OCS Report
BOEM 2013-0110

Oil-Spill Risk Analysis

Gulf of Mexico Outer Continental Shelf (OCS) Lease Sales, Eastern Planning Area, 2012-2017, and Eastern OCS Program, 2012-2051

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Acronyms

bbl	barrel= 42 U.S. gallons
Bbbl	Billion barrels = 10^9 barrels
BOEM	Bureau of Ocean Energy Management
CPA	Central Planning Area
EIS	Environmental Impact Statement
EPA	Eastern Planning Area
GOM	Gulf of Mexico
HAPC	Habitat Areas of Particular Concern
ID	Identification
MMS	Minerals Management Service
OCS	Outer Continental Shelf
OSRA	Oil Spill Risk Analysis
POM	Princeton Ocean Model
WPA	Western Planning Area
USDOI	United States Department of the Interior

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1.0 Introduction

The Federal Government plans to offer for oil and gas leasing the U.S. Outer Continental Shelf (OCS) lands in the Eastern Planning Area (EPA) of the Gulf of Mexico (GOM) as shown on the front cover. Because oil spills may occur from activities associated with offshore oil exploration, production, and transportation resulting from these lease sales, the U.S. Department of the Interior (USDOI), Bureau of Ocean Energy Management (BOEM) conducts a formal oil-spill risk analysis (OSRA) to support the environmental impact statement (EIS) that is completed prior to conducting the proposed leasing of these areas. This report summarizes results of that analysis, the objective of which was to estimate the risk of oil-spill contact to sensitive offshore and onshore environmental resources and socioeconomic features from oil spills accidentally occurring from the OCS activities.

The occurrence of oil spills is fundamentally a matter of probability. There is no certainty regarding the amount of oil that would be produced, or the size or likelihood of a spill that could occur during the estimated life of a given lease sale. Neither can the winds and ocean currents that transport oil spills be known for certain. A probabilistic event, such as an oil-spill occurrence or oil-spill contact to an environmentally sensitive area, cannot be predicted, but an estimate of its likelihood (its probability) can be quantified. An OSRA Report quantifies these probabilities.

The OSRA was conducted in three parts, corresponding to different aspects of the overall problem.

1. The probability of oil-spill occurrence, which is based on estimated volumes of oil produced and transported and on spill rates derived from historic data.
2. Calculated trajectories of oil spills from hypothetical spill locations to locations of various environmental resources, which are simulated using the OSRA Model (Smith et al., 1982).
3. The combination of results of the first two parts to estimate the overall oil-spill risk if there is oil development.

This report is available from the BOEM website (http://www.boem.gov).

2.0 Framework of the Analysis

Many factors are considered when producing an OSRA report. These include the proposed action, the estimated volume of oil resources in the area proposed for leasing, the location of the proposed action, and environmental resources in or near the area proposed for leasing.

2.1 The Proposed Actions and the Eastern OCS Program

The proposed Federal actions addressed in this report are oil and gas lease sales in the EPA of the Gulf of Mexico OCS (Figure B-1). Under the *Final Outer Continental Shelf Oil and Gas Leasing Program: 2012-2017 (Five-Year Program)* (United States Department of the Interior (USDOI), BOEM, 2012 5-Year Program), there will be two sales in the EPA, one in 2014 and one in 2016 (USDOI-BOEM 2012). The purpose of the proposed Federal actions is to offer for lease those areas that may contain economically recoverable oil and natural gas resources. The Eastern OCS Program comprises all future operations that will occur over a 40-year time period (2012-2051) from proposed, existing, and future leases in the EPA. The development scenario assumes that the oil produced in the lease areas will be transported to shore predominantly by pipelines, with a small quantity transported by barge/shuttle tankers (LaBelle 2001).

The proposed action analyzed in this report is one "typical" EPA lease sale. A set of ranges for resource estimates and projected exploration and development activities developed for the "typical" proposed action was used to analyze spill risk. The analyses of oil-spill risk for the "typical" proposed action are expected to be "typical" of any of the other proposed EPA sales scheduled in the 5-Year Program. In other words, each of the proposed sales in the Five-Year Program is expected to be within the ranges used for the analyzed "typical" proposed action in the planning area.

2.2 Estimated Volume of Oil Resources

For this analysis, both benefits and risks are functions of the volume of oil produced and are mutually dependent. For example, greater volumes of produced oil are associated with greater economic benefits, as well as greater risks. If the benefits are evaluated by assuming production of a specific amount of oil, then the corresponding risks should be stated conditionally, such as "the risks are…, given that the volume is…" Any statements about the likelihood of a particular volume of oil being developed also apply to the likelihood of the corresponding benefits and risks.

The resource estimates are presented for the following scenarios:

Proposed Action—the range of oil resources estimated to be leased, discovered, and produced over a 40-year time period as a result of a typical EPA lease sale, as found in the proposed Five-Year Program for 2012-2017 (USDOI-BOEM 2012)

OCS Program—the range of oil resources estimated to be leased, discovered, and produced as a result of prior lease sales, the proposed actions, and future lease sales that will occur during the life of a proposed action, which is 40 years, the duration of a lease (USDOI-BOEM 2013).

The range in oil resource projections used to develop the proposed actions and OCS Program scenarios are based on resource and reserves estimates as presented in the *2011 Assessment of Undiscovered Technically Recoverable Oil and Gas Resources of the Nation's Outer Continental Shelf* (USDOI-BOEM 2011), current industry information, and historical trends. The resource estimates for the proposed actions are based on two factors: (1) the conditional estimates of undiscovered, unleased, conventionally recoverable oil and gas resources in the proposed lease sale areas; and (2) estimates of the portion or percentage of these resources assumed to be leased, discovered, developed, and produced as a result of the proposed actions. The estimates of undiscovered, unleased, conventionally recoverable oil and gas resources are based upon a comprehensive appraisal of the conventionally recoverable petroleum resources of the Nation as of January 1, 2009. Due to the inherent uncertainties associated with an assessment of undiscovered resources, probabilistic techniques were employed, and the results were reported as a range of values corresponding to different probabilities of occurrence. A thorough discussion of the methodologies employed and the results obtained in the assessment are presented in USDOI-BOEM (2011). The estimates of the portion of the resources assumed to be leased, discovered, developed, and produced as a result of the proposed actions are based upon logical sequences of events that incorporate past experience, current conditions, and foreseeable development strategies. A wealth of historical data and information derived from over 50 years of oil and gas exploration, development, and production activities were used extensively by BOEM (formerly the Minerals Management Service [MMS]). The undiscovered, unleased, conventionally recoverable resource estimates for the proposed actions are expressed as ranges, from low to high. The range reflects a range of projected economic valuations of the produced oil and gas.

The projected life of all exploration, development, production, and abandonment activities that result from a typical proposed lease sale is assumed to be 40 years. This is based on averages for the amount of time required for these activities for Gulf of Mexico (GOM) leases.

Based on the resource estimates described above, an estimate of amount of oil to be produced from a given area is estimated, and the estimate is presented in billion barrels (Bbbl). The projected oil production in Bbbl for a typical proposed lease sale and the OCS Program are shown in Table 1 below.

Table 1. Projected Oil Production for the OCS Program and for a Typical Proposed Lease Sale

Action or Program	Estimated Production (Bbbl[1])	Analysis Period
Proposed Action		
Eastern GOM	0.071	40 years
OCS Program		
Western GOM	0.211	40 years

[1] Bbbl= Billion barrels = 10^9 barrels; 1 barrel = 42 U.S. gallons

2.3 Location of the Proposed Action (versus Domain/Study Areas)

The proposed action involves leasing in only the EPA; however the study area includes the entire GOM and surrounding area.

The EPA (shown in Figure B-1) encompasses the eastern portion of U.S. OCS waters within the Gulf of Mexico. It extends from the limit of State offshore waters seaward to the limits of the Exclusive Economic Zone.

The geographic boundaries that encompass the environmental resources at risk from a hypothetical oil spill from OCS operations in the lease areas are shown in Figure B-1. This area is called the domain. Although few hypothetical oil spills were likely to extend beyond the borders of the domain within 30 days after release (the maximum elapsed time considered), we have tracked and tabulated some spills that would travel beyond the open-ocean boundaries. These spills could contact land or other environmental resources outside the domain.

2.4 Environmental Resources Considered in the Analysis

The environmental resources considered in this analysis were selected by BOEM analysts in the Gulf of Mexico OCS Region with supplementary input from the National Marine Fisheries Service and the U.S. Fish and Wildlife Service. BOEM analysts also used information from its Environmental Studies Program results, literature reviews, and professional exchange with other scientists to define resources. The analysts used geographic digital information on the biological, physical, and socioeconomic resources that could be exposed to contact from OCS oil spills to create maps of resource locations vulnerable to oil-spill impact. These maps (Figures B-2 through B-17) depict locations that were analyzed by the OSRA Model, representing either the locations of onshore environmental resource habitats or the surface waters overlying or surrounding offshore environmental features. Some maps were specifically created to represent the location of a resource or resource habitat, while other maps, such as those for counties or parishes, are used to assess risk to multiple resources, even though the map is not labeled with the names of those resources. Discussions of risks to all considered resources can be found in the EIS that is prepared for each proposed action.

All of the onshore, coastal environmental resource locations were represented by one or more partitions of the coastline (herein called land). The study area coastline was partitioned into 210 equidistant land segments of approximately 10-mile (16-kilometer) length. The partitions were formed by creating straight lines between two points projected onto the coast; therefore, the actual miles of shoreline represented by each land segment may be greater than 10 miles, depending upon the complexity of the coastal area.

In addition, the state offshore waters were included as environmental resources. The limits of State waters have been defined by the States and range from 3 to 9 nautical miles. Texas and Florida state offshore waters extend 3 marine leagues (just over 9 nautical miles) seaward from the baseline from which the breadth of the territorial sea is measured (1 marine league = 1,8228.3 feet). Louisiana state offshore waters extend 3 imperial nautical miles seaward of the baseline from which the breadth of the territorial sea is measured (1 imperial nautical mile = 6,080 feet). Mississippi and Alabama State offshore waters extend 3 nautical miles seaward of the baseline from which the breadth of the territorial sea is measured (1 nautical mile = 6,076 feet).

The offshore and onshore environmental resources and socioeconomic features that are examined in this OSRA Report are listed in Tables A-3 and A-4, along with their identification (ID) numbers. Periods of habitat or beach use are identified in parentheses.

These tables also indicate which figures illustrate the areas associated with each resource. Appendix B contains the figures, which show the locations of each potentially affected resource (Figures B-2 through B-17).

3.0 Oil-Spill Risk Analysis

The OSRA was conducted in three parts, corresponding to different aspects of the overall problem:

1. The probability of oil-spill occurrence (discussed in Section 3.1),
2. The trajectories of oil spills from hypothetical spill locations to various environmental resources (described in Section 3.2), and
3. A combination of the first two analyses to estimate the overall oil-spill risk of both spill occurrence and spill contact if there is oil development (presented in Section 3.3).

Risk analyses may be characterized as "hazard-based" or "risk-based." A hazard-based analysis examines possible events regardless of their low (or high) likelihood. For example, a potential impact would not lose significance because the risk has been reduced due to an increase in the level of control, such as engineering standards. A risk-based analysis, on the other hand, does take into account the likelihood of the event occurring or the measures that can be taken to mitigate against its potential impacts.

This OSRA is designed for use as a risk-based assessment. Therefore, the likelihood of oil spills (≥ 1,000 barrels [bbl] in size) occurring on the OCS plays an integral role in the analysis. In addition to the estimated chance of spills occurring, the analysis entails an extensive oil-spill trajectory model. Results from the trajectory analysis provide input to the final product by estimating where spills might travel on the ocean's surface and what resources might be contacted.

Results from the OSRA are, therefore, expressed as the combined probability of spills both occurring and contacting modeled offshore and coastal environmental resource locations.

Note that the analysis estimates spill contacts, not spill impacts. Further measures that should be evaluated to determine impacts, such as the natural weathering of oil spills and the effects of cleanup activities, are not directly factored into the analysis but should be added to the interpretation of its results.

3.1 Probability of Oil Spills Occurring

The probability of oil spills occurring assumes that spills occur independently of each other as a Poisson process. The Poisson process is a statistical distribution that is commonly used to model random events. The probability of oil spills occurring is based on spill rates derived from the historical OCS platform and OCS pipeline spill record and the historical tanker spill record in U.S. waters, and it depends on the volume of oil produced and transported. All types of accidental spills greater than or equal to 1,000 bbl were considered in this analysis. These spills include those from well blowouts, other accidents that occur on platforms, and during transportation of oil to shore. These spills were classified as platform, pipeline, or tanker spills. This classification allows the analyst to compare the risks from each spill source due to a proposed action, relative to the risks of spill occurrence and contact due to any alternatives being considered.

Anderson et al. (2012) examined oil-spill occurrence rates applicable to the OCS. Their results are adjusted for recent experience and based upon more complete databases than were available for earlier analyses (Anderson and LaBelle, 1990, 1994, 2000; Lanfear and Amstutz, 1983); their results indicated that some significant changes had occurred in the spill rates for platforms, pipelines, and tankers. This report uses the updated spill occurrence rates from Anderson et al (2012).

Spill rates are expressed as number of spills per billion barrels (spills/Bbbl) produced or transported. (A billion barrels (Bbbl) is defined as 10^9 bbl of oil). Spills of different sizes are analyzed when calculating the rates of spills per Bbbl oil produced. Spills less than 1,000 bbls are addressed in the EIS for each proposed action without the use of trajectory modeling because smaller spills may not persist in the environment long enough to be simulated by trajectory modeling. Spills greater than or equal to 1,000 bbl persist in the environment long enough to be modeled and are addressed in OSRA reports. Larger spills are likely to be identified and reported; therefore, these records are more comprehensive than those of smaller spills.

Two basic criteria were used in selecting the volume of oil handled as the risk exposure variable: (1) the exposure variable should be simple to define, and (2) it should be a quantity that can be estimated. The volume of oil produced or transported was the chosen exposure variable primarily for the following reasons: historic volumes of oil produced and transported are well documented; using these volumes makes the calculation of the estimated oil-spill occurrence rate simple—the ratio of the number of historic spills to the volume of oil produced or transported; and future volumes of oil production and transportation are routinely estimated. The volume of oil and gas to be produced for a proposed action and for the Gulfwide OCS Program is estimated from an assessment of oil resources by using comprehensive geological and geophysical databases and related models. In addition, the BOEM analysts estimate other exposure variables, such as number of platforms and tanker trips, as a function of the volume of oil estimated to be produced or transported.

Anderson et al. (2012) analyzed platform and pipeline spills in Federal waters that occurred from OCS oil and gas development from 1964 through 2010 and crude oil tanker spills that occurred in U.S. waters from 1974 through 2008. In these analyses, every spill record was examined and verified to the furthest extent possible. Each spill was classified for size, product spilled, and spill source according to its applicability to the analysis. Spill rates (in spills per Bbbl of oil produced at platforms on the OCS or transported by pipelines on the OCS or tankers traversing the OCS) were estimated for platforms, pipelines and tankers on the OCS, as shown in Table 2.

Table 2. Oil Spill Rates

Spill Source	Number of Spills	
	≥ 1,000 bbl[1] (spills /Bbbl[2])	≥10,000 bbl[1] (spills /Bbbl[2])
OCS	0.25	0.13
OCS Pipelines	0.88	0.18
OCS Tankers	0.34	0.11

[1] bbl = barrels = 42 U.S. gallons

[2] Bbbl= Billion barrels = 10^9 barrels

Source: Anderson, et al 2012

The spill rates in Table 2, which are based on a 15-year period (1996-2010) for OCS platforms and pipelines and a 20-year period (1989-2008) for tankers, as found in Anderson et al. (2012) were used in this OSRA study as best representing current technology.

Using Bayesian techniques, Devanney and Stewart (1974) showed that the probability of *n* oil-spill contacts can be described by a negative binomial distribution. Smith et al. (1982), however, noted that when actual exposure is much less than historical exposure, as is the case here, the negative binomial distribution can be approximated by a Poisson distribution. The Poisson distribution has a significant advantage in calculations because it is defined by only one parameter, the assumed number of spills. If $p(n,i)$ is the probability of exactly *n* contacts to environmental resource *i*, then:

$$p(n,i) = \frac{\lambda_i^{\,n} \cdot e^{-\lambda i}}{n!}$$

where *n* is the specific number of spills (0, 1, 2, ..., *n*), *e* is the base of the natural logarithm, and λ is the parameter of the Poisson distribution. For oil spills, the Poisson parameter (λ) is equal to the spill rate multiplied by the volume of oil to be produced or transported. The spill rate has dimensions of number of spills/Bbbl, and the volume is expressed in Bbbl. Therefore, λ denotes the mean number of spills estimated to occur as a result of production or transportation of a specific volume of oil.

