the Gulf is created by laying limestone, recycled oyster shells or similar substrate in nearshore waters to enhance oyster culture for commercial and recreational oyster fisheries and promote invertebrate communities needed to support a healthy food web. Much of the natural oyster reef habitat in the Gulf is degraded due to freshwater diversions, habitat alteration, overfishing and, more recently, impacts resulting from the BP Deepwater Horizon oil disaster (Livingston et al., 1999; Beck et al., 2011; McCrea-Strub et al., 2011; Furlong, 2012). If successfully established, artificial oyster reefs can help maintain natural oyster populations and restore ecosystem services in areas where degradation has occurred (Furlong, 2012).

If artificial reefs are employed, the best management practices and principles that are rooted in science should be identified and followed. It is important to determine how an artificial reef will function and what effects it will have in the marine environment in order to prevent environmental degradation. The Gulf States Marine Fisheries Commission developed Guidelines for Marine Artificial Reef Materials (ASMFC & GSMFC, 2004). The U.S. Department of Commerce provided further guidance in its National Artificial Reef Plan, a set of best practices for the placement, construction and evaluation of artificial reefs (NOAA, 2007).

See related map and narrative on Eastern Oyster Reefs, Red Snapper and Recreational Fishing Effort.

Data Compilation and Mapping Methods

Data on locations of artificial reefs were obtained from the following agencies managing the artificial reef programs in their respective states: Florida Fish and Wildlife Conservation Commission (2011); Alabama Department of Conservation and Natural Resources (2008); Mississippi Department of Marine Resources (2010); Louisiana Department of Wildlife and Fisheries (2012); and Texas Parks and Wildlife Department (2012). Reef data were compiled into a single file geodatabase. Each state maintains data on different characteristics of artificial reefs such as materials, date deployed, height of structure and area covered by reef material. Where possible, data fields representing similar information on reefs for each state were combined into common data fields to maintain data integrity. Reefs were symbolized on the map based on the state of origin for these data.

Data Quality

Data quality for Map 53 in U.S. waters is good. Each of the five Gulf states maintains its own reef database, which provides useful information on artificial reef locations and materials used. The definition of an artificial reef may be different from state to state. For example, one state might define an artificial reef as any small, single structure that may or may not be located close to an adjacent reef, while another state may classify an artificial reef as a reef complex composed of contiguous structures within a broader area. Because there is no common metric for what defines an artificial reef among the U.S. Gulf states, reef structures and reef counts are not necessarily equivalent across states. The reader is advised to obtain the database in question for each state if more detailed information is sought. No analogous data on artificial reef locations were available for the coastal waters of Cuba and Mexico.

Synthesis and Conclusions

The coastal and offshore waters of the Gulf harbor thousands of artificial reef sites, deployed mainly for enhancing commercial or recreational fisheries. Interest in artificial reefs for marine habitat or fisheries restoration is increasing. An important consideration for their use in restoration is whether they will provide ecosystem services similar to those damaged or lost from other human influences. Artificial reefs might be an appropriate restoration strategy for creating new opportunities in angling, snorkeling, scientific research or related activities, but their substitution for natural marine habitat or contribution to fisheries productivity is less clear.

