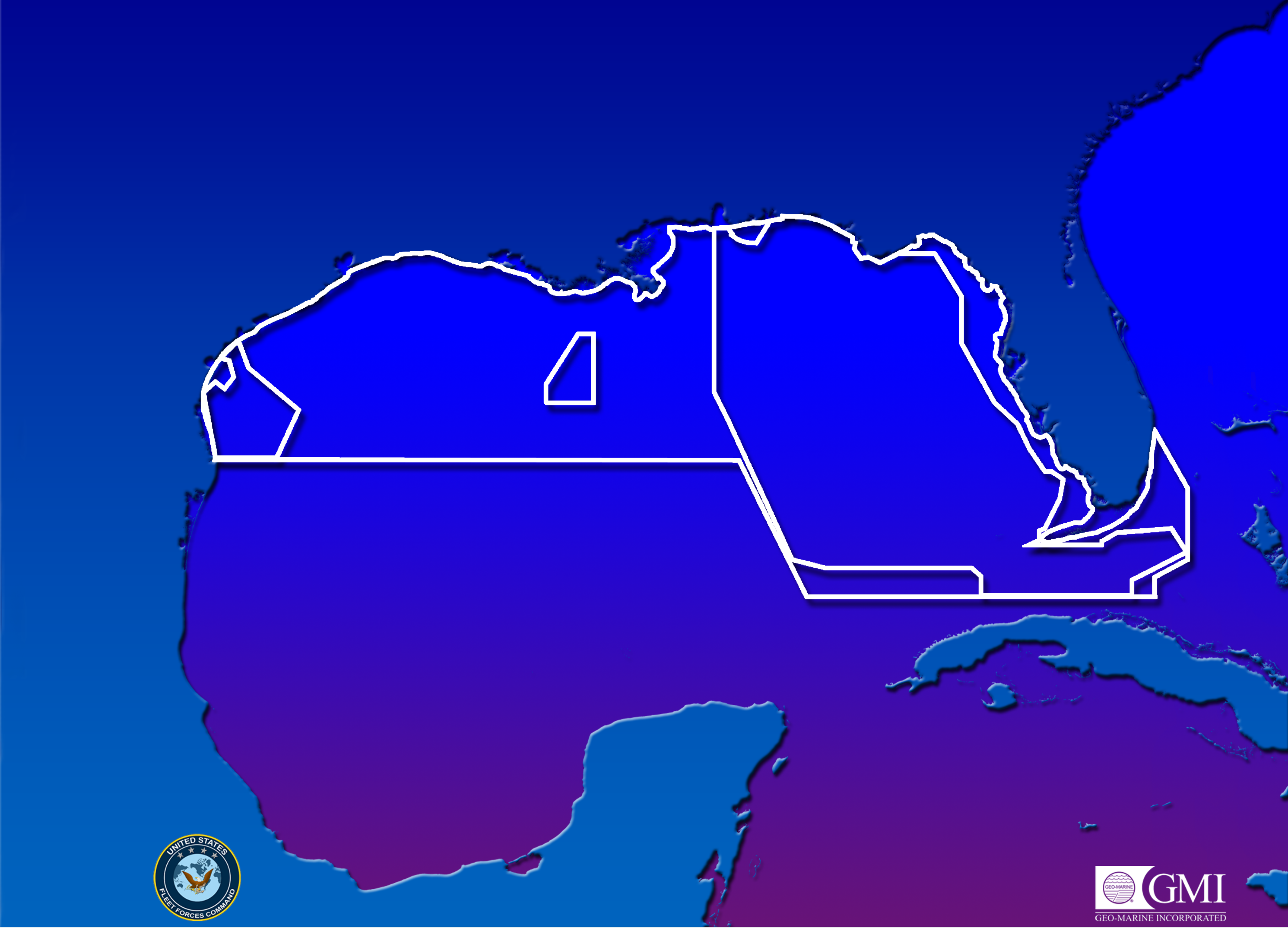
NAVY OPAREA DENSITY ESTIMATES (NODE) FOR THE GOMEX OPAREA

FINAL REPORT

AUGUST 2007



GEO-MARINE INCORPORATED

CONTACT:
NAVAL FACILITIES ENGINEERING COMMAND, ATLANTIC
ATTN: MR. JOEL BELL, CODE EV52JB
6506 HAMPTON BOULEVARD, BUILDING A
NORFOLK, VA 23508-1278
JOEL.T.BELL@NAVY.MIL
TELEPHONE: 757.322.4854

PREPARED FOR:
DEPARTMENT OF THE NAVY,
U.S. FLEET FORCES COMMAND

CONTRACT:N62470-02-9997
TASK ORDER: 0046

NAVY OPAREA DENSITY ESTIMATES (NODE) FOR THE GOMEX OPAREA

FINAL REPORT
AUGUST 2007

For More Information Contact:
Naval Engineering Command, Atlantic
Attn: Mr. Joel T. Bell
6506 Hampton Boulevard, Building A
Norfolk, Virginia 23508-1278
Joel.T.Bell@navy.mil
757.322.4854

Prepared By:
Geo-Marine, Inc.
2201 Avenue K, Suite A2
Plano, Texas 75074

Prepared For:
Department of the Navy,
Contract: N62470-02-D-9997
Task Order: 0046

Suggested Citation: DON (Department of the Navy), 2007. Navy OPAREA Density Estimates (NODE) for the GOMEX OPAREA. Naval Facilities Engineering Command, Atlantic; Norfolk, Virginia. Contract N62470-02-D-9997, Task Order 0046. Prepared by Geo-Marine, Inc., Hampton, Virginia.

Title Page Photograph: Dagmar Fertl

TABLE OF CONTENTS

TABLE OF CONTENTS
(continued)

Page

LIST OF FIGURES

This page intentionally left blank

LIST OF TABLES

This page intentionally left blank

LIST OF ACRONYMS AND ABBREVIATIONS

θ	Angle
°	Degrees
%	Percent
AUTEC	Atlantic Undersea Test and Evaluation Center
AVHRR	Advanced Very High-Resolution Radiometer
BSS	Beaufort Sea State
C	Celsius
chl *a*	Chlorophyll *a*
CREEM	Centre for Research into Ecological and Environmental Modelling
CV	Coefficient of Variation
DoN	Department of the Navy
DSM	Density Surface Model
EEZ	Exclusive Economic Zone
EGMTTA	Eastern Gulf of Mexico Testing and Training Areas
ESA	Endangered Species Act
EWTA	Eglin Water Test Areas
g (0)	Probability of Detecting an Animal on the Survey Trackline
GAM	Generalized Additive Model
GCV	Generalized Cross Validation
GMI	Geo-Marine, Inc.
GOMEX	Gulf of Mexico
km	Kilometer(s)
km^2	Square Kilometer(s)
m	Meter(s)
mg/m^3	Milligram(s) Per Cubic Meter
MMPA	Marine Mammal Protection Act
MRA	Marine Resources Assessment
NASA	National Aeronautics and Space Administration
Navy	United States Navy
NE	Northeast
NEPA	National Environmental Policy Act
NM	Nautical Mile(s)
NMFS	National Marine Fisheries Service
NMFS-SEFSC	National Marine Fisheries Service-Southeast Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
NODE	Navy Operating Area Density Estimate
OPAREA	Operating Area
PO.DAAC	Physical Oceanography Distributed Active Archive Center
PBR	Potential Biological Removal
PSD	Perpendicular Sighting Distance
RSM	Response Surface Model
SAR	Stock Assessment Report
SEAMAP	Southeast Area Monitoring and Assessment Program
SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
sec	Second(s)
spp.	Species
SST	Sea Surface Temperature
TACTS	Tactical Aircrew Combat Training System
U.S.	United States
USAF	United States Air Force
VHF	Very High Frequency
yr	Year

This page intentionally left blank

ACKNOWLEDGMENTS

Geo-Marine, Inc. thanks Drs. Lance Garrison and Keith Mullin with the National Marine Fisheries Service-Southeast Fisheries Science Center (NMFS-SEFSC) for providing recent aerial and shipboard survey data used to estimate marine mammal and sea turtle densities. Geo-Marine, Inc. appreciates all of the assistance and input from Drs. Eric Rexstad, Louise Burt, Len Thomas, Steve Buckland, and David Borchers with the Centre for Research into Ecological and Environmental Modelling (CREEM).

This page intentionally left blank

1.0 INTRODUCTION

The Department of the Navy (DoN) is committed to demonstrating environmental stewardship while executing its national defense mission. DoN is also responsible for compliance with a suite of federal environmental and natural resources laws and regulations, including the National Environmental Policy Act (NEPA), the Marine Mammal Protection Act (MMPA), and the Endangered Species Act (ESA). In order to comply with these mandates, up-to-date, area-specific marine mammal and sea turtle density estimates for the Operating Areas (OPAREAs) and adjacent regions were the Navy trains are required.

The United States (U.S.) Navy (Navy) Fleet Forces Command contracted Geo-Marine, Inc. (GMI) to prepare a Navy OPAREA Density Estimate (NODE) report for marine mammals and sea turtles found in the U.S. Gulf of Mexico (GOMEX), including the GOMEX Complex, the Key West Complex, and the Eastern GOMEX Testing and Training Areas (EGMTTA) (DoN 2007b). For the purposes of this NODE report, the GOMEX Complex, the Key West Complex, EGMTTA, and their surrounding region (**Figure 1-1**; DoN 2007b) were considered as one unit that is hereinafter referred to as the "GOMEX study area." The goal of this NODE report is to provide a compilation of the most recent data and information on the occurrence, distribution, and density of marine mammals and sea turtles in this area for the purposes of environmental planning and regulatory compliance documentation.

A Marine Resource Assessment (MRA) for the Northeast OPAREAs (DoN 2007b) serves as the foundation reference document upon which this document is built and should be referenced for additional detail on the biology and ecology of each individual species included in this NODE.

Report Organization

This report consists of six chapters:

- *Chapter 1: Introduction*—provides information on the study area, as well as survey coverage;
- *Chapter 2: Methodology*—briefly describes the methods and analytical mechanisms/decisions involved in calculating the density estimates;
- *Chapter 3: Density Estimates*—lists the species and provides relevant distributional ecology information, discusses caveats to density derivations; and presents the density estimates in tabular form;
- *Chapter 4: List of Preparers*—lists all individuals who helped prepare the report;
- *Chapter 5: Literature Cited*—lists the literature cited in this report; and
- *Appendix: Spatial Model Output*—provides the output used to determine model fit.

1.1 LOCATION OF STUDY AREA

The study area for the GOMEX MRA (DoN 2007b) and this density report encompasses the northern or U.S. waters of the GOMEX, including the Florida Straits. The GOMEX study area occupies waters offshore of all five U.S. GOMEX coast states: Texas, Louisiana, Mississippi, Alabama, and Florida and extends seaward to the U.S. exclusive economic zone (EEZ) (**Figure 1-1**). Covering 384,152 square kilometers (km^2) of the marine environment, the GOMEX study area spans coastal to deepwater habitats and encompasses waters shallower than 10 meters (m) in bottom depth near the Florida Keys to waters greater than 3,000 m in bottom depth near the center of the GOMEX.

Usage of the Navy OPAREAs in the GOMEX and Key West complexes is scheduled by either the U.S. Air Force (USAF) or Navy. All Eglin Water Test Areas (EWTAs) (**Figure 1-1**) as well as Warning Areas W-151 (Panama City OPAREA), W-168, and W-470 are scheduled by the USAF, while W-228 (Corpus Christi OPAREA), W-92 (New Orleans OPAREA), W-155 (Pensacola OPAREA), and the Key West Complex (including W-174, W-465, Key West Tactical Aircrew Combat Training System [TACTS], Bonefish, and the Key West OPAREA) are scheduled by the Navy. Further information on the GOMEX and Key West complexes may be found in the MRA for the Eastern GOMEX (DoN 2003).

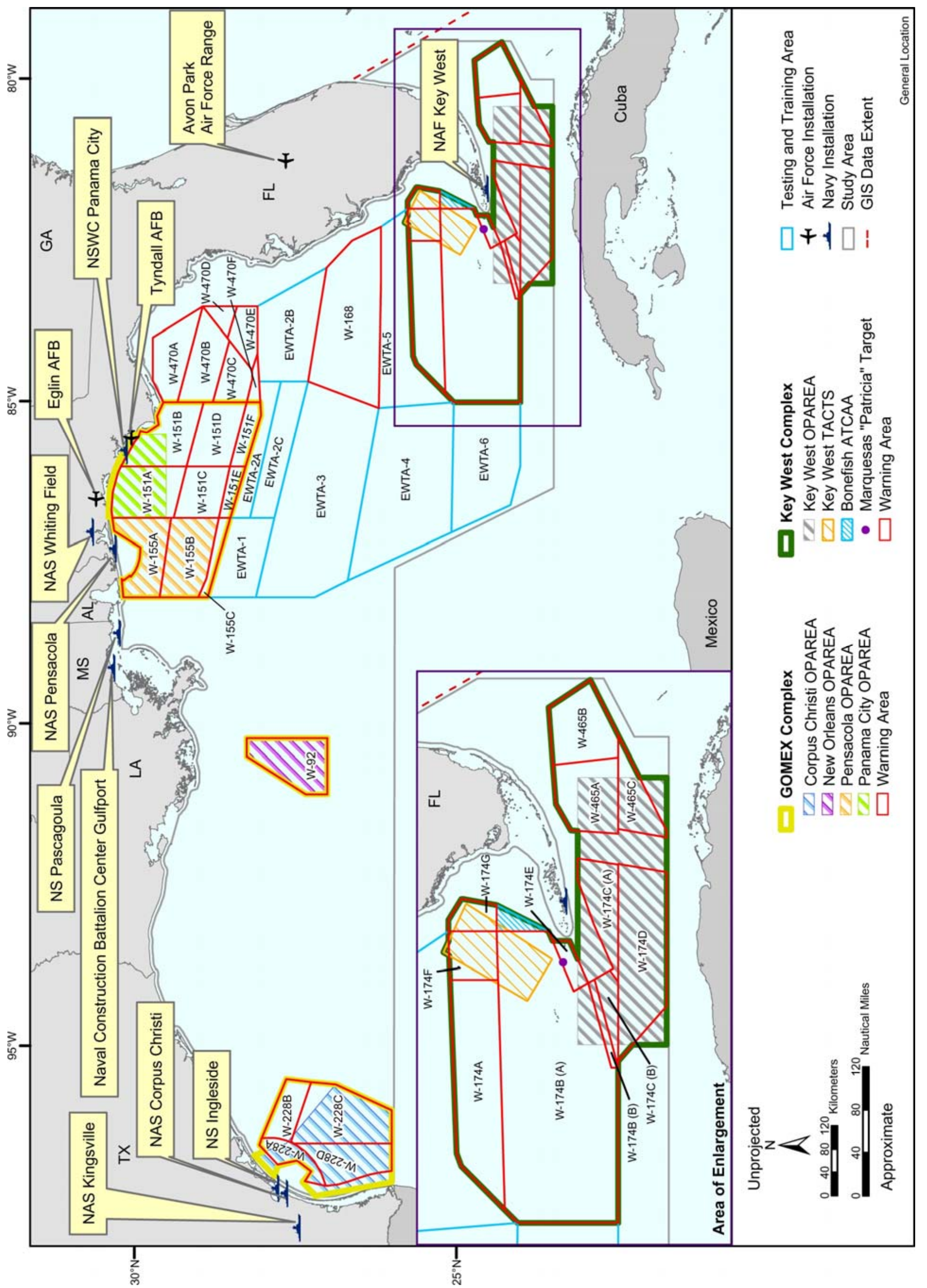


Figure 1-1. The GOMEX study area and the Navy's testing and training areas.

Two small islands belonging to the Commonwealth of The Bahamas, located approximately 70 nautical miles (NM) south of mainland Florida, lie within the study area for the GOMEX MRA and this density report. The islands are called Cay Sal and Elbow Cay; they are uninhabited. Cay Sal Bank, the submarine bank upon which these and numerous smaller islands sit, extends beyond the study area and is a popular, albeit remote, site for recreational diving. The MRA for Southeastern Florida and Atlantic Undersea Test and Evaluation Center (AUTEC)-Andros OPAREA (DoN 2007a) should be referred to for a description of the marine resources associated with The Bahamas. No further discussion of these or any other Bahamian islands will appear in this report.

This page intentionally left blank

2.0 METHODOLOGY

Density estimates for cetaceans were either modeled from data or derived from abundance estimates found in the National Oceanic and Atmospheric Administration (NOAA) stock assessment report (SAR; (Waring et al. 2007) and in this report, are referred to as SAR-derived estimates. The abundance estimates in the SAR are from Mullin and Fulling (2004). **Section 2.5** describes the model-based approach, while **Section 2.8** discusses the process for SAR-derived estimates.

2.1 General Introduction

The statistical concept to appreciate in estimating animal abundance or density at small spatial scales is the distinction between model- and design-based approaches. Uncertainty in population assessment can be addressed in either of these two methods. In the design-based approach, predicting the number of animals in areas where surveys (sampling effort) did not occur is taken into account through survey design (e.g., “representative samples”). In a model-based approach, the sampling effort is extrapolated from areas with survey effort to areas of no survey effort using a model.

In this report, GMI used the model-based approach by constructing a model of animal density and applied that model to regions (and/or seasons) where sampling effort (surveys) did not occur. This approach is not perfect, because models are simplifications of the actual biological mechanisms that give rise to animal distribution. However, design-based surveys that apply the usual sampling techniques, such as stratification, cannot provide estimates at the small spatial scales required by the Navy when planning operations.

Regardless of the approach used, numerous comparisons will be made between past density/abundance estimates using designed-based surveys for the GOMEX study area and the recent model-based estimates presented here. Therefore, it is necessary to address various caveats to these different approaches and how the density estimates were generated.

Density Estimates

Animal abundance in the GOMEX study area was recently addressed by Fulling et al. (2003) and Mullin and Fulling (2004); the NOAA marine mammal SAR for the northern GOMEX (Waring et al. 2007) is based on these reports. Individual species density estimates were produced for those species with a sufficient number of sightings to create unique detection functions. Species with insufficient data were not analyzed using models. These species density estimates were derived from the SAR and references within that document (i.e., Mullin and Fulling 2004). Individual species density estimates for seasons lacking survey data were “predicted” using the density surface models (DSMs) presented in **Chapter 3**.

2.1.1 Data Used

2.1.1.1 Cetaceans

For this report, all analyses for cetaceans were based on data collected through the National Marine Fisheries Service-Southeast Fisheries Science Center’s (NMFS-SEFSC) shipboard surveys conducted between 1996 and 2004 (see **Section 2.2**). The earlier surveys (those conducted prior to 2003) were run in conjunction with Southeast Area Monitoring and Assessment Program (SEAMAP) cruises designed as ichthyoplankton sampling surveys. These cruises were designed around the sampling protocol for collecting the ichthyoplankton samples with the marine mammal observations taking place between the sampling stations. This resulted in large tracks of effort that were parallel to the bathymetry. While analyzing these data using a designed-based approach, Mullin and Fulling (2004) deleted these tracklines resulting in a loss of numerous sightings from the dataset for use in the analyses. This was done to avoid surveying areas of animal concentration (along depth contours), thereby creating a potential bias in the density estimate. This is not a concern for model-based approaches. Therefore, all on-effort transects were included in these analyses increasing both the amount of effort and the numbers of sightings. “On-effort” means that the observers were in place and actively searching for cetaceans and/or sea turtles and that the observation platform was on its trackline. The density estimates produced in this report are therefore different, because effort and recorded observations are different.

2.1.1.2 Sea Turtles

Density estimates for sea turtles were calculated using aerial survey data provided by NMFS-SEFSC (see **Section 2.2** for more information) using data collected in Beaufort Sea State (BSS) ≤4 (see specifics below). Estimates were generated for the leatherback turtle, loggerhead turtle, Kemp's ridley turtle, and the group Hardshell Turtles in the same manner as marine mammal species. The species in the group Hardshell Turtles include green, hawksbill, Kemp's ridley turtles, unidentified hardshell turtles, and possible occurrences of the olive ridley turtle (*Lepidochelys olivacea*). Species in this group were pooled together since the numbers of sightings of each species or group were not sufficient to allow spatial modeling. This category did not include leatherback turtles since identification is not difficult. The sea turtle estimates produced are for continental shelf waters only, since only this portion of the study area was covered by aerial surveys.

Estimates were generated for the leatherback turtle, loggerhead turtle, Kemp's ridley turtle, and the group Hardshell Turtles in the same manner as marine mammal species. The species incorporated into the Hardshell Turtles category include green, hawksbill, were pooled together since the numbers of sightings for each species or group did not allow spatial modeling. This category did not include leatherback turtles since identification is not difficult. The sea turtle estimates produced are for continental shelf waters only, since only this portion of the study area was covered by aerial surveys.

2.1.1.3 Age of Data and Annual Variability

All data used for density estimation of cetaceans adhered to the guidelines established by NOAA/National Marine Fisheries Service (NMFS; Wade and Angliss 1997) recommending that no data older than 8 years (yrs) be used to calculate potential biological removal (PBR). These guidelines were not applied to the sea turtle density estimation since there were no current (<8 yrs) surveys that could be used for those analyses.

Data used in these analyses were restricted to the seasons/years for which the surveys were conducted. Temporal and spatial variability is to be expected; this is why these data were analyzed using spatial modeling techniques.

2.2 Description of Survey Effort in the GOMEX Study Area

Shipboard and aerial line-transect surveys conducted by the NMFS-SEFSC in the GOMEX study area provide the on-effort marine mammal and sea turtle sighting data used in this report. For a complete description of the all the surveys, please refer to the source documents listed in **Tables 2-1** and **2-2**, brief descriptions of the surveys are found in the GOMEX MRA (DoN 2007b). Areas of coverage by each survey are depicted in **Figures 2-1** through **2-4**.

Shipboard Surveys—Shipboard surveys were conducted on either the 52 m NOAA Ship *Oregon II* or the 68 m NOAA Ship *Gordon Gunter* and consisted of two types: 1) shelf surveys, which occurred during summer and covered waters between the 10 and 200 m isobaths; and 2) oceanic surveys, typically conducted in the spring between the 200 m isobath and the EEZ. Until 2003, surveys were conducted in conjunction with the SEAMAP cruises. Difficulties with these cruises dealt with non-random survey effort (due to predetermined tracklines) and a lack of complete coverage of the study area due to night time transits. Therefore, all potential animal habitats could not be surveyed in one cruise. Additionally, the survey lines sometimes ran parallel to bathymetry gradients and were excluded from previous analyses. Recent (2003 and 2004) oceanic surveys dedicated to cetacean abundance estimation (using standard line transect survey methodology for cetaceans) were also included in these data. As noted earlier, more information about the surveys can be found in **Table 2-1** and **Figures 2-1** and **2-2**.

Only shipboard surveys were used to estimate densities for cetaceans. The shipboard surveys could not be used to generate reliable density estimates for sea turtles due to the difficulty in spotting them from a ship. Therefore, only aerial surveys were used in the calculation of the density estimates for sea turtles.

Aerial Surveys—Three primary aerial surveys were conducted by the NMFS-SEFSC: GulfCet I, GulfCet II, and the GOMEX surveys. The GulfCet aerial surveys were conducted quarterly; with the study area for GulfCet I encompassed by the longitude of the Florida-Alabama border and the Texas-México border, taking place between the 100 m and 2,000 m isobaths. GulfCet II surveys were biannual surveys covering the shelf and offshore waters (out to the 2,000 m isobath) off Alabama and Florida. The GOMEX surveys were fall surveys that covered bays, sounds, estuaries and shelf waters out to the 200 m isobath. The GOMEX surveys only covered 1/3 of the GOMEX study area each year; and therefore, did not cover all regions in one survey. As noted earlier, more information about the surveys can be found in **Table 2-2** and **Figures 2-3** and **2-4**.

2.3 DATA PREPARATION

All datasets received were standardized for uniformity (ensuring variable names and formats matched, etc.) and run through a series of quality assurance steps. Data sets of identical observation platforms (i.e., aerial or shipboard) were combined regardless of year, season, or location for analysis. This was done to provide a more comprehensive view of the overall distribution and relative density of cetaceans and sea turtles throughout the GOMEX study area.

2.3.1 Preparation of the Sighting Data

During the NMFS-SEFSC surveys, up to three separate species may be recorded for each sighting event. All sightings were identified to the lowest possible level (species). If identification to species level was not possible, then the observation was not included in the analyses, with the exception of species which fell into the three groups of Beaked Whales, *Kogia* species (spp.), and Hardshell Turtles.

2.3.1.1 Seasonal Definitions

Methods for defining the seasonal breakdown for the GOMEX study area are available in DoN (DoN 2007b). The seasons are defined as:

- Winter—December 23 through April 2
- Spring—April 3 through July 1
- Summer—July 2 through September 28
- Fall—September 29 through December 22

The seasons were defined by calculating a mean sea surface temperature (SST) value for a region representing the majority of the study area and plotting the annual change in the mean SST for the region. A fifth-order polynomial curve was fit to the data, and a slope analysis technique was applied to the polynomial curve to divide the calendar year into four seasons based on changes in the SST. Although the dates each of the seasons represents may be different than the standard seasonal definitions, the intuitive meaning for each of the seasons still applies. That is, winter and summer are still the times of year with the lowest and highest SST, respectively, while spring and fall represent transitional periods between the two temperature extremes.

2.3.1.2 Calculation of Survey Effort

Ship survey data provided by the NMFS-SEFSC were collected as a series of latitude and longitude points every two minutes. Daily survey effort was calculated as a summation of the distance between each successive point, after the coordinates were converted to radians. To accomplish this, the latitude and longitude coordinates were converted from degrees (°) to radians. Once in radians, the coordinates were then used to calculate the great circle distance in kilometers (km) between successive latitude and longitude positions. All of the individual distances between points were summed for each day to produce an estimate of daily effort for each cruise. These, in turn, were summed to provide a total estimate of effort for all days and surveys combined.

Aerial survey data were collected as a series of latitude and longitude points every 10 seconds (sec). Survey effort was calculated as the summation of the distance between successive points for each transects line. Each transect line was then used in density calculation of sea turtles using the same methods as cetaceans.

Only "on-effort" portions of the tracklines conducted in BSS ≤4 (with the exception of Beaked Whales for with only sightings occurring in BSS <u><</u>2 were included) were used for analyses.

Table 2-1. National Marine Fisheries Service-Southeast Fisheries Science Center shipboard survey information used for density estimation for the Gulf of Mexico study area.