Oil-spill occurrence estimates for spills greater than or equal to 1,000 bbl were calculated for production and transportation of oil during the 40-year analysis period associated with the proposed action in the EPA and the Eastern OCS Program (2012-2051). These probabilities are based on the volume of oil estimated to be found, produced, and transported over the life of a typical lease sale and on the rates that have been calculated for oil spills from OCS platforms, pipelines, and tankers by Anderson et al. (2012). The probabilities of one or more oil spills greater than or equal to 1,000 bbl occurring as a result of OCS exploration, development, and production and transportation resulting from a typical lease sale or resulting from the OCS Program are found in Table A-1. The probabilities for spills greater than or equal to 10,000 bbl are shown in Table A-2.

3.2 Oil-Spill Trajectory Simulations

The goal of an oil-spill risk analysis is to answer the question: What is the probability of oil and gas development from a platform in a given area to cause oil, if it is spilled, to contact specific shorelines or sensitive environmental resources? To achieve this goal, the OSRA model must estimate where an oil spill might begin, where it is likely to move, and where the shorelines and environmental resources are, relative to that potential movement. From these analyses, the probability of contact to a given area is calculated.

Locations of hypothetical spill sites are addressed in Section 3.2.1. Ocean current and wind inputs used in the OSRA Model are described in Section 3.2.2, and the trajectories of hypothetical spills are addressed in Section 3.2.3. The outputs of the OSRA Model are a series of probabilities of a contact between a hypothetical spill in a specific area and an environmental resource or a specific segment of the shoreline. These are introduced in Section 3.2.4. Finally, Section 3.2.5 lists factors that are not included in OSRA modeling and discusses how the exclusion of those factors affect the model's results.

3.2.1 Hypothetical Spill Locations and Timing

To model where a spill might go, one needs to know where and when it began. To provide a location from which a hypothetical spill begins, the OSRA Model uses hypothetical spill locations called launch points. The OSRA Model initiates hypothetical oil spills uniformly in space and time from within the study area, in this case the EPA, as shown in Figure B-1.

At distance intervals of one-tenth of a degree ($1/10^o$) of latitude (about 11 kilometers) and intervals of $1/10^o$ of longitude (about 10 kilometers), 30 launch points for hypothetical spills were identified in the EPA. The spatial resolution of the spill simulations [$1/10^o$ north-south and $1/10^o$ east-west] was selected so that it was well within the spatial resolution of the input data.

The number of simulated spills per launch point is very conservative. OSRA estimates and tracks one spill per launch point per day for the 15 years of the available wind and current data. Trajectories of hypothetical spills were initiated every day (a 1-day interval) from each of the launch points in space over the simulation period from January 1, 1993 to December 31, 2007. A total of one spill per day for each of the 30 launch points for 15 years was calculated.

The OSRA Model integrates the spill velocities (a linear superposition of surface ocean currents and empirical wind drift) by integrating velocity in time to produce the spill trajectories. The time step selected was 1 hour to fully utilize the spatial resolution of the ocean current field and to achieve a stable set of trajectories. The velocity field was bi-linearly interpolated from the 3-hourly or 1-hourly grid to get velocities at 1-hour intervals. Time steps smaller than 1 hour were analyzed previously (Price et al. 2002) and were found to not produce significant differences in the simulated trajectories after 30 model days, so the 1-hour time step was chosen for this analysis.

The chosen number of trajectories per site was small enough to be computationally practical and large enough to reduce the random sampling error to an insignificant level. Also, the weather-scale changes in the winds are at least minimally sampled with simulated spills started daily. The interval of time between releases (1 day) was sufficiently short to sample weather-scale changes in the input winds (Price et al. 2002).

The sensitivity tests on the OSRA Model (Price et al. 2002) indicated that, statistically, the above-mentioned spatial resolution ($1/10^{o}$ by $1/10^{o}$) and time resolution (1-day) are sufficient to represent the spatial and time variations of the oil-spill trajectories in the area. At this resolution, over 160,000 oil-spill trajectories were tracked from the launch points in the EPA, based on the wind and current data during the period from 1993 to 2007.

3.2.2 Ocean Current Data and Wind Simulations as Inputs to OSRA

This section describes two major inputs for the OSRA model: the model that is used to provide data on ocean currents, and the data that are used for wind speeds and wind directions.

Spilled oil moves on the ocean surface because of ocean currents and winds. Complex surface ocean currents exert a shear force on the spilled oil from below. In addition, prevailing winds exert an additional shear forces on the spill from above. The combination of these two forces causes the movement of spilled oil away from its initial spill location.

The OSRA Model: The OSRA Model was designed to track the potential movements of potential oil spills before they happen. The model, which was originally developed by Smith et al. (1982) and enhanced by BOEM over the years (LaBelle and Anderson 1985; Ji et al. 2002, 2004, 2011; Ji, Johnson and Marshall 2004), simulates oil-spill transport using realistic data fields of winds and ocean currents in the GOM. The model calculates the movement of hypothetical spills by successively integrating time sequences of two spatially gridded input fields: the surface ocean currents and the sea-level winds. In this fashion, the OSRA Model generates time sequences of hypothetical oil-spill locations–essentially, oil-spill trajectories.

Conducting an oil-spill risk analysis requires detailed information on ocean currents and wind fields (Ji 2004). The ocean currents inputs are numerically computed from an ocean circulation model of the GOM that is driven by meteorological forces (the near-surface winds and the total heat fluxes) that have been analyzed and by observed river inflow into the GOM (Oey 2005; 2008).

The Modified Princeton Ocean Model: The model used to provide ocean current data for the OSRA model is a version of the Princeton Ocean Model (POM), which is an enhanced version of the earlier-constructed Mellor-Blumberg Model. It is a three-dimensional, time-dependent, primitive equation model using orthogonal curvilinear coordinates in the horizontal dimension and a topographically conformal coordinate in the vertical dimension. The use of these coordinates allows for a realistic coastline and bottom topography, including a sloping shelf, to be represented in the model simulation. The model incorporates the

Mellor-Yamada turbulence closure model to provide a parameterization of the vertical mixing process through the water column.

The prognostic variables of the modified POM are velocity, temperature, salinity, turbulence kinetic energy, and turbulence macroscale. The momentum equations are nonlinear and incorporate a variable Coriolis parameter. Prognostic equations governing the thermodynamic quantities (temperature and salinity) account for water mass variations brought about by highly time-dependent coastal upwelling processes. The processes responsible for eddy production, movement, and eventual dissipation are also included in the model physics. Other computed variables used in the modified POM include density, vertical eddy viscosity, and vertical eddy diffusivity.

The modified POM calculation was performed by Princeton University (Oey 2005; 2008). This simulation covered the 15-year period, 1993 through 2007, and the results were saved at 3-hour intervals. The simulation period covers the data available for this study. These modified POM runs included the assimilation of sea surface altimeter observations to improve the ocean model results.

The modified POM simulations were extensively skill-assessed with many observations from the GOM (Oey 2005; 2008). These extensive sets of observations afford a rigorous test of the modified POM's ability to reproduce ocean transport as well as prominent features of the Gulf such as the Loop Current and strong mesoscale eddies, which are easily observed from satellite-borne instrumentation. With these observations and with other current measurements from moored current meters, a good determination of the model's veracity was made. The modified POM reproduced the characteristics of the GOM surface currents both on and off the continental shelf. The surface current field manifests all the dominant structures in time and space as the observed currents and is, therefore, applicable in the statistical estimation of future spill risk that the OSRA Model makes. The surface currents from the modified POM calculation were used for input into the OSRA Model.

Wind Data Used as OSRA Model Input: For surface wind data, the OSRA Model incorporates concurrent wind fields, which are the 6-hourly surface wind speeds and directions, as analyzed by the European Center for Medium Range Weather Forecasting. The OSRA Model used the same wind field to calculate the empirical wind drift of the simulated spills.

3.2.3 Trajectory Simulations

In the trajectory simulation portion of the OSRA Model, many hypothetical oil-spill trajectories are produced by numerically integrating a temporally- and spatially-varying ocean current field, and superimposed on that an empirical wind-induced drift of the hypothetical oil spills (Samuels et al. 1982). Collectively, the trajectories represent a statistical ensemble of simulated oil-spill displacements produced by a field of winds derived from observations and numerically derived ocean currents. The historical data on winds and currents in the GOM are assumed to be statistically similar to those that will occur in the Gulf during future offshore activities. In other words, the oil-spill risk analysts assume that the frequency of strong wind events in the wind field is the same as what will occur during future offshore activities. By inference, the frequencies of contact by the simulated oil spills are the same as what could occur from actual oil spills during future offshore activities.

A cluster analysis (Everitt 1993) is used to further divide the planning areas into hypothetical spill subareas. Cluster analysis is a multivariate technique that groups entities based on similar characteristics. In the case of the Central Planning Area (CPA) and the Western Planning Area (WPA) of the GOM, BOEM used the probability of contact to shoreline segments to identify offshore areas that showed similar risk, based on similarity in patterns of trajectories. In the case of the EPA, a single cluster was assumed for the entire planning area because the portion of the EPA being considered for leasing is very small in comparison to the size of the CPA and WPA.

To account for the risk of spills occurring from the transportation of oil to shore via pipeline, generalized pipeline corridors originating within the offshore cluster area(s) and terminating at existing major oil pipeline shore bases were identified. These pipeline corridors represent the complex matrix of pipeline systems existing offshore that are likely to be used in support of each proposed action. The oil volume estimated to be produced within the cluster area was proportioned among likely pipeline corridor routes, representing the transportation of the oil beginning within the cluster area and terminating at State/Federal boundaries proximate to known pipeline shore bases.

3.2.4 Spill-Resource Contact Probabilities

In addition to the ocean current, and the surface wind data, and the hypothetical spill locations, another portion of the OSRA Model tabulates the simulated oil spill contacts to specific locations or environmental resources.

To locate environmental resources, the model contains the geographical boundaries of a variety of identified environmental features. At each successive time step, the OSRA Model compares the location of the hypothetical spills against the geographic boundaries of shoreline and designated offshore environmental resources. The OSRA Model then counts the number of “contacts,” which is comprised of the number of oil-spill contacts to segments of shoreline (counties/parishes) plus the occurrences of oil-spill contact to sensitive environmental areas during the time periods that the habitat is known to be used by the resource. A contact to a shoreline will stop the trajectory of an oil spill; no re-washing is assumed in this model. A contact to an environmental resource that is not a shoreline (like the Flower Garden Banks, for example) will not stop the calculation of the trajectory in OSRA.

After specified periods of time, the OSRA Model will divide the total number of contacts by the total number of simulated oil spills from a given geographic location. Recall that the number of simulated spills for this OSRA report is one hypothetical spill per day multiplied by fifteen years multiplied by 30 launch points within the proposed lease area. The ratios between the total number of contacts and total simulated spills are the estimated probabilities of oil-spill contact from offshore activities at that geographic location, assuming spill occurrence.

Finally, the frequencies of oil-spill contact are computed for designated oil-spill travel times (e.g., 3, 10, or 30 days). This is calculated by dividing the total number of oil-spill contacts by the total number of hypothetical spills initiated in the model from a given hypothetical spill location. The frequencies of oil-spill contact are the model-estimated probabilities of oil-spill contact. The OSRA Model output provides the estimated probabilities of contact to all identified offshore environmental resources and segments of shoreline from locations chosen to represent hypothetical oil spills from oil production and transportation facilities, at several selected oil-spill travel times. The OSRA Model combines the statistics for shoreline contacts by the trajectories to calculate the average probabilities of shoreline contact.

3.2.5 Factors Not Considered in the OSRA Model

There are factors not explicitly considered by the OSRA Model that can affect the transport of spilled oil as well as the dimensions, volume, and nature of the oil spills contacting environmental resources or the shoreline. These include possible cleanup operations, chemical composition of the spilled oil, weathering of oil spills, or the spreading and splitting of oil spills. The OSRA analysts have chosen to take a more environmentally conservative approach by presuming that no oil-spill-response activities occur and by assuming complete persistence of spilled oil over the selected time duration of the trajectories. These assumptions make the OSRA model's calculated probabilities conservative.

3.3 Conditional Probabilities of Contact

The probability that an oil spill will contact a specific environmental resource within a given time of travel from a certain location or spill point is termed a *conditional probability*, the condition being that a spill is assumed to have occurred. Each trajectory was allowed to continue for as long as 30 days. However, if the hypothetical spill contacted shoreline sooner than 30 days after the start of the spill, the spill trajectory was terminated, and the contact was recorded.

The trajectories simulated by the model represent only hypothetical pathways of oil slicks; they do not involve any direct consideration of cleanup, dispersion, or weathering processes that could alter the quantity or properties of oil that might eventually contact the environmental resource locations. However, an implicit analysis of weathering and decay can be considered by choosing a travel time for the simulated oil spills when they contact environmental resource locations that represent the likely persistence of the oil slick on the water surface. BOEM performed an analysis of the likely weathering of a typical offshore oil spill of 1,000 bbl or greater occurring under the proposed action scenarios (USDOI, BOEM 2013). The analysis of the slick's fate showed that a typical GOM oil slick of 1,000 bbl or greater, exposed to typical winds and currents, would not persist on the water surface beyond 30 days. Therefore, OSRA Model trajectories were analyzed only up to 30 days. Any spill contacts occurring on or before 30 days elapsed time are reported in the probability tables. Conditional probabilities of contact with environmental resource locations and land segments within 10 and 30 days of travel time were calculated for each of the hypothetical spill sites by the model to serve as input into the final calculation of risk.

3.4 Combined Probabilities of Contact

A critical difference exists between the conditional probabilities and the combined probabilities calculated. Conditional probabilities depend only on the winds and currents in the study area. Combined probabilities, on the other hand, depend not only on the winds and currents, but also on the chance of spill occurrence, the estimated volume of oil to be produced or transported, and the oil transportation scenario. The combined probabilities for this analysis of the proposed action activities are presented in Tables A-3 and A-4.

In calculating the combined probabilities of both oil-spill contact and oil-spill occurrence, the following steps are performed:

1. To address the probability of spill contact for a set of n_t environmental resources and n_l launch points, the conditional probabilities can be represented in a matrix form. Let [C] be an $n_t \times n_l$ matrix, where each element $c_{i,j}$ is the probability that an oil spill will contact environmental resource i, given that a spill occurs at launch point j. Note that launch points can represent potential starting points of spills from production areas or from transportation routes.

2. Oil-spill occurrence can be represented by another matrix [S]. With n_l launch points and n_s production sites, the dimensions of [S] are $n_l \times n_s$. Let each element $s_{j,k}$ be the estimated mean number of spills occurring at launch point j owing to production of a unit volume (1 Bbbl) of oil at site k. These spills can result from either production or transportation. The $s_{j,k}$ can be determined as a function of the volume of oil (spills/Bbbl). Each column of [S] corresponds to one production site and one transportation route. If alternative and mutually exclusive transportation routes are considered for the same production site, they can be represented by additional columns of [S], thus increasing n_s.

3. The unit risk matrix [U] is defined as:

$$[U] = [C] \times [S]$$

   [U] has dimensions $n_t \times n_{s.}$. Each element $u_{i,k}$ corresponds to the estimated mean number of spills occurring and contacting environmental resource i, owing to the production of a unit volume (1 Bbbl) of oil at site k.

4. To convert this number into a number that reflects the expected oil production volume, a value for volume must be included. With [U], the mean contacts to each environmental resource are estimated, given a set of oil volumes at each site. Let [V] be a vector of dimension n_s where each element v_k corresponds to the volume of oil expected to be found at production site k. Then, if [L] is a vector of dimension n_t, where each element λ_i corresponds to the mean number of contacts to environmental resource i, the formula is:

$$[L] = [U] \times [V]$$

Thus, estimates of the mean number of oil spills that are likely to occur and contact environmental resources (or land segments) can be calculated. (Note that, as a statistical parameter, the mean number can assume a fractional value, even though fractions of oil spills have no physical meaning.)