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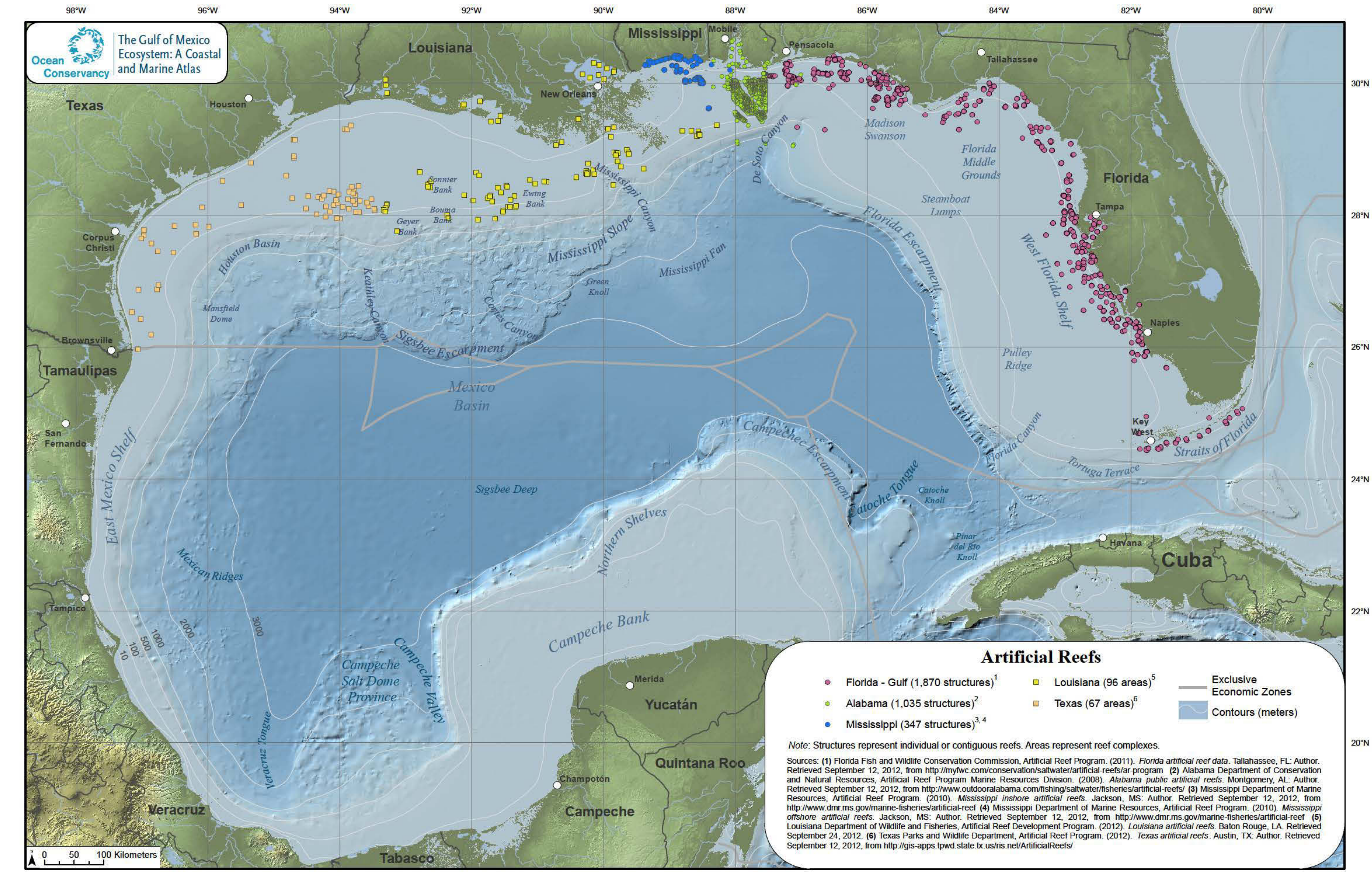
MAP 53 *(next page)*. **ARTIFICIAL REEFS**



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Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Louisiana
Mississippi
Mobile
Pensacola
Tallahassee
Texas
Houston
New Orleans
Madison Swanson
Florida Middle Grounds
Florida
Steamboat Lumps
Tampa
Corpus Christi
Houston Basin
Sonnier Bank
Ewing Bank
Bouma Bank
Geyer Bank
Mississippi Canyon
De Soto Canyon
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Green Knoll
Mansfield Dome
Keathley Canyon
Coronas Canyon
Sigsbee Escarpment
Brownsville
Tamaulipas
Naples
Pulley Ridge
Mexico Basin
San Fernando
East Mexico Shelf
Key West
Straits of Florida
Florida Canyon
Tortuga Terrace
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Sigsbee Deep
Northern Shelves
Pinar del Rio Knoll
Havana
Cuba
Mexican Ridges
Tampico
3000
2000
1000
500
100
10
Campeche Bank
Campeche Valley
Campeche Salt Dome Province
Merida
Yucatán
Veracruz Tongue
Quintana Roo
Champotón
Veracruz
Campeche
Tabasco
0 50 100 Kilometers
Artificial Reefs
Florida - Gulf (1,870 structures)[1]
Alabama (1,035 structures)[2]
Mississippi (347 structures)[3, 4]
Louisiana (96 areas)[5]
Texas (67 areas)[6]
Exclusive Economic Zones
Contours (meters)
Note: Structures represent individual or contiguous reefs. Areas represent reef complexes.
Sources: (1) Florida Fish and Wildlife Conservation Commission, Artificial Reef Program. (2011). Florida artificial reef data. Tallahassee, FL: Author. Retrieved September 12, 2012, from http://myfwc.com/conservation/saltwater/artificial-reefs/ar-program (2) Alabama Department of Conservation and Natural Resources, Artificial Reef Program Marine Resources Division. (2008). Alabama public artificial reefs. Montgomery, AL: Author. Retrieved September 12, 2012, from http://www.outdooralabama.com/fishing/saltwater/fisheries/artificial-reefs/ (3) Mississippi Department of Marine Resources, Artificial Reef Program. (2010). Mississippi inshore artificial reefs. Jackson, MS: Author. Retrieved September 12, 2012, from http://www.dmr.ms.gov/marine-fisheries/artificial-reef (4) Mississippi Department of Marine Resources, Artificial Reef Program. (2010). Mississippi offshore artificial reefs. Jackson, MS: Author. Retrieved September 12, 2012, from http://www.dmr.ms.gov/marine-fisheries/artificial-reef (5) Louisiana Department of Wildlife and Fisheries, Artificial Reef Development Program. (2012). Louisiana artificial reefs. Baton Rouge, LA. Retrieved September 24, 2012. (6) Texas Parks and Wildlife Department, Artificial Reef Program. (2012). Texas artificial reefs. Austin, TX: Author. Retrieved September 12, 2012, from http://gis-apps.tpwd.state.tx.us/ris.net/ArtificialReefs/