Dates	Source	Platform	Location	Strata Covered
1996 17 April to 08 June (Figure 2-1)	Mullin and Hoggard (2000); Mullin and Fulling (2004)	R/V *Oregon II* Cruise OT-96-02(220)	Mobile Bay, AL to Tampa, FL	18.5 kilometers (km) from the coastline to the 2,000 m isobath
1997 17 April to 09 June (Figure 2-1)	Mullin and Hoggard (2000); Mullin and Fulling (2004)	R/V *Oregon II* Cruise OT-97-02(225)	Mobile Bay, AL to Tampa, FL	18.5 km from the coastline to the 2,000 m isobath
1998 03 to 30 September (Figure 2-2)	Mullin et al. (1998); Fulling et al. (2003)	R/V *Gordon Gunter* Cruise GU-98-01(1)	Brownsville, TX to Tampa Bay, FL	App. between the 20 m and 500 m isobaths
1999 22 April to 02 June (Figure 2-1)	Hubard and Mullin (1999); Mullin and Fulling (2004)	R/V *Oregon II* Cruise OT-99-03(234)	Brownsville, TX to Tampa Bay, FL	App. between the 200 m and the EEZ
1999 31 August to 20 September (Figure 2-2)	Mullin and Drass (1999); Fulling et al. (2003)	R/V *Gordon Gunter* Cruise 99-02(3)	Brownsville, TX to Tampa Bay, FL	App. between the 20 m and 500 m isobaths
2000 18 April to 30 May (Figure 2-1)	Hubard and Mullin (2000); Mullin and Fulling (2004); Fulling et al. (2003)	R/V *Gordon Gunter* Cruise GU-00-02(7)	Brownsville, TX to Tampa Bay, FL	App. between the 200 m and the EEZ
2000 05 September to 02 October (Figure 2-2)	Mullin and Drass (2000); Fulling et al. (2003)	R/V *Oregon II* Cruise OT-00-06(242)	Brownsville, TX to Tampa Bay, FL	App. between the 20 m and 500 m isobaths
2001 17 April to 31 May (Figure 2-1)	NMFS-SEFSC (2001); Mullin and Fulling (2004)	R/V *Gordon Gunter* Cruise GU-01-02(12)	Brownsville, TX to Tampa Bay, FL	App. between the 200 m and the EEZ

Table 2-1. Continued.

Dates	Source	Platform	Location	Strata Covered
2001 31 August to 28 September (Figure 2-2)	Hubard et al. (2001)	R/V *Gordon Gunter* Cruise GU-01-05(14)	Brownsville, TX to Key West, FL	App. between the 20 m and 500 m isobaths
2003 14 June to 17 August (Figure 2-2)	NMFS-SEFSC (2003)	R/V *Gordon Gunter* Cruise GU-03-02(23)	Brownsville, TX to Key West, FL	App. between the 200 m and the EEZ
2004 13 April to 11 June (Figure 2-1)	NMFS-SEFSC (2004)	R/V *Gordon Gunter* Cruise GU-04-02(27)	Brownsville, TX east into the FL Straits to 81˚W	App. between the 200 m and the EEZ

Table 2-2. National Marine Fisheries Service-Southeast Fisheries Science Center aerial survey information used to assist with sea turtle density estimation for the Gulf of Mexico study area.

Dates	Source	Platform	Location	Strata covered
1992 10 August to 19 September (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1992 13 September to 24 October (Figure 2-4)	Blaylock and Hoggard (1994); Epperly et al. (2002)	NOAA Twin Otter	Brownsville, TX to Lafayette, LA	Shoreline to approximately 9.3 km past the 193 m isobath
1992 03 November to 16 December (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1993 01 February to 22 March (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1993 25 April to 01 June (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1993 01 to 21 August (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1993 17 September to 19 October (Figure 2-3)	Blaylock and Hoggard (1994); Epperly et al. (2002)	NOAA Twin Otter	Lafayette, LA to Cedar Key, FL	Shoreline to approximately 9.3 km past the 193 m isobath
1993 31 October to 16 December (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1994 31 January to 15 March (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths
1994 02 May to 02 June (Figure 2-4)	Hansen et al. (1996); Mullin et al. (2004)	NOAA Twin Otter	Brownsville, TX to Mobile Bay, AL	Between the 100 m and 2,000 m isobaths

Table 2-2. Continued.

Dates	Source	Platform	Location	Strata covered
1994 28 September to 09 November (Figure 2-3)	McDaniel et al. (2000); Epperly et al. (2002)	NOAA Twin Otter	Cedar Key, FL to Key West, FL	Shoreline to approximately 9.3 km past the 193 m isobath
1996 11 to 31 July (Figure 2-4)	Mullin and Hoggard (2000)	NOAA Twin Otter	Mobile Bay, AL to Tampa, FL	18.5 km from the coastline to the 2,000 m isobath
1996 18 September to 29 October (Figure 2-3)	Epperly et al. (2002); DoN (2005)	NOAA Twin Otter	Brownsville, TX to Lafayette, LA	Shoreline to approximately 9.3 km past the 193 m isobath
1997 07 February to 20 March (Figure 2-4)	Mullin and Hoggard (2000)	NOAA Twin Otter	Mobile Bay, AL to Tampa, FL	18.5 km from the coastline to the 2,000 m isobath
1997 15 July to 06 August (Figure 2-4)	Mullin and Hoggard (2000)	NOAA Twin Otter	Mobile Bay, AL to Tampa, FL	18.5 km from the coastline to the 2,000 m isobath
1998 08 February to 14 March (Figure 2-4)	Mullin and Hoggard (2000)	NOAA Twin Otter	Mobile Bay, AL to Tampa, FL	18.5 km from the coastline to the 2,000 m isobath

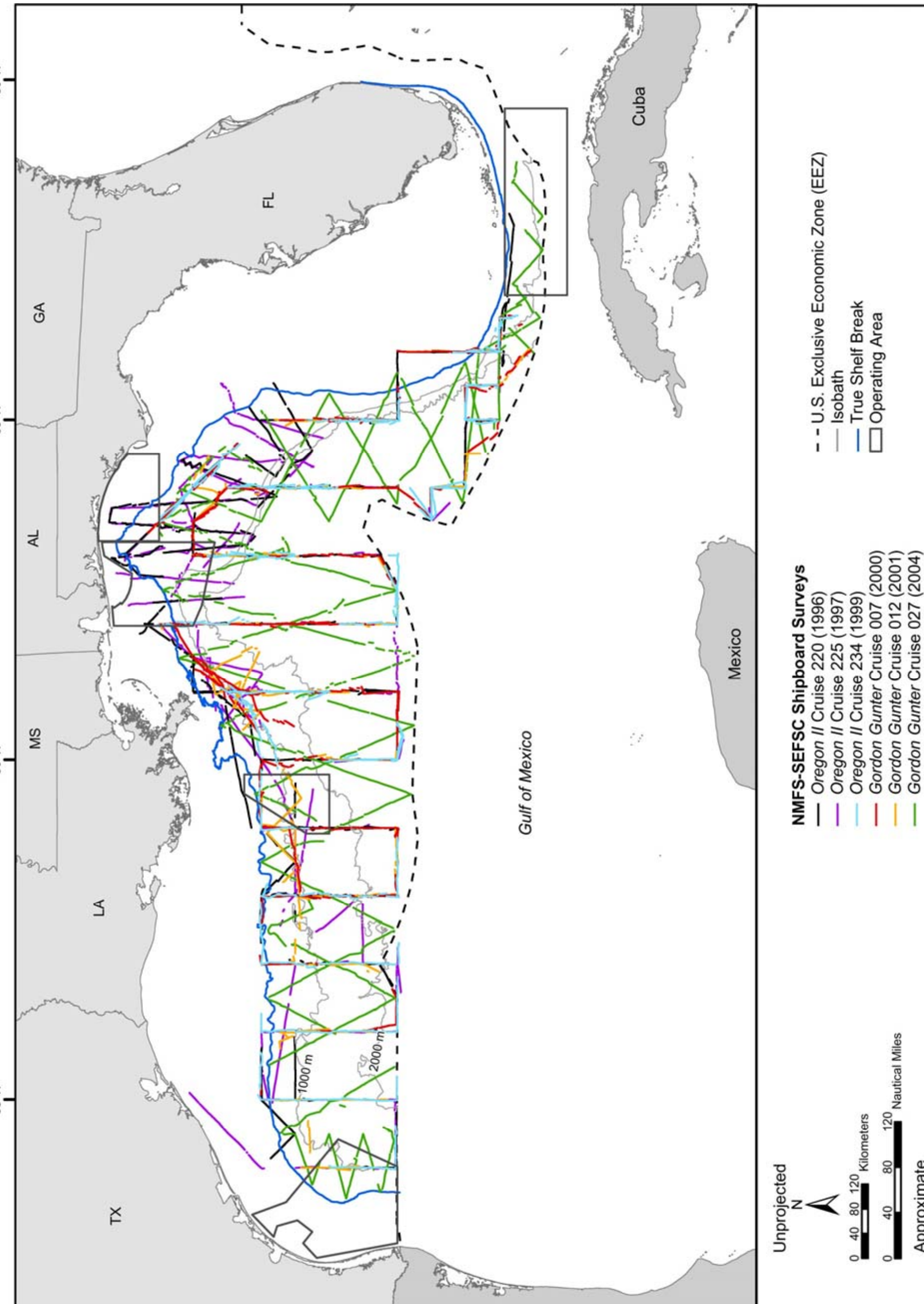


Figure 2-1. Shipboard survey effort conducted during the spring by the National Marine Fisheries Service-Southeast Fisheries Science Center in the Gulf of Mexico study area.

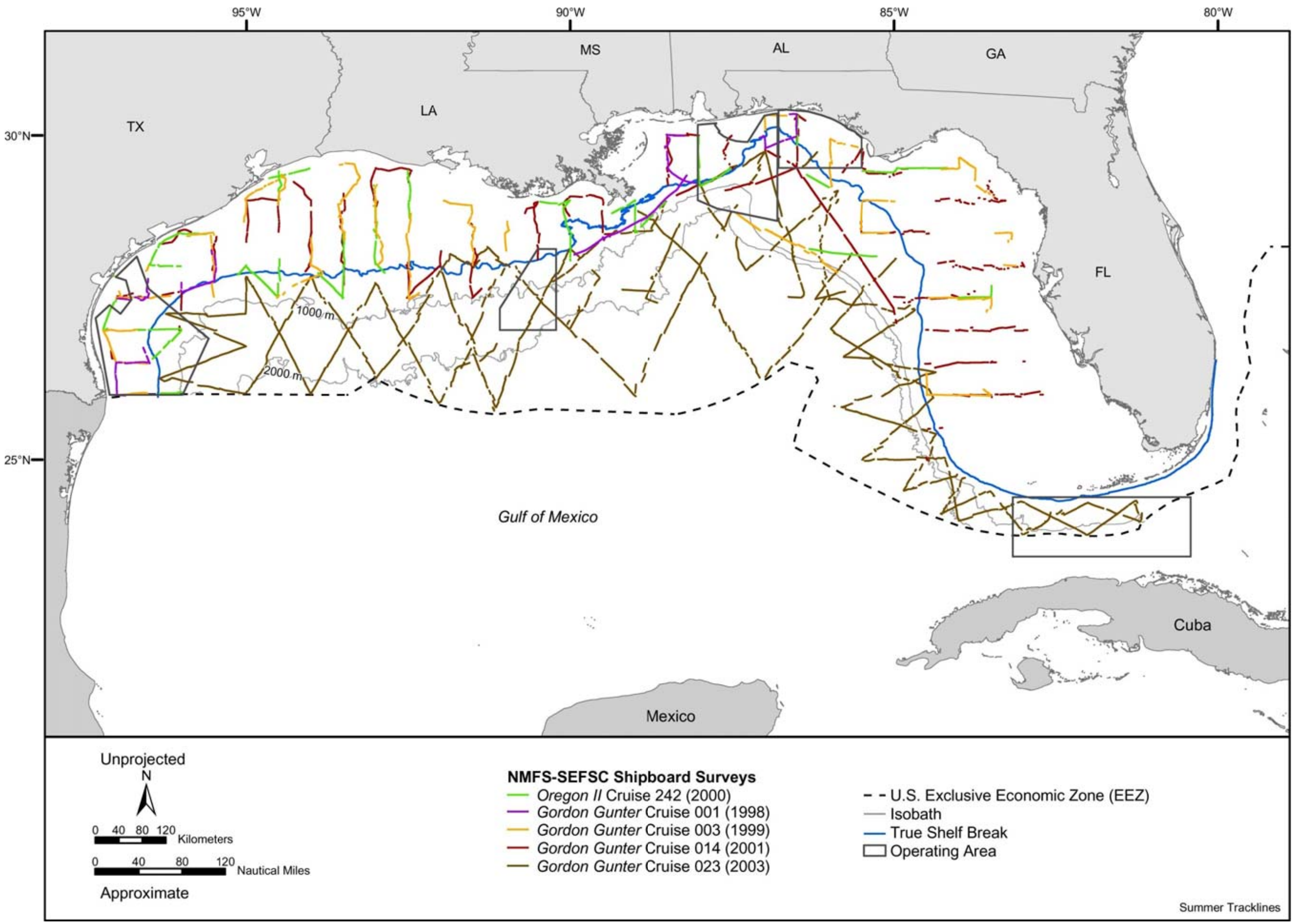


Figure 2-2. Shipboard survey effort conducted during the summer by the National Marine Fisheries Service-Southeast Fisheries Science Center in the Gulf of Mexico study area.

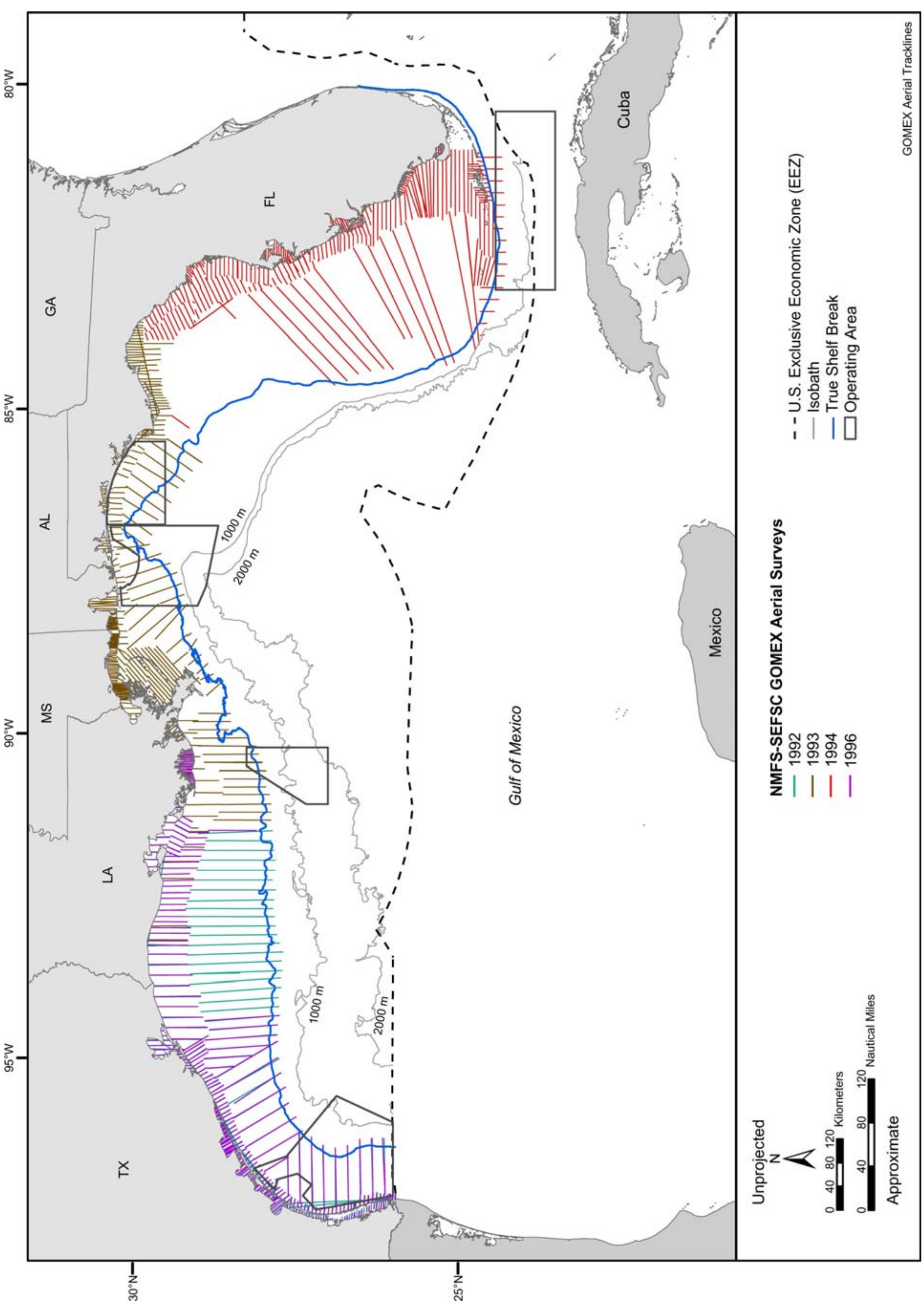


Figure 2-3. Aerial survey effort conducted by the National Marine Fisheries Service-Southeast Fisheries Science Center in the Gulf of Mexico study area.

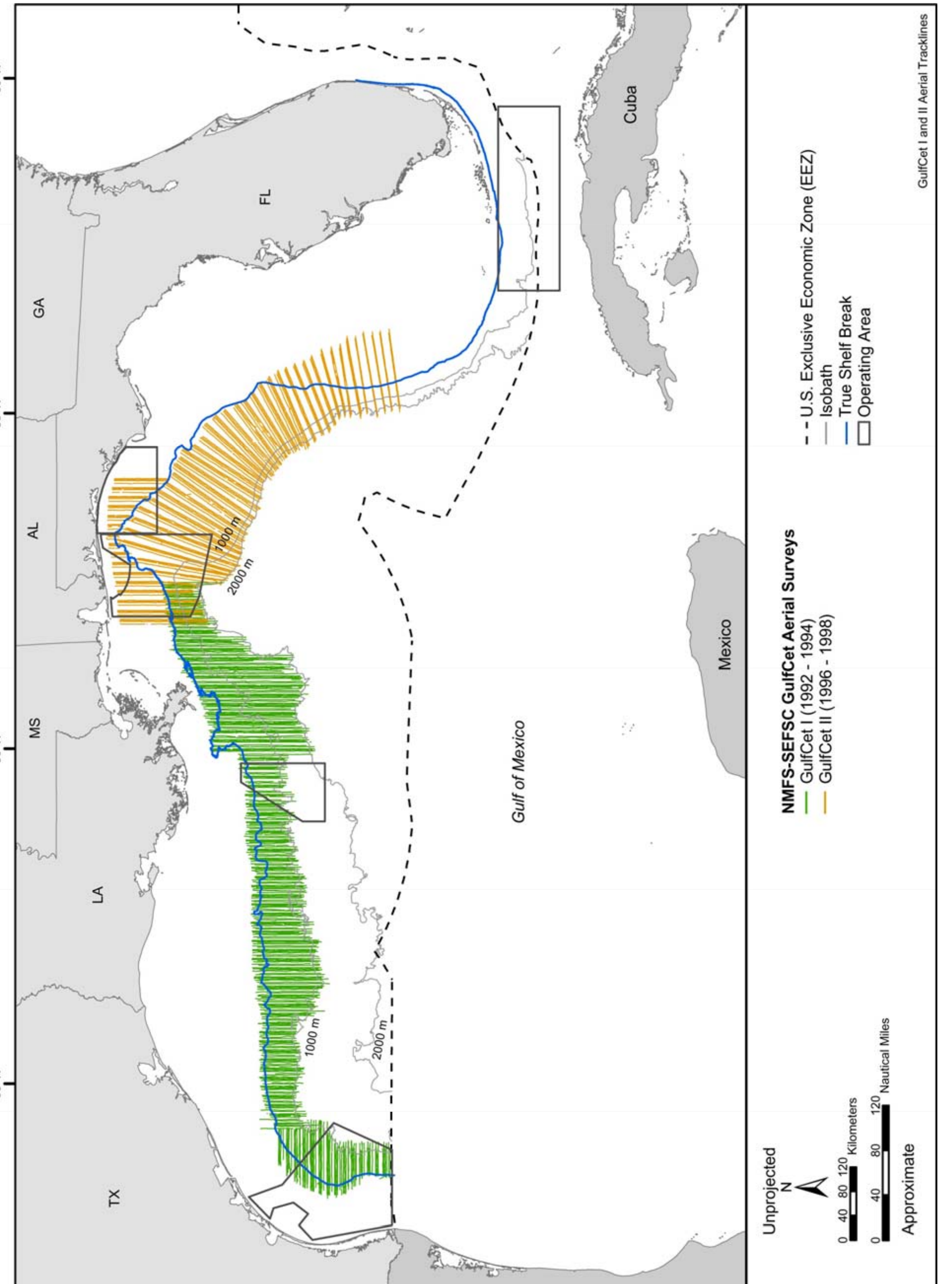


Figure 2-4. Aerial survey effort conducted by the National Marine Fisheries Service-Southeast Fisheries Science Center in the Gulf of Mexico study area.

2.3.1.3 Calculation of the Perpendicular Sighting Distance

There were two separate methods used for calculating the perpendicular sighting distance (PSD) for each sighting: one for ship-based and the other for plane-based (**Figure 2-5**). To calculate the PSD for ship-based sightings, in accordance with Lerczak and Hobbs (1998), the bearing and reticle of the sighting was used in combination with the height of the platform above the water's surface. A similar, yet simpler method was used for the aerial surveys with angle (*θ*) or bin (in 10° increments) used in combination with the aircraft altitude.

2.4 MODELING FRAMEWORK

The key step in the first phase of modeling line transect data is partitioning survey effort into segments. Within those segments, estimates of the number of animals within segments are produced that take into account incomplete detectability of animals.

The method of analyzing estimated abundances per segment surveyed was developed by Hedley et al. (1999). Their original application consisted of dividing each transect into small segments, enumerating the area of the segments and the number of animals in each segment. Descriptions of this technique for modeling were expanded upon by Hedley (2000) and Hedley and Buckland (2004). Recent overviews of modeling cetacean detections were published by Ferguson et al. (2006b; 2006a) and Redfern et al. (2006). Briefly, the estimated number of animals per segment was related to the static and dynamic habitat covariates (bottom depth, latitude, longitude, SST and chlorophyll *a* [chl *a*]) by fitting a generalized additive model (GAM; Wood 2006).

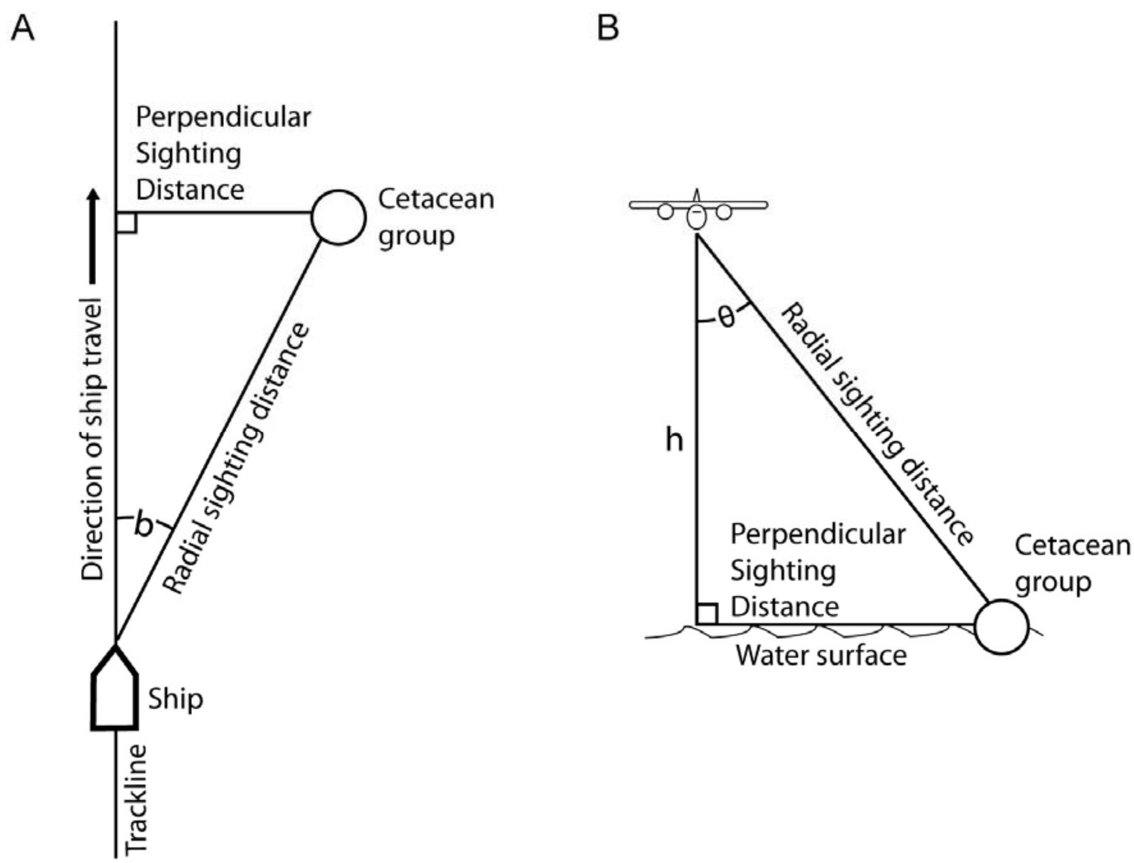


Figure 2-5. Diagram of PSD and other sighting parameters for shipboard (A) and aerial (B) surveys (b and *θ* = angle between track-line and animal group, h = altitude).

Fitting detection functions to line transect data is thoroughly described by Buckland et al. (2001); this forms the basis of GMI's ability to estimate the probability of detection. Geo-Marine, Inc. restricted the detection function modeling to the half normal and hazard rate key functions without adjustment terms. GMI did not explicitly include covariates in the fitting of detection functions; instead GMI limited the analyses to detections made in BSS≤4.

Geo-Marine, Inc. combined all surveys, regardless of season or location, to provide the greatest possible number of sightings. By combining surveys, GMI was able to increase the number of sightings for all species. Individual detection functions were estimated for species with 30 or more sightings. In some cases, species with few sightings were pooled into larger groups prior to analysis. This was done for Beaked Whales (Cuvier's beaked whale and *Mesoplodon* spp.), *Kogia* spp. (pygmy and dwarf sperm whales), and Hardshell Turtles (green, hawksbill, Kemp's ridley turtles, and potentially the olive ridley turtle).