4.0 Discussion

4.1 Summary of Results

As one might expect, environmental resource locations closest to the spill sites have the greatest risk of contact. As the model run duration increases, more of the identified environmental resources and shoreline segments could have meaningful probabilities of contact ($\geq$0.5%). The longer transit times up to 30 days allowed by the model enable more hypothetical spills to reach the environmental resources and the shoreline from more distant spill locations. With increased travel time, the complex patterns of wind and ocean currents produce eddy-like motions of the oil spills and multiple opportunities for a spill to make contact with any given environmental resource or shoreline segment.

For instance, Table A-4 provides the probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 bbl, and the number of spills (mean) that could occur and could contact a certain offshore environmental resource within 10 days and within 30 days, given the estimated volume of oil produced from a proposed action in the GOM Eastern Planning Area. This table shows that environmental resource # 76 is West Manatee rare habitat, which is illustrated on Figure B-5. This habitat has a probability of less than 0.5 percent of being contacted by spilled oil within 10 days, if there is an oil spill from a proposed action in the EPA with an oil production volume of 0.071 Bbbl (Table A-4). Its probability increases to 1 percent of being contacted by the spilled oil within 30 days.

4.2 Related Environmental Studies

The BOEM maintains an active Environmental Studies Program, which develops, conducts, and oversees scientific research specifically to inform policy decisions regarding development of OCS energy and mineral resources (http://www.boem.gov/studies/).With relevance to OSRA, numerous past and present studies have focused on issues related to physical oceanography and oil-spill fates and effects. Examples of recent or current studies that have led to improvements in the OSRA model (or can lead to improvements in the OSRA model after study completion) include:

- OSRA model sensitivity tests
- Simulation modeling of ocean circulation
- Assessment of remote sensing observations
- Lagrangian stochiastic models
- Reducing uncertainties in surface current and ocean-state data:

OSRA Model Sensitivity Analysis: Ji et al. (2011) discussed the improvements on the OSRA Model and the model sensitivity tests. The OSRA model is tested on a Microsoft Windows-based workstation with eight CPUs. The combination of code parallelization, code optimization, and I/O optimization has greatly improved the computational efficiency. Applying the model to the Gulf of Mexico using 16 years of winds and ocean currents, it is found that the enhanced OSRA model can provide important information on the behavior of oil spills more accurately and efficiently.

Simulation Modeling of Ocean Circulation: The *Deepwater Horizon* oil spill emphasized the need for improved modeling of deepwater blowouts in the Gulf of Mexico, including the transport and fate of both surface and subsurface plumes. To address this need, a four-year study entitled "Simulation Modeling of Ocean Circulation and Oil Spills in the Gulf of Mexico" (GM-11-02) was developed and competitively awarded to Applied Science Associates, Inc. in September 2011. The overarching goals of this study are to accurately simulate plume behavior during large, deep oil spills and to address a variety of scenario runs related to potential spill outcomes. Specific objectives are as follows: (1) to develop an integrated oil-spill model using output from an existing 3D ocean circulation model for the Gulf of Mexico, (2) to predict oil plume transport and fate, (3) to validate oil plume trajectories and concentrations with existing observations from the water surface, in the water column, deposition along shorelines, and in sediments, and (4) to conduct scenario runs to inform BOEM risk assessment and oil-spill contingency planning, as well as National Environmental Protection Act documents, on the range of possible spill outcomes. Improved algorithms related to oil spill movement and fate, as well as 3D modeling capabilities developed as part of this study, will be considered for incorporation into future OSRA modeling activities.

Assessment of Remote Sensing Observations: In addition, numerous remote-sensing observations have been collected during past spill events, including the *Deepwater Horizon* spill in the Gulf of Mexico. Given this large dataset of recent observations, there was clearly a need for a more in-depth analysis of both satellite and aerial imagery in order to more precisely quantify wind and ocean current forcing on oil-spill movement and fate. Thus, a three-year study entitled "Remote Sensing Assessment of Surface Oil Transport and Fate during Spills in the Gulf of Mexico" (GM-12-02) was developed and competitively awarded to Florida State University in August 2012. Specific objectives of this study are as follows: (1) to develop and apply remote-sensing algorithms for characterizing surface oil, (2) to provide an oil transport and weathering model and physical forcing fields for analyzing surface oil distributions, (3) to analyze the effects of oceanographic and wind forcing on the transport and character of oil, and (4) to examine mixing processes that influence surface oil transport. Specifically, a dataset of imagery (e.g., Synthetic Aperture Radar , ocean color, and aerial) will be analyzed using validated hydrodynamic and wind models for the Gulf of Mexico, along with the Oil Spill Contingency and Response model by SINTEF for oil transport and weathering. (SINTEF is the acronym for the Foundation for Scientific and Industrial Technology in Norwegian.) Updated spill transport and fate algorithms developed as an outcome of this study will be considered for inclusion in future versions of the OSRA modeling.

Lagrangian Stochastic Models: In support of BOEM's policy of using the best available information for safe operations and environmental protection, BOEM has explored new methodologies as an alternative approach to the traditional trajectory model. BOEM has a contract with the University of Miami to apply Lagrangian Stochastic Models (LSMs) to track oil spills (M11PC00034). The University of Miami team has developed three LSMs that will be adapted to the GOM region to estimate the dispersion events at the submesoscale time scales, as these processes play a critical role for transport of oil spills and other pollutants.

Reducing Uncertainties in Surface Current and Ocean-State Data: In addition, BOEM is working to improve the OSRA model by reducing uncertainties in two areas: (1) uncertainties associated with hydrodynamic-model simulated surface currents and ocean-state variables in the GOM, and (2) uncertainties in the estimate of probability of potential oil-spill contacts with environmental resources. Each of these goals is of interest to BOEM, as well as to the scientific community and to natural resource managers who are responsible for stewardship and protection activities. These goals for improving the model are discussed below, with the focus on the second aspect.

Surface currents for simulating oil-spill trajectories in the OSRA model are provided by ocean circulation model. Currently, BOEM's OSRA model is based on the surface currents generated by the Princeton Regional Ocean Forecast System (PROFS) and on the re-analysis winds used to force the PROFS. The deterministic approach with one set of input could be improved by incorporating several sets of input from different proven ocean models to run the OSRA, because the ocean model output might be subject to uncertainties, such as uncertainties related to surface winds from various atmospheric re-analysis products. Thus, BOEM has embarked on a study to improve oil-spill risk analysis in the GOM using a multiple hydrodynamic model approach. An ensemble of OSRA model solutions will be generated using the output from these hydrodynamic models, and the solutions will be statistically analyzed to understand the uncertainty in the probability of the potential oil-spill contacts with environmental resources in the GOM.

As Part A of this study, BOEM contracted with Florida State University through the Cooperative Agreement on "Data Assimilative Ocean Hindcast for Oil Spill Risk Analysis in the Gulf of Mexico" (M12AS00001). Florida State University will deliver to BOEM a Hybrid Coordinate Ocean Model-based data assimilative modeling framework that can be used to accurately hindcast ocean currents and other ocean-state variables needed for oil-spill risk analysis in the GOM. The end product will be a high-resolution dataset (in space and time) from 2003 to 2012 that provides consistent and accurate estimates of the ocean state variables that are needed for oil-spill risk analysis.

In Part B of this study, the Naval Research Laboratory, through an Interagency Agreement with BOEM, will deliver to BOEM the model output from the Navy Coastal Ocean Model (NCOM) for the period 2003-2012 in the GOM (M12PG00030). The NCOM has been adapted to run in real time for the Intra-Americas Sea Ocean Nowcast/Forecast System (IASNFS) since 2003. The IASNFS covers the GOM, the Caribbean Sea, and the Straits of Florida.

The results of these studies will allow BOEM to provide more accurate information about oil-spill risk management and contingency planning in the GOM to state and local government agencies in the future.

5.0 References

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Appendix A. Oil-Spill Risk Analysis Tables

Table A-1. Oil-spill occurrence probability estimates for offshore spills greater than or equal to 1,000 barrels resulting from the proposed actions in the Gulf of Mexico Eastern Planning Area (2012-2017) and the Eastern OCS Program (2012-2051)

Action or Program	Production Volume (Bbbl)[1]	Mean Number of Spills from			Mean Number of Spills (Total)	Probability (% Chance) of One or More Spills from			Probability (% Chance) of One or More Spills (Total)
		Platforms[2]	Pipelines	Tankers		Platforms	Pipelines	Tankers	
Proposed Actions									
Eastern GOM	0.071	0.01	0.01	0.00	0.02	1	1	n	2
OCS Program									
Eastern GOM	0.21	0.03	0.04	0.00	0.07	3	4	n	6

[1] Bbbl= billion (10^9) barrels; a barrel is 42 U.S. gallons
[2] Platforms refers to facilities used in exploration, development, or production.
n= less than 0.5%
** = greater than 99.5%.

Table A-2. Oil-spill occurrence probability estimates for offshore spills greater than or equal to 10,000 barrels resulting from the proposed actions in the Gulf of Mexico Eastern Planning Area (2012-2017) and the Eastern OCS Program (2012–2051)

Action or Program	Production Volume (Bbbl)[1]	Mean Number of Spills from			Mean Number of Spills (Total)	Probability (% Chance) of One or More Spills from			Probability (% Chance) of One or More Spills (Total)
		Platforms[2]	Pipelines	Tankers		Platforms	Pipelines	Tankers	
Proposed Actions									
Eastern GOM	0.071	0.01	0.01	0.00	0.02	1	1	n	2
OCS Program									
Eastern GOM	0.21	0.03	0.04	0.00	0.07	3	4	n	6

1 Bbbl= billion (10^9) barrels; a barrel is 42 U.S. gallons
[2] Platforms refers to facilities used in exploration, development, or production.
n= less than 0.5%
** = greater than 99.5%.

Table A-3. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain offshore environmental resource locations within 10 and 30 days						
ID #	Offshore Environmental Resource Locations	Figure Showing Resource Location	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
1	Cayman Islands	B-1	n	n	0	0
2	Northwest Bahamas	B-1	n	n	0	0
3	Northeast Bahamas	B-1	n	n	0	0
4	Midwest Bahamas	B-1	n	n	0	0
5	Mideast Bahamas	B-1	n	n	0	0
6	South Bahamas	B-1	n	n	0	0
7	Jamaica	B-1	n	n	0	0
8	TX State Waters	B-2	n	n	0	0
9	West LA State Waters	B-2	1	1	0.01	0.01
10	East LA State Waters	B-2	1	1	0.01	0.01
11	MS State Waters	B-2	n	n	0	0
12	AL State Waters	B-2	n	n	0	0
13	FL Panhandle State Waters	B-2	n	n	0	0
14	West FL State Waters	B-2	n	n	0	0
15	Tortugas State Waters	B-2	n	n	0	0
16	Southeast FL State Waters	B-2	n	n	0	0
17	Northeast FL State Waters	B-2	n	n	0	0
18	Mexican State Waters	B-2	n	n	0	0
31	Nearshore Seafloor (0-20m), "N1"	B-11	n	n	0	0
32	Nearshore Seafloor (0-20m), "N2"	B-11	n	n	0	0
33	Nearshore Seafloor (0-20m), "N3"	B-11	n	n	0	0
34	Nearshore Seafloor (0-20m), "N4"	B-11	n	n	0	0
35	Nearshore Seafloor (0-20m), "N5"	B-11	1	1	0.01	0.01
36	Nearshore Seafloor (0-20m), "N6"	B-11	1	1	0.01	0.01
37	Nearshore Seafloor (0-20m), "N7"	B-11	1	1	0.01	0.01
38	Nearshore Seafloor (0-20m), "N8"	B-11	n	n	0	0
39	Nearshore Seafloor (0-20m), "N9"	B-11	n	n	0	0
40	Nearshore Seafloor (0-20m), "N10"	B-11	n	n	0	0
41	Nearshore Seafloor (0-20m), "N11"	B-11	n	n	0	0
42	Nearshore Seafloor (0-20m), "N12"	B-11	n	n	0	0
43	Nearshore Seafloor (0-20m), "N13"	B-11	n	n	0	0
44	Nearshore Seafloor (0-20m), "N14"	B-11	n	n	0	0
45	Nearshore Seafloor (0-20m), "N15" - Tortugas	B-11	n	n	0	0
46	Shelf Seafloor (20-300m), "S1"	B-11	n	n	0	0
47	Shelf Seafloor (20-300m), "S2"	B-11	n	n	0	0
48	Shelf Seafloor (20-300m), "S3"	B-11	n	1	0	0.01
49	Shelf Seafloor (20-300m), "S4"	B-11	1	2	0.01	0.02
50	Shelf Seafloor (20-300m), "S5"	B-11	1	2	0.01	0.02

Table A-3. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain offshore environmental resource locations within 10 and 30 days (continued)						
ID #	**Offshore Environmental Resource Locations**	**Figure Showing Resource Location**	**Probability (%)**		**Mean**	
			10 days	**30 days**	**10 days**	**30 days**
51	Shelf Seafloor (20-300m), "S6"	B-11	1	2	0.01	0.02
52	Shelf Seafloor (20-300m), "S7"	B-11	1	2	0.01	0.02
53	Shelf Seafloor (20-300m), "S8"	B-11	n	1	0	0.01
54	Shelf Seafloor (20-300m), "S9"	B-11	n	1	0	0.01
55	Shelf Seafloor (20-300m), "S10"	B-11	n	n	0	0
56	Shelf Seafloor (20-300m), "S11"	B-11	n	n	0	0
57	Shelf Seafloor (20-300m), "S12"	B-11	n	n	0	0
58	Shelf Seafloor (20-300m), "S13"	B-11	n	n	0	0
59	Shelf Seafloor (20-300m), "S14"	B-11	n	n	0	0
60	Deepwater Seafloor (300m-Outer Jurisdiction), "D1"	B-11	n	n	0	0
61	Deepwater Seafloor (300m-Outer Jurisdiction), "D2"	B-11	n	n	0	0
62	Deepwater Seafloor (300m-Outer Jurisdiction), "D3"	B-11	n	n	0	0
63	Deepwater Seafloor (300m-Outer Jurisdiction), "D4"	B-11	n	n	0	0
64	Deepwater Seafloor (300m-Outer Jurisdiction), "D5"	B-11	n	n	0	0
65	Deepwater Seafloor (300m-Outer Jurisdiction), "D6"	B-11	n	n	0	0
66	Deepwater Seafloor (300m-Outer Jurisdiction), "D7"	B-11	n	n	0	0
67	Deepwater Seafloor (300m-Outer Jurisdiction), "D8"	B-11	n	n	0	0
68	Deepwater Seafloor (300m-Outer Jurisdiction), "D9"	B-11	n	1	0	0.01
69	Deepwater Seafloor (300m-Outer Jurisdiction), "D10"	B-11	n	1	0	0.01
70	Deepwater Seafloor (300m-Outer Jurisdiction), "D11"	B-11	n	1	0	0.01
71	Deepwater Seafloor (300m-Outer Jurisdiction), "D12"	B-11	1	2	0.01	0.02
72	Deepwater Seafloor (300m-Outer Jurisdiction), "D13"	B-11	1	2	0.01	0.02
73	Deepwater Seafloor (300m-Outer Jurisdiction), "D14"	B-11	1	2	0.01	0.02
74	Deepwater Seafloor (300m-Outer Jurisdiction), "D15"	B-11	2	3	0.02	0.03