9.5 Fish & Shellfish Hatcheries

Description

Hatcheries are land-based facilities where aquatic organisms, such as finfish or shellfish, are raised in captivity and then released into fresh or marine waters. In general, the purpose of hatcheries is fisheries enhancement. Supplementing wild populations with hatchery-raised juvenile stock increases the number of fish or shellfish available to commercial or recreational fisheries. In the Gulf of Mexico, hatcheries specializing in marine shellfish and finfish are owned and operated by state fish and wildlife management agencies, universities and private entities.

Map 54 shows the distribution of select major hatcheries in the Gulf and the marine species they produce: red snapper (*Lutjanus campechanus*), red drum (*Sciaenops ocellatus)*, spotted seatrout (*Cynoscion nebulosus*), striped bass (*Morone saxatilis*), southern flounder (*Paralichthys lethostigma*), common snook (*Centropomus undecimalis*), cobia (*Rachycentron canadum*), Eastern oyster (*Crassostrea virginica*), bay scallop (*Argopecten irradians*), hard clam (*Mercenaria mercenaria*) and long-spined sea urchin (*Diadema antillarum*).

Spotted seatrout and red drum, two commonly cultured marine finfish, are examples of hatchery-reared species used to potentially enhance recreational fisheries and offset declines in wild populations. The Texas Parks and Wildlife Department hatcheries release some 25 million juvenile marine finfish annually into coastal waters in an effort to mitigate the effects of habitat loss and fishing pressure on wild stocks (TPWD, 2012). Some Gulf hatcheries are researching and developing stock enhancement programs for offshore reef fish species, such as red snapper, as a way to potentially improve fisheries management and support a commercial aquaculture industry (Chapin et al., 2009; Gulf Coast Research Laboratory, 2012). Gulf hatcheries culture several types of invertebrates, such as bivalves (e.g., Eastern oyster, bay scallops and several clam species), which are the most prevalent and are grown for mostly commercial fisheries and to restore depleted stocks (Brumbaugh & Coen, 2009; Furlong, 2012).

Conservation of wild fish populations through stock augmentation and enhanced fishing opportunity are among the potential benefits of hatcheries (Willis et al., 1995). However, impacts on the genetic integrity of wild fish through crossbreeding and undesirable ecological interactions, such as increased competition, are potential concerns (Rand et al., 2012). The implementation of science-based principles to determine when augmentation through hatcheries is appropriate, along with monitoring operations and performance, may promote conservation and fishing opportunity while preventing, detecting and minimizing negative effects (Paquet et al., 2011).

See related maps and narratives on Eastern Oyster Reefs, Red Snapper, Red Drum, Observed Change in Sea Surface Temperature, Ocean Acidification, Projected Sea Level Rise and Recreational Fishing Effort.

Data Compilation and Mapping Methods

Data used to illustrate the location and primary species of hatcheries across the U.S. Gulf were obtained from various state agencies and universities through personal communications with researchers in the region. Hatchery data for Florida were obtained from: Chris Topping, personal communication (2012); Eric Latimer, personal communication (2012); Chris Young, personal communication (2012); Curtis D. Hemmel, personal communication (2012); Ken Leber, personal communication (2012); and Edwin Connery, personal communication (2012). Alabama data were obtained from Scott Rikard, personal communication (2012) and Kevin Anson, personal communication (2012). Data for Mississippi were obtained from Reginald Blaylock, personal communication (2012) and Michael Boatright, personal communication (2012). Louisiana data were provided by John Supan, personal communication (2012).