After fitting GAMs to the survey data, the resulting DSM is applied to a prediction grid superimposed upon the GOMEX study area. In this way, animal density can be predicted in regions of the GOMEX study area where little survey effort was conducted. The resulting values are prediction grid cell-specific densities that are depicted in the remainder of this report. Because survey data were only available for spring and/or summer, the species/group density estimates for those seasons were predicted using only the survey data from that particular season. Density estimates for seasons without survey data were generated using all survey data available, regardless of season, and using only the static covariates (depth, latitude, and longitude) for the models.

2.5 STEPS IN DENSITY SURFACE MODELING OF LINE TRANSECT DATA

After all shipboard survey data were manipulated as described in **Section 2.6** below, the following iterative steps were used to estimate the abundance, and subsequent density, of cetaceans and sea turtles in the GOMEX study area:

I. Survey data segmentation (program SAS®)
II. Detection function modeling (program DISTANCE)
    a. Diagnostics and model selection
    b. Interpretation of program DISTANCE output
III. Data preparation of covariates for the DSM (program MATLAB®)
    a. Import of remote sensed data (dynamic variables; SST and chl *a*)
    b. Import of static variables (bottom depth, latitude, and longitude)
    c. Define study area boundaries
IV. DSM modeling (GAM; programs R and MATLAB®)
    a. Diagnostics and model selection
    b. Significance of covariates
    c. Deviance explained
    d. Generalized Cross Validation (GCV) score
    e. Density estimate evaluation
V. DSM prediction (programs DISTANCE and R)
    a. Density estimation at the study area level
    b. Extrapolate to areas/seasons where survey data were not collected
VI. Density estimation at smaller scales
    a. Seasonal estimates
    b. Area specific estimates
VII. Measures of precision
    a. Variance estimation
    b. Bootstrap samples

Estimating Bias - *g(0)*

The probability of detecting an object that is on a transect line, *g(0)*, is very important to generating reliable abundance estimates. A *g(0)* value of 1 indicates that 100 percent (%) of the animals are detected; it is rare that this assumption holds true. Various factors are involved in estimating *g(0)*, including: sightability/detectability of the animal (species-specific behavior, school size, blow characteristics, dive characteristics, and dive interval); viewing conditions, (sea state, wind speed, wind direction, sea swell, and glare); observers (experience, fatigue, and concentration), and platform characteristics (pitch, roll, yaw, speed, and height above water). Thomsen et al. (2005) provides a complete and recent discussion of *g(0)*, factors which affect the detectability of the animals, and current thoughts on how to account for detection bias. Failure to address *g(0)* results in abundance and/or density estimates which are biased and underestimated.

For the purpose of this report, GMI assumed *g(0)* = 1. This is an unrealistic assumption for many of the species addressed in this report, particularly those with long dive times (i.e., beaked whales and the sperm whale) or that are difficult to detect as a result of their size or behavior (i.e., minke whale and *Kogia* spp.). However, estimates of *g(0)* were not calculated during the surveys which GMI's analyses were based.. Furthermore, there are no *g(0)* estimates available for any species in the GOMEX from shipboard or aerial surveys. As stated above, by assuming *g(0)* = 1 for these analyses, the abundance and density estimates for most of the species are underestimated. The magnitude of the bias is species-, area-, and platform-specific. The magnitude of g(0) variation is provided in a table of *g(0)* values from various areas, methods of calculations, and platforms for each of the species addressed in this report (**Table 2-3**). This table is only meant to provide a reference as to what g(0) values have been calculated or applied in other studies; these values are **NOT** to be used to adjust density estimates within this report.

2.6 SPATIAL MODELING DATA MANIPULATION

2.6.1 Segmentation Process

To calculate density estimates using spatial modeling, it was necessary to parse the survey data into segments. When producing the segments, the goal was to have at least 15% of the segments contain one or more sightings. To determine the approximate segment length for each species or species group, the following equation was used:

$$l_S = \frac{E \cdot 0.15}{n_s} \qquad \text{(Equation 1)}$$

where E = the total amount of effort in km for all surveys; n_s = the total number of sightings of the species or species group in question; and l_s = the approximate length of each segment. For some of the less-frequently observed species or species groups, this approach resulted in excessive segment lengths. In these cases, the segment length was limited to 60 km. The effort during each day of each survey was then divided into segments based on the calculated segment length. If the remainder of effort left over at the end of the day was less than half the approximate segment length, then it was added to the last segment created. Otherwise, if the leftover effort was greater than the approximate segment length, it became a new segment.

2.6.2 Covariate Data

Incorporating Remote Sensed Data—Remote sensed data (SST and chl *a*), were combined with the survey data based on the appropriate latitude, longitude, and season, to allow for species/group density estimation in each season. For the aerial surveys, bottom depth was also applied in a similar manner, because it was not collected during the actual surveys.

Remote Sensed Data Sources—Maps of SST were created from data available through the Physical Oceanography Distributed Active Archive Center (PO.DAAC) that is sponsored jointly by the National Aeronautics and Space Administration (NASA) and the NOAA (Goddard DAAC 1986). Sea surface

Table 2-3. Range of estimates for g(0) for each cetacean species found in the Gulf of Mexico study area that have density estimates provided. These numbers were either determined by the source or applied by the source for abundance/density estimation analyses in the particular geographic location. Values provided are NOT to be used to adjust density estimates within this report.

g(0)	Location	Platform	Source
Threatened/Endangered Cetacean Species			
Sperm whale (*Physeter macrocephalus*)			
0.28-0.57	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.19-0.29	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.53-1.00	U.S. West Coast	Shipboard	(Barlow 1995; Barlow and Gerrodette 1996; Barlow and Sexton 1996; Barlow 2003a; Barlow and Taylor 2005)
0.95-0.98	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.87	Hawaii	Shipboard	(Barlow 2003b, 2006)
0.32	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)
Non-Threatened/Non-Endangered Cetacean Species			
Bryde's whale (*Balaenoptera edeni*)			
0.90-1.00	U.S. West Coast	Shipboard	(Barlow 1995, 2003a)
0.90	Hawaii	Shipboard	(Barlow 2003b, 2006)
***Kogia* spp.**			
0.29-0.55	U.S. Atlantic Coast	Shipboard	(Palka 2006)
0.19-0.79	U.S. West Coast	Shipboard	(Barlow 1995; Barlow and Sexton 1996; Barlow 1999, 2003a)
0.35	Hawaii	Shipboard	(Barlow 2003b, 2006)
Ziphiidae (Beaked Whales)			
0.46-0.51	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.19-0.21	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.13-1.00	U.S. West Coast	Shipboard	(Barlow 1995; Barlow and Sexton 1996; Barlow 1999; Carretta et al. 2001; Barlow 2003a; Barlow et al. 2006)
0.23-0.45	Hawaii	Shipboard	(Barlow 2003b, 2006)*
0.27	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)
0.95-0.98	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
Bottlenose dolphin (*Tursiops truncatus*)			
0.62-0.99	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.58-0.77	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.74-1.00	U.S. West Coast	Shipboard	(Barlow 1995, 2003a)
0.67-0.96	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Spinner dolphin (*Stenella longirostris*)			
0.61-0.76	U.S. Atlantic Coast	Shipboard	(Palka 2006)
0.77-1.0	U.S. West Coast	Shipboard	(Barlow 2003a)
0.77-1.0	Hawaii	Shipboard	(Barlow 2003b, 2006)

Table 2-3. Continued.

g(0)	Location	Platform	Source
Threatened/Endangered Cetacean Species			
Pantropical spotted dolphin (*Stenella attenuata*)			
0.37-0.94	U.S. Atlantic Coast	Shipboard	(Palka 2006)*
0.77-1.00	U.S. West Coast	Shipboard	(Barlow 2003a)
0.76-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Atlantic spotted dolphin (*Stenella frontalis*)			
0.37-0.94	U.S. Atlantic Coast	Shipboard	(Palka 2006)**
Striped dolphin (*Stenella coeruleoalba*)			
0.61-0.77	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.77-1.00	U.S. West Coast	Shipboard	(Barlow 1995, 2003a)
0.76-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Rough-toothed dolphin (*Steno bredanensis*)			
0.74-1.00	U.S. West Coast	Shipboard	(Barlow 2003a)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Fraser's dolphin (*Lagenodelphis hosei*)			
0.76-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Risso's dolphin (*Grampus griseus*)			
0.51-0.84	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.58-0.77	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.74-1.00	U.S. West Coast	Shipboard	(Barlow 1995, 2003a)
0.67-0.96	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
False killer whale (*Pseudorca crassidens*)			
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Pygmy killer whale (*Feresa attenuata*)			
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Killer whale (*Orcinus orca*)			
0.90	U.S. West Coast	Shipboard	(Barlow 2003a)
0.95-0.98	U.S. West Coast	Aerial	(Forney et al. 1995)
0.90	Hawaii	Shipboard	(Barlow 2003b, 2006)
0.96	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)
Melon-headed whale (*Peponocephala electra*)			
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
Pilot whale (*Globicephala* spp.)			
0.48-0.67	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.19-0.29	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.74-1.00	U.S. West Coast	Shipboard	(Barlow 2003a)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003b, 2006)
0.93	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)

* per Barlow (2006), Longman's beaked whale (*Indopacetus pacificus*) is not included in Ziphiidae for estimation of g(0) due to its more similar behavior to pilot whales

** g(0) provided for collective grouping of the 2 spotted dolphin species temperature data were compiled from weekly averaged Advanced Very High-Resolution Radiometer (AVHRR) version 5.0 satellite data, which contain multi-channel SST pixel data (NASA 2000). Seasonal averages of chl *a* concentrations were compiled from monthly averaged Sea-viewing Wide Field-of-view Sensor (SeaWiFS) project data to provide a proxy for primary productivity in the GOMEX study area (NASA 1998).

SST and Seasonal Delineation—Data for 1996 to 2004 for the GOMEX study area were extracted from the global SST dataset (NASA 2000). The pixel values were converted to SST values using the following function:

$$\text{SST } (° \text{ Celsius [C]}) = (0.075 \cdot \text{DN}) - 3.0 \qquad \text{(Equation 2)}$$

where, DN = pixel value. The analysis was performed using a custom application developed with the MATLAB® software package.

The grid-cell size for the seasonal SST data was 4 km^2. The range of SST values for the GOMEX study area were associated with a color spectrum grading from blue to red that represents cooler to warmer SST (°C), respectively.

Chl *a* —Pixel data for the study area and vicinity from 1998 to 2004 were extracted and converted to chl *a* values using MATLAB® and the following function:

$$\text{Chl } a \text{ (mg/m}^3) = 10^{(\text{DN} \cdot 0.015) - 2.0} \qquad \text{(Equation 3)}$$

where DN is the pixel value.

The chl *a* data were parsed into seasons, and the 9 km^2 grid cell size was interpolated down to 4 km^2, to produce the same grid size as SST. The seasonal range of chl *a* concentrations (in milligrams per cubic meter [mg/m^3]) is visualized in figures as a color spectrum, with chl *a* concentrations increasing from blue to red.

Bathymetry—For each prediction grid cell, bottom depth was queried from NOAA's bathymetry data for the centroide of each grid cell using 30 arc second bathymetry data (NOAA 2001c; NOAA 2001b; NOAA 2001a). These values, as well as SST, chl *a*, latitude, and longitude were used in the GAM within the program DISTANCE.

Prediction Grid Development—The prediction grid area was defined by the area between the 10 m isobath and the EEZ, extending from Brownsville, TX to the Florida Straits. All survey data used here fell within the defined area. Prediction grids were formatted in a flat file format for import into the program DISTANCE, with each latitude and longitude point having an assigned depth, SST, and chl *a* value.

Grid Size Determination—Prediction grids with approximately 10 km^2, 20 km^2, and 40 km^2 grid cell sizes were developed. The optimal grid cells size was determined for each species based on segment length.

DSM Output Review—The DSM estimates of density for each cell in the prediction grid were imported and displayed using custom applications developed with the MATLAB® software package. On effort sightings were overlaid on the density surface for visual reference and comparison.

2.7 DENSITY SURFACE MODEL SELECTION

Thirty-nine combinations of the dynamic and static covariates were fitted to segment-specific estimated abundance. From these combinations, the five best models (chosen by the program DISTANCE based on GCV score) were evaluated using the following criteria: (1) significance of each smooth variable; (2) total deviance explained; (3) GCV score; and (4) density estimate. Lower GCV scores indicate a better fit of the DSM. If a variable in the model was determined to be not significant, the variable was excluded and the model was rerun to determine if the resulting GCV score was lowered. If the GCV score decreased, the variable was left out of the DSM. On occasion, the deviance explained was extremely high (>80%), and it was necessary to further evaluate the model based upon the density estimate. In most cases, these high levels of deviance explained resulted in extremely high density estimates (infinity in most cases), likely due to edge effects (an unchecked upward or downward trend in the model that extends beyond the observed data to the edge of the coverage area resulting in artificially high or low estimates of abundance and density). The concept of parsimony (using the fewest predictors to adequately describe the response) was invoked to assist in the model selection. As each variable introduced into the model adds to the uncertainty, models with fewer predictors are preferred. In addition, utilizing too many parameters can result in "connect-the-dots" curve-fitting and little predictive power beyond the observed responses. Therefore, once the models examined had been reduced to a subset in which the scores on all criteria were in agreement, and thereby predicted the best fit, the model with the fewest significant covariates was selected.

Variance Estimation

For design-based estimators of abundance, variance can be calculated analytically. However, using the model-based estimates of abundance with GAM methods, obtaining an analytic expression for variance was impractical. Robust estimates of variance can be obtained by employing appropriate resampling techniques. Parametric bootstrapping was used to estimate the variance in the density estimates obtained in this study. The form of parametric bootstrap was a “moving window” (Efron and Tibshirani 1993), that shuffled residuals from the fitted DSM among segments within transects (Burt, M.L., University of St Andrews, pers. comm., August 2006). A sampling unit is defined to be a block of *m* consecutive segments, thus, the first block is defined by the first *m* segments in a transect. The block then moves on one, so that the first segment is dropped and another one added and so on to the end of the series. Blocks of segments are then chosen at random, with replacement from all possible blocks in a transect and pasted back together to create a bootstrap sample. The advantage of this method is that by carefully choosing the block size, observations more than *m* segments apart will be independent, and the correlation present in segments less than *m* units apart will be retained. However, the observations in the cetacean surveys cannot be moved around at random as in the application to time series, because they are associated with explanatory variables. However, residuals, rather than the detections, can be moved around at random. Thus, blocks of residuals were chosen at random and with replacement, and bolted back onto the original data to create the bootstrap sample and thus preserving the spatial coverage of the original surveys.

Given the bootstrap samples, the model selected for the original data is refit to obtain species density estimates from each pseudosample. The sample variances of these estimates provide the bootstrap estimates of the components of variance from the spatial modeling. The component of variance related to detection probability in the count model must then be incorporated to obtain the overall variance estimates of density. The delta method (see Seber 1982) was used to combine both components of variance in the density estimation.

The bootstrapping technique assesses the overall precision of the fitted response surface model (RSM) to any given response variable (e.g., number of animals within a segment), operating as though the number of animals within a given transect segment is known. However, in the case here, the number of animals within a segment is not known, but rather was estimated applying a Horvitz-Thompson-like estimator, using the detection function selected for each species. The second step of the variance calculations takes into account the uncertainty of estimating the number of animals within a segment (attributable to estimation of the parameters of the detection function).

Bootstrapping was repeated 499 times. Bootstrap estimates were then ordered from largest to smallest and the quartiles corresponding to 95% end points of the distribution of bootstrap estimates were reported (Buckland et al. 2001).

Models were not all inclusive

Real-time oceanographic data are preferable for constructing DSMs. However, these data were: not available for all cruises; were not available for all cells of the prediction grid (which covers the entire GOMEX); and would require extensive post-processing time. Instead, the DSMs used some remote sensed data, including SST and chl *a*. Problems can arise with using these types of data, because they are not correlated directly with each individual sighting. The five covariates considered during the modeling process included SST, chl *a*, bottom depth, latitude, and longitude. SST and chl *a* were used as two dynamic covariates in the modeling. The static covariates were bottom depth, latitude, and longitude. SST and chl *a* were generated by averaging each of the values across three months (the seasons were defined by SST; DoN 2005).

Various researchers have worked on habitat modeling and animal distribution in recent years (e.g., Baumgartner 1997; Combs 2005; Ward et al. 2005; Barlow 2006; Ferguson et al. 2006b; Kaschner et al. 2006; Redfern et al. 2006). These studies have used several other covariates including zooplankton biomass, bottom slope, thermocline depth, distance from shore, sea surface height, and prey resources. While these additional variables would certainly improve the density estimates, the purpose of this project was to estimate densities, and not to generate comprehensive habitat models. Due to time constraints, GMI was unable to fully investigate all potential environmental and biological variables that may influence animal distribution. The DSMs were limited to data which were readily obtainable and required minimal processing. While this is not optimal, it is practical, and it is an improvement to previous density estimation work for the GOMEX study area. Geo-Marine, Inc.'s approach is the first attempt to model animal densities in the GOMEX study area; it is meant to act as a working tool to assist the Navy in compliance with environmental mandates and will serve as the basis for future modeling work.

2.8 In the Absence of a Spatial Model (SAR-Derived Density Estimates)

For several species, there were not enough sightings to be able to produce a density surface using program DISTANCE. When a density surface could not be generated for a given species or species group based on the shipboard surveys, density estimates based on the abundance estimates provided in the SAR (Waring et al. 2007) were used instead. Density estimates were derived by taking the species abundance and dividing it by the area (km^2) of ocean over which that abundance was calculated. The resulting density estimate was then applied uniformly to all cells in a 10 km^2 resolution grid covering the area in question. In the northern GOMEX, density estimates were only generated from SAR abundance estimates for eight oceanic (occurring beyond the shelf break) species or species groups including Bryde's whale, Clymene dolphin, false killer whale, Fraser's dolphin, killer whale, melon-headed whale, pygmy killer whale, and short-finned pilot whale.

3.0 DENSITY ESTIMATES

There are 29 marine mammal species that occur in the GOMEX: 28 cetacean and 1 sirenian species (DoN 2007b). The West Indian manatee (*Trichechus manatus*) is not expected to occur as far offshore as the OPAREA boundaries; therefore it is not addressed in this report. Due to a lack of sufficient survey data, of the 28 cetacean species, only 13 species were able to be modeled to produce density surfaces (**Table 3-1**; five of the thirteen are included in the two species groups of *Kogia* spp. and Beaked Whales) (**Table 3-1**). The density surfaces for eight additional species were created by applying a SAR-derived density estimate to the entirety of the appropriate region (either shelf or oceanic waters).

Density estimates for cetaceans were either modeled from data or derived from abundance estimates found in the NOAA SAR (Waring et al. 2007) and in this report, are referred to as SAR-derived estimates. The abundance estimates in the SAR are from Mullin and Fulling (2004). **Section 2.5** describes the model-based approach, while **Section 2.8** discusses the process for SAR-derived estimates.

There are also five sea turtle species with occurrence records within the GOMEX study area (DoN 2007b); abundance/density estimates are provided for leatherback and loggerhead turtles, while a pooled estimate is provided for the remaining hard-shelled turtles (Kemp's ridley, green, and hawksbill turtles and any extralimital occurrences of the olive ridley turtle).

Basic habitat preference and distribution information is presented here for each species (or group) to provide relevant information as it relates to density estimation. For a detailed description of the protected species presented here, please refer to the GOMEX MRA (DoN 2007b) for their status, habitat preferences, distribution within the GOMEX study area, and aspects of their behavior and life history, as well as acoustics and hearing capabilities.

Spatial modeling output used to determine model-fit is found in the **Appendix**. All density estimates (model or SAR-derived) can be found in **Table 3.2**.

Table 3-1. Marine mammal and sea turtle species (or groups) found in the Gulf of Mexico study area for which density estimates are provided. Naming convention matches that used by the National Marine Fisheries Service.

<u>**Threatened/Endangered Cetacean Species**</u>	
Sperm whale*	*Physeter macrocephalus*
<u>**Non-Threatened/Non-Endangered Cetacean Species**</u>	
Bryde's whale**	*Balaenoptera edeni*
Kogia* spp.	
Pygmy sperm whale	*Kogia breviceps*
Dwarf sperm whale	*Kogia sima*
Beaked Whales*	
Cuvier's beaked whale	*Ziphius cavirostris*
Gervais' beaked whale	*Mesoplodon europaeus*
Blainville's beaked whale	*Mesoplodon densirostris*
Rough-toothed dolphin*	*Steno bredanensis*
Bottlenose dolphin*	*Tursiops truncatus*
Pantropical spotted dolphin*	*Stenella attenuata*
Atlantic spotted dolphin*	*Stenella frontalis*
Striped dolphin*	*Stenella coeruleoalba*
Spinner dolphin*	*Stenella longirostris*
Clymene dolphin**	*Stenella clymene*
Risso's dolphin*	*Grampus griseus*
Fraser's dolphin**	*Lagenodelphis hosei*
Killer whale**	*Orcinus orca*
False killer whale**	*Pseudorca crassidens*
Pygmy killer whale**	*Feresa attenuata*
Melon-headed whale**	*Peponocephala electra*
Short-finned pilot whale**	*Globicephala macrorhynchus*
<u>**Sea Turtles**</u>	
Leatherback*	*Dermochelys coriacea*
Loggerhead*	*Caretta caretta*
Hardshell Turtles*	
Green	*Chelonia mydas*
Hawksbill	*Eretmochelys imbricate*
Kemp's ridley	*Lepidochelys kempii*
Loggerhead	*Caretta caretta*
Olive ridley	*Lepidochelys olivacea*
Unidentified hardshell	(does not include Leatherback)

* Indicates species for which density estimates were derived through spatial modeling of NMFS-SEFSC survey data.

** Indicates species for which density estimates were derived from the NOAA Stock Assessment Report (Waring et al. 2007) that are based on analyses by Mullin and Fulling (2004).

Table 3-2. Seasonal point estimates of abundance for cetaceans and sea turtles in the Gulf of Mexico Study Area. Both model- and SAR-derived estimates are presented. SAR-derived estimates are the "best" estimates of abundance from Waring et al. (2007) based on Mullin and Fulling (2004).

Species/Species Group	Seasons			
	Spring	Summer	Fall	Winter
Model-Derived Density Estimates				
Cetaceans				
Sperm whale (*Physeter macrocephalus*)	808	851	851	851
Kogia spp.	489	489	489	489
Beaked Whales (Family Ziphiidae)	492	310	310	310
Rough-toothed dolphin (*Steno bredanensis*)	1,961	1,961	1,961	1,961
Bottlenose dolphin (*Tursiops truncatus*)	49,509	39,598	49,509	49,509
Pantropical spotted dolphin (*Stenella attenuata*)	102,174	81,034	102,174	102,174
Atlantic spotted dolphin (*Stenella frontalis*)	32,227	32,227	32,227	32,227
Striped dolphin (*Stenella coeruleoalba*)	4,389	4,389	4,389	4,389
Spinner dolphin (*Stenella longirostris*)	10,266	10,266	10,266	10,266
Risso's dolphin (*Grampus griseus*)	1,976	1,976	1,976	1,976
Sea Turtles				
Leatherback sea turtle (*Dermochelys coriacea*)	1,468	1,468	1,468	1,468
Loggerhead sea turtle (*Caretta caretta*)	8,867	8,867	8,867	8,867
Hardshell Turtles	13,062	13,062	13,062	13,062
SAR-Derived Density Estimates				
Bryde's whale (*Balaenoptera edeni*)	40	40	40	40
Clymene dolphin (*Stenella clymene*)	17,355	17,355	17,355	17,355
Fraser's dolphin (*Lagenodelphis hosei)*	726	726	726	726
Killer whale (*Orcinus orca*)	133	133	133	133
False killer whale (*Pseudorca crassidens*)	1,038	1,038	1,038	1,038
Pygmy killer whale (*Feresa attenuata)*	408	408	408	408
Melon-headed whale (*Peponocephala electra*)	3,451	3,451	3,451	3,451
Short-finned pilot whale (*Globicephala macrorhynchus*)	2,388	2,388	2,388	2,388

This page intentionally left blank

3.1 MARINE MAMMALS

All marine mammal species are afforded protection by the MMPA. Additionally, the sperm whale is the only threatened/endangered species in the GOMEX study area that has sufficient data to estimate densities. In this section, individual species with density estimates are addressed first and are followed by the species groups as listed in **Table 3-1**. Those species with model-based density estimates are presented first, followed by those with SAR-derived estimates.

Threatened/Endangered Cetaceans

Five baleen whale species (blue, fin, humpback, North Atlantic right, and sei) and one toothed whale species (sperm whale) have documented occurrence in the GOMEX study area (Jefferson and Schiro 1997; Würsig et al. 2000; DoN 2007b). Only the sperm whale had enough sightings to calculate densities; therefore, no other endangered species are included in this report.

Note of Interest*—It is generally considered that any occurrences of both the critically endangered North Atlantic right whale (Eubalaena glacialis) and the endangered humpback whale (Megaptera novaeangliae) are individuals that have accidentally strayed into the GOMEX from wintering grounds in the southeastern U.S. or Caribbean, respectively (Jefferson and Schiro 1997). It should be noted that both of these species have been sighted more often than would be expected in recent years. Recent records of North Atlantic right whale include two mother/calf pairs, one off the Florida Panhandle in 2004 and another in Corpus Christi Bay, Texas in January 2006 (Anonymous 2006). Since the review conducted by Weller et al. (1996), there have been occasional reports of humpback whales off the Florida Panhandle, including most recently during April 2006 (Pitchford, T., Florida Fish and Wildlife Research Institute, pers. comm., 6 June 2006).*

3.1.1 Species with Model-based Density Estimates

➢ Sperm Whale (*Physeter macrocephalus*)

Distribution and habitat preferences:

- Sperm whales occur year-round in the GOMEX, aggregating along the continental slope and in canyon regions (e.g., Davis et al. 1998; Baumgartner et al. 2001; Jochens et al. 2006). GulfCet surveys found that most sperm whales were concentrated around the 1,000 m isobath, south of the Mississippi River Delta (Davis et al. 1998; Davis et al. 2000; Baumgartner et al. 2001). This is an area that has been recognized for high densities of sperm whales and represents a habitat where they can be predictably found (Mullin et al. 1994b; Davis and Fargion 1996; Davis et al. 1998; Biggs et al. 2000; Weller et al. 2000; Würsig et al. 2000; Baumgartner et al. 2001; Davis et al. 2002; Jochens et al. 2006).

- Tagging data demonstrated that some individuals spend several months at a time in the Mississippi River Delta and the Mississippi Canyon for several months, while other individuals move to other locations the rest of the year (Jochens et al. 2006). Segregation between the sexes was noted during one year of survey by Jochens et al. (2006). Females and immatures showed high site fidelity to the region south of the Mississippi River Delta and Mississippi Canyon on the upper continental slope and in the western GOMEX. Males were found on the upper continental slope, but also move more often into the central GOMEX and into areas of the lower continental slope and abyssal (depths greater than 3,000 m) region (Jochens et al. 2006). Males were mainly found in the DeSoto Canyon and along the Florida slope.