Table A-3. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain offshore environmental resource locations within 10 and 30 days (continued)						
ID #	Offshore Environmental Resource Locations	Figure Showing Resource Location	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
75	Deepwater Seafloor (300m-Outer Jurisdiction), "D16"	B-11	3	4	0.03	0.04
76	Deepwater Seafloor (300m-Outer Jurisdiction), "D17"	B-11	3	4	0.03	0.04
77	Deepwater Seafloor (300m-Outer Jurisdiction), "D18"	B-11	3	3	0.03	0.03
78	Deepwater Seafloor (300m-Outer Jurisdiction), "D19"	B-11	3	3	0.03	0.03
79	Deepwater Seafloor (300m-Outer Jurisdiction), "D20"	B-11	1	2	0.01	0.02
80	Deepwater Seafloor (300m-Outer Jurisdiction), "D21"	B-11	3	3	0.03	0.03
81	Deepwater Seafloor (300m-Outer Jurisdiction), "D22"	B-11	2	2	0.02	0.02
82	Deepwater Seafloor (300m-Outer Jurisdiction), "D23"	B-11	1	1	0.01	0.01
83	Deepwater Seafloor (300m-Outer Jurisdiction), "D24"	B-11	2	3	0.02	0.03
84	Deepwater Seafloor (300m-Outer Jurisdiction), "D25"	B-11	n	1	0	0.01
85	Deepwater Seafloor (300m-Outer Jurisdiction), "D26"	B-11	n	1	0	0.01
86	Deepwater Seafloor (300m-Outer Jurisdiction), "D27"	B-11	n	n	0	0
87	Deepwater Seafloor (300m-Outer Jurisdiction),	B-11	n	n	0	0
88	Deepwater Seafloor (300m-Outer Jurisdiction), "D29"	B-11	n	n	0	0
89	Deepwater Seafloor (300m-Outer Jurisdiction), "D30"	B-11	n	n	0	0
90	North Atlantic Right Whale Critical Habitat	B-12	n	n	0	0
91	North Atlantic Right Whale SE Seasonal Management Area (Nov 15-Apr 15)	B-12	n	n	0	0
92	Sargassum (March/April)	B-13	n	n	0	0
93	Sargassum (May/June)	B-13	n	n	0	0
94	Sargassum (July/August)	B-13	1	1	0.01	0.01
95	Seagrass-Wakulla County	B-13	n	n	0	0
96	Seagrass-Jefferson County	B-13	n	n	0	0
97	Seagrass-Taylor County	B-13	n	n	0	0
98	Seagrass-Dixie County	B-13	n	n	0	0
99	Seagrass-Levy County	B-13	n	n	0	0

Table A-3. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain offshore environmental resource locations within 10 and 30 days (continued)						
ID #	**Offshore Environmental Resource Locations**	**Figure Showing Resource Location**	**Probability (%)**		**Mean**	
			10 days	**30 days**	**10 days**	**30 days**
100	Topographic Features (Mysterious Bank)	B-14	n	n	0	0
101	Topographic Features (Blackfish Ridge Bank)	B-14	n	n	0	0
102	Topographic Features (Dream Bank)	B-14	n	n	0	0
103	Topographic Features (Southern Bank)	B-14	n	n	0	0
104	Topographic Features (Hospital Bank)	B-14	n	n	0	0
105	Topographic Features (North Hospital Bank)	B-14	n	n	0	0
106	Topographic Features (Aransas Bank)	B-14	n	n	0	0
107	Topographic Features (South Baker Bank)	B-14	n	n	0	0
108	Topographic Features (Baker Bank)	B-14	n	n	0	0
109	Topographic Features (Big Dunn Bar Bank)	B-14	n	n	0	0
110	Topographic Features (Small Dunn Bar Bank)	B-14	n	n	0	0
113	Topographic Features (Claypile Bank)	B-14	n	n	0	0
114	Topographic Features (Applebaum Bank)	B-14	n	n	0	0
115	Topographic Features (Coffee Lump Bank)	B-14	n	n	0	0
116	East Flower Garden Bank	B-15	n	n	0	0
117	West Flower Garden Bank	B-15	n	n	0	0
118	Topographic Features (MacNeil Bank)	B-14	n	n	0	0
119	Topographic Features (29 Fathom Bank)	B-14	n	n	0	0
120	Topographic Features (Rankin-1 Bank)	B-14	n	n	0	0
121	Topographic Features (Rankin-2 Bank)	B-14	n	n	0	0
122	Topographic Features (Bright Bank)	B-14	n	n	0	0
123	Topographic Features (Geyer Bank)	B-14	n	n	0	0
124	Topographic Features (Elvers Bank)	B-14	n	n	0	0
125	Topographic Features (McGrail Bank)	B-14	n	n	0	0
126	Sonnier Bank	B-15	n	n	0	0
127	Topographic Features (Bouma Bank)	B-14	n	n	0	0
128	Topographic Features (Rezak Bank)	B-14	n	n	0	0
129	Topographic Features (Sidner Bank)	B-14	n	n	0	0
130	Topographic Features (Parker Bank)	B-14	n	n	0	0
131	Topographic Features (Alderdice Bank)	B-14	n	n	0	0
132	Topographic Features (Fishnet Bank)	B-14	n	n	0	0
133	Topographic Features (Sweet Bank)	B-14	n	n	0	0
134	Topographic Features (Jakkula Bank)	B-14	n	n	0	0
135	Topographic Features (Ewing-1 Bank)	B-14	n	n	0	0
136	Topographic Features (Ewing-2 Bank)	B-14	n	n	0	0
137	Topographic Features (Diaphus Bank)	B-14	n	n	0	0
138	Topographic Features (Sackett Bank)	B-14	n	n	0	0
139	Pinnacle Trend	B-15	1	1	0.01	0.01
140	Chandeleur Islands	B-15	1	1	0.01	0.01
141	Florida Middle Ground	B-15	n	n	0	0

Table A-3. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain offshore environmental resource locations within 10 and 30 days (continued)						
ID #	Offshore Environmental Resource Locations	Figure Showing Resource Location	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
142	Pulley Ridge	B-15	n	n	0	0
143	Madison Swanson	B-15	n	n	0	0
144	Steamboat Lumps	B-15	n	n	0	0
145	Dry Tortugas	B-15	n	n	0	0
146	Tortugas Ecological Reserve (North)	B-15	n	n	0	0
147	Tortugas Ecological Reserve (South)	B-15	n	n	0	0
148	Florida Keys National Marine Sanctuary	B-15	n	n	0	0
149	FL State Waters (both East Coast and Gulf)	B-15	n	n	0	0
150	Key Biscayne National Park	B-15	n	n	0	0
151	Texas Clipper and South Texas Platform - Dive Area (Apr-Nov)	B-16	n	n	0	0
152	Port Lavaca/Liberty Ship Reef - Dive Area (Apr-Nov)	B-16	n	n	0	0
153	High Island - Dive Area (Apr-Nov)	B-16	n	n	0	0
154	West Cameron - Dive Area (Apr-Nov)	B-16	n	n	0	0
155	Galveston Area (Block GA 393) - Dive Area (Apr-	B-16	n	n	0	0
156	Cognac Platform (Block MC 194) - Dive Area	B-17	n	n	0	0
157	Horseshoe Rigs (Block MP 306) - Dive Area (Apr-Nov)	B-17	n	n	0	0
158	Vermilion Area - Dive Area (Apr-Nov)	B-16	n	n	0	0
159	Vermilion Area, South Addition - Dive Area (Apr-Nov)	B-16	n	n	0	0
160	Bay Marchand - Dive Area (Apr-Nov)	B-16	n	n	0	0
161	South Timbalier - Dive Area (Apr-Nov)	B-16	n	1	0	0.01
162	South Timbalier Area, South Addition - Dive Area (Apr-Nov)	B-17	n	n	0	0
163	Panhandle FL - Dive Area (Apr-Nov)	B-17	n	n	0	0
164	Tampa - Dive Area (Apr-Nov)	B-17	n	n	0	0
165	SE FL - Dive Area (Apr-Nov)	B-17	n	n	0	0
166	Daytona Beach - Dive Area (Apr-Nov)	B-17	n	n	0	0
167	Jacksonville - Dive Area (Apr-Nov)	B-17	n	n	0	0
168	Stetson Bank (Apr-Nov)	B-15	n	n	0	0
169	East Flower Garden Bank (Apr-Nov)	B-15	n	n	0	0
170	West Flower Garden Bank (Apr-Nov)	B-15	n	n	0	0
171	Chandeleur Islands (Apr-Nov)	B-15	n	1	0	0.01
172	Tortugas Ecological Reserve (North) (Apr-Nov)	B-15	n	n	0	0
173	Tortugas Ecological Reserve (South) (Apr-Nov)	B-15	n	n	0	0
174	Florida Keys National Marine Sanctuary (Apr-Nov)	B-15	n	n	0	0

Table A-3. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain offshore environmental resource locations within 10 and 30 days (continued)

ID #	Offshore Environmental Resource Locations	Figure Showing Resource Location	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
175	TX State Waters (Nov-Apr)	B-2	n	n	0	0
176	West LA State Waters (Nov-Apr)	B-2	n	1	0	0.01
177	East LA State Waters (Nov-Apr)	B-2	1	1	0.01	0.01
178	MS State Waters (Nov-Apr)	B-2	n	n	0	0
179	AL State Waters (Nov-Apr)	B-2	n	n	0	0
180	FL Panhandle State Waters (Nov-Apr)	B-2	n	n	0	0
181	West FL State Waters (Nov-Apr)	B-2	n	n	0	0
182	Tortugas State Waters (Nov-Apr)	B-2	n	n	0	0
183	Southeast FL State Waters (Nov-Apr)	B-2	n	n	0	0
184	Northeast FL State Waters (Nov-Apr)	B-2	n	n	0	0

Notes: ** = Greater than 99.5%; n = less than 0.5%

Table A-4. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain onshore environmental resource habitats, recreational beaches, or county shorelines within 10 and 30 days

ID #	Onshore Environmental Resource Locations	Figure Showing Resource	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
1	Cameron, TX	B-3	n	n	0	0
2	Willacy, TX	B-4	n	n	0	0
3	Kenedy, TX	B-3	n	n	0	0
4	Kleberg, TX	B-4	n	n	0	0
5	Nueces, TX	B-3	n	n	0	0
6	Aransas, TX	B-4	n	n	0	0
7	Calhoun, TX	B-3	n	n	0	0
8	Matagorda, TX	B-4	n	n	0	0
9	Brazoria, TX	B-3	n	n	0	0
10	Galveston, TX	B-4	n	n	0	0
11	Chambers, TX	B-3	n	n	0	0
12	Jefferson, TX	B-4	n	n	0	0
13	Cameron, LA	B-3	n	n	0	0
14	Vermilion, LA	B-4	n	n	0	0
15	Iberia, LA	B-3	n	n	0	0
16	St. Mary, LA	B-4	n	n	0	0
17	Terrebonne, LA	B-3	n	n	0	0
18	Lafourche, LA	B-4	n	n	0	0
19	Jefferson, LA	B-3	n	n	0	0
20	Plaquemines, LA	B-4	1	1	0.01	0.01
21	St. Bernard, LA	B-3	n	n	0	0
22	Hancock, MS	B-4	n	n	0	0
23	Harrison, MS	B-3	n	n	0	0
24	Jackson, MS	B-4	n	n	0	0
25	Mobile, AL	B-3	n	n	0	0
26	Baldwin, AL	B-4	n	n	0	0
27	Escambia, FL	B-3	n	n	0	0
28	Santa Rosa, FL	B-4	n	n	0	0
29	Okaloosa, FL	B-3	n	n	0	0
30	Walton, FL	B-4	n	n	0	0
31	Bay, FL	B-3	n	n	0	0
32	Gulf, FL	B-4	n	n	0	0
33	Franklin, FL	B-3	n	n	0	0
34	Wakulla, FL	B-4	n	n	0	0
35	Jefferson, FL	B-3	n	n	0	0
36	Taylor, FL	B-4	n	n	0	0
37	Dixie, FL	B-3	n	n	0	0

Table A-4. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain onshore environmental resource habitats, recreational beaches, or county shorelines within 10 and 30 days (continued)

ID #	Onshore Environmental Resource Locations	Figure Showing Resource	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
38	Levy, FL	B-4	n	n	0	0
39	Citrus, FL	B-3	n	n	0	0
40	Hernando, FL	B-4	n	n	0	0
41	Pasco, FL	B-3	n	n	0	0
42	Pinellas, FL	B-4	n	n	0	0
43	Hillsborough, FL	B-3	n	n	0	0
44	Manatee, FL	B-4	n	n	0	0
45	Sarasota, FL	B-3	n	n	0	0
46	Charlotte, FL	B-4	n	n	0	0
47	Lee, FL	B-3	n	n	0	0
48	Collier, FL	B-4	n	n	0	0
49	Monroe, FL	B-3	n	n	0	0
50	Dade, FL	B-4	n	n	0	0
51	Broward, FL	B-3	n	n	0	0
52	Palm Beach, FL	B-4	n	n	0	0
53	Martin, FL	B-3	n	n	0	0
54	St. Lucie, FL	B-4	n	n	0	0
55	Indian River, FL	B-3	n	n	0	0
56	Brevard, FL	B-4	n	n	0	0
57	Volusia, FL	B-3	n	n	0	0
58	Flagler, FL	B-4	n	n	0	0
59	St. Johns, FL	B-3	n	n	0	0
60	Duval, FL	B-4	n	n	0	0
61	Nassau, FL	B-3	n	n	0	0
62	TX	B-1	n	n	0	0
63	LA	B-1	1	2	0.01	0.02
64	MS	B-1	n	n	0	0
65	AL	B-1	n	n	0	0
66	FL	B-1	n	n	0	0
67	Tamaulipas, Mexico	B-1	n	n	0	0
68	Veracruz-Llave, Mexico	B-1	n	n	0	0
69	Tabasco, Mexico	B-1	n	n	0	0
70	Campeche, Mexico	B-1	n	n	0	0
71	Yucatan, Mexico	B-1	n	n	0	0
72	Quintana Roo, Mexcio	B-1	n	n	0	0
73	Belize (country)	B-1	n	n	0	0
74	Cuba	B-1	n	n	0	0
75	West Indian Manatee Habitat	B-5	n	n	0	0

Table A-4. Probabilities (expressed as percent chance) of one or more offshore spills greater than or equal to 1,000 barrels occurring from a proposed action in the Eastern GOM Planning Area and contacting certain onshore environmental resource habitats, recreational beaches, or county shorelines within 10 and 30 days (continued)						
ID #	Onshore Environmental Resource Locations	Figure Showing Resource	Probability (%)		Mean	
			10 days	30 days	10 days	30 days
76	West Indian Manatee Sporadic Habitat (Apr-Oct)	B-5	n	1	0	0.01
77	West Indian Manatee Rare Habitat (Apr-Oct)	B-5	n	1	0	0.01
78	Alabama Beach Mouse Habitat	B-6	n	n	0	0
79	Perdido Key Beach Mouse Habitat	B-6	n	n	0	0
80	Santa Rosa Beach Mouse Habitat	B-6	n	n	0	0
81	Choctawhatchee Beach Mouse Habitat	B-6	n	n	0	0
82	St. Andrews Beach Mouse Habitat	B-6	n	n	0	0
83	Southeastern Beach Mouse Habitat	B-6	n	n	0	0
84	Anastasia Island Beach Mouse Habitat	B-6	n	n	0	0
85	Smalltooth Sawfish Critical Habitat	B-7	n	n	0	0
86	Short Nose Sturgeon Habitat (Sep-Mar)	B-8	n	n	0	0
87	Gulf Sturgeon Critical Habitat	B-9	n	1	0	0.01
88	Gulf Sturgeon Habitat	B-8	1	2	0.01	0.02
89	TX Coastal Bend Beach Area	B-10	n	n	0	0
90	TX Matagorda Beach Area	B-10	n	n	0	0
91	TX Galveston Beach Area	B-10	n	n	0	0
92	TX Sea Rim State Park	B-10	n	n	0	0
93	LA Beach Areas	B-10	n	n	0	0
94	AL/MS Gulf Islands	B-10	n	n	0	0
95	AL Gulf Shores	B-10	n	n	0	0
96	FL Panhandle Beach Area	B-10	n	n	0	0
97	FL Big Bend Beach Area	B-10	n	n	0	0
98	FL Southwest Beach Area	B-10	n	n	0	0
99	FL Ten Thousand Islands Area	B-10	n	n	0	0
100	FL Southeast Beach Area	B-10	n	n	0	0
101	FL Centraleast Beach Area	B-10	n	n	0	0
102	FL Northleast Beach Area	B-10	n	n	0	0
Notes: ** = Greater than 99.5%; n = less than 0.5%						