Publicly owned or contracted hatcheries that raise species for release into marine waters of the Gulf were included on this map. This includes cases where the animals are initially enclosed in containers in the marine environment before harvest, as in the case of hard clams. Private commercial operations that raise marine animals in enclosed ponds, not open to the marine environment, for commercial harvest were not included.

Data Quality

Data quality for Map 54 is good in the U.S. and fair for Cuba and Mexico. Data for hatcheries in Mexico and Cuba were based on interviews with a number of researchers familiar with international activity in the Gulf of Mexico (John Supan, personal communication, 2012; Chris Young, personal communication, 2012; Daniel Benetti, personal communication, 2012).

Synthesis and Conclusions

Several large hatcheries are in operation across the U.S. Gulf states. These facilities raise fish in captivity before releasing them into coastal waters, mainly for fisheries enhancement. Species produced in the greatest numbers in Gulf hatcheries are spotted seatrout, red drum and Eastern oyster. Efforts are underway to develop hatchery programs for offshore reef species like red snapper. As hatcheries expand in the Gulf region, the implementation of science-based best practices, such as rigorous monitoring, will be important to track performance to ensure that conservation and fisheries goals are met and any negative biological or ecological impacts are detected and addressed.

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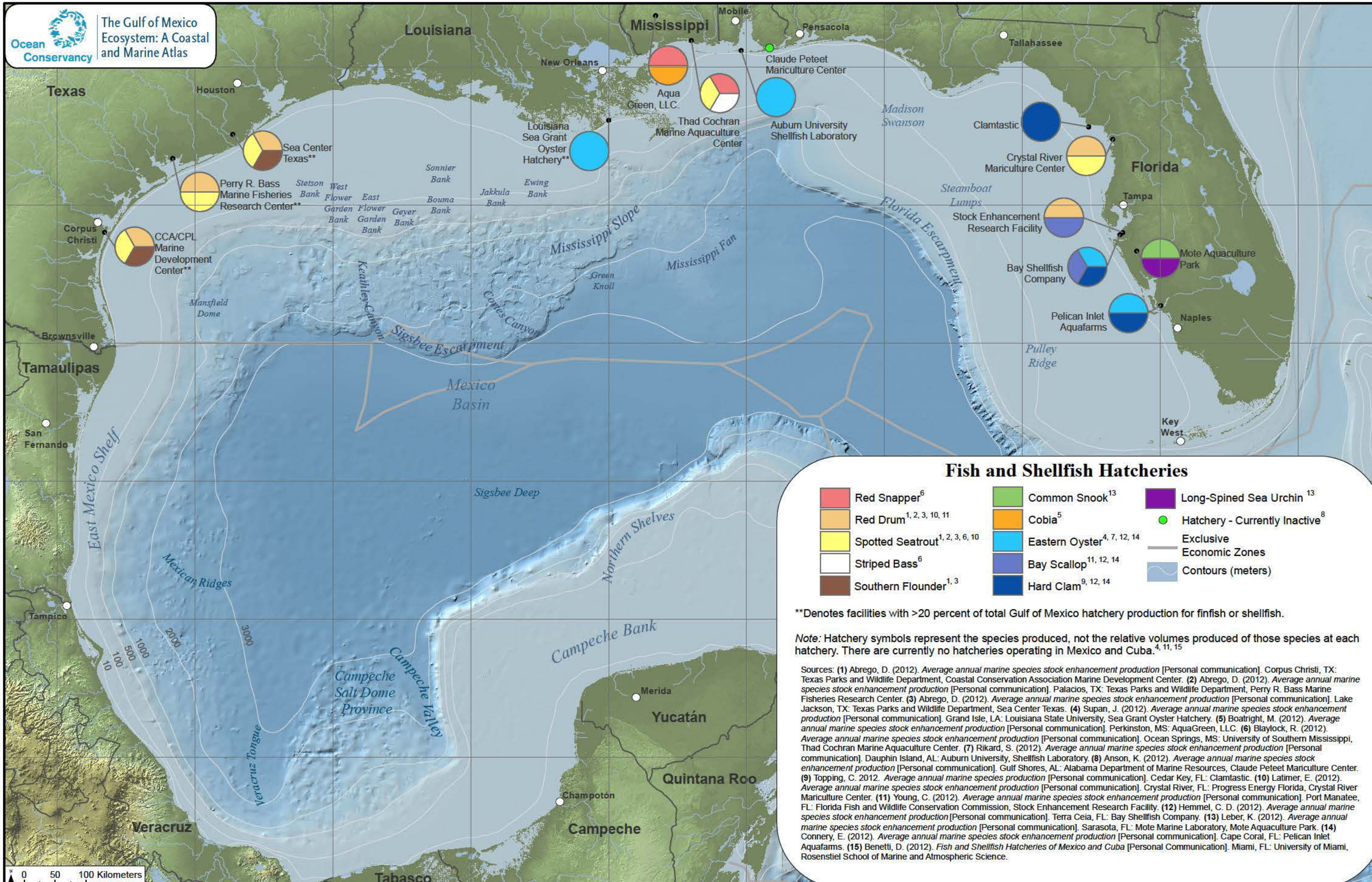
MAP 54 *(next page)*. **FISH AND SHELLFISH HATCHERIES**