- In the GOMEX, higher numbers of sperm whales are found in areas of cyclonic circulation and cyclone-anticylone confluence (Biggs et al. 2000; Baumgartner et al. 2001; Davis et al. 2002; Jochens and Biggs 2004; Jochens et al. 2006). Data suggest that sperm whales appear to adjust their movements to stay in or near cold-core rings (Davis et al. 2000; Davis et al. 2002). This would demonstrate that sperm whales shift their movements in relation to prey concentrations.

Table 3-3. Density surface model results for the sperm whale by season. These are abundance estimates for the sperm whale in the Gulf of Mexico study area.

Density Surface Model (DSM)	Abundance
Spring	808
Summer	851
Fall	851
Winter	851

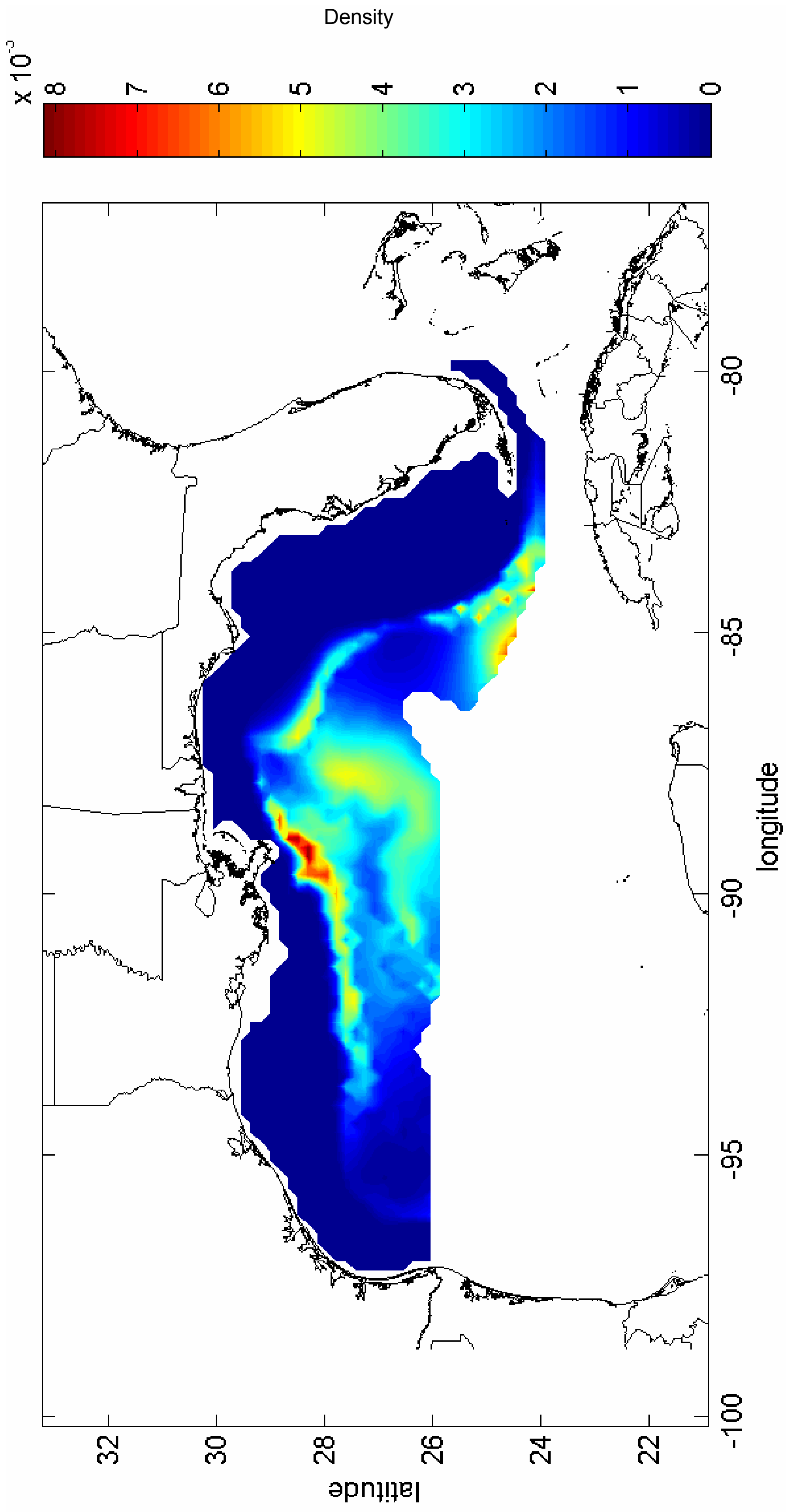


Figure 3-1. Density surface for the sperm whale in the Gulf of Mexico study area during summer, fall, and winter.

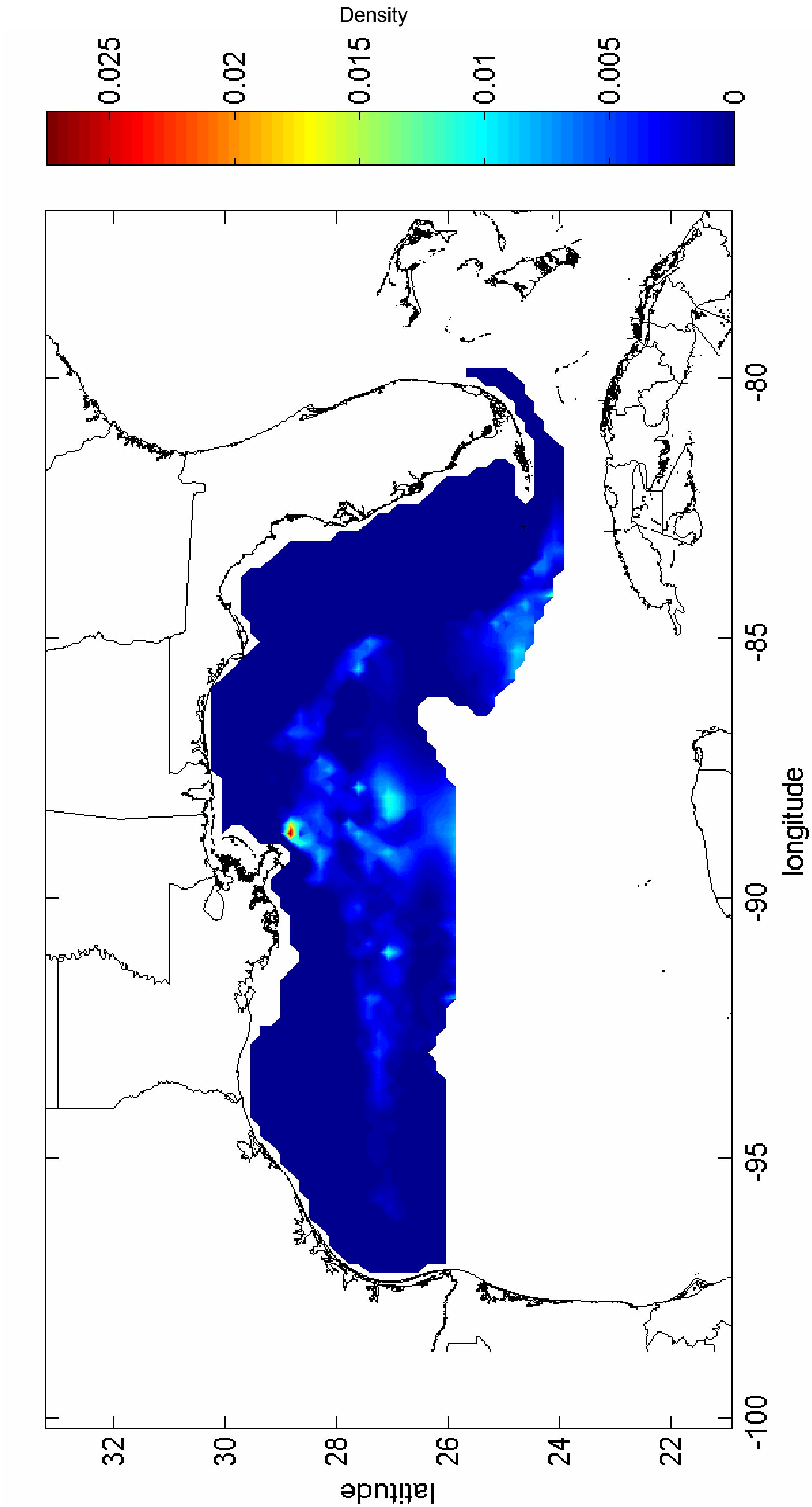


Figure 3-2. Density surface for the sperm whale during spring in the Gulf of Mexico study area.

➢ *Kogia* spp.

There are two species that make up this category: the pygmy sperm whale (*Kogia breviceps*) and the dwarf sperm whale (*Kogia sima*).

Distribution and habitat preferences:

- Globally, both species of *Kogia* generally occur in waters along the continental shelf break and over the continental slope (e.g., Baumgartner et al. 2001; McAlpine 2002; MacLeod et al. 2004; Baird 2005).

- In the GOMEX, *Kogia* spp. are distributed mostly over the upper continental slope (Baumgartner et al. 2001; Fulling and Fertl 2003).

- Fulling and Fertl (2003) reported that 67% of *Kogia* spp. sightings in the GOMEX were between the shelf break and the 2,000 m isobath; 46% of these were on the upper continental slope between the 500 and 1,000 m isobaths. Although there has been little survey effort seaward of the 3,000 m isobath, there were some sightings of individuals in those very deep waters.

- There is no evidence that *Kogia* regularly occur in continental shelf waters of the GOMEX (Davis et al. 2000), however, there were some sighting records in waters over the continental shelf (Fulling and Fertl 2003).

- Fulling and Fertl (2003) remarked on the noticeable concentration of sightings in continental slope waters near the MS River Delta.

Table 3-4. Density surface model results for *Kogia* spp. by season. These are abundance estimates for *Kogia* spp. in the Gulf of Mexico study area.

Density Surface Model (DSM)	Abundance
Spring	489
Summer	489
Fall	489
Winter	489

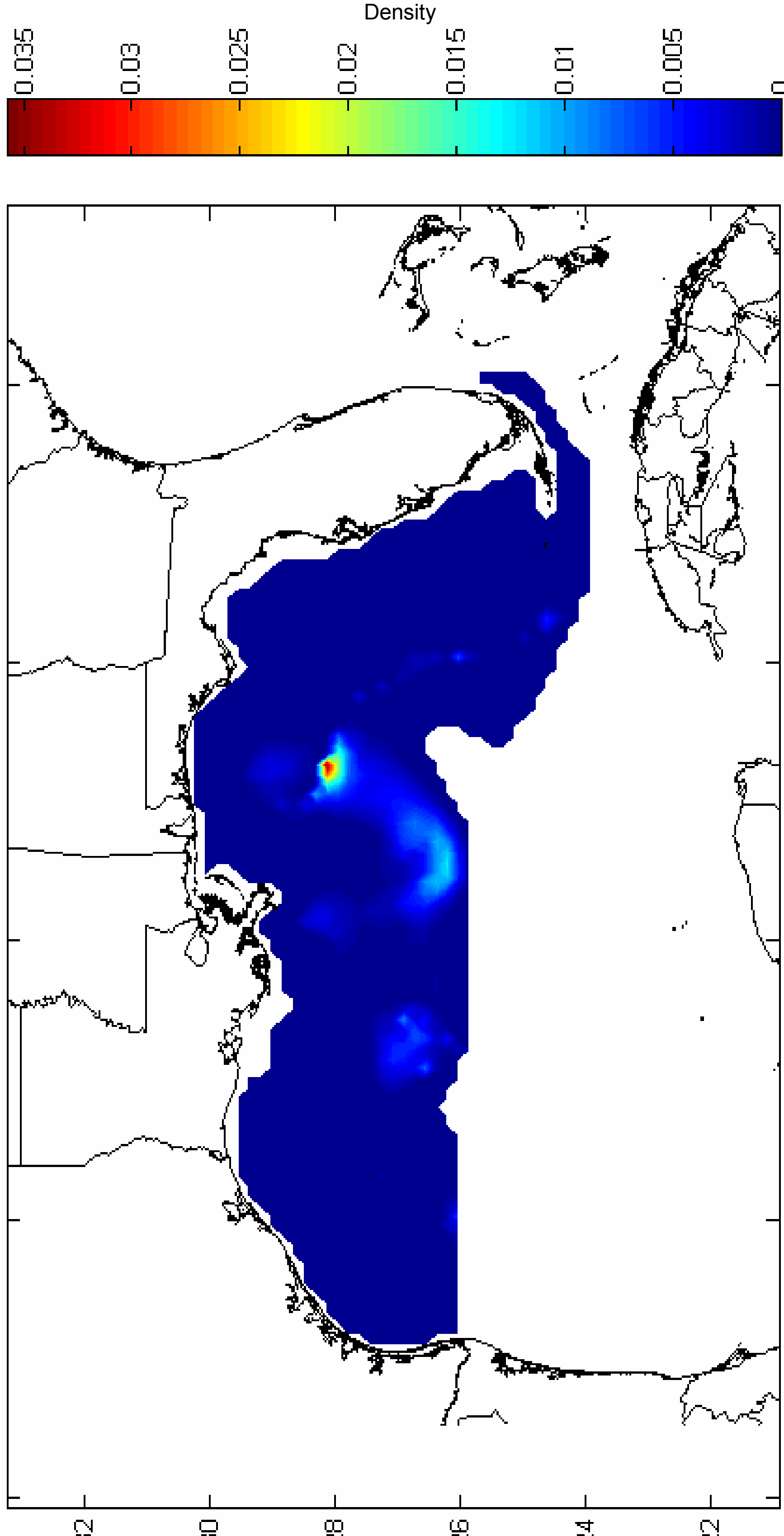


Figure 3-3. Density surface for *Kogia* spp. during all seasons in the Gulf of Mexico study area.

➢ Beaked Whales (Family Ziphiidae)

There are three species of beaked whales that may occur in the GOMEX, these are the Cuvier's, Gervais', and Blainville's beaked whales. There is only one stranding record for the Sowerby's beaked whale (*Mesoplodon bidens*); this species is considered to be more northerly distributed and, therefore, extralimital to the GOMEX (Jefferson and Schiro 1997; MacLeod et al. 2006).

Distribution and habitat preferences:

- The Cuvier's beaked whale is the most widely distributed beaked whale species (MacLeod et al. 2006). It is probably the most common beaked whale species occurring in the GOMEX (Jefferson and Schiro 1997). The Blainville's beaked whale is the most widely distributed of the *Mesoplodon* spp.; it is considered to inhabit all tropical, sub-tropical and warm-temperate waters, with occasional occurrences in cold-temperate areas (MacLeod et al. 2006). The Gervais' beaked whale is endemic to the warm-temperate to tropical Atlantic (MacLeod et al. 2006).

- World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Cañadas et al. 2002; Pitman 2002; MacLeod et al. 2004; Ferguson et al. 2006a; MacLeod and Mitchell 2006). Areas of steep bathymetry, such as submarine canyons have also been described as important habitat (e.g., Waring et al. 2001; D'Amico et al. 2003; MacLeod et al. 2004). Beaked whales in the eastern tropical Pacific are found in waters over the continental slope to the abyssal plain, ranging from well-mixed to highly stratified (Ferguson et al. 2006a).

- Beaked whales are expected to occur year-round throughout the GOMEX in waters off the continental shelf break (Jefferson and Schiro 1997; Davis et al. 1998). The northern GOMEX continental shelf margins recently were identified as known key areas for beaked whales, in a global review by MacLeod and Mitchell (2006). Habitat characterization modeling for the GOMEX predicted areas greater than 1,000 m in bottom depth as potential beaked whale habitat (Ward et al. 2005). The probability of beaked whale presence reaches a maximum along the slope, decreasing towards the continental shelf and deep abyssal region (Ward et al. 2005).

- World-wide, beaked whales only rarely stray over the continental shelf (Pitman 2002). In the GOMEX, a few beaked whale sightings on the continental shelf are reported (e.g., Fritts et al. 1983b; Esher et al. 1992).

Table 3-5. Density surface model results for Beaked Whales by season. These are abundance estimates for Beaked Whales in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring*	492
Summer	297
Fall	297
Winter	297

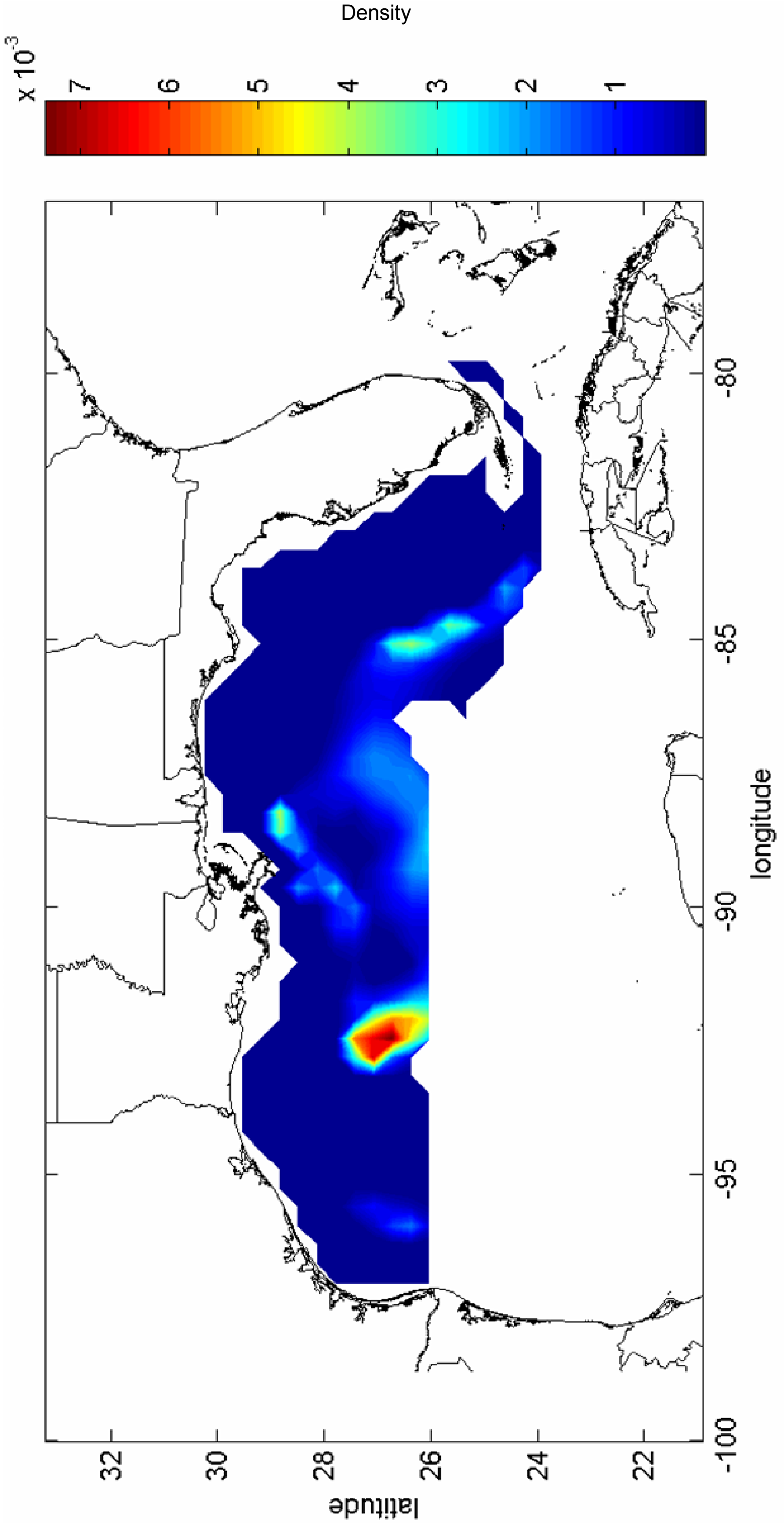


Figure 3-4. Density surface for Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area.

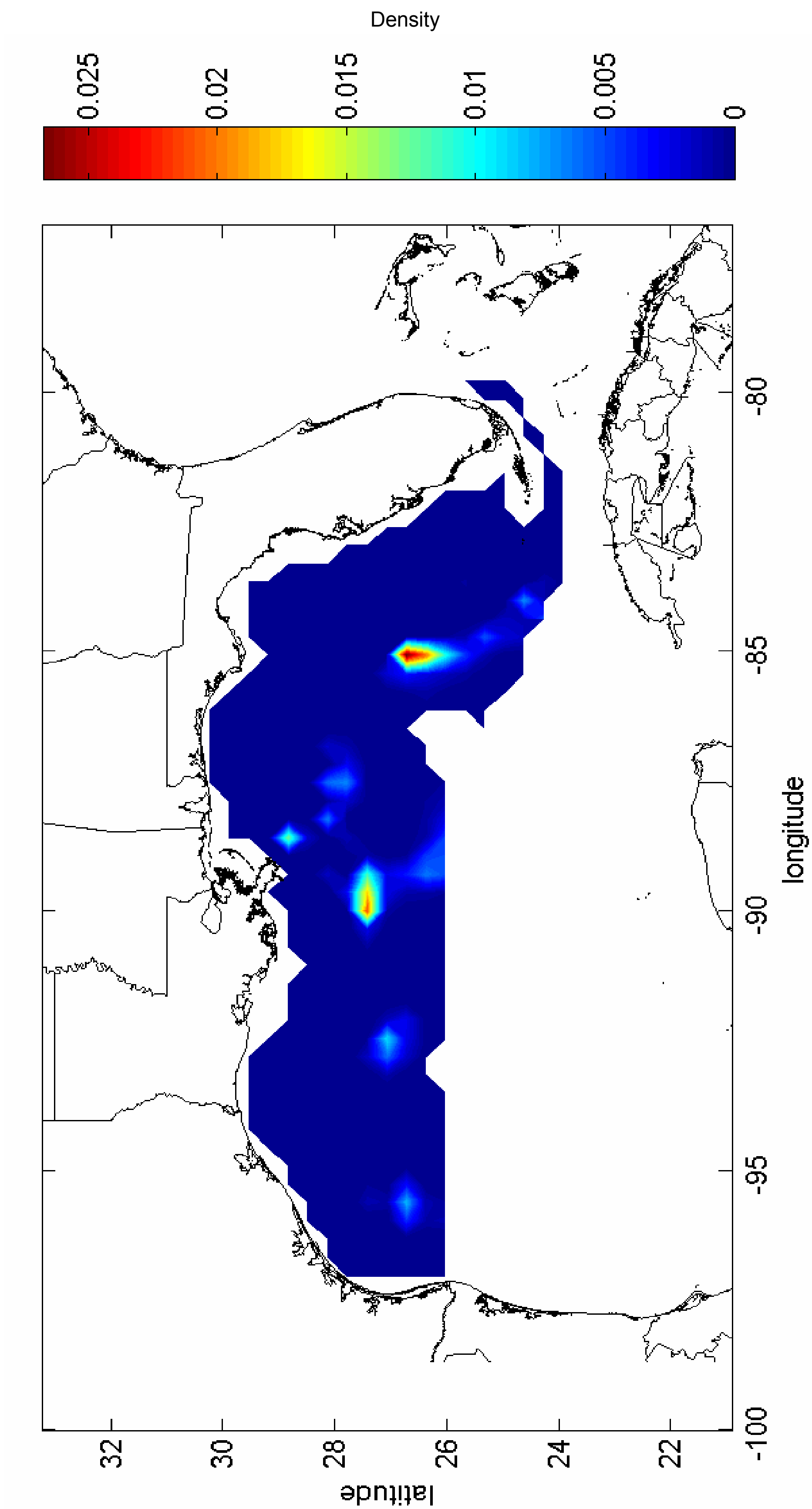


Figure 3-5. Surface density for Beaked Whales during spring in the Gulf of Mexico study area.

➢ Rough-toothed Dolphin (*Steno bredanensis*)

Distribution and habitat preferences:

- In the GOMEX, the rough-toothed dolphin occurs primarily over the deeper waters (bottom depths of 950 to 1,100 m) off the continental shelf (Davis et al. 1998).

- Occurrences over the continental shelf, off the Florida Panhandle and central Texas in northeastern GOMEX, are known from tagging and survey data (Wells et al. 1999; Fulling et al. 2003). Two separate mass strandings of rough-toothed dolphins occurred in the Florida Panhandle during December 1997 and 1998 (Rhinehart et al. 1999). Four stranded rough-toothed dolphins (three with satellite-linked transmitters) were rehabilitated and released in 1998 off the Gulf Coast of Florida (Wells et al. 1999). Water depth at tracking locations of these individuals averaged 195 m off the Florida Panhandle (Wells et al. 1999).

- During May 2005, seven more rough-toothed dolphins (stranded in the Florida Keys in March 2005 and rehabilitated) were tagged (two with satellite, the others with very high frequency [VHF]) and released by the Marine Mammal Conservancy in the Florida Keys (Wells, R., Mote Marine Laboratory, pers. comm., 29 January 2007). During an initial period of apparent disorientation in the shallow waters west of Andros Island, they continued to the east, then moved north through Crooked Island Passage, and paralleled the West Indies (Wells, R., Mote Marine Laboratory, pers. comm., 29 January 2007). The last signal placed them northeast (NE) of the Lesser Antilles (Wells, R., Mote Marine Laboratory, pers. comm., 29 January 2007). During September 2005, two more individuals (stranded with the previous group in the Florida Keys in March 2005 and rehabilitated) were satellite-tagged and released east of the Florida Keys by the Marine Mammal Conservancy (Wells, R., Mote Marine Laboratory, pers. comm., 29 January 2007). The tagging data demonstrated that these individuals proceeded south to a deep trench close to the north coast of Cuba (Wells, R., Mote Marine Laboratory, pers. comm., 29 January 2007).

Table 3-6. Density surface model results for the rough-toothed dolphin by season. These are abundance estimates for the rough-toothed dolphin in the Gulf of Mexico study area.