Appendix B. Oil-Spill Risk Analysis Figures

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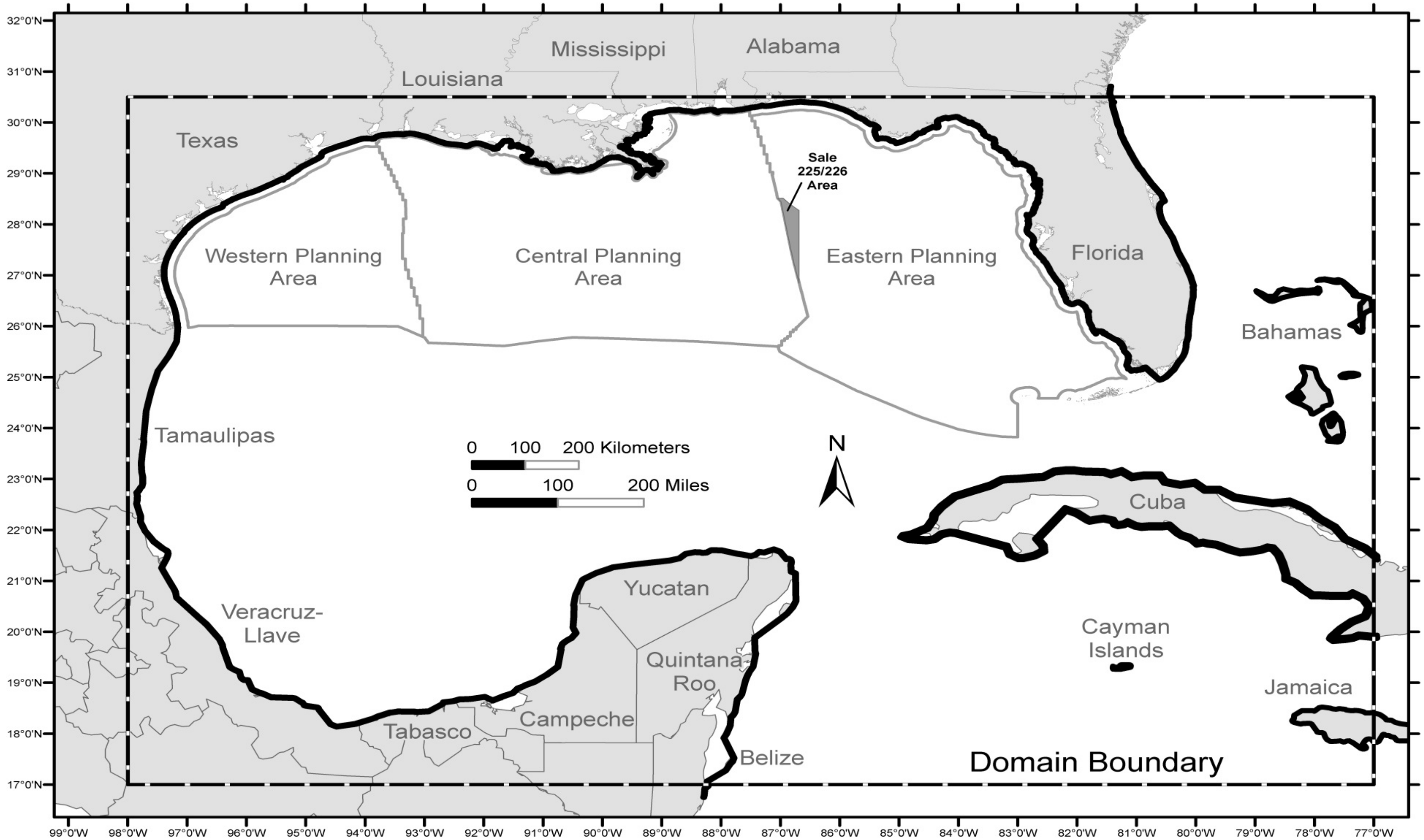

Figure B-1. Domain, planning areas, proposed sale area, and locations of countries and U.S. and Mexican states.

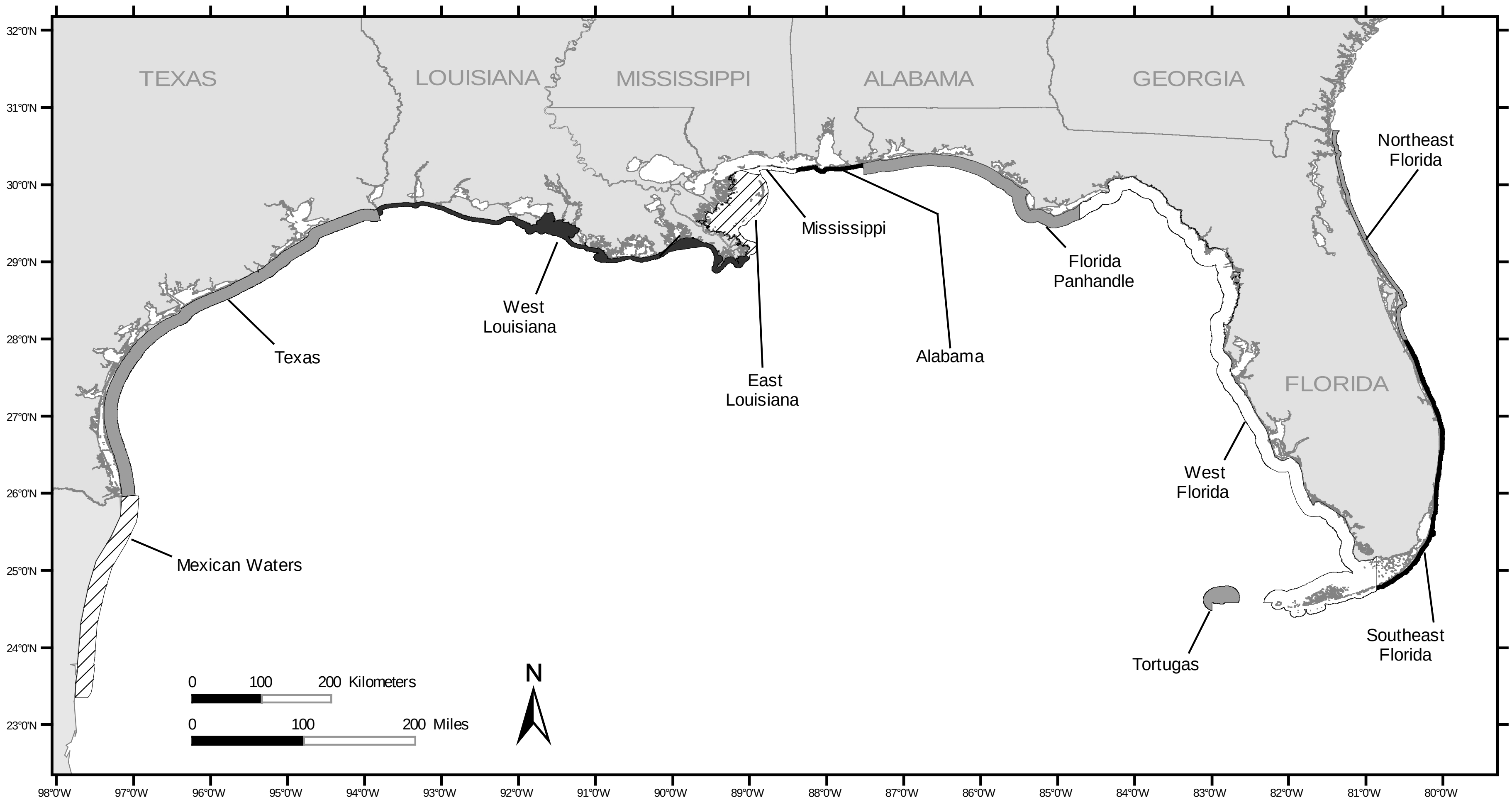

Figure B-2. Locations of state offshore waters for Mexico, Texas, Louisiana, Mississippi, Alabama, and Florida.

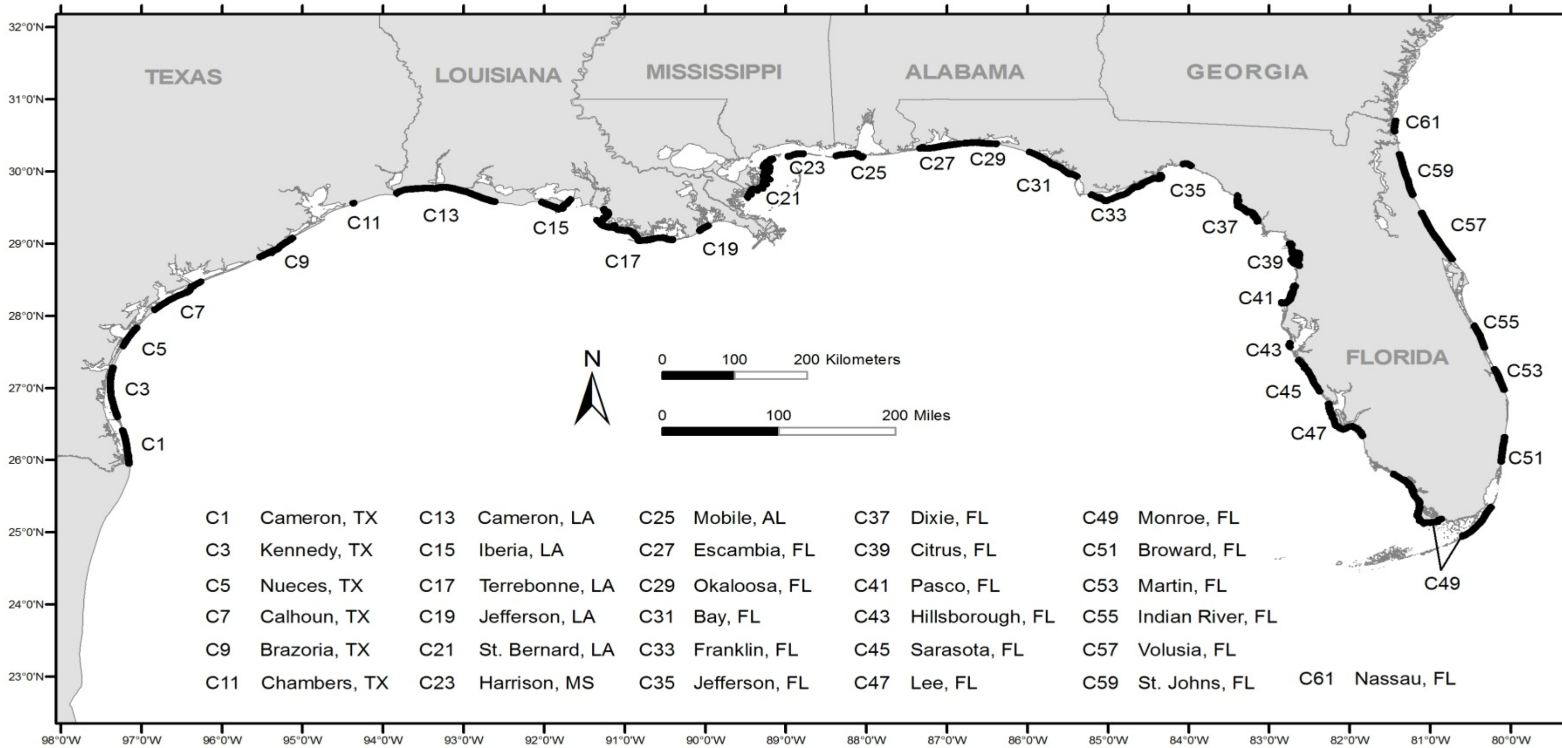

Figure B-3. Locations of Gulf of Mexico counties and parishes (set 1).

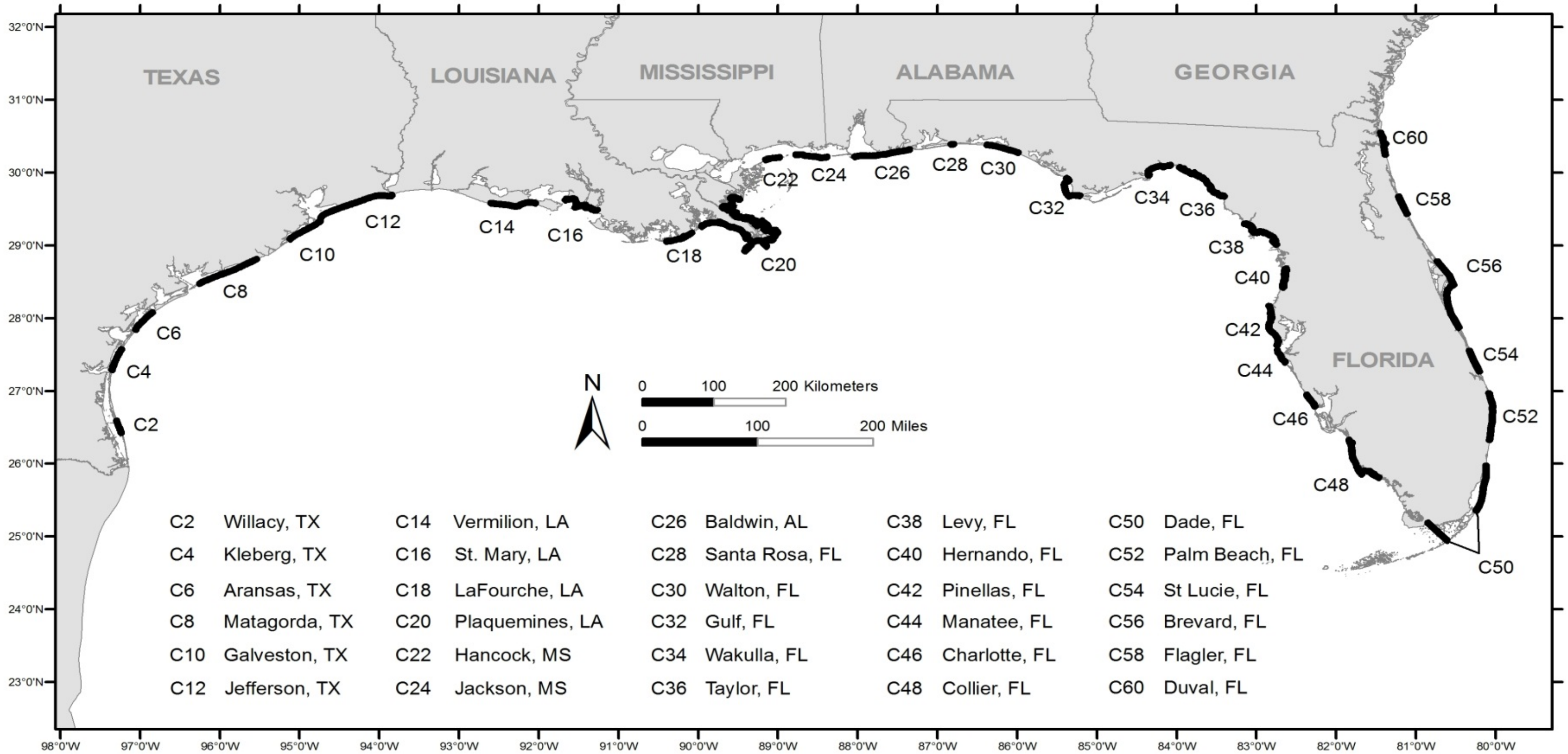

Figure B-4. Locations of Gulf of Mexico counties and parishes (set 2).