Ocean Conservancy
The Gulf of Mexico Ecosystem: A Coastal and Marine Atlas
Fish and Shellfish Hatcheries
98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Texas
Louisiana
Mississippi
Florida
Tamaulipas
Veracruz
Tabasco
Campeche
Yucatán
Quintana Roo
Houston
New Orleans
Mobile
Pensacola
Tallahassee
Tampa
Naples
Key West
Corpus Christi
Brownsville
San Fernando
Tampico
Merida
Champotón
CCA/CPL Marine Development Center**
Perry R. Bass Marine Fisheries Research Center**
Sea Center Texas**
Louisiana Sea Grant Oyster Hatchery**
Aqua Green, LLC.
Thad Cochran Marine Aquaculture Center
Auburn University Shellfish Laboratory
Claude Peteet Mariculture Center
Clamtastic
Crystal River Mariculture Center
Stock Enhancement Research Facility
Bay Shellfish Company
Mote Aquaculture Park
Pelican Inlet Aquafarms
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Geyer Bank
Sonnier Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Madison Swanson
Steamboat Lumps
Pulley Ridge
Florida Escarpment
Mississippi Slope
Mississippi Fan
Green Knoll
Keathley Canyon
Cortes Canyon
Sigsbee Escarpment
Mansfield Dome
Mexico Basin
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Red Snapper[6]
Red Drum[1, 2, 3, 10, 11]
Spotted Seatrout[1, 2, 3, 6, 10]
Striped Bass[6]
Southern Flounder[1, 3]
Common Snook[13]
Cobia[5]
Eastern Oyster[4, 7, 12, 14]
Bay Scallop[11, 12, 14]
Hard Clam[9, 12, 14]
Long-Spined Sea Urchin[13]
Hatchery - Currently Inactive[8]
Exclusive Economic Zones
Contours (meters)
**Denotes facilities with >20 percent of total Gulf of Mexico hatchery production for finfish or shellfish.
Note: Hatchery symbols represent the species produced, not the relative volumes produced of those species at each hatchery. There are currently no hatcheries operating in Mexico and Cuba.[4, 11, 15]
Sources: **(1)** Abrego, D. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Corpus Christi, TX: Texas Parks and Wildlife Department, Coastal Conservation Association Marine Development Center. **(2)** Abrego, D. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Palacios, TX: Texas Parks and Wildlife Department, Perry R. Bass Marine Fisheries Research Center. **(3)** Abrego, D. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Lake Jackson, TX: Texas Parks and Wildlife Department, Sea Center Texas. **(4)** Supan, J. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Grand Isle, LA: Louisiana State University, Sea Grant Oyster Hatchery. **(5)** Boatright, M. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Perkinston, MS: AquaGreen, LLC. **(6)** Blaylock, R. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Ocean Springs, MS: University of Southern Mississippi, Thad Cochran Marine Aquaculture Center. **(7)** Rikard, S. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Dauphin Island, AL: Auburn University, Shellfish Laboratory. **(8)** Anson, K. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Gulf Shores, AL: Alabama Department of Marine Resources, Claude Peteet Mariculture Center. **(9)** Topping, C. 2012. *Average annual marine species production* [Personal communication]. Cedar Key, FL: Clamtastic. **(10)** Latimer, E. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Crystal River, FL: Progress Energy Florida, Crystal River Mariculture Center. **(11)** Young, C. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Port Manatee, FL: Florida Fish and Wildlife Conservation Commission, Stock Enhancement Research Facility. **(12)** Hemmel, C. D. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Terra Ceia, FL: Bay Shellfish Company. **(13)** Leber, K. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Sarasota, FL: Mote Marine Laboratory, Mote Aquaculture Park. **(14)** Connery, E. (2012). *Average annual marine species stock enhancement production* [Personal communication]. Cape Coral, FL: Pelican Inlet Aquafarms. **(15)** Benetti, D. (2012). *Fish and Shellfish Hatcheries of Mexico and Cuba* [Personal Communication]. Miami, FL: University of Miami, Rosenstiel School of Marine and Atmospheric Science.