Density Surface Model (DSM)	Abundance
Spring	1,961
Summer	1,961
Fall	1,961
Winter	1,961

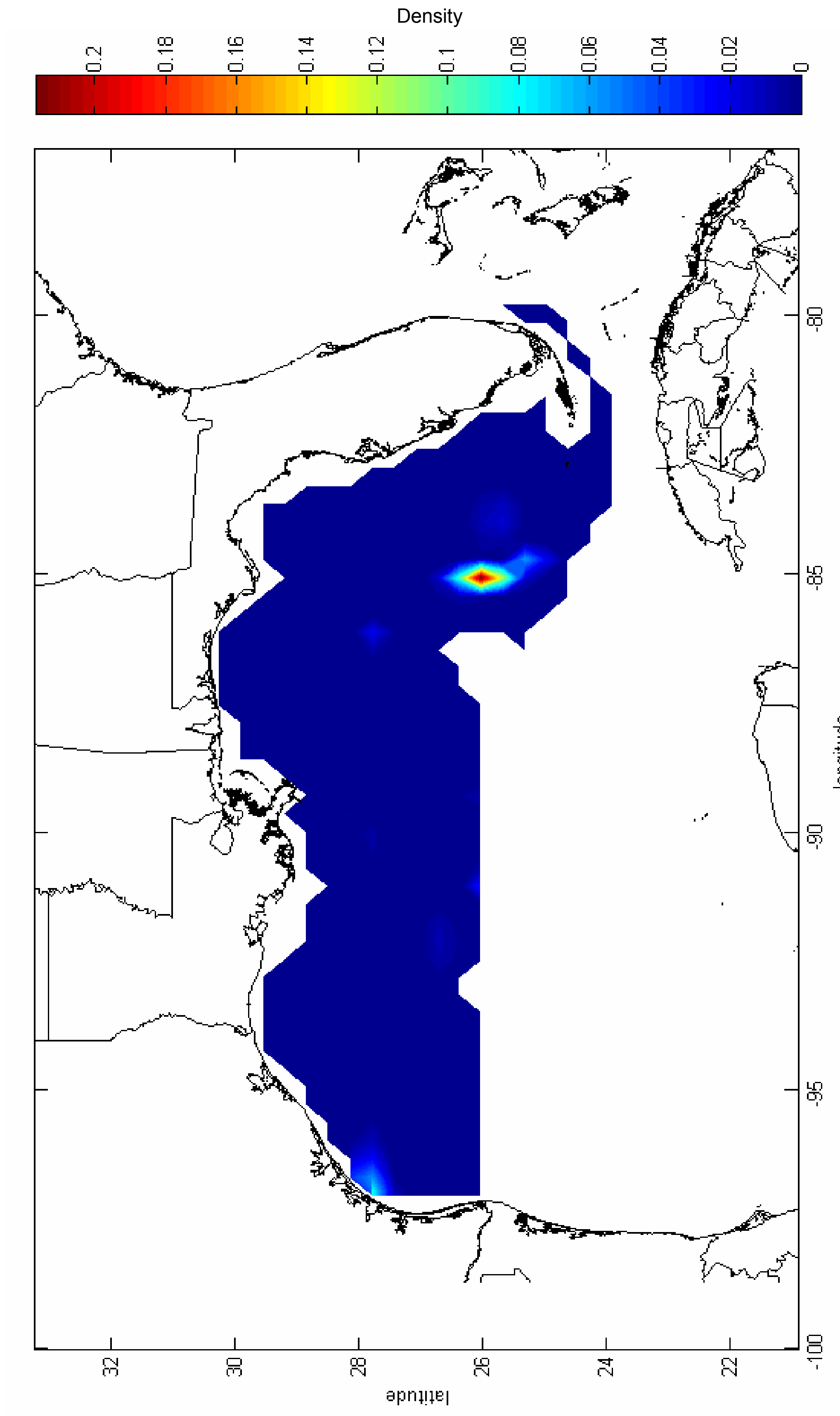


Figure 3-6. Density surface for the rough-toothed dolphin during all seasons in the Gulf of Mexico study area.

➢ Bottlenose Dolphin (*Tursiops truncatus)*

The category for bottlenose dolphins includes both the coastal (nearshore) and the offshore forms. As noted by Mullin and Fulling (2004), if genetic structure for this species in the GOMEX is similar to that for the species in the western North Atlantic (offshore form ≥34 km from shore and bottom depth greater than 34 m), then all bottlenose dolphins in oceanic waters are the offshore ecotype.

Distribution and habitat preferences:

- The bottlenose dolphin is regularly found in shallow waters of the continental shelf. The bottlenose dolphin is the most widespread and most common cetacean in coastal waters of the GOMEX (Würsig et al. 2000; Fulling et al. 2003; Mullin et al. 2004).

- Mullin et al. (2004) reported sighting bottlenose dolphins in waters with bottom depths averaging less than 300 m. Bottlenose dolphins appear to have an almost bimodal distribution in the GOMEX: the shallow continental shelf (0 to 150 m) and just seaward of the shelf break (200 to 750 m) (Baumgartner et al. 2001). These regions may represent the individual depth preferences for the nearshore and offshore forms. Baumgartner et al. (2001) hypothesized a potential association of bottlenose dolphins with oceanographic fronts at the shelf break.

- Mullin and Fulling (2004) reported encountering bottlenose dolphins primarily in upper continental slope waters less than 1,000 m in bottom depth, with highest densities in the northeastern GOMEX.

- Mullin and Fulling (2004) reported that groups of bottlenose dolphins were generally confined to the shelf break except in the northeastern GOMEX, where their distribution extended well seaward of the shelf break.

Table 3-7. Density surface model results for the bottlenose dolphin by season. These are abundance estimates for the bottlenose dolphin in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring	49,509
Summer*	39,598
Fall	49,509
Winter	49,509

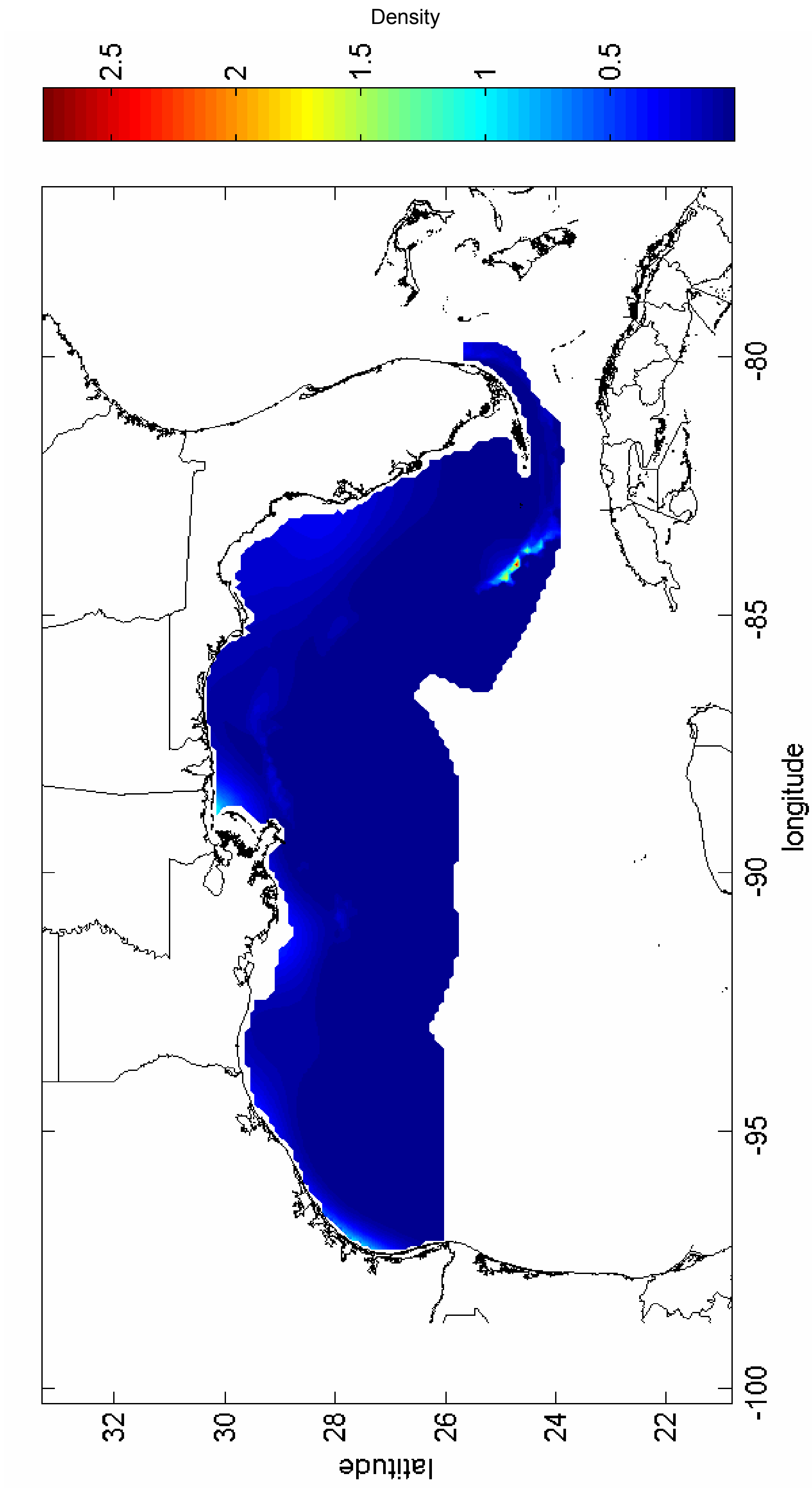


Figure 3-7. Density surface for the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area.

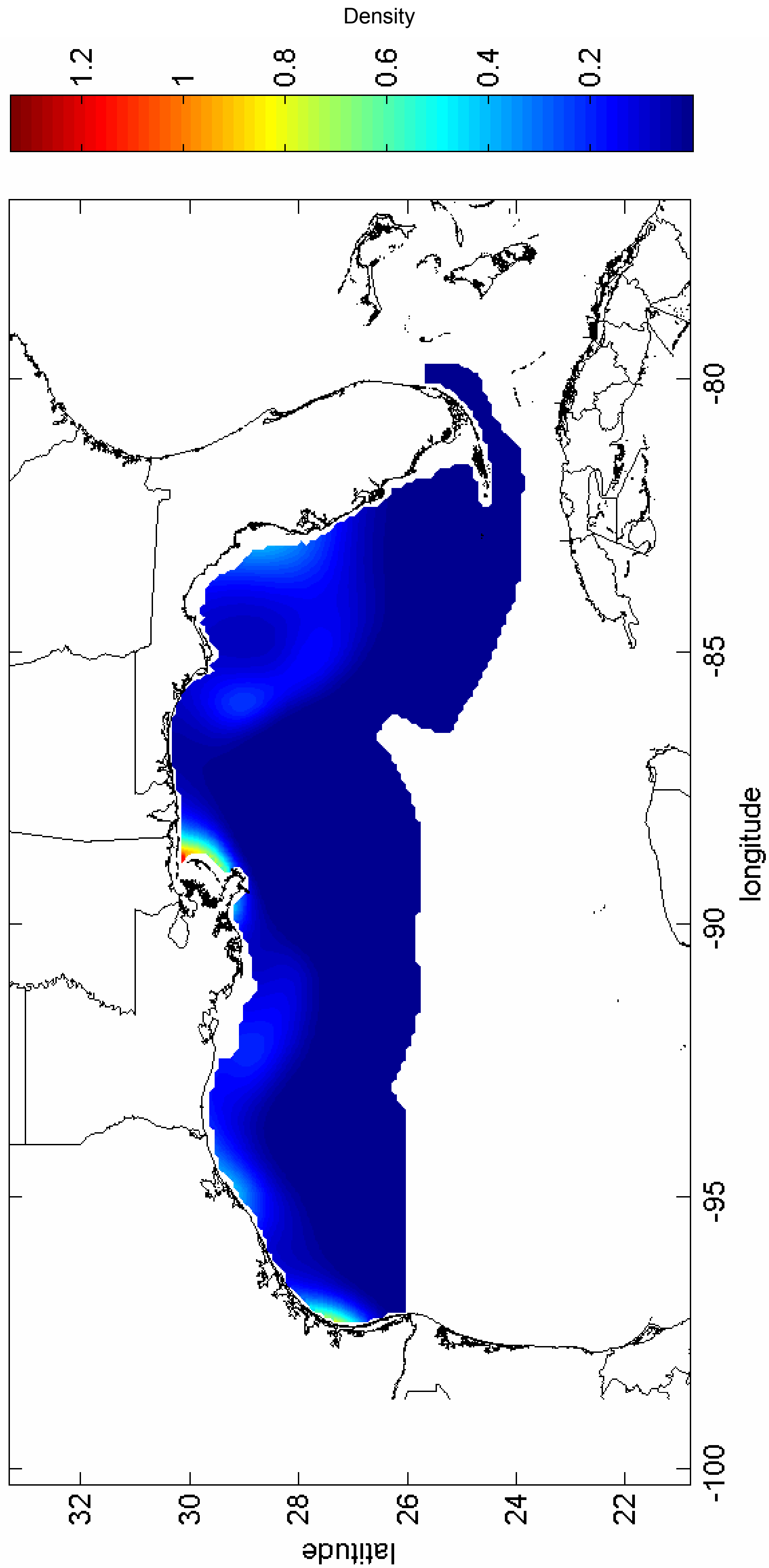


Figure 3-8. Density surface for the bottlenose dolphin during summer in the Gulf of Mexico study area.

➢ Pantropical Spotted Dolphin (*Stenella attenuata*)

Distribution and habitat preferences:

- Most sightings of this species in the GOMEX extend from the upper continental slope out over the abyssal region (Davis et al. 1998; Baumgartner et al. 2001; Mullin and Fulling 2004). Mullin et al. (2004) reported that sightings for this species were made in waters with a mean bottom depth of greater than 1,000 m.

- The pantropical spotted dolphin is rarely found on the continental shelf in the GOMEX (Jefferson and Schiro 1997).

- Baumgartner et al. (2001) reported that pantropical spotted dolphins in the GOMEX do not appear to have a preference for any one habitat (within the Loop Current, inside a cold-core eddy, or along the continental slope), while Davis et al. (2000; 2002) reported finding oceanic stenellids more often over the lower continental slope and abyssal regions in areas of cyclonic or confluence circulation. Baumgartner et al. (2001) noted that while no such relationship was detected in their study, other factors including temporal variability in habitat associations could easily account for this difference in the study results.

Table 3-8. Density surface model results for the pantropical spotted dolphin by season. These are abundance estimates for the pantropical spotted dolphin in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring*	102,174
Summer	81,034
Fall	81,034
Winter	81,034

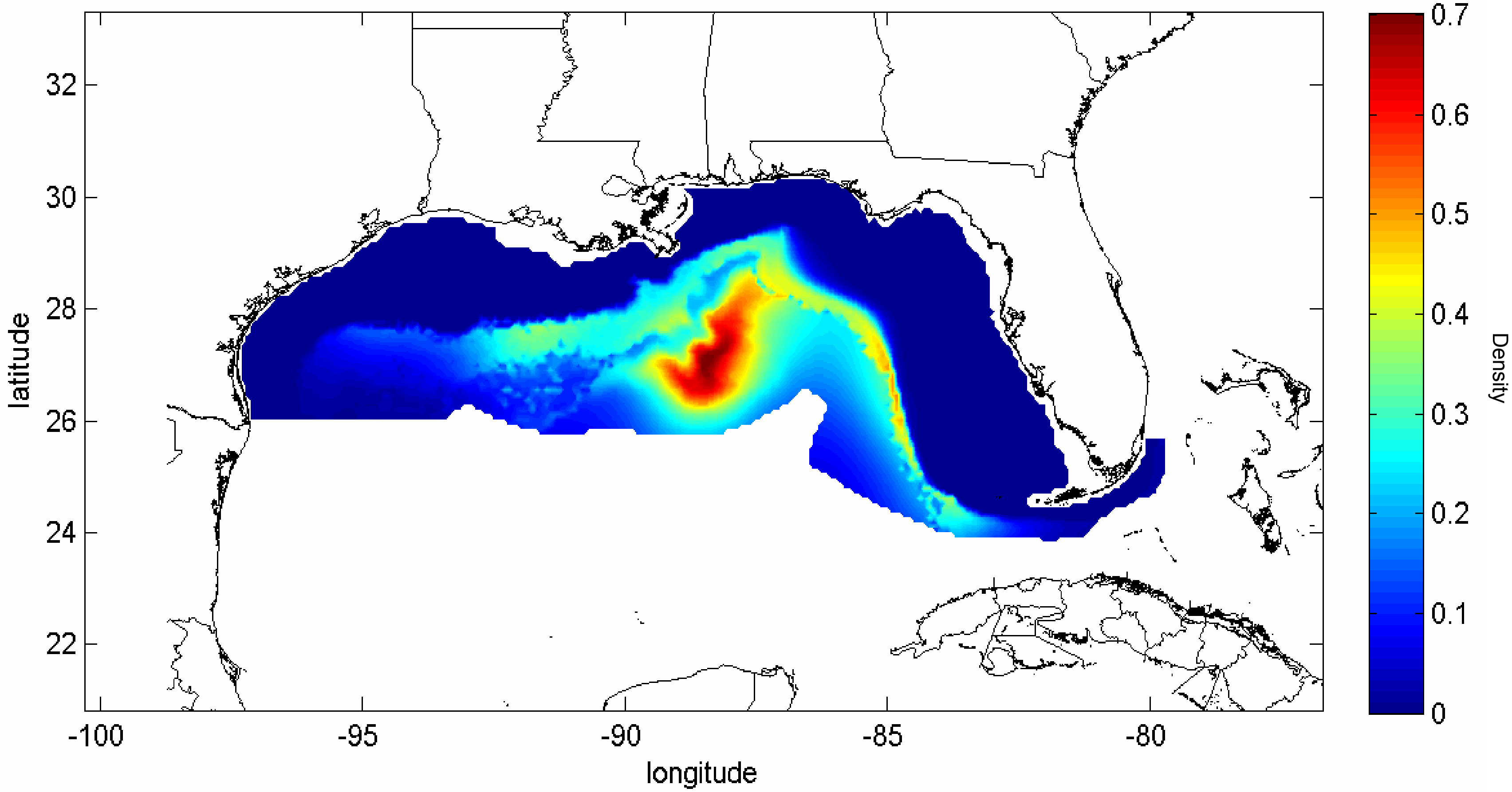


Figure 3-9. Density surface for the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area.

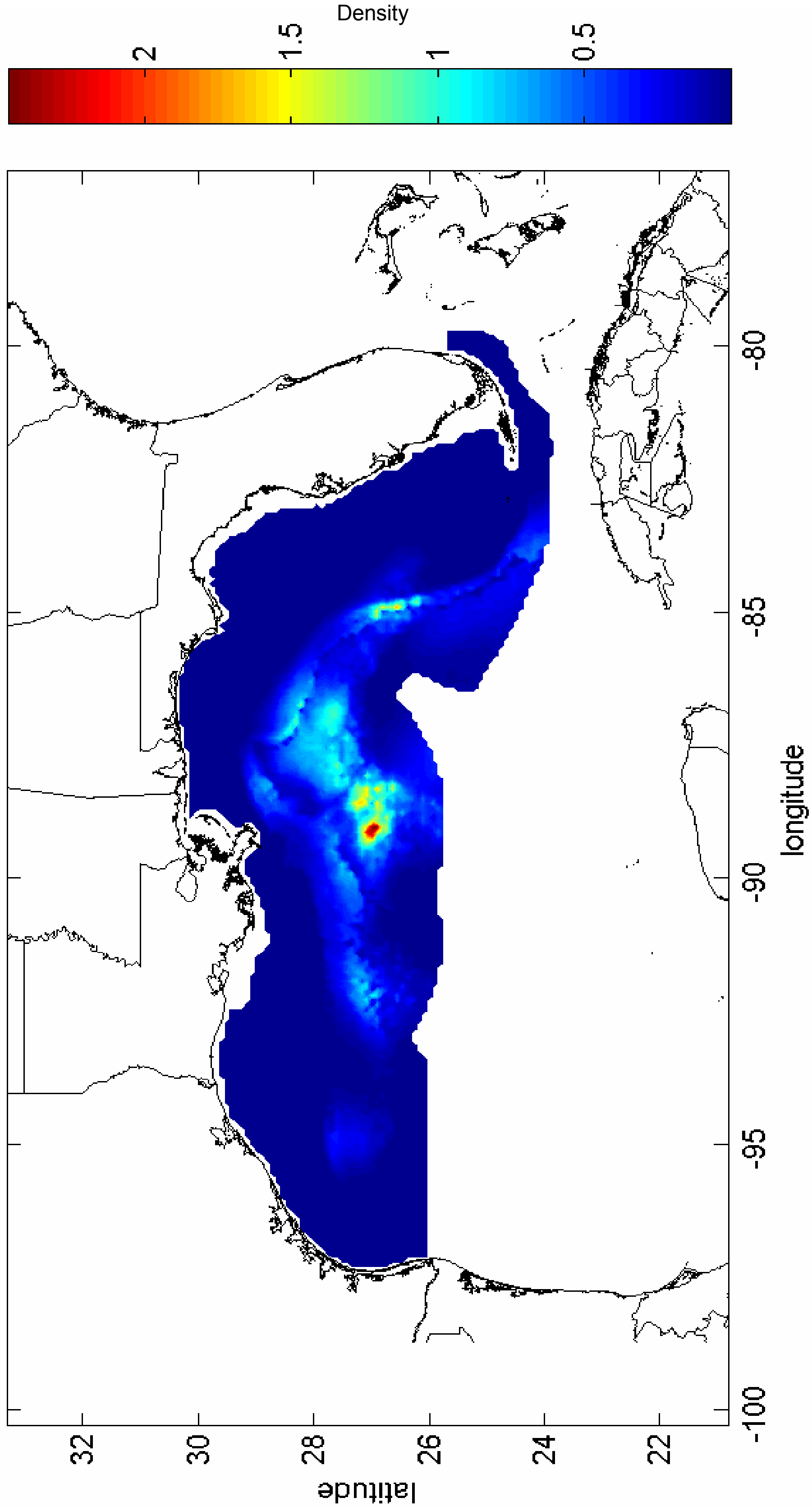


Figure 3-10. Density surface for the pantropical spotted dolphin during spring in the Gulf of Mexico study area.

➢ Atlantic Spotted Dolphin (*Stenella frontalis*)

Distribution and habitat preferences:

- This species primarily occurs on the continental shelf in the GOMEX (Mills and Rademacher 1996; Davis et al. 1998; Davis et al. 2002; Fulling et al. 2003; Griffin and Griffin 2003).

- Griffin and Griffin (2003) specifically noted a mid-shelf (20 to 180 m) habitat preference in the eastern GOMEX.

- In their less common habitat of oceanic waters of the GOMEX, Atlantic spotted dolphins usually occur near the shelf break in waters less than 500 m in bottom depth (Davis et al. 1998; Mullin et al. 2004).

Table 3-9. Density surface model results for the Atlantic spotted dolphin by season. These are abundance estimates for the Atlantic spotted dolphin in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring	32,227
Summer*	32,227
Fall	32,227
Winter	32,227

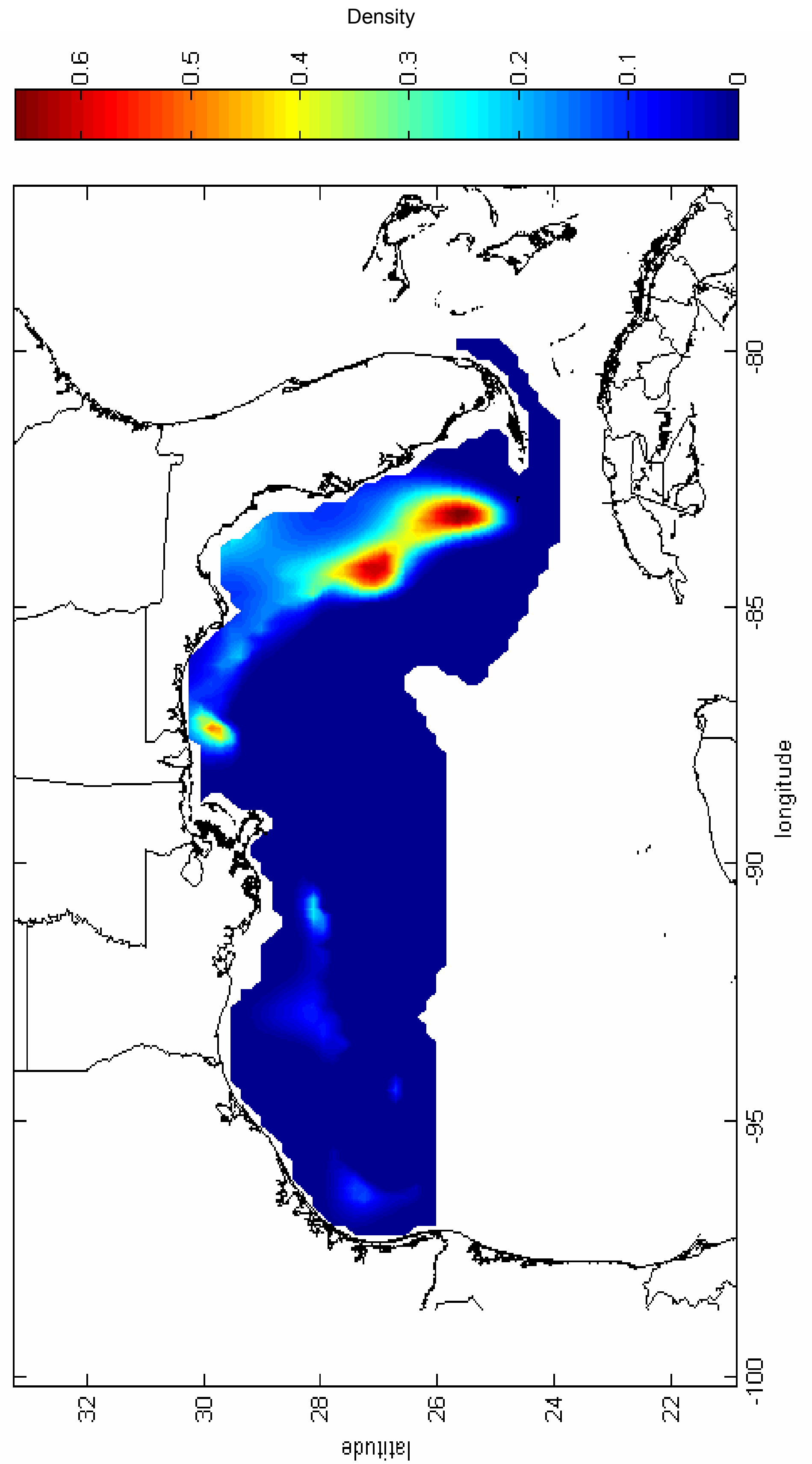


Figure 3-11. Density surface for the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area.

➢ Striped Dolphin *(Stenella coeruleoalba)*

Distribution and habitat preferences:

- Striped dolphins are usually found outside the continental shelf, typically over the continental slope out to oceanic waters, often associated with convergence zones and waters influenced by upwelling (Au and Perryman 1985).