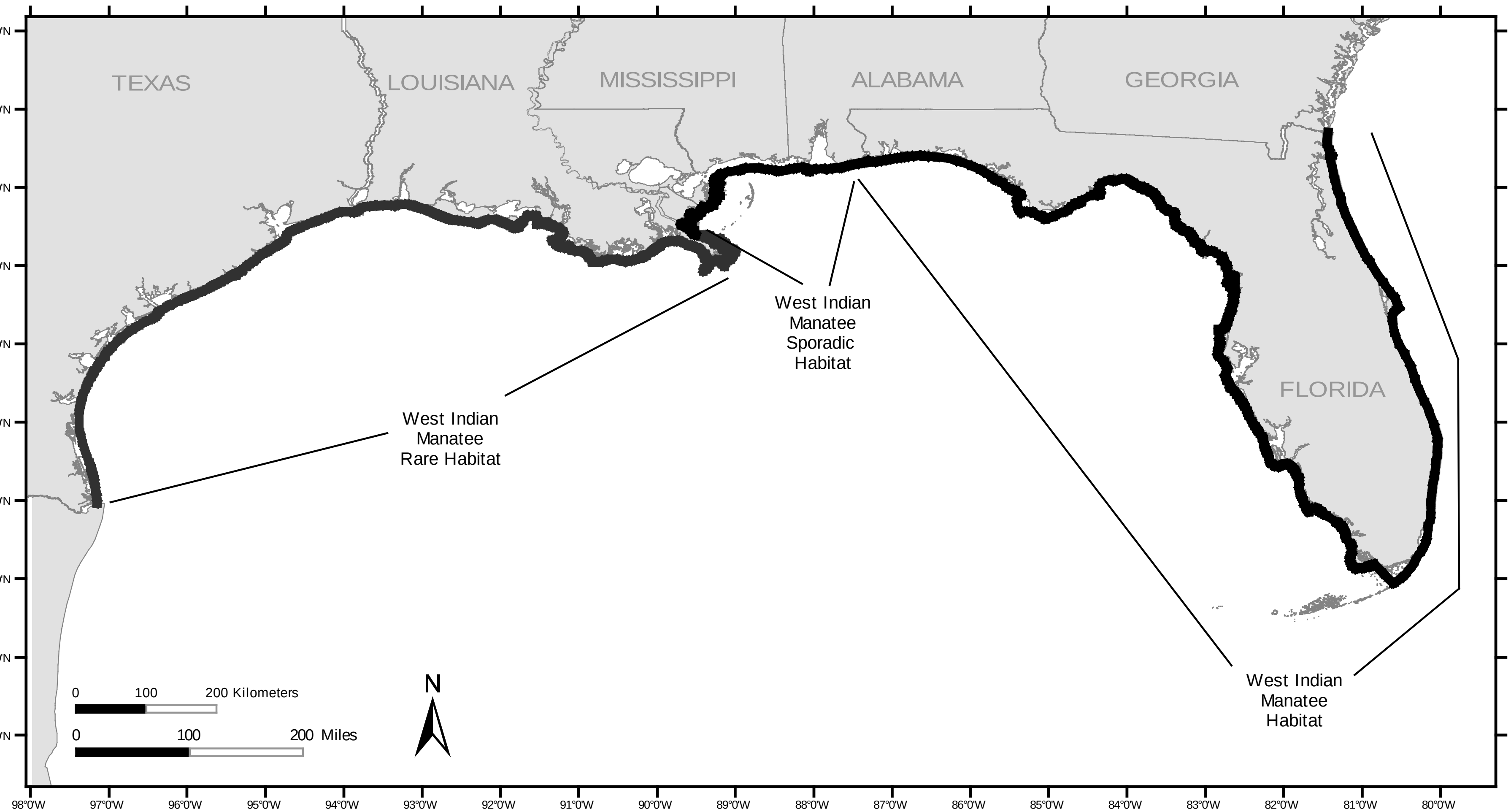

Figure B-5. Locations of manatee habitat.

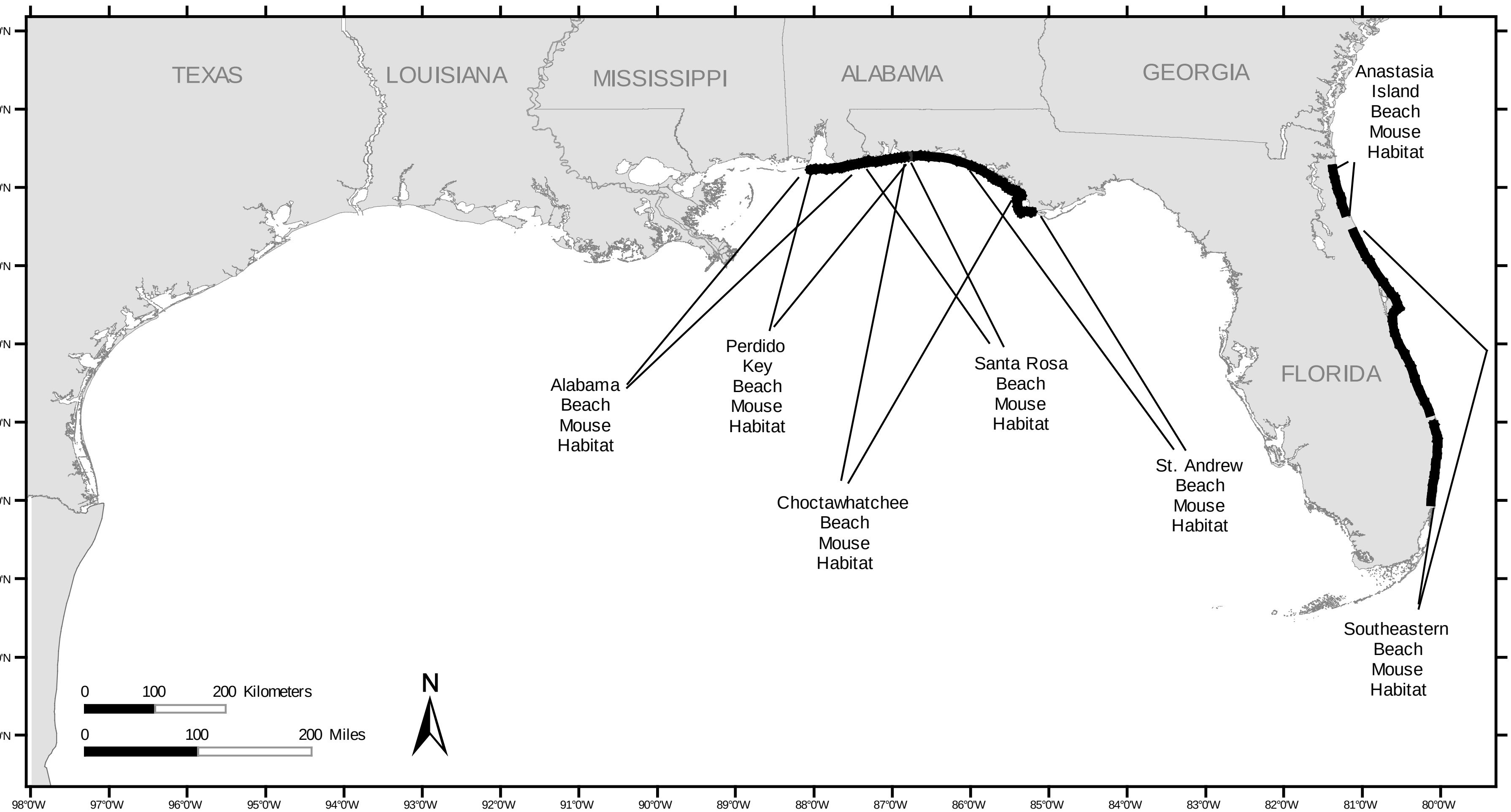

Figure B-6. Locations of beach mice habitat.

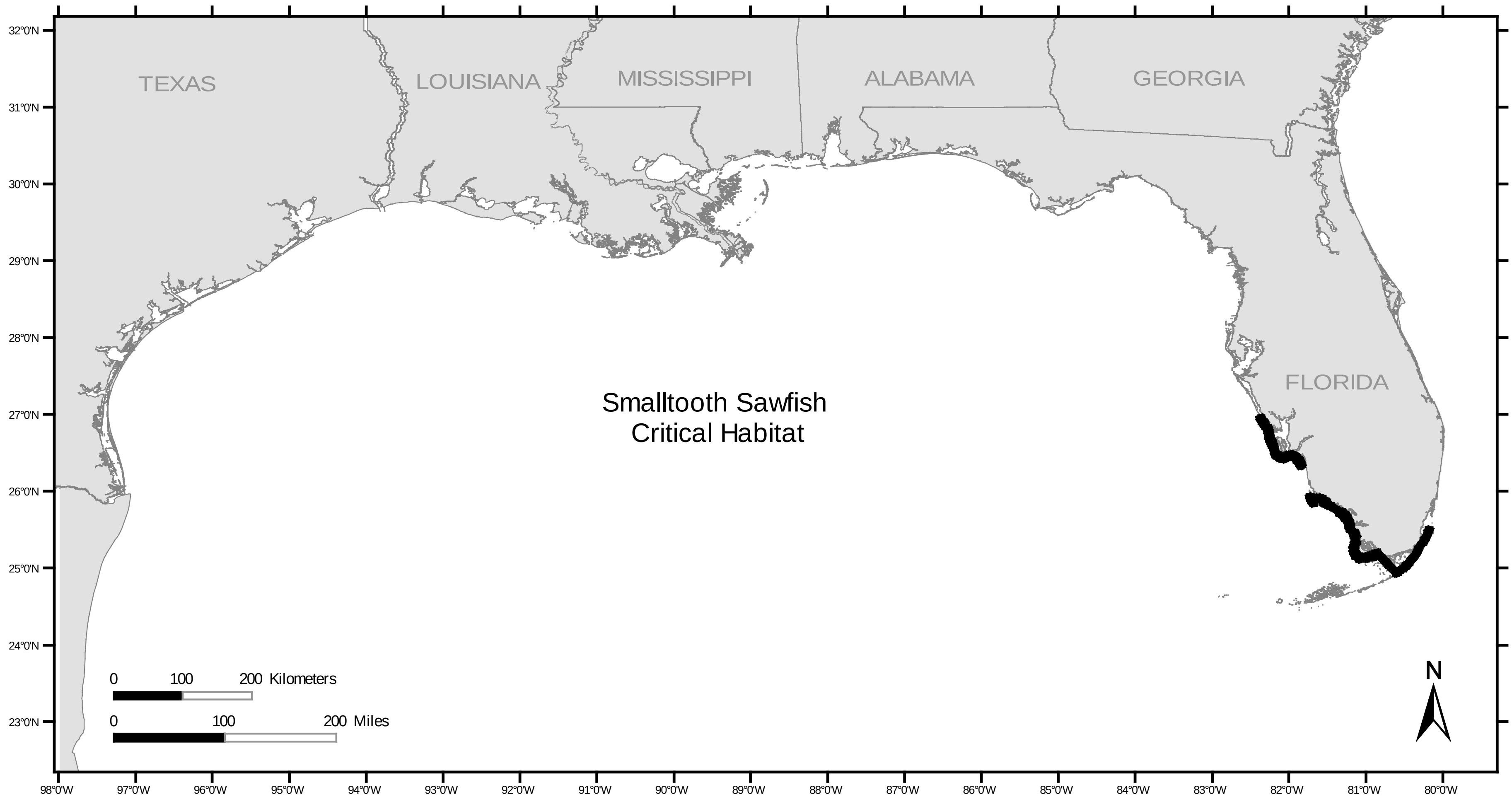

Figure B-7. Locations of smalltooth sawfish critical habitat.

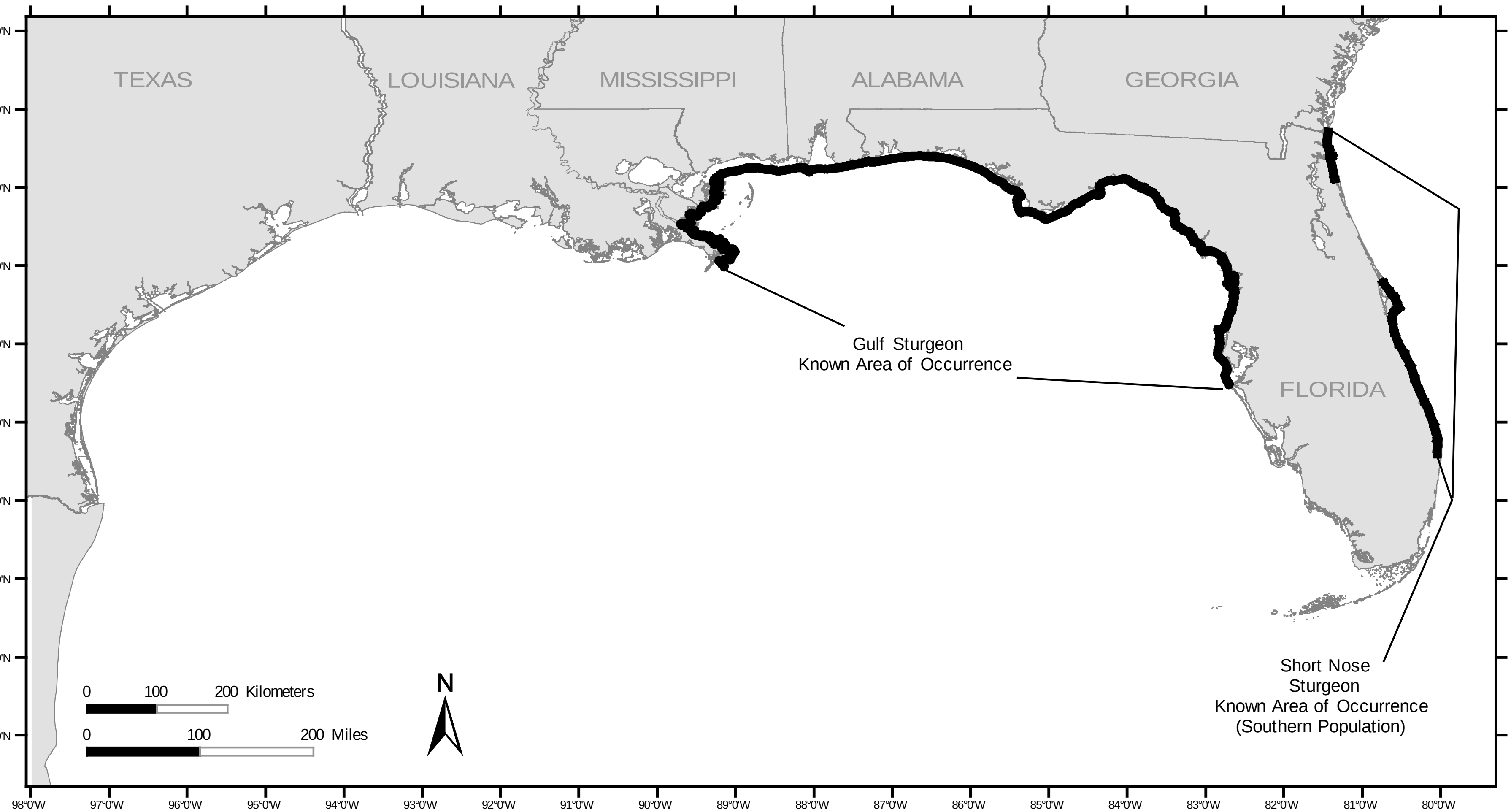

Figure B-8. Locations of Gulf sturgeon and short nose sturgeon known areas of occurrence.

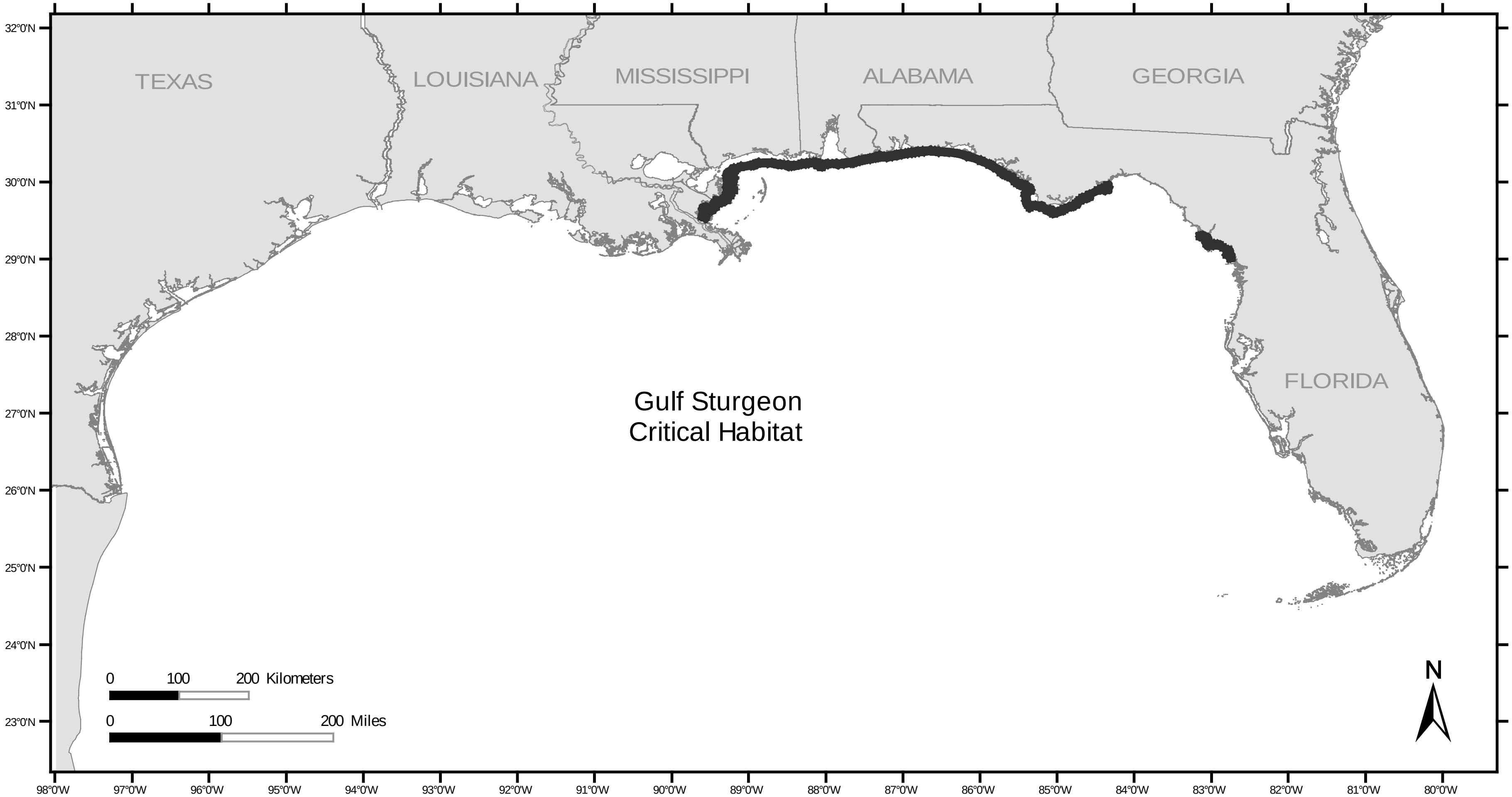

Figure B-9. Locations of Gulf sturgeon critical habitat.