9.6 Coastal & Marine Protected Areas

Description

The U.S., Mexico and Cuba have designated several coastal and marine protected areas in the Gulf of Mexico (Map 55). In waters of the U.S., marine protected areas (MPAs) are defined by MPA Executive Order 13158 as "any area of the marine environment that has been reserved by federal, state, territorial, tribal, or local laws or regulations to provide lasting protection for part or all of the natural and cultural resources therein." Because of this broad definition, areas classified as MPAs can vary greatly in their purpose and level of environmental protection. For example, some special areas are set aside for recreation similar to national parks, while others are designated for purposes of fishery management. Fisheries closures and essential fish habitat also afford some level of protection to Gulf fish populations or their habitats, but because this protection is limited either in duration or specificity, they are not what we consider traditional MPAs and are therefore not included on Map 55. The majority of the Gulf's MPAs (about 99 percent) allow a variety of human activities, such as fishing and other extractive uses (NOAA, 2012b). Only the remaining 1 percent of MPAs in the Gulf have more stringent restrictions, such as designated no-take areas, where the extraction or significant destruction of any natural or cultural resources is prohibited (NOAA, 2012b).

There are two national marine sanctuaries in the Gulf: Florida Keys and Flower Garden Banks. The Florida Keys National Marine Sanctuary covers about 9,600 square kilometers (2,800 square nautical miles) and surrounds the most extensive coral reef in U.S. waters. The Flower Garden Banks National Marine Sanctuary comprises three separate protected salt dome formations in the northwestern Gulf. It supports a unique and diverse ecological community, including the northernmost coral reefs in the U.S. (NOAA, 2012a).

Habitat Areas of Particular Concern (U.S.) and Florida aquatic preserves receive some degree of protection, but are not MPAs per se. Habitat Areas of Particular Concern are designated because they are areas that are rare, particularly susceptible to human-induced degradation, ecologically important or environmentally stressed. Florida Aquatic Preserves are state-owned submerged lands that are established to preserve the natural or existing condition of an area so that their exceptional aesthetic, biological and scientific values may endure for the enjoyment of future generations.

Other conservation areas, including those on or within 80 kilometers (50 miles) of the coast, are links between land and sea and often provide many important benefits, such as wildlife and fisheries habitat nutrient retention and storm buffering. Examples include national estuarine research reserves, national wildlife refuges and wildlife management areas.

Connectivity among reserves is important for larval transport between sink and source areas, ecosystem resiliency and recovery from disturbance (McLeod et al., 2009). No-take marine reserves can increase the density, diversity and biomass of organisms within the reserves, providing additional ecosystem services (Dugan & Davis, 1993; Roberts & Hawkins, 2000; Halpern, 2003). MPAs also may help support the vitality and resilience of marine ecosystems susceptible to the effects of climate change (Keller et al., 2009). An MPA network among the U.S., Mexico and Cuba has been proposed to strengthen efforts to study and conserve marine resources, enhance international cooperation and conservation, and create opportunities to study connectivity and biologically diverse habitats (Nash & McLaughlin, 2012).

See related maps and narratives on Sea Surface Currents, Corals, Coastal Population Density and Projected Sea Level Rise.

Data Compilation and Mapping Methods

Map 55 highlights areas that receive some degree of protection and that are managed for the benefit of native species, natural habitats or ecosystem services. Coastal protected areas within the terrestrial environment of the U.S. were obtained from the Conservation Biology Institute (2010). National marine sanctuaries of the U.S. were obtained from NOAA (2008). Areas designated as Marine Habitat Areas of Particular Concern in the U.S. were obtained from the Gulf States Marine Fisheries Commission (2004). Areas within Florida designated as aquatic preserves were obtained from the Office of Coastal and Aquatic Managed Areas (1997). Coastal protected areas of Mexico and Cuba, whether terrestrial or marine, were obtained from the International Union for Conservation of Nature and the United Nations Environment Programme (2010).

Data Quality

Data quality for Map 55 is good. Delineations of the administrative boundaries of protected areas included on this map, albeit at different levels of management, are believed to be represented accurately at the 1:5,575,680 scale of this map.

Synthesis and Conclusions

Marine protected areas offer varying degrees of protection for habitats and species in the Gulf. Marine, coastal and terrestrial conservation areas create important linkages between habitats and may provide a suite of ecosystem services such as enhanced fisheries productivity, biodiversity and enhanced recovery after an environmental disturbance. An MPA network coordinated among the governments of the U.S., Mexico and Cuba could enhance international cooperation and conservation, and create opportunities to study connectivity and biologically diverse habitats.