- Davis et al. (2000; 2002) reported finding oceanic stenellids more often over the lower continental slope and abyssal regions in areas of cyclonic or confluence circulation.

Table 3-10. Density surface model results for the striped dolphin by season. These are abundance estimates for the striped dolphin in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring*	4,389
Summer	4,389
Fall	4,389
Winter	4,389

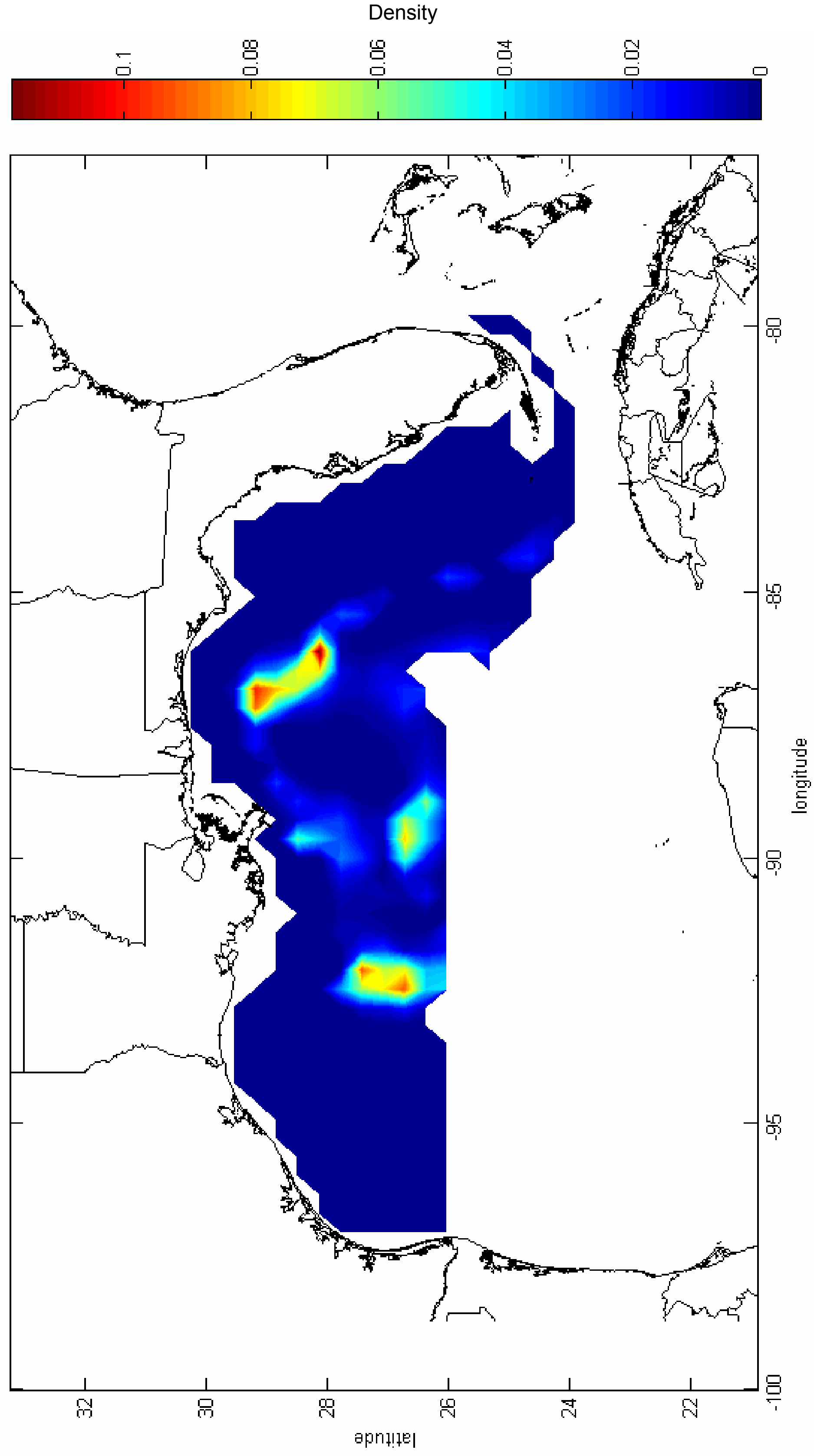


Figure 3-12. Density surface for the striped dolphin during all seasons in the Gulf of Mexico study area.

➢ Spinner Dolphin (*Stenella longirostris*)

Distribution and habitat preferences:

- Most of the spinner dolphin sightings in the GOMEX are east of the MS River (Mullin and Hansen 1999; Würsig et al. 2000; Mullin and Fulling 2004).

- Distribution in the GOMEX is primarily in deeper waters (bottom depth greater than 2,000 m) (Davis et al. 1998; Mullin and Fulling 2004).

- Davis et al. (2000; 2002) reported finding oceanic stenellids more often over the lower continental slope and abyssal regions in areas of cyclonic or confluence circulation.

Table 3-11. Density surface model results for the spinner dolphin by season. These are abundance estimates for the spinner dolphin in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring*	10,266
Summer	10,266
Fall	10,266
Winter	10,266

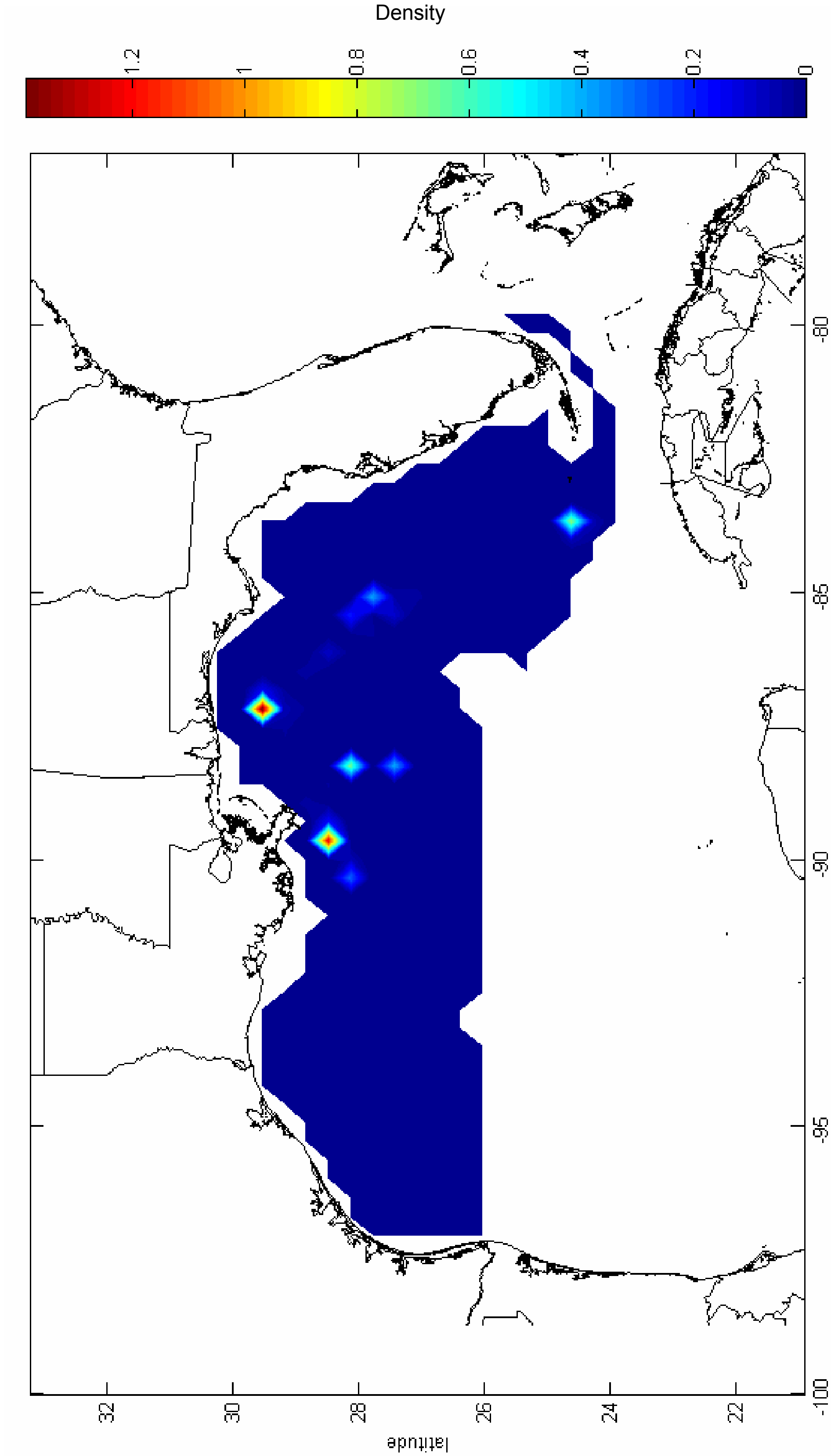


Figure 3-13. Density surface for the spinner dolphin during all seasons in the Gulf of Mexico study area.

- <u>Risso's Dolphin</u> (*Grampus griseus*)

Distribution and habitat preferences:

- A number of studies world-wide have noted that Risso's dolphins are found along the continental slope (CETAP 1982; Baumgartner 1997; Mignucci-Giannoni 1998; Kruse et al. 1999).

- There is a strong correlation between Risso's dolphin distribution and the steeper portions (200 to 1,000 m) of the upper continental slope in the GOMEX (e.g., Davis et al. 1998; Baumgartner et al. 2001; Davis et al. 2002; Mullin et al. 2004). This is most likely the result of cephalopod distribution in the same area (Baumgartner 1997).

Table 3-12. Density surface model results for the Risso's dolphin by season. These are abundance estimates for the Risso's dolphin in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring	1,976
Summer*	1,976
Fall	1,976
Winter	1,976

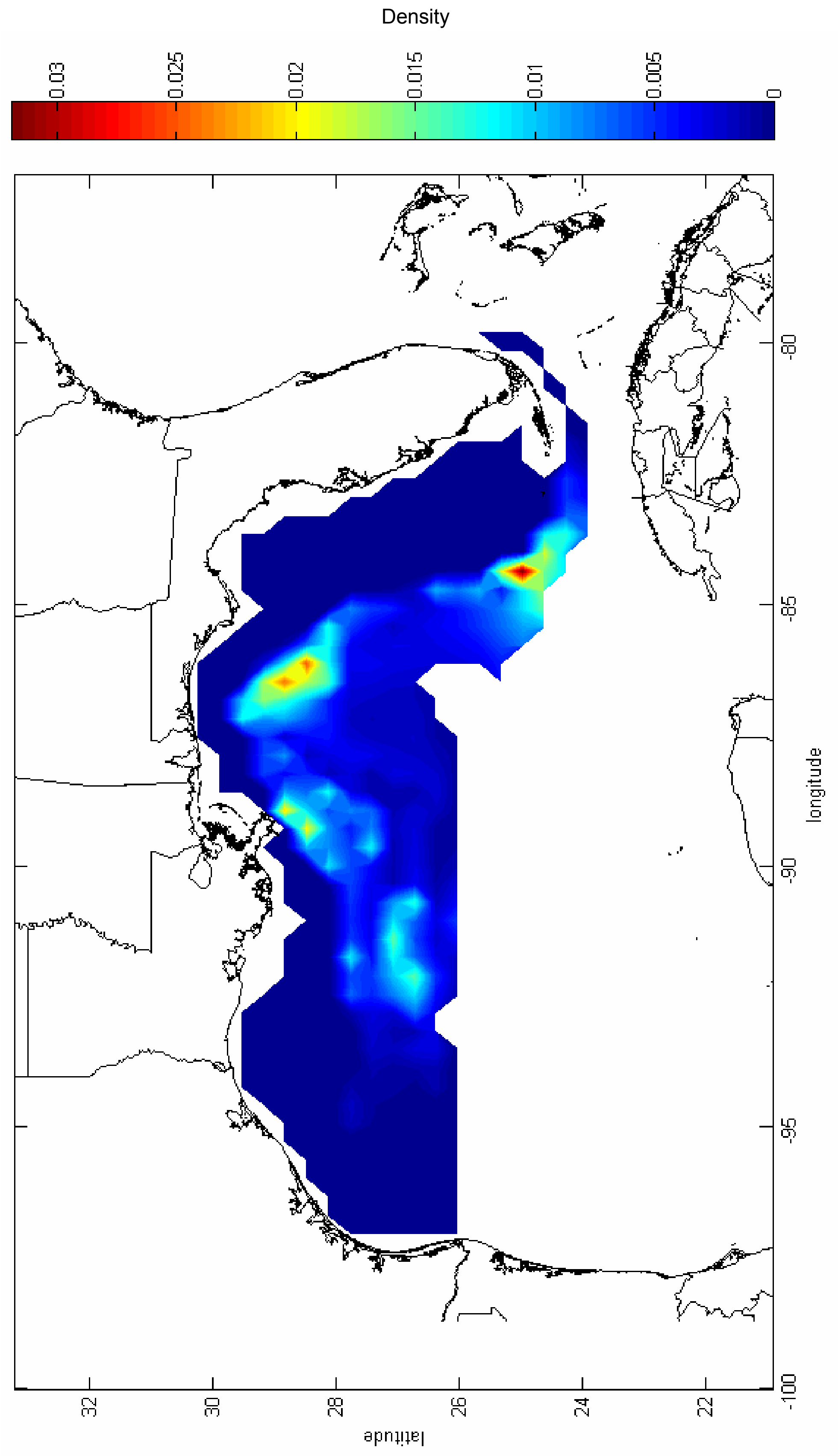


Figure 3-14. Density surface for the Risso's dolphin during all seasons in the Gulf of Mexico study area.

3.1.2 Species with SAR-derived Density Estimates

➢ Bryde's Whale (*Balaenoptera edeni*)

Distribution and habitat preferences:

- In the GOMEX, all Bryde's whale sightings have been predominantly near the shelf break in and near DeSoto Canyon and off western Florida (Mullin et al. 1994b; Davis and Fargion 1996; Jefferson and Schiro 1997; Davis et al. 1998; Davis et al. 2000).

- The Bryde's whale may occur throughout the year in the GOMEX (Jefferson and Schiro 1997; Würsig et al. 2000).

Density and abundance estimates

- The "best" estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

➢ Clymene Dolphin (*Stenella clymene*)

Distribution and habitat preferences:

- There are more Clymene dolphin records from the GOMEX than from the rest of this species' range combined (Jefferson et al. 1995; Fertl et al. 2003).

- Clymene dolphins are typically sighted in offshore waters offshore of the shelf break; Fertl et al. (2003) reported that Clymene dolphins were sighted in waters with a mean bottom depth of 1,870 m, throughout their range. There has not been much survey effort in waters with a bottom depth greater than 3,000 m in the GOMEX, yet there are documented sightings (e.g., Fertl et al. 2003).

- In a study of habitat preferences in the GOMEX, oceanic stenellids were found more often on the lower continental slope and in deepwater areas in regions of cyclonic or confluence circulation (Davis et al. 2002).

- Mullin and Fulling (2004) noted that Clymene dolphins were sighted primarily west of Mobile Bay.

Density and abundance estimates

- The "best" estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

➢ Fraser's Dolphin (*Lagenodelphis hosei*)

Distribution and habitat preferences:

- Fraser's dolphins are not sighted regularly in the GOMEX (Leatherwood et al. 1993; Ortega-Ortiz 2002; Mullin and Fulling 2004).

- This species generally prefers oceanic waters (Leatherwood et al. 1993; Jefferson and Leatherwood 1994). Sightings in the GOMEX have been seaward of the continental shelf break (Baumgartner 1997).

Density and abundance estimates

- The "best" estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

➢ Killer Whale (*Orcinus orca*)

Distribution and habitat preferences:

- Globally, killer whales are found in the open sea, as well as in coastal areas (Dahlheim and Heyning 1999).

- Killer whales are sighted year-round in the northern GOMEX (Jefferson and Schiro 1997; O'Sullivan and Mullin 1997; Würsig et al. 2000). Sightings are generally clumped in a broad region south of the MS River Delta, in waters ranging in bottom depth from 42 to 2,571 m (O'Sullivan and Mullin 1997). Mullin and Fulling (2004) reported that killer whales were sighted primarily west of Mobile Bay.

- Sightings also have been made in waters over the continental shelf (including close to shore) (Jefferson and Schiro 1997; O'Sullivan and Mullin 1997).

Density and abundance estimates

➢ The "best" estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

➢ False Killer Whale (*Pseudorca crassidens*)

Distribution and habitat preferences:

- This species is found primarily in oceanic and offshore areas world-wide (Baird 2002).

- Most sightings of false killer whales in the GOMEX are on the upper continental slope (Davis et al. 2002).

- False killer whales sometimes make their way into shallower waters. There have been sightings from over the continental shelf (Davis and Fargion 1996; Jefferson and Schiro 1997). Many sightings were reported by sport fishermen in the mid-1960s of "blackfish" (most likely false killer whales based on the descriptions) in waters offshore of Pensacola and Panama City, Florida (Brown et al. 1966).

- Most false killer whale sightings in the GOMEX are east of Mobile Bay (Mullin and Fulling 2004).

➢ Pygmy Killer Whale (*Feresa attenuata*)

Distribution and habitat preferences:

- This species does not appear to be common in the GOMEX (Davis and Fargion 1996; Jefferson and Schiro 1997; Davis et al. 2000; Würsig et al. 2000).

- In the northern GOMEX, this species is found primarily in deeper waters off the continental shelf and over the abyssal region (Davis et al. 2002). Sightings are typically over the upper continental slope (Jefferson and Schiro 1997; O'Sullivan and Mullin 1997; Würsig et al. 2000).

Density and abundance estimates

- The “best” estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

➢ <u>Melon-headed Whale</u> (*Peponocephala electra*)

Distribution and habitat preferences:

- Little information is available on the general habitat preferences of this species. Most melon-headed whale sightings in the GOMEX are in deep waters, well beyond the continental shelf break and out over the abyssal region (Mullin et al. 1994a; Davis and Fargion 1996; Davis et al. 2002).
-
- Mullin and Fulling (2004) reported that melon-headed whales were sighted primarily west of Mobile Bay.

Density and abundance estimates

- The “best” estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

➢ <u>Short-Finned Pilot Whale</u> (*Globicephala macrorhynchus*)

Based on known distribution and habitat preferences of pilot whales, it is assumed that all of the pilot whale records in the northern GOMEX are of the short-finned pilot whale.

Distribution and habitat preferences:

- Pilot whales are typically found over the continental shelf break, in slope waters, and in areas with steep bottom topography (Olson and Reilly 2002). A number of studies have suggested that the distribution and movements of *Globicephala* spp. coincide closely with the abundance of squid (Hui 1985; Payne and Heinemann 1993; Bernard and Reilly 1999).

- Sightings in the GOMEX are primarily on the upper continental slope (Payne and Heinemann 1993).

- While pilot whales are typically distributed along the continental shelf break, movements over the continental shelf are commonly observed in the northeastern U.S. (Jefferson and Schiro 1997). In the GOMEX, pilot whales are sometimes seen in waters over the continental shelf (Mullin et al. 2004).

- Mullin and Fulling (2004) reported that short-finned pilot whales were sighted primarily west of Mobile Bay.

- There is a preponderance of pilot whales in the historical records for the northern GOMEX. Pilot whales, however, are less often reported during recent surveys, such as GulfCet (Jefferson and Schiro 1997; Würsig et al. 2000). The reason for this apparent decline is not known, but Jefferson and Schiro (1997) suggested that abundance or distribution patterns might have changed over the past few decades, perhaps due to changes in available prey species.

Density and abundance estimates

- The “best” estimate of abundance for this species came from the SAR (Waring et al. 2007) based on analyses by Mullin and Fulling (2003). For the purpose of this report, this estimate was applied to the entire Southeast study area and across all seasons.

This page intentionally left blank

3.2 SEA TURTLES

All sea turtle species are listed as threatened or endangered under the ESA. Braun-McNeill and Epperly (2004) noted an increase in sea turtle sightings (specifically, hard-shelled species) in nearshore waters as water temperatures warmed, particularly in a westward direction, along the northern GOMEX. Braun-McNeill and Epperly (2004) also found that the pattern reversed in the late summer and fall, as water temperatures cooled, with turtles concentrating in Florida. In this section, individual species with density estimates are addressed first and are followed by the species representing the rest of the hard-shelled turtles listed in **Table 3-1**.

Density estimates for sea turtles were calculated using aerial survey data provided by NMFS-SEFSC (see **Section 2.2** for more information) using data collected in BSS ≤4 (see specifics below). Estimates were generated for the leatherback turtle, loggerhead turtle, Kemp's ridley turtle, and the group Hardshell Turtles in the same manner as marine mammal species. The species in the group Hardshell Turtles include green, hawksbill, Kemp's ridley turtles, unidentified hardshell turtles, and possible occurrences of the olive ridley turtle (*Lepidochelys olivacea*). Species in this group were pooled together since the numbers of sightings of each species or group were not sufficient to allow spatial modeling. This category did not include leatherback turtles since identification of leatherback turtles is not difficult. The sea turtle estimates produced are for continental shelf waters only, since only this portion of the study area was covered by aerial surveys.

Estimates were generated for the leatherback turtle, loggerhead turtle, Kemp's ridley turtle, and the group Hardshell Turtles in the same manner as marine mammal species. The species incorporated into the Hardshell Turtles category include green, hawksbill, were pooled together since the numbers of sightings for each species or group did not allow spatial modeling. This category did not include leatherback turtles since identification is not difficult. The sea turtle estimates produced are for continental shelf waters only, since only this portion of the study area was covered by aerial surveys.

3.2.1 Individual Species

➢ Leatherback Turtle (*Dermochelys coriacea*)

Distribution and habitat preferences

- Leatherback turtles are the most oceanic and wide-ranging of all sea turtle species. Post-hatchlings and early juveniles are entirely oceanic and restricted to waters warmer than 26°C (NMFS and USFWS 1992; Eckert 2002). Late juveniles and adults range from deep, mid-ocean habitats to the continental shelf and nearshore waters (Schroeder and Thompson 1987; Shoop and Kenney 1992; Grant and Ferrell 1993; Epperly et al. 1995).

- Juvenile and adult foraging habitats include both coastal feeding areas in temperate waters and offshore feeding areas in tropical waters (Frazier 2001).

- Leatherbacks occur year-round in the deep, offshore waters of the GOMEX (in particular, waters in the vicinity of DeSoto Canyon) for feeding, resting, and as migratory corridors (Landry and Costa 1999; Davis et al. 2000).

- Leatherbacks also occur in shallow waters over the continental shelf. Individuals have been observed feeding on dense aggregations of jellyfish in nearshore waters off the Florida Panhandle, the Mississippi River Delta, and the Texas coast (Leary 1957; Collard 1990; Lohoefener et al. 1990).

- This species often undertakes extensive migrations following depth contours for thousands of kilometers (Morreale et al. 1996; Hughes et al. 1998). Tagging studies in the North Atlantic Ocean have indicated many variations in overwintering and onshore-offshore occurrence patterns (Lee and Palmer 1981). The migratory cycles of adult leatherbacks often include movements between temperate and tropical waters.

- In recent years, low levels of nesting activity have been documented on both Florida Panhandle and south Florida beaches (Meylan et al. 1995).

Table 3-13. Density surface model results for the leatherback turtle by season. These are abundance estimates for the leatherback turtle in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring	1,468
Summer	1,468
Fall*	1,468
Winter	1,468

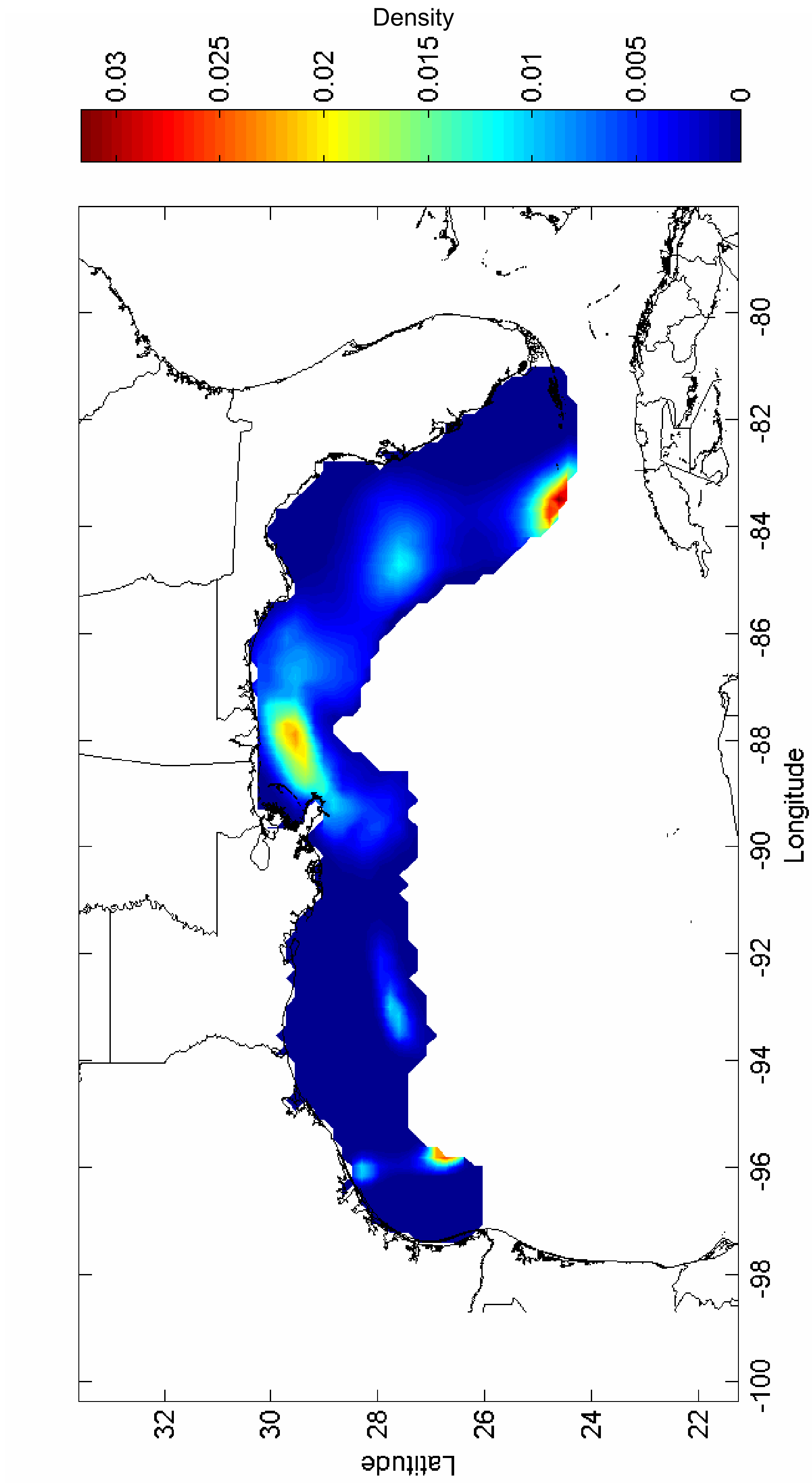


Figure 3-15. Density surface for the leatherback turtle during all seasons in the Gulf of Mexico study area.