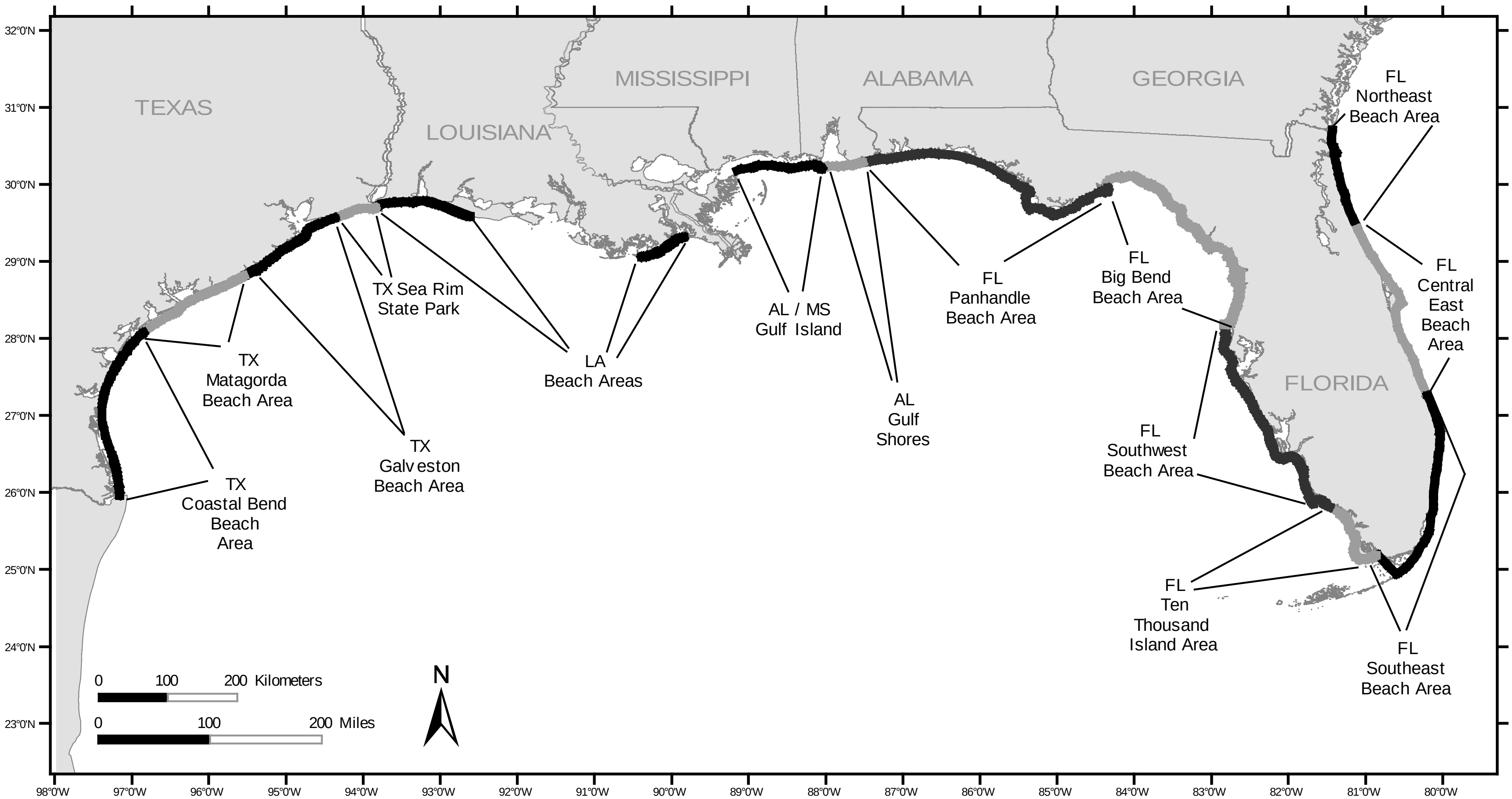

Figure B-10. Locations of recreational beaches.

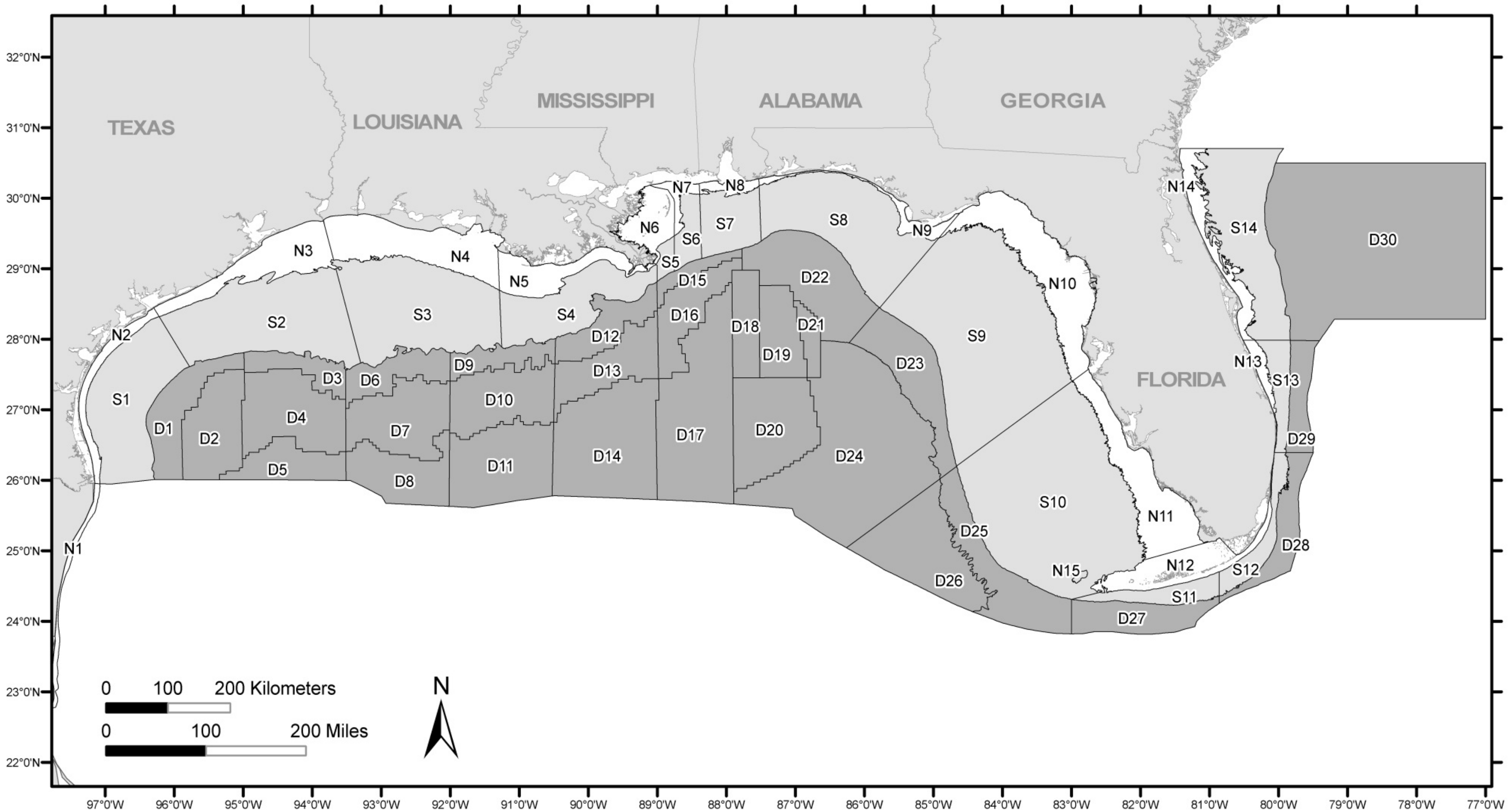

Figure B-11. Locations of nearshore (“N”, 0-20 m), shelf (“S”, 20-300 m), and deepwater (“D”, 300 m to outer jurisdiction) seafloor polygons.

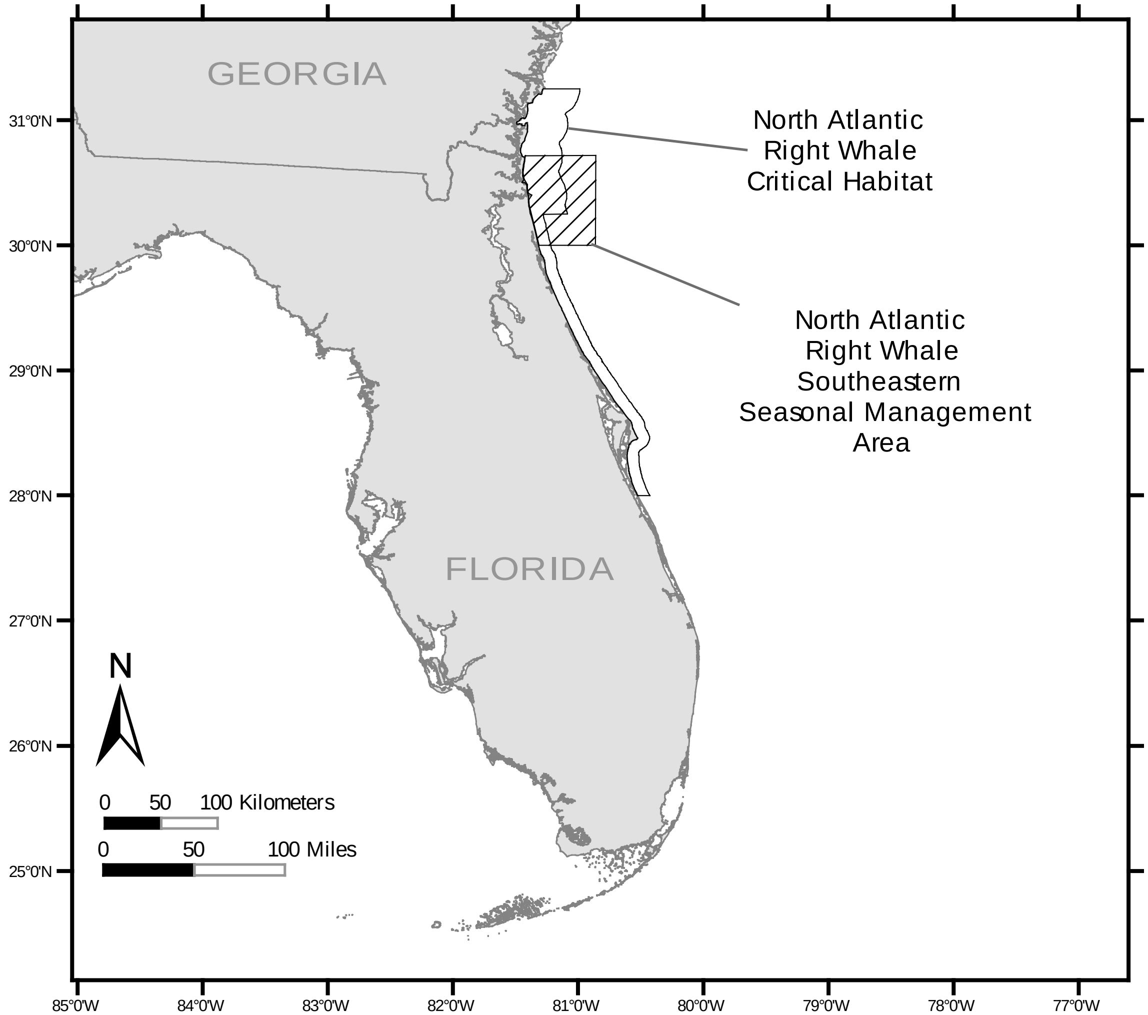

Figure B-12. Locations of North Atlantic right whale critical habitat and southeastern seasonal management area.

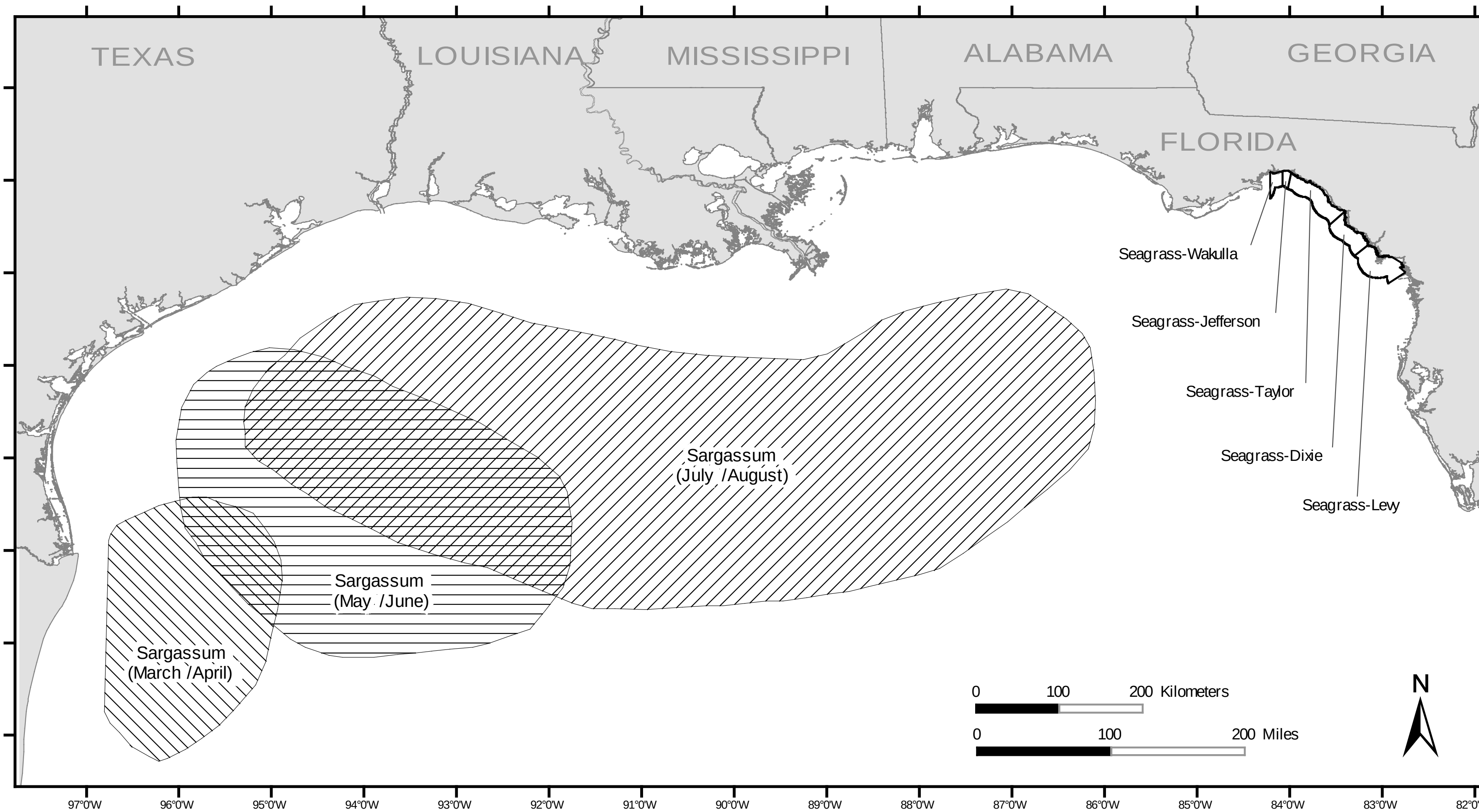

Figure B-13. Locations of Sargassum and Seagrass.