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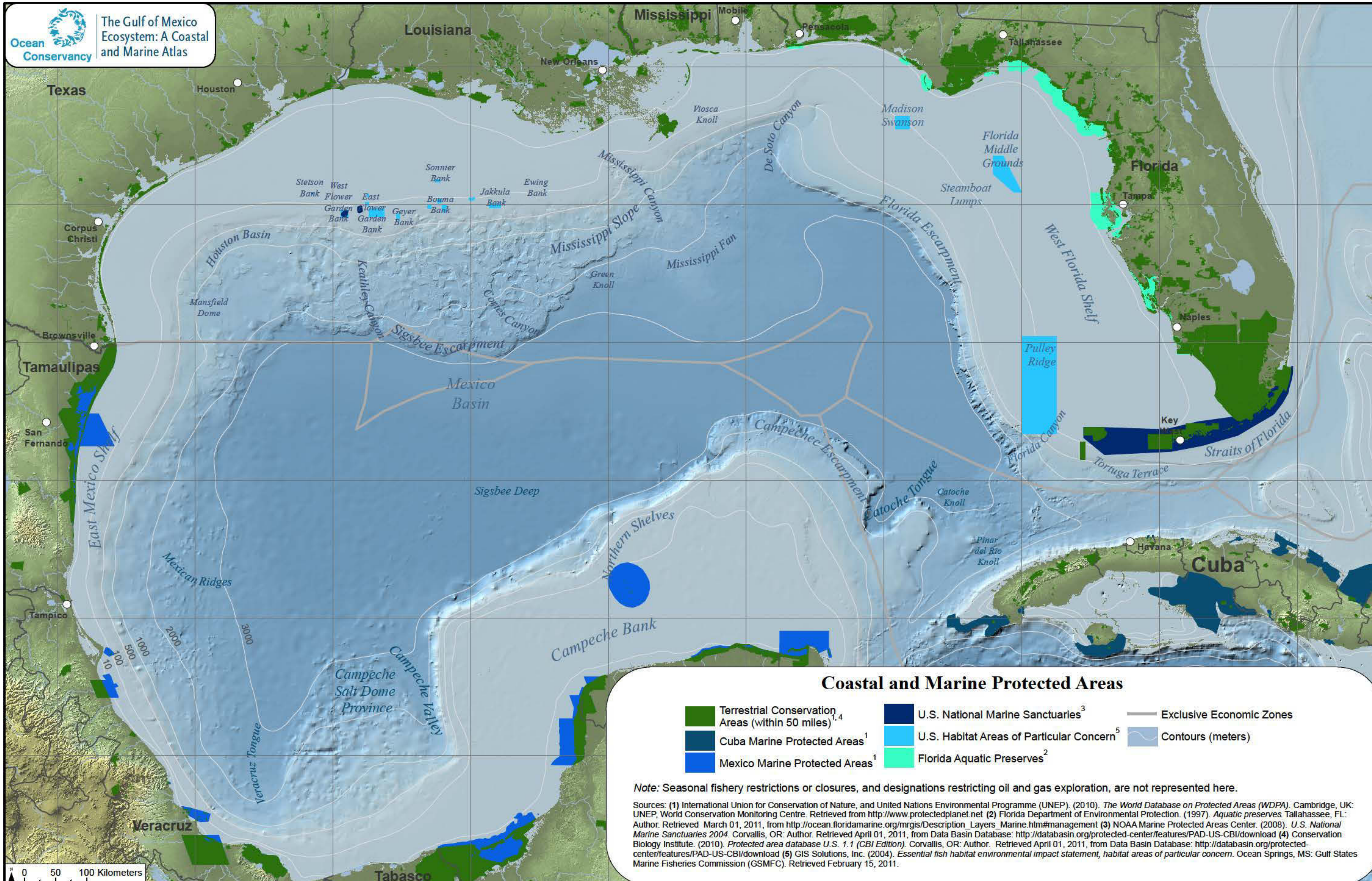
MAP 55 *(next page)*. **COASTAL AND MARINE PROTECTED AREAS**