➢ Loggerhead Turtle (*Caretta caretta*)

Distribution and habitat preferences

- The loggerhead turtle occurs worldwide in habitats ranging from coastal estuaries to waters far beyond the continental shelf (Dodd 1988).

- Loggerheads are primarily oceanic as post-hatchlings and early juveniles, often occurring in *Sargassum* driftlines where they are transported throughout the ocean by dominant currents (Carr 1987; Witherington 1994).

- Late juveniles and adults routinely occur in shallow, continental shelf habitats such as bays, sounds, and lagoons (Fritts et al. 1983a; Shoop and Kenney 1992). The shallow bays and sounds of the eastern GOMEX (e.g., Chandeleur Sound; Mobile, Escambia, and Tampa bays) likely serve as important developmental habitats for late juvenile loggerheads (Lohoefener et al. 1990; Davis et al. 2000).

- In the GOMEX, loggerhead turtles can be found throughout the year in both continental shelf and slope waters from southeastern Florida to southern Texas. Loggerhead abundance in continental slope waters of the eastern GOMEX is known to increase during the winter, as the temperatures of inshore and nearshore waters approach the lower thermal limits of this species (Davis et al. 2000).

- Juvenile loggerheads are known to inhabit offshore waters in the GOMEX where they are often associated with artificial reefs and oil platforms (Fritts 1983; Davis et al. 2000). These offshore habitats provide juveniles with an abundance of prey as well as sheltered locations where they can rest (Rosman et al. 1987). Adult loggerhead turtles reside in similar habitats, although their feeding behavior is more benthic-oriented; thus, they are more likely to be found in nearshore rather than offshore waters.

- Based on sighting and nesting surveys, the density and abundance of loggerhead turtles is much higher in the northeastern GOMEX than in the northwestern (Fritts et al. 1983a; Davis et al. 2000). This is likely due to the fact that adult loggerheads seldom use the beaches of Texas and Louisiana as nesting habitats and juveniles do not use the northwestern GOMEX as a development habitat as extensively as they use the northeastern GOMEX (Landry and Costa 1999).

Table 3-14. Density surface model results for the loggerhead turtle by season. These are abundance estimates for the loggerhead turtle in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring	8,867
Summer	8,867
Fall*	8,867
Winter	8,867

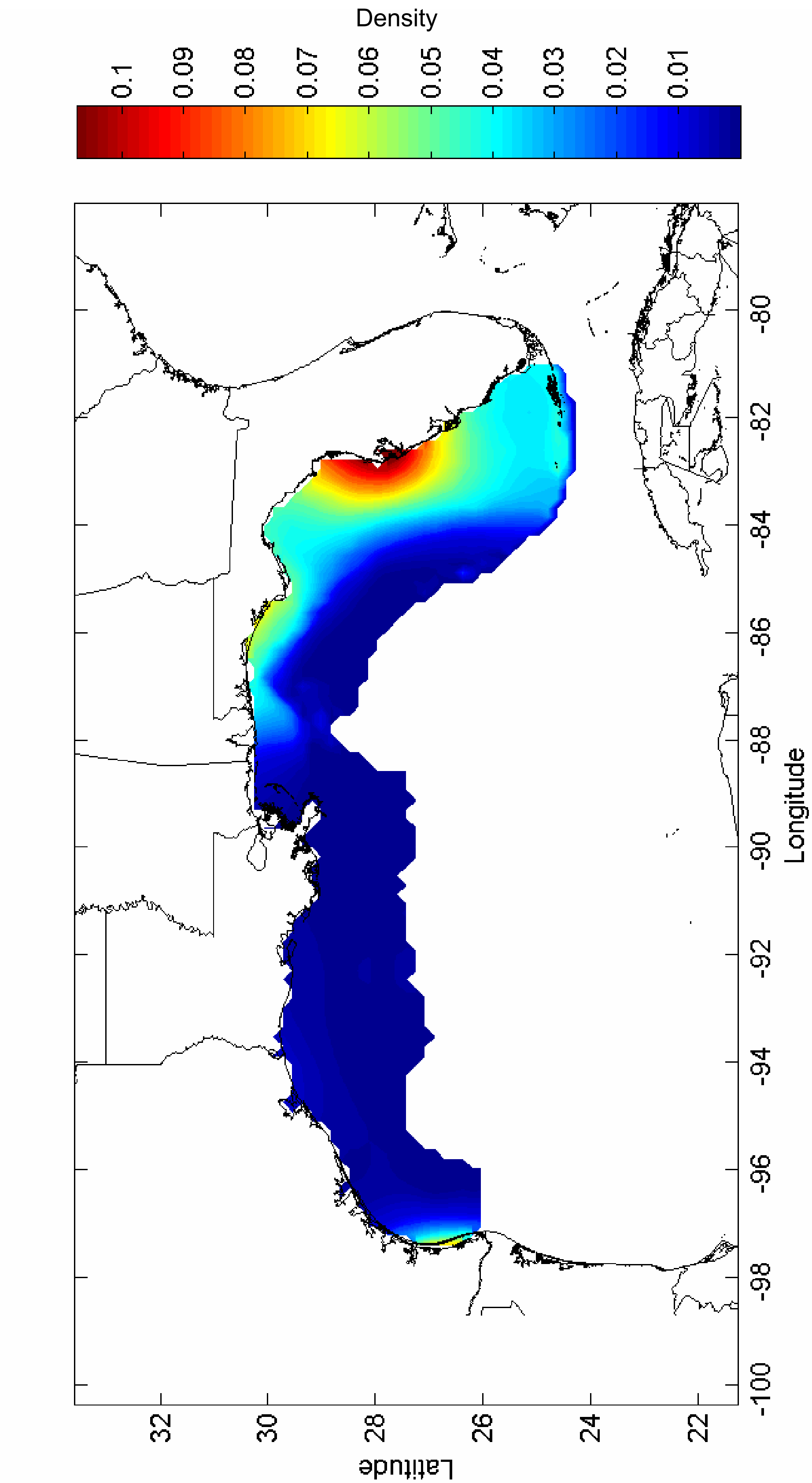


Figure 3-16. Density surface for the loggerhead turtle during all seasons in the Gulf of Mexico study area.

3.2.2 Species Groups

Hardshell Turtles

This group includes the hardshelled turtle species - the loggerhead, Kemp's ridley, green, hawksbill, and extralimital (in the Florida Keys and along the Atlantic coast of the U.S) occurrences of the olive ridley turtle and includes any sightings of unidentified hardshelled turtle individuals (**Table 3-1**). The unidentified Hardshell category did not include leatherback turtles since identification of leatherback turtles is not difficult. The distribution and habitat preference information for the loggerhead turtle is listed in **Section 3.2.1** along with the density estimates for this species. The distribution and habitat preference information for the rest of the species in the Hardshell Turtles group are listed below and followed by the density results for the group.

➢ Kemp's Ridley Turtle (*Lepidochelys kempii*)

Distribution and habitat preferences

- Kemp's ridley turtles occur in open-ocean and *Sargassum* habitats as post-hatchlings and early juveniles (e.g., Witherington and Hirama 2006). They move as large juveniles and adults to benthic, nearshore feeding grounds along the U.S. Atlantic and Gulf coasts (Lutcavage and Musick 1985; Landry and Costa 1999; Seney and Musick 2005). Adults appear to remain in the GOMEX, with occasional occurrences in the Atlantic Ocean.

- Kemp's ridley turtles primarily occur in shallow (bottom depth <50 m) continental shelf waters of the northern GOMEX year-round.

- Primary feeding habitats include warm-temperate to subtropical sounds, bays, estuaries, tidal passes, shipping channels, and beachfront waters where preferred food, including the blue crab (*Callinectes sapidus)*, occurs (Lutcavage and Musick 1985; Landry and Costa 1999; Seney and Musick 2005).

- In the GOMEX, the western coast of Florida (particularly the Cedar Keys area), the eastern coast of Alabama, the mouth of the Mississippi River, and the coastal waters off western Louisiana and eastern Texas have been identified as important developmental regions for the Kemp's ridley (Rudloe et al. 1991; Schmid et al. 2002).

- Results of habitat suitability modeling revealed that the most optimal habitats for Kemp's ridleys are those with a bottom depth of less than 10 m and a SST between 22° and 32°C (Coyne et al. 2000). Postnesting Kemp's ridleys travel along coastal corridors generally shallower than 50 m in bottom depth (Morreale et al. 2007).

- Nesting primarily occurs on a single beach at Rancho Nuevo, Tamaulipas, México (USFWS and NMFS 1992), although additional activity is documented in South TX (Meylan et al. 1990; Weber 1995; Foote and Mueller 2002; Phillips 2003; Shaver and Wibbels 2007)

➢ Green Turtle (*Chelonia mydas*)

Distribution and habitat preferences

- Green turtles are distributed worldwide in tropical and subtropical waters (Ernst et al. 1994).

- Post-hatchling and early-juvenile green turtles may take refuge in and around *Sargassum* rafts (Carr and Meylan 1980; Carr 1987; Witherington and Hirama 2006).

- Nearshore water temperatures play a major role in determining green turtle distribution along the Atlantic and Gulf coasts of the U.S.

- The optimal developmental habitats for late juveniles and foraging adults are warm, shallow waters (3 to 5 m in bottom depth), with an abundance of submerged aquatic vegetation, and located in close proximity to nearshore reefs or rocky areas, used by green turtles for resting (e.g., Holloway-Adkins 2006).

- In some locales, such as Hawaii, green turtles also may forage in deeper waters, as deep as 20 to 50 m (Brill et al. 1995).

- The preferred habitats of green turtles are located primarily along the coasts of southwestern Florida and southern Texas (Renaud et al. 1995; Landry and Costa 1999). Juvenile green turtles also utilize the inshore and nearshore waters of central Florida (e.g., Cedar Keys, Homosassa Springs, Crystal River, and Tampa Bay) throughout the year as developmental habitats (NMFS and USFWS 1991; Dodd 1995). Aside from the Florida Keys, Florida Bay, and Cedar Keys regions, green turtles in the northern GOMEX are most likely to reside in inshore waters (e.g., lagoons, channels, inlets, and bays) where seagrass beds and macroalgae are abundant. These areas include Texas's Laguna Madre and most of Florida's Gulf Coast estuaries, such as Pensacola Bay, St. Joseph Bay, Tampa Bay, and Charlotte Harbor. Additional areas supporting juvenile green populations are the shallow bays and sounds of the northeastern GOMEX (e.g., Chandeleur Sound; Mobile and Escambia bays).

- Green turtles may also be found in offshore waters of the GOMEX during reproductive or developmental migrations.

- Suitable nesting beaches are located throughout the region, from northern México and southern Texas in the western GOMEX to southern Florida and the Florida Panhandle in the eastern GOMEX (NMFS and USFWS 1991; Meylan 1995). The highest concentration of nesting activity in the GOMEX occurs in Monroe County, Florida, which includes most of the Florida Keys and the Dry Tortugas (Meylan 1995).

➢ Hawksbill Turtle (*Eretmochelys imbricata*)

Distribution and habitat preferences

- Juvenile and adult hawksbills are found in the GOMEX, the Caribbean Sea, and along the coast of southeastern Florida (Witzell 1983; NMFS and USFWS 1993).

- Hawksbill turtles inhabit oceanic waters as post-hatchlings and small juveniles, where they are sometimes associated with driftlines and floating patches of *Sargassum* (Parker 1995; Witherington and Hirama 2006).

- The developmental habitats for juvenile benthic-stage hawksbills are the same as the primary feeding grounds for adults; these include tropical, nearshore waters associated with coral reefs, hard bottoms, or estuaries with mangroves (Musick and Limpus 1997). Coral reefs are recognized as optimal hawksbill habitat for juveniles, sub-adults, and adults (NMFS and USFWS 1993; Diez et al. 2003). Ledges, caves, and root systems, often interspersed among these habitats, provide hawksbills refuge and shelter (NMFS and USFWS 1993). Sparse hard-bottom communities, cliff-wall habitats with soft corals and invertebrates are also considered important developmental habitat (Diez et al. 2003).

- In neritic habitats, the resting areas for late juveniles and adults are generally located in deeper waters (i.e., on sandy bottoms at the base of a reef flat) than their foraging areas (Houghton et al. 2003). Late juveniles generally reside on shallow reefs less than 18 m deep. However, as they mature into adults, hawksbills move to deeper habitats and may forage to depths greater than 90 m. Benthic-stage hawksbills are seldom found in waters beyond the continental or insular shelf, unless they are in transit between distant foraging or nesting grounds (NMFS and USFWS 1993).

- Hawksbills prefer alternate sites for resting and foraging. Resting sites tend to be of greater depths than foraging areas, although bottom topography influences site selection as well (Houghton et al. 2003).

- Shallow seagrass beds may also serve as important developmental habitats for late juveniles (Diez et al. 2003).

- In the GOMEX, the hawksbill primarily inhabits shallow, nearshore waters off southern Florida year-round. Small numbers of hawksbill occurrences are documented annually from southeastern Florida (Palm Beach, Broward, and Dade counties) through the Florida Keys to coastal waters just northwest of Tampa Bay, where the northernmost stranding records occur.

- Hawksbills are rarely observed in waters off the Florida Panhandle, Alabama, Mississippi, Louisiana, and Texas (Rabalais and Rabalais 1980; Witzell 1983; Rester and Condrey 1996). Hawksbill sightings in these areas likely involve early juveniles that are born on nesting beaches in México and have drifted north with the predominant currents (Landry and Costa 1999).

- Hawksbills tend to nest in multiple, small, scattered colonies, with the most significant nesting in the western North Atlantic Ocean occurring along the Yucatan Peninsula, México. Hawksbill nesting within the continental U.S. is restricted to beaches in southern Florida and the Florida Keys, although even there it is extremely rare (Dodd 1995).

Table 3-15. Density surface model results for Hardshell Turtles by season. These are abundance estimates for Hardshell Turtles in the Gulf of Mexico study area. *Season from which the model was fit.

Density Surface Model (DSM)	Abundance
Spring	13,062
Summer	13,062
Fall*	13,062
Winter	13,062

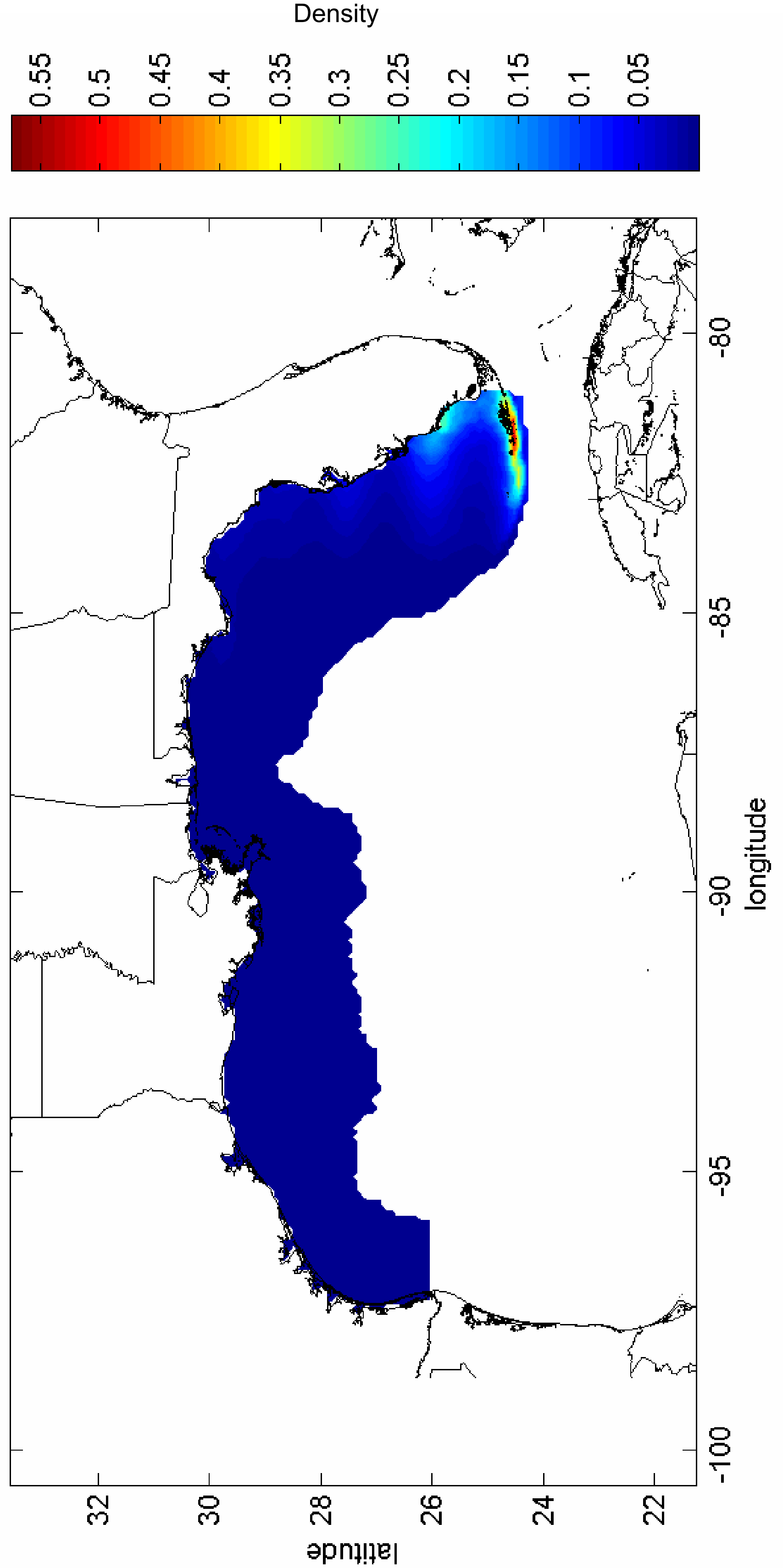


Figure 3-17. Density surface for Hardshell Turtles during all seasons in the Gulf of Mexico study area.

This page intentionally left blank

4.0 LIST OF PREPARERS

Name/Title/Affiliation	Education	Project Role
Joel T. Bell Marine Mammal Biologist Naval Facilities Engineering Command, Atlantic Norfolk, Virginia	M.E.M., Coastal Environmental Management Duke University B.S., Marine Science Kutztown University	Navy Technical Representative and Technical Review
Deanna R. Rees Wildlife Biologist Naval Facilities Engineering Command, Atlantic Norfolk, Virginia	B.S., Wildlife Resources University of Idaho	Alternate Navy Technical Representative and Technical Review
Mandy Shoemaker Naval Facilities Engineering Command, Atlantic Norfolk, Virginia	M.E.M., Coastal Environmental Management Duke University B.S., Marine Biology University of California Santa Cruz	Navy Technical Representative
Dan L. Wilkinson Vice President, Environmental Resources Geo-Marine, Inc. Plano, Texas	Ph.D., Botany Texas A&M University M.S., Zoology Stephen F. Austin State University B.S., Biology Central State University	Program Manager
Gregory L. Fulling, Ph.D. Senior Fisheries Biologist Senior Project Manager Marine Sciences-Plano Geo-Marine, Inc. Plano, Texas	Ph.D., Marine Biology The University of Southern Mississippi M.S., Biology Angelo State University B.S., Biology Eastern Washington University	Project Manager, Technical Lead
Eric Rexstad, Ph.D. Centre for Research into Ecological and Environmental Modelling (CREEM) University of St. Andrews St. Andrews, Scotland	Ph.D., Wildlife Biology Colorado State University M.S., Wildlife Ecology Utah State University B.S., Computer Science Luther College	Technical Lead, Technical Review
Anurag Kumar Marine Scientist/ Acoustician Geo-Marine, Inc. Hampton, Virginia	M.S., Marine Science Moss Landing Marine Laboratories, California State University B.S., Biology California State University	Data Analysis, Methodology
J. Carter Watterson Marine Scientist/Fisheries Biologist Geo-Marine, Inc. Hampton, Virginia	M.S., Marine Sciences Dauphin Island Sea Lab, University of South Alabama B.A., Biology University of Richmond	Data Analysis, Methodology, Technical Review

LIST OF PREPARERS
(continued)

Name/Title/Affiliation	Education	Project Role
Dagmar Fertl Senior Marine Mammal Biologist Geo-Marine, Inc. Plano, Texas	M.S., Wildlife and Fisheries Sciences Texas A&M University B.S., Biology Trinity University	Protected Species, Technical Review
Peter Gehring GIS Manager Geo-Marine, Inc. Plano, Texas	M.S., Environmental Science Miami University B.S., Zoology/Biochemistry Miami University	GIS QA/QC
Joseph Kaskey Senior Environmental Scientist Geo-Marine, Inc. Plano, Texas	M.S., Botany Southern Illinois University B.A., Biological Sciences Southern Illinois University	Technical Review
Kevin Knight Senior GIS Analyst Geo-Marine, Inc. Plano, Texas	B.S., Geology University of Texas	GIS Documentation, Data Management, Interactive GIS Tool Development
Tamara Lunsman Marine Scientist Geo-Marine, Inc. Plano, Texas	Ph.D., Marine Science University of California Santa Barbara B.S., Marine Biology Texas A&M University at Galveston	Document Preparation
Matthew Moore GIS Analyst Geo-Marine, Inc. Hampton, Virginia	B.S., Geography Old Dominion University	Graphic Design, GIS Map Production
Anna Perry Report Production Geo-Marine, Inc. Plano, Texas	M.S., Geology Baylor University B.S., Geology Clemson University	Report Production, Acronyms and Abbreviations
Cheryl Schroeder Manager, Marine Sciences: Virginia Office Senior Oceanographer Hampton, Virginia	M.S., Biological Oceanography University of Rhode Island B.S., Marine Biology Texas A&M University	Technical Review
Amy Whitt Marine Mammal Biologist Geo-Marine, Inc. Plano, Texas	M.E.M., Coastal Environmental Management Duke University B.S., Biology Lyon College	Protected Species

LIST OF PREPARERS
(continued)

Name/Title/Affiliation	Education	Project Role
Matthew Wryk GIS Analyst Geo-Marine, Inc. Hampton, Virginia	B.S., Biology Old Dominion University	Map Production, GIS Quality Control

This page intentionally left blank

5.0 LITERATURE CITED

Anonymous. 2006. Wayward whales in the Gulf of Mexico. Right Whale News 13(2):8-9.

Au, D.W.K. and W.L. Perryman. 1985. Dolphin habitats in the eastern tropical Pacific. Fishery Bulletin 83(4):623-643.

Baird, R.W. 2002. False killer whale *Pseudorca crassidens*. Pages 411-412 in Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Baird, R.W. 2005. Sightings of dwarf (*Kogia sima*) and pygmy (*K. breviceps*) sperm whales from the main Hawaiian Islands. Pacific Science 59(3):461-466.

Barlow, J. 1995. The abundance of cetaceans in California waters. Part I: Ship surveys in summer and fall of 1991. Fishery Bulletin 93(1):1-14.

Barlow, J. 1999. Trackline detection probability for long-diving whales. Pages 209-221 in Garner, G.W., S.C. Amstrup, J.L. Laake, B.F.J. Manly, L.L. McDonald, and D.G. Robertson, eds. Marine mammal survey and assessment methods. Rotterdam, Netherlands: A.A. Balkema.

Barlow, J. 2003a. Preliminary estimates of the abundance of cetaceans along the U.S. west coast: 1991-2001. NMFS-SWFSC Administrative Report LJ-03-03:1-31.

Barlow, J. 2003b. Cetacean abundance in Hawaiian waters during summer/fall of 2002. NMFS-SWFSC Administrative Report LJ-03-13:1-20.

Barlow, J. 2006. Cetacean abundance in Hawaiian waters estimated from a summer/fall survey in 2002. Marine Mammal Science 22(2):446-464.

Barlow, J. and S. Sexton. 1996. The effect of diving and searching behavior on the probability of detecting track-line groups, g_o, of long-diving whales during line-transect surveys. NMFS-SWFSC Administrative Report LJ-96-14:1-21.

Barlow, J. and T. Gerrodette. 1996. Abundance of cetaceans in California waters based on 1991 and 1993 ship surveys. NOAA Technical Memorandum NMFS-SWFSC-233:1-15.

Barlow, J. and B.L. Taylor. 2005. Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey. Marine Mammal Science 21(3):429-445.

Barlow, J., M.C. Ferguson, W.F. Perrin, L. Ballance, T. Gerrodette, G. Joyce, C.D. MacLeod, K. Mullin, D.L. Palka, and G. Waring. 2006. Abundance and densities of beaked and bottlenose whales (family Ziphiidae). Journal of Cetacean Research and Management 7(3):263-270.

Baumgartner, M.F. 1997. The distribution of Risso's dolphin (*Grampus griseus*) with respect to the physiography of the northern Gulf of Mexico. Marine Mammal Science 13(4):614-638.

Baumgartner, M.F., K.D. Mullin, L.N. May, and T.D. Leming. 2001. Cetacean habitats in the northern Gulf of Mexico. Fishery Bulletin 99:219-239.

Bernard, H.J. and S.B. Reilly. 1999. Pilot whales *Globicephala* Lesson, 1828. Pages 245-279 in Ridgway, S.H. and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego, California: Academic Press.

Biggs, D.C., R.R. Leben, and J.G. Ortega-Ortiz. 2000. Ship and satellite studies of mesoscale circulation and sperm whale habitats in the northeast Gulf of Mexico during GulfCet II. Gulf of Mexico Science 18(1):15-22.

Blaylock, R.A. and W. Hoggard. 1994. Preliminary estimates of bottlenose dolphin abundance in southern U.S. Atlantic and Gulf of Mexico continental shelf waters. NOAA Technical Memorandum NMFS-SEFSC-356:1-10.

Braun-McNeill, J. and S.P. Epperly. 2004. Spatial and temporal distribution of sea turtles in the western North Atlantic and the U.S. Gulf of Mexico from Marine Recreational Fishery Statistics Survey (MRFSS). Marine Fisheries Review 64(4):50-56.

Brill, R.W., G.H. Balazs, K.N. Holland, R.K.C. Chang, S. Sullivan, and J. George. 1995. Daily movements, habitat use, and submergence intervals of normal and tumor-bearing juvenile green turtles (*Chelonia mydas* L.) within a foraging area in the Hawaiian Islands. Journal of Experimental Marine Biology and Ecology 185:203-218.

Brown, D.H., D.K. Caldwell, and M.C. Caldwell. 1966. Observations on the behavior of wild and captive false killer whales, with notes on associated behavior of other genera of captive delphinids. Los Angeles County Museum Contributions in Science 95:1-32.

Buckland, S.T., D.R. Anderson, K.P. Burnham, J.L. Laake, D.L. Borchers, and L. Thomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. New York, New York: Oxford University Press.

Cañadas, A., R. Sagarminaga, and S. García-Tiscar. 2002. Cetacean distribution related with depth and slope in the Mediterranean waters off southern Spain. Deep-Sea Research I 49:2053-2073.

Carr, A. 1987. New perspectives on the pelagic stage of sea turtle development. Conservation Biology 1(2):103-121.

Carr, A. and A.B. Meylan. 1980. Evidence of passive migration of green turtle hatchlings in *Sargassum*. Copeia 1980(2):366-368.

Carretta, J.V., B.L. Taylor, and S.J. Chivers. 2001. Abundance and depth distribution of harbor porpoise (*Phocoena phocoena*) in northern California determined from a 1995 ship survey. Fishery Bulletin 99:29-39.

CETAP (Cetacean and Turtle Assessment Program). 1982. Characterization of marine mammals and turtles in the Mid- and North Atlantic areas of the U.S. Outer Continental Shelf. Contract AA551-CT8-48. Prepared for U.S. Bureau of Land Management, Washington, D.C. by Cetacean and Turtle Assessment Program, University of Rhode Island, Graduate School of Oceanography, Kingston, Rhode Island.

Collard, S.B. 1990. Leatherback turtles feeding near a watermass boundary in the eastern Gulf of Mexico. Marine Turtle Newsletter 50:12-14.

Combs, R. 2005. Development of mission avoidance zones through habitat suitability modeling in the Eglin Gulf Test and Training Range: Development of a geo-database. Project No. 05-270. Washington, D.C.: Department of Defense Legacy Resource Management Program.

Coyne, M.S., M.E. Monaco, and A.M. Landry, Jr. 2000. Kemp's ridley habitat suitability index model. Page 60 in Abreu-Grobois, F.A., R. Briseño-Dueñas, R. Márquez-Millán, and L. Sarti-Martínez, eds. Proceedings of the Eighteenth International Sea Turtle Symposium. NOAA Technical Memorandum NMFS-SEFSC-436.

D'Amico, A., A. Bergamasco, P. Zanasca, S. Carniel, E. Nacini, N. Portunato, V. Teloni, C. Mori, and R. Barbanti. 2003. Qualitative correlation of marine mammals with physical and biological parameters in the Ligurian Sea. IEEE Journal of Oceanic Engineering 28(1):29-43.

Dahlheim, M.E. and J.E. Heyning. 1999. Killer whale *Orcinus orca* (Linnaeus, 1758). Pages 281-322 in Ridgway, S.H. and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego, California: Academic Press.

Davis, R.W. and G.S. Fargion, eds. 1996. Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico, final report. Volume II: Technical report. OCS Study MMS 96-0027. New Orleans, Louisiana: Minerals Management Service.

Davis, R.W., W.E. Evans, and B. Würsig, eds. 2000. Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: Distribution, abundance and habitat associations. Volume 2: Technical report. USGS/BRD/CR-1999-0006 and OCS Study MMS 2000-003. New Orleans, Louisiana: Minerals Management Service.

Davis, R.W., G.S. Fargion, N. May, T.D. Leming, M. Baumgartner, W.E. Evans, L.J. Hansen, and K. Mullin. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western Gulf of Mexico. Marine Mammal Science 14(3):490-507.

Davis, R.W., J.G. Ortega-Ortiz, C.A. Ribic, W.E. Evans, D.C. Biggs, P.H. Ressler, R.B. Cady, R.R. Leben, K.D. Mullin, and B. Würsig. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. Deep-Sea Research I 49:121-142.

Diez, C.E., X. Vélez-Zuazo, and R.P. Van Dam. 2003. Hawksbill turtles in seagrass beds. Marine Turtle Newsletter 102:8-10.

Dodd, C.K. 1988. Synopsis of the biological data on the loggerhead sea turtle *Caretta caretta* (Linnaeus 1758). Biological Report 88(14). Washington, D.C.: U.S. Fish and Wildlife Service.

Dodd, C.K. 1995. Marine turtles in the southeast. Pages 121-123 in LaRoe, E.T., G.S. Farris, C.E. Puckett, P.D. Doran, and M.J. Mac, eds. Our living resources - A report to the nation on the distribution, abundance, and health of U.S. plants, animals, and ecosystems. Washington, D.C.: National Biological Service.

DoN (Department of the Navy). 2003. Marine resources assessment for the Eastern Gulf of Mexico Testing and Training Areas. Final report. Contract number N62470-95-D-1160, CTO 0053.

Norfolk, Virginia: Atlantic Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

DoN (Department of the Navy). 2005. Marine resources assessment for the Gulf of Mexico--Draft report. Contract number N62470-02-D-9997, CTO 0030. Norfolk, Virginia: Department of the Navy, U.S. Fleet Forces Command. Prepared by Geo-Marine, Inc., Hampton, Virginia.

DoN (Department of the Navy). 2007a. Marine resources assessment for the Southeastern Florida and the AUTEC-Andros operating area. Contract number N62470-02-D-9997, CTO 0034. Norfolk, Virginia: Atlantic Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

DoN (Department of the Navy). 2007b. Marine resources assessment for the Gulf of Mexico. Contract number N62470-02-D-9997, CTO 0030. Norfolk, Virginia: Atlantic Division, Naval Facilities Engineering Command. Prepared by Geo-Marine, Inc., Plano, Texas.

Eckert, S.A. 2002. Distribution of juvenile leatherback sea turtle *Dermochelys coriacea* sightings. Marine Ecology Progress Series 230:289-293.

Efron, B. and R.J. Tibshirani. 1993. An introduction to the bootstrap. London, England: Chapman & Hall/CRC.

Epperly, S., L. Avens, L. Garrison, T. Henwood, W. Hoggard, J. Mitchell, J. Nance, J. Poffenberger, C. Sasso, E. Scott-Denton, and C. Yeung. 2002. Analysis of sea turtle bycatch in the commercial shrimp fisheries of southeast U.S. waters and the Gulf of Mexico. NOAA Technical Memorandum NMFS-SEFSC 490:1-88.

Epperly, S.P., J. Braun, and A. Veishlow. 1995. Sea turtles in North Carolina waters. Conservation Biology 9:384-394.

Ernst, C.H., J.E. Lovich, and R.W. Barbour. 1994. Turtles of the United States and Canada. Washington, D.C.: Smithsonian Institution Press.

Esher, R.J., C. Levenson, and T.D. Drummer. 1992. Aerial surveys of endangered and protected species in the *Empress II* ship trial operating area in the Gulf of Mexico. Final report. NRL/MR/7174-92-7002. Stennis Space Center, Mississippi: Naval Research Laboratory.

Ferguson, M.C., J. Barlow, S.B. Reilly, and T. Gerrodette. 2006a. Predicting Cuvier's *(Ziphius cavirostris)* and *Mesoplodon* beaked whale population density from habitat characteristics in the eastern tropical Pacific Ocean. Journal of Cetacean Research and Management 7(3):287-299.

Ferguson, M.C., J. Barlow, P. Fiedler, S.B. Reilly, and T. Gerrodette. 2006b. Spatial models of delphinid (family Delphinidae) encounter rate and group size in the eastern tropical Pacific Ocean. Ecological Modelling 193:645-662.

Fertl, D., T.A. Jefferson, I.B. Moreno, A.N. Zerbini, and K.D. Mullin. 2003. Distribution of the Clymene dolphin *Stenella clymene*. Mammal Review 33(3):253-271.

Foote, J.J. and T.L. Mueller. 2002. Two Kemp's ridley (*Lepidochelys kempii*) nests on the central Gulf coast of Sarasota County Florida (USA). Pages 252-253 in Mosier, A., A. Foley, and B. Brost, eds. Proceedings of the Twentieth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-477.

Forney, K.A. and J. Barlow. 1993. Preliminary winter abundance estimates for cetaceans along the California coast based on a 1991 aerial survey. Reports of the International Whaling Commission 43:407-415.

Forney, K.A., J. Barlow, and J.V. Carretta. 1995. The abundance of cetaceans in California waters. Part II: Aerial surveys in winter and spring of 1991 and 1992. Fishery Bulletin 93(1):15-26.

Frazier, J.G. 2001. General natural history of marine turtles. Pages 3-17 in Eckert, K.L. and F.A. Abreu-Grobois, eds. Proceedings: Marine Turtle Conservation in the Wider Caribbean Region: A Dialogue for Effective Regional Management. 16-18 November 1999. Santo Domingo, Dominican Republic.

Fritts, T.H. 1983. Oil and gas impacts on marine turtles in the Gulf of Mexico. Pages 49-64 in Owens, D., D. Crowell, G. Dienberg, M. Grassman, S. McCain, Y. Morris, N. Schwantes, and T. Wibbels, eds. Proceedings of the Western Gulf of Mexico Sea Turtle Workshop. College Station: Texas A&M University.

Fritts, T.H., W. Hoffman, and M.A. McGehee. 1983a. The distribution and abundance of marine turtles in the Gulf of Mexico and nearby Atlantic waters. Journal of Herpetology 17(4):327-344.

Fritts, T.H., A.B. Irvine, R.D. Jennings, L.A. Collum, W. Hoffman, and M.A. McGehee. 1983b. Turtles, birds, and mammals in the northern Gulf of Mexico and nearby Atlantic waters. FWS/OBS-82/65. Washington, D.C.: U.S. Fish and Wildlife Service.

Fulling, G.L. and D. Fertl. 2003. *Kogia* distribution in the northern Gulf of Mexico. Pages 13-16 in Odell, D.K. and N.B. Barros, eds. Abstracts, Workshop on the Biology of Kogia held on 13 December 2003, Greensboro, North Carolina, USA.

Fulling, G.L., K.D. Mullin, and C.W. Hubard. 2003. Abundance and distribution of cetaceans in outer continental shelf waters of the U.S. Gulf of Mexico. Fishery Bulletin 101:923-932.

Goddard DAAC (Distributed Active Archive Center). 1986. Coastal Zone Color Scanner (CZCS) Level 3 monthly parameter subsets. Greenbelt, Maryland: NASA Goddard DAAC.

Grant, G.S. and D. Ferrell. 1993. Leatherback turtle, *Dermochelys coriacea* (Reptilia: Dermochelidae): Notes on near-shore feeding behavior and association with cobia. Brimleyana 19:77-81.

Griffin, R.B. and N.J. Griffin. 2003. Distribution, habitat partitioning, and abundance of Atlantic spotted dolphins, bottlenose dolphins, and loggerhead sea turtles on the eastern Gulf of Mexico continental shelf. Gulf of Mexico Science 21(1):23-34.

Hansen, L.J., K.D. Mullin, T.A. Jefferson, and G.P. Scott. 1996. Visual surveys aboard ships and aircraft. Pages 55-132 in Davis, R.W. and G.S. Fargion, eds. Distribution and abundance of cetaceans in the north-central and western Gulf of Mexico. Volume 2: Technical report. OCS Study MMS 96-0027. New Orleans, Louisiana: Minerals Management Service.

Hedley, S.L. 2000. Modelling heterogeneity in cetacean surveys. Ph.D. diss., University of St Andrews.

Hedley, S.L. and S.T. Buckland. 2004. Spatial models for line transect sampling. Journal of Agricultural, Biological, and Environmental Statistics 9(2):181-199.

Hedley, S.L., S.T. Buckland, and D.L. Borchers. 1999. Spatial modelling from line transect data. Journal of Cetacean Research and Management 1(3):255-264.

Holloway-Adkins, K.G. 2006. Juvenile green turtles (*Chelonia mydas*) foraging on a high-energy, shallow reef on the east coast of Florida, USA. Page 193 in Abstracts, Twenty-sixth Annual Symposium on Sea Turtle Biology and Conservation. 3-8 April 2006. Island of Crete, Greece.

Houghton, J.D.R., M.J. Callow, and G.C. Hays. 2003. Habitat utilization by juvenile hawksbill turtles (*Eretmochelys imbricata*, Linnaeus, 1766) around a shallow water coral reef. Journal of Natural History 37:1269-1280.

Hubard, C.W. and K.D. Mullin. 1999. Report of a cetacean survey of oceanic waters of the northern Gulf of Mexico aboard NOAA Ship *Oregon II* (cruise 234) 22 April-2 June 1999. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

Hubard, C.W. and K.D. Mullin. 2000. Report of a cetacean survey of oceanic waters of the northern Gulf of Mexico aboard NOAA Ship *Gordon Gunter* (cruise 007) 18 April-30 May 2000. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

Hubard, C.W., P.J. Bond, and K.D. Mullin. 2001. Report of a cetacean survey of continental shelf waters of the northern Gulf of Mexico aboard NOAA Ship *Gordon Gunter* cruise GU-01-05 (14), 28 August - 29 September 2001. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

Hughes, G.R., P. Luschi, R. Mencacci, and F. Papi. 1998. The 7000-km oceanic journey of a leatherback turtle tracked by satellite. Journal of Experimental Marine Biology and Ecology 229:209-217.

Hui, C.A. 1985. Undersea topography and the comparative distributions of two pelagic cetaceans. Fishery Bulletin 83(3):472-475.

Jefferson, T.A. and S. Leatherwood. 1994. *Lagenodelphis hosei*. Mammalian Species 470:1-5.

Jefferson, T.A. and A.J. Schiro. 1997. Distribution of cetaceans in the offshore Gulf of Mexico. Mammal Review 27(1):27-50.

Jefferson, T.A., D.K. Odell, and K.T. Prunier. 1995. Notes on the biology of the Clymene dolphin (*Stenella clymene*) in the northern Gulf of Mexico. Marine Mammal Science 11(4):564-573.

Jochens, A., D. Biggs, D. Engelhaupt, J. Gordon, N. Jaquet, M. Johnson, R. Leben, B. Mate, P. Miller, J. Ortega-Ortiz, A. Thode, P. Tyack, J. Wormuth, and B. Würsig. 2006. Sperm whale seismic study in the Gulf of Mexico. Summary report, 2002-2004. OCS Study MMS 2006-034. New Orleans, Louisiana: Minerals Management Service.

Jochens, A.E. and D.C. Biggs. 2004. Sperm whale seismic study in the Gulf of Mexico. Annual Report: Year 2. OCS Study MMS 2004-067. New Orleans, Louisiana: Minerals Management Service.

Kasamatsu, F. and G.G. Joyce. 1995. Current status of Odontocetes in the Antarctic. Antarctic Science 7(4):365-379.

Kaschner, K., R. Watson, A.W. Trites, and D. Pauly. 2006. Mapping world-wide distributions of marine mammal species using a relative environmental suitability (RES) model. Marine Ecology Progress Series 316:285-310.

Kruse, S., D.K. Caldwell, and M.C. Caldwell. 1999. Risso's dolphin *Grampus griseus* (G. Cuvier, 1812). Pages 183-212 in Ridgway, S.H. and R. Harrison, eds. Handbook of marine mammals. Volume 6: The second book of dolphins and the porpoises. San Diego, California: Academic Press.

Landry, A.M., Jr. and D. Costa. 1999. Status of sea turtle stocks in the Gulf of Mexico with emphasis on the Kemp's ridley. Pages 248-268 in Kumpf, H., K. Steidinger, and K. Sherman, eds. The Gulf of Mexico large marine ecosystem: Assessment, sustainability, and management. Malden, Massachusetts: Blackwell Science.

Leary, T.R. 1957. A schooling of leatherback turtles, *Dermochelys coriacea coriacea*, on the Texas coast. Copeia 1957(3):232.

Leatherwood, S., T.A. Jefferson, J.C. Norris, W.E. Stevens, L.J. Hansen, and K.D. Mullin. 1993. Occurrence and sounds of Fraser's dolphins (*Lagenodelphis hosei*) in the Gulf of Mexico. Texas Journal of Science 45(4):349-354.

Lee, D.S. and W.M. Palmer. 1981. Records of leatherback turtles, *Dermochelys coriacea* (Linnaeus), and other marine turtles in North Carolina waters. Brimleyana 5:95-106.

Lerczak, J.A. and R.C. Hobbs. 1998. Calculating sighting distances from angular readings during shipboard, aerial, and shore-based marine mammal surveys. Marine Mammal Science 14(3):590-599.

Lohoefener, R., W. Hoggard, K. Mullin, C. Roden, and C. Rogers. 1990. Association of sea turtles with petroleum platforms in the north-central Gulf of Mexico. OCS Study MMS 90-0025. New Orleans, Louisiana: Minerals Management Service.

Lutcavage, M. and J.A. Musick. 1985. Aspects of the biology of sea turtles in Virginia. Copeia 1985(2):449-456.

MacLeod, C., W.F. Perrin, R. Pitman, J. Barlow, L. Ballance, A. D'Amico, T. Gerrodette, G. Joyce, K.D. Mullin, D.L. Palka, and G.T. Waring. 2006. Known and inferred distributions of beaked whale species (Cetacea: Ziphiidae). Journal of Cetacean Research and Management 7(3):271-286.

MacLeod, C.D. and G. Mitchell. 2006. Key areas for beaked whales worldwide. Journal of Cetacean Research and Management 7(3):309-322.

MacLeod, C.D., N. Hauser, and H. Peckham. 2004. Diversity, relative density and structure of the cetacean community in summer months east of Great Abaco, Bahamas. Journal of the Marine Biological Association of the United Kingdom 84:469-474.

McAlpine, D.F. 2002. Pygmy and dwarf sperm whales *Kogia breviceps* and *K. sima*. Pages 1007-1009 in Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

McDaniel, C.J., L.B. Crowder, and J.A. Priddy. 2000. Spatial dynamics of sea turtle abundance and shrimping intensity in the U.S. Gulf of Mexico. Conservation Ecology. Accessed 1 August 2003. http://www.consecol.org/vol4/iss1/art15.

Meylan, A. 1995. Sea turtle migration - evidence from tag returns. Pages 91-100 in Bjorndal, K.A., ed. Biology and conservation of sea turtles, Rev. ed. Washington, D.C.: Smithsonian Institution Press.

Meylan, A., B. Schroeder, and A. Mosier. 1995. Sea turtle nesting activity in the state of Florida, 1979-1992. Florida Marine Research Publications No. 52. St. Petersburg, Florida: Florida Department of Natural Resources.

Meylan, A., P. Castaneda, C. Coogan, T. Lozon, and J. Fletemeyer. 1990. First recorded nesting by Kemp's ridley in Florida, USA. Marine Turtle Newsletter 48:8-9.

Mignucci-Giannoni, A.A. 1998. Zoogeography of cetaceans off Puerto Rico and the Virgin Islands. Caribbean Journal of Science 34(3-4):173-190.

Mills, L.R. and K.R. Rademacher. 1996. Atlantic spotted dolphins (*Stenella frontalis*) in the Gulf of Mexico. Gulf of Mexico Science 14(2):114-120.

Morreale, S.J., E.A. Standora, J.R. Spotila, and F.V. Paladino. 1996. Migration corridor for sea turtles. Nature 384:319-320.

Morreale, S.J., P.T. Plotkin, D.J. Shaver, and H.J. Kalb. 2007. Adult migration and habitat utilization: Ridley turtles in their element. Pages 213-229 in Plotkin, P., ed. Biology and conservation of ridley sea turtles. Baltimore, Maryland: Johns Hopkins University Press.

Mullin, K.D. and D.M. Drass. 1999. Report of a cetacean survey of continental shelf waters of the northern Gulf of Mexico aboard NOAA Ship *Gordon Gunter* (Cruise 99-02) 31 August-30 September 1999. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

Mullin, K.D. and L.J. Hansen. 1999. Marine mammals of the northern Gulf of Mexico. Pages 269-277 in Kumpf, H., K. Steidinger, and K. Sherman, eds. The Gulf of Mexico large marine ecosystem: Assessment, sustainability, and management. Malden, Massachusetts: Blackwell Science.

Mullin, K.D. and W. Hoggard. 2000. Visual surveys of cetaceans and sea turtles from aircraft and ships. Pages 111-171 in Davis, R.W., W.E. Evans, and B. Würsig, eds. Cetaceans, sea turtles and seabirds in the northern Gulf of Mexico: Distribution, abundance and habitat associations. Volume 2: Technical report. OCS Study MMS 2000-003. New Orleans, Louisiana: Minerals Management Service.

Mullin, K.D. and D.M. Drass. 2000. Report of a cetacean survey of continental shelf waters of the northern Gulf of Mexico aboard NOAA Ship *Oregon II* (Cruise 242) 5 September - 2 October 2000. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

Mullin, K.D. and G.L. Fulling. 2004. Abundance of cetaceans in the oceanic northern Gulf of Mexico, 1996-2001. Marine Mammal Science 20(4):787-807.

Mullin, K.D., K.S. Maze, and C.W. Hubard. 1998. Report of a cetacean survey of continental shelf waters of the northern Gulf of Mexico aboard NOAA Ship *Gordon Gunter* (Cruise 001) 3-30 September 1998. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

Mullin, K.D., W. Hoggard, and L.J. Hansen. 2004. Abundance and seasonal occurrence of cetaceans in outer continental shelf and slope waters of the north-central and northwestern Gulf of Mexico. Gulf of Mexico Science 22(1):62-73.

Mullin, K.D., T.A. Jefferson, L.J. Hansen, and W. Hoggard. 1994a. First sightings of melon-headed whales (*Peponocephala electra*) in the Gulf of Mexico. Marine Mammal Science 10(3):342-348.

Mullin, K.D., W. Hoggard, C.L. Roden, R.R. Lohoefener, C.M. Rogers, and B. Taggart. 1994b. Cetaceans on the upper continental slope in the north-central Gulf of Mexico. Fishery Bulletin 92:773-786.

Musick, J.A. and C.J. Limpus. 1997. Habitat utilization and migration of juvenile sea turtles. Pages 137-163 in Lutz, P.L. and J.A. Musick, eds. The biology of sea turtles. Boca Raton, Florida: CRC Press.

NASA (National Aeronautics and Space Administration). 1998. Goddard Earth Sciences Data and Information Services Center, Distributed Active Archive Center. Accessed 23 January 2004. ftp://disc1.gsfc.nasa.gov/data/czcs/level_3/monthly_data/subsets/Chlor/.

NASA (National Aeronautics and Space Administration). 2000. AVHRR oceans pathfinder global equalangle best weekly SST averages (NOAA/NASA). Goddard Earth Sciences Data and Information Services Center, Distributed Active Archive Center. Accessed 4 May 2004. ftp://disc1.gsfc.nasa.gov/data/avhrr/tile_8km/.

NMFS-SEFSC (National Marine Fisheries Service-Southeast Fisheries Science Center). 2001. Cruise results, spring Southeast Area Monitoring and Assessment Program (SEAMAP) ichthyoplankton survey and cetacean survey: NOAA Ship *Gordon Gunter* cruise GU-01-02, 17 April - 31 May 2001. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

NMFS-SEFSC (National Marine Fisheries Service-Southeast Fisheries Science Center). 2003. Cruise results, NOAA Ship *Gordon Gunter* cruise GU-03-02, 12 June - 18 August 2003: A study of oceanic cetaceans in the northern Gulf of Mexico. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

NMFS-SEFSC (National Marine Fisheries Service-Southeast Fisheries Science Center). 2004. Cruise results, NOAA Ship *Gordon Gunter* cruise GU-04-02 (027), 13 April - 11 June 2004: A study of sperm whales and other oceanic cetaceans in the Northern Gulf of Mexico. Unpublished cruise report. Pascagoula, Mississippi: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service) and USFWS (U.S. Fish and Wildlife Service). 1991. Recovery plan for U.S. population of Atlantic green turtle. Washington, D.C.: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service) and USFWS (U.S. Fish and Wildlife Service). 1992. Recovery plan for leatherback turtles in the U.S. Caribbean, Atlantic and Gulf of Mexico. Washington, D.C.: National Marine Fisheries Service.

NMFS (National Marine Fisheries Service) and USFWS (U.S. Fish and Wildlife Service). 1993. Recovery plan for hawksbill turtles in the U.S. Caribbean Sea, Atlantic Ocean, and Gulf of Mexico. St. Petersburg, Florida: National Marine Fisheries Service.

NOAA (National Oceanic and Atmospheric Administration). 2001a. Southeast regional bathymetry/topography gridded surface. NOAA Coastal Services Center. Accessed July 2001. http://www.csc.noaa.gov/opis/html/btopogrd.html.

NOAA (National Oceanic and Atmospheric Administration). 2001b. Central Gulf of Mexico, Geophysical Data System for gridded bathymetric data, NGDC coastal relief model. Volume 4, ver. 4.1. [CD-ROM]. Boulder, Colorado: National Geophysical Data Center.

NOAA (National Oceanic and Atmospheric Administration). 2001c. Florida and eastern Gulf of Mexico, geophysical data system for gridded bathymetric data. Volume 4, ver. 4.1. [CD-ROM]. Boulder, Colorado: National Geophysical Data Center.

O'Sullivan, S. and K.D. Mullin. 1997. Killer whales (*Orcinus orca*) in the northern Gulf of Mexico. Marine Mammal Science 13:141-147.

Olson, P.A. and S.B. Reilly. 2002. Pilot whales *Globicephala melas* and *G. macrorhynchus*. Pages 898-903 in Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Ortega-Ortiz, J.G. 2002. Multiscale analysis of cetacean distribution in the Gulf of Mexico. Ph.D. diss., Texas A&M University.

Palka, D. 2005a. Shipboard surveys in the northwest Atlantic: Estimation of *g(0)*. European Cetacean Society Newsletter 44(Special Issue):32-37.

Palka, D. 2005b. Aerial surveys in the northwest Atlantic: Estimation of *g(0)*. European Cetacean Society Newsletter 44(Special Issue):12-17.

Palka, D.L. 2006. Summer abundance estimates of cetaceans in US North Atlantic Navy operating areas. Northeast Fisheries Science Center Reference Document 06-03. Woods Hole, Massachusetts: National Marine Fisheries Service.

Parker, L.G. 1995. Encounter with a juvenile hawksbill turtle offshore Sapelo Island, Georgia. Marine Turtle Newsletter 71:19-22.

Payne, P.M. and D.W. Heinemann. 1993. The distribution of pilot whales (*Globicephala* spp.) in shelf/shelf-edge and slope waters of the Northeastern United States, 1978-1988. Reports of the International Whaling Commission (Special Issue 14):51-68.

Phillips, J.N. 2003. Share the beach: Alabama sea turtle nest monitoring program: 2003 annual report. Gulf Shores, Alabama: Bon Secour National Wildlife