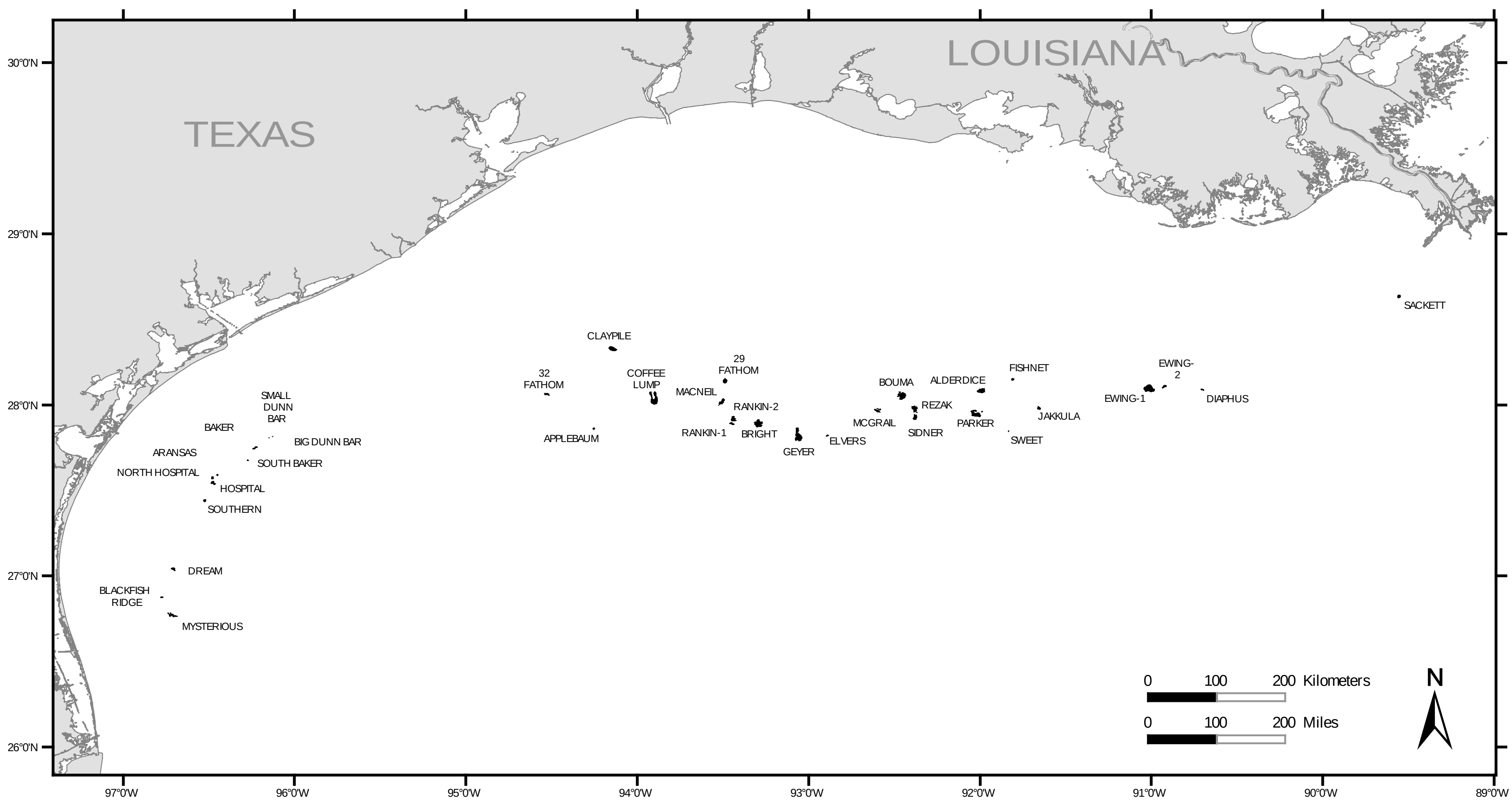

Figure B-14. Locations of topographic features.

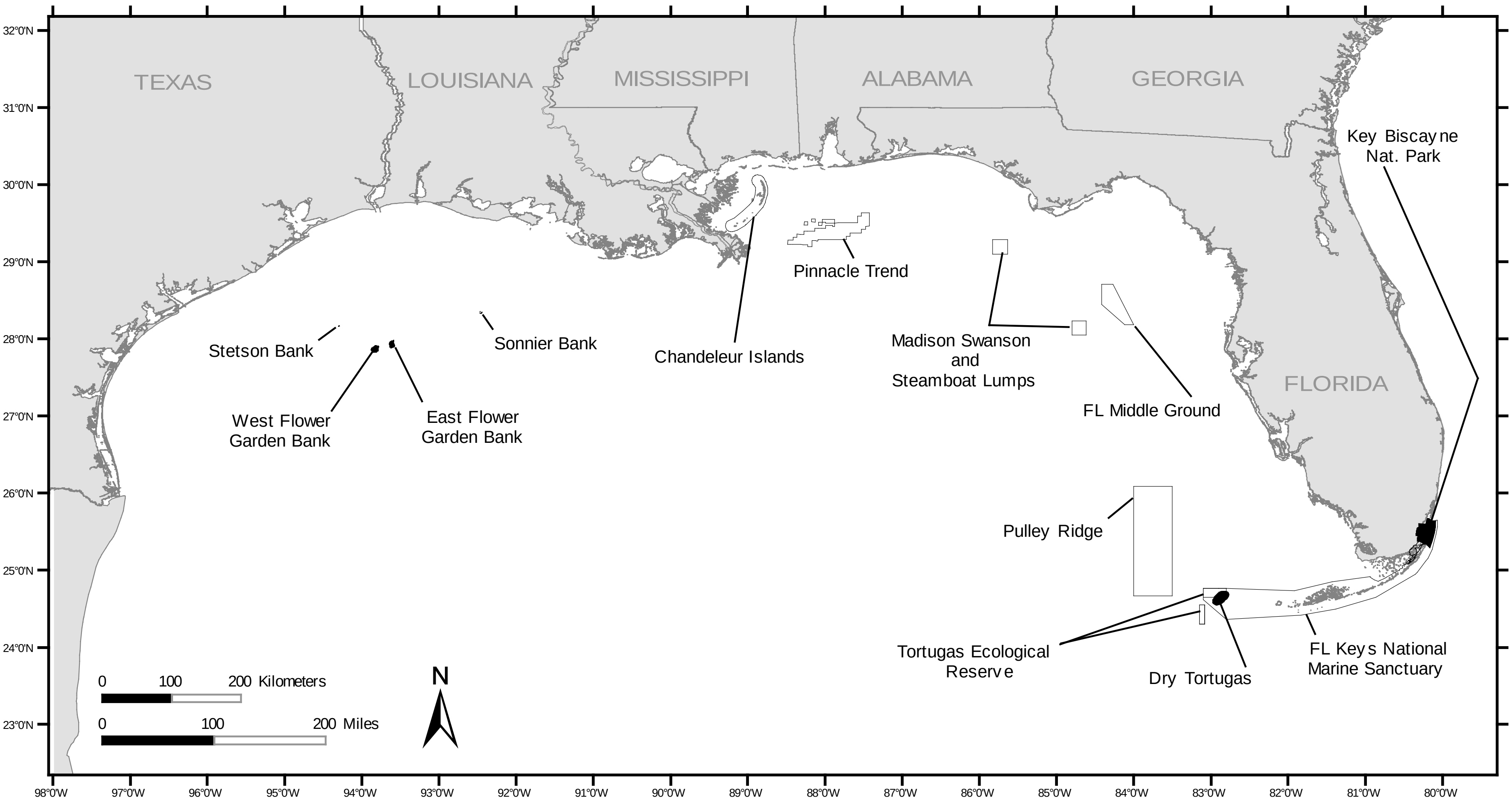

Figure B-15. Locations of Habitat Areas of Particular Concern (HAPC).

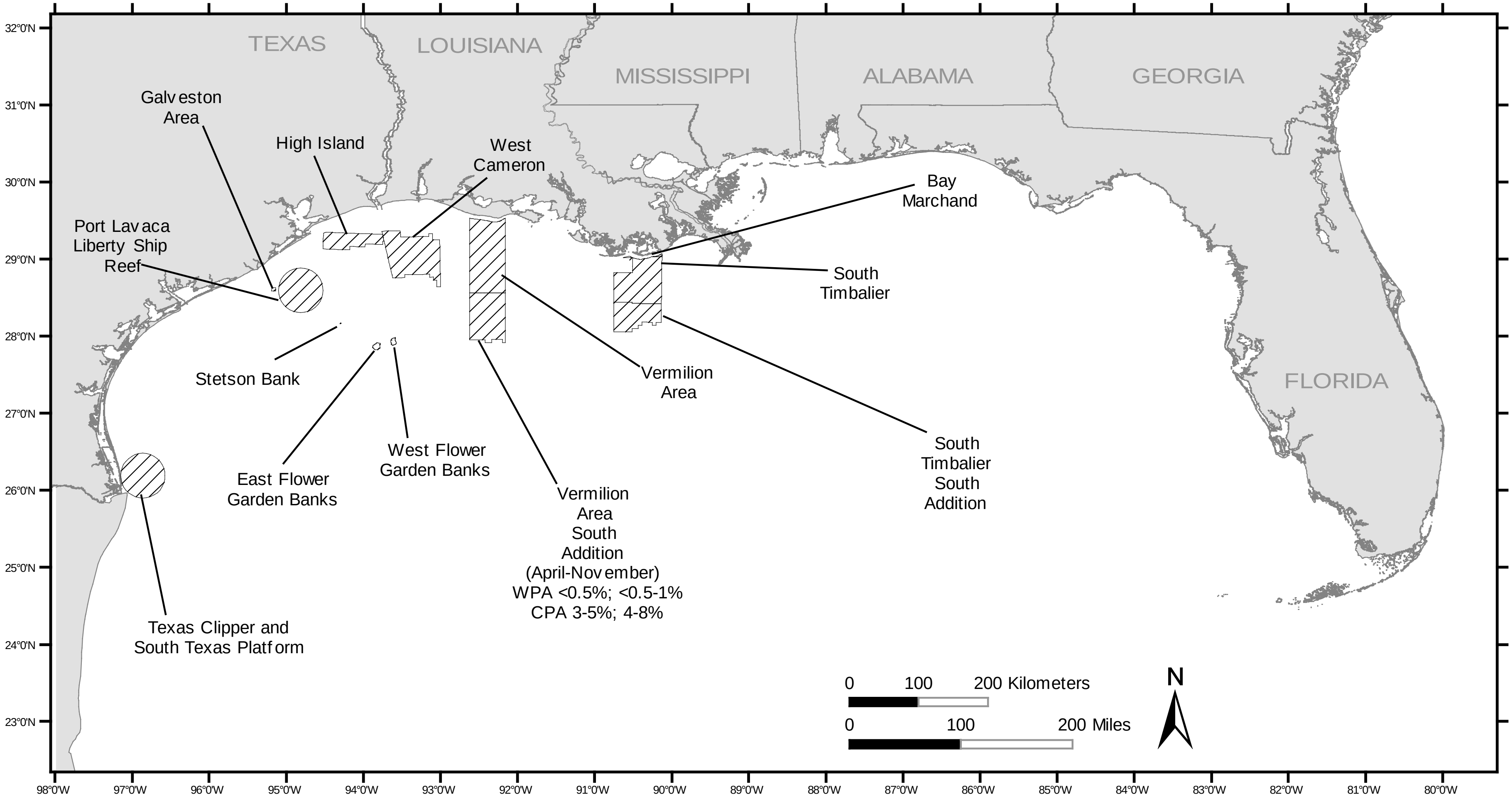

Figure B-16. Locations of recreational dive areas in the western Gulf of Mexico.

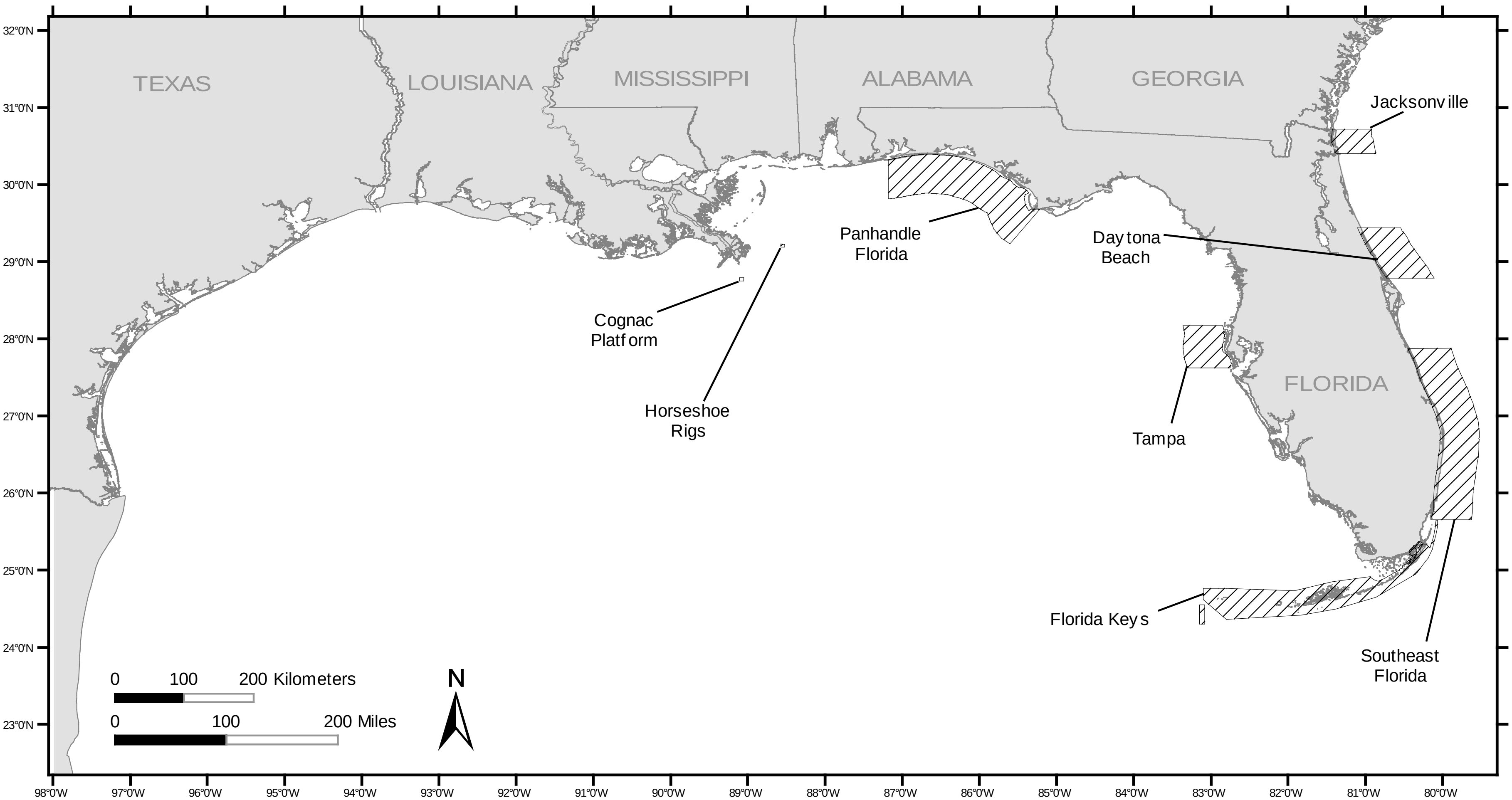

Figure B-17. Locations of recreational dive areas in the eastern Gulf of Mexico.

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The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the sound use of our land and water resources, protecting our fish, wildlife and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island communities.

The Bureau of Ocean Energy Management

The Bureau of Ocean Energy Management (BOEM) works to manage the exploration and development of the nation's offshore resources in a way that appropriately balances economic development, energy independence, and environmental protection through oil and gas leases, renewable energy development and environmental reviews and studies.