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98°W
96°W
94°W
92°W
90°W
88°W
86°W
84°W
82°W
80°W
30°N
28°N
26°N
24°N
22°N
20°N
Mississippi
Mobile
Pensacola
Tallahassee
Louisiana
New Orleans
Texas
Houston
Florida
Tampa
Naples
Key West
Corpus Christi
Brownsville
Tamaulipas
San Fernando
Tampico
Veracruz
Tabasco
Havana
Cuba
Viosca Knoll
Madison Swanson
Florida Middle Grounds
Steamboat Lumps
De Soto Canyon
Mississippi Canyon
Mississippi Slope
Mississippi Fan
Florida Escarpment
West Florida Shelf
Stetson Bank
West Flower Garden Bank
East Flower Garden Bank
Sonnier Bank
Geyer Bank
Bouma Bank
Jakkula Bank
Ewing Bank
Houston Basin
Keathley Canyon
Green Knoll
Mansfield Dome
Sigsbee Escarpment
Cortes Canyon
Mexico Basin
Pulley Ridge
Florida Canyon
Tortuga Terrace
Straits of Florida
Campeche Escarpment
Catoche Tongue
Catoche Knoll
Pinar del Rio Knoll
Sigsbee Deep
East Mexico Shelf
Mexican Ridges
Northern Shelves
Campeche Bank
Campeche Salt Dome Province
Campeche Valley
Veracruz Tongue
10
100
500
1000
2000
3000
0 50 100 Kilometers
Coastal and Marine Protected Areas
Terrestrial Conservation Areas (within 50 miles)[1, 4]
Cuba Marine Protected Areas[1]
Mexico Marine Protected Areas[1]
U.S. National Marine Sanctuaries[3]
U.S. Habitat Areas of Particular Concern[5]
Florida Aquatic Preserves[2]
Exclusive Economic Zones
Contours (meters)
Note: Seasonal fishery restrictions or closures, and designations restricting oil and gas exploration, are not represented here.
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Abbreviations & Acronyms

ASMFC – Atlantic States Marine Fisheries Commission
BOEM – Bureau of Ocean Energy Management (Formerly MMS and BOEMRE)
BOEMRE – Bureau of Ocean Energy Management, Regulation and Enforcement (Formerly MMS, now BOEM)
BRD – Bycatch Reduction Device
BTNEP – Barataria-Terrebonne National Estuary Program
CBC – Christmas Bird Count
CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora
CRTF – Coral Reef Task Force
DDT – dichloro-diphenyl-trichloroethane
DWH – Deepwater Horizon
EFH – Essential Fish Habitat
ELB – Electronic Logbook
EPA – Environmental Protection Agency
FWC – Florida Fish and Wildlife Conservation Commission
FWRI – Florida Fish and Wildlife Research Institute
GIS – Geographic Information Systems
GMFMC – Gulf of Mexico Fishery Management Council
GSMFC – Gulf States Marine Fisheries Commission
ICCAT – International Commission for the Conservation of Atlantic Tunas
INEGI – Instituto Nacional de Estadística y Geografía
IUCN – International Union for Conservation of Nature
IPCC – International Panel on Climate Change
LIDAR – Light Detection and Ranging
LDEQ – Louisiana Department of Environmental Quality
LDWF – Louisiana Department of Wildlife and Fisheries
LIDAR – Light Detection and Ranging
LUMCON – Louisiana Universities Marine Consortium
MDMR – Mississippi Department of Marine Resources
MMC – Marine Mammal Commission
MMS – Minerals Management Service (now BOEM)
MPA – Marine Protected Area
MRIP – Marine Recreational Information Program
NMFS – National Marine Fisheries Service
NOAA – National Oceanic and Atmospheric Administration
OSCAR – Ocean Surface Current Analyses – Real Time
PCBs – Polychlorinated Biphenyls
PMEL – Pacific Marine Environmental Laboratory
SAFMC – South Atlantic Fishery Management Council
SAR – Synthetic Aperture Radar
SEDAR – Southeast Data, Assessment, and Review
SEAMAP – Southeast Area Monitoring and Assessment Program
SST – Sea Surface Temperature
TED – Turtle Excluder Device
TPWD – Texas Parks and Wildlife Department
UNEP – United Nations Environment Programme
USDA – United States Department of Agriculture
USFWS – United States Fish and Wildlife Service
USGS – United States Geological Survey

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For more than two decades, Ocean Conservancy's Gulf Restoration and Fisheries program has advocated for science-based restoration plans and projects that address the entire Gulf of Mexico as one interconnected ecosystem. Key accomplishments include: successfully promoting the use of fishing gear that reduces environmental impacts, including the number of fish and endangered sea turtles that are caught and killed incidentally; transforming regional fishery management systems to focus on science-based plans that end overfishing and restore depleted fish populations; and developing a framework to guide restoration efforts in the region. We are now combining our regional expertise with a seasoned team of *Exxon Valdez* oil spill experts to ensure the effective restoration and enhancement of the Gulf ecosystem and its dependent communities

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400 Poydras Street, Suite 1990 // New Orleans, LA 70130
www.oceanconservancy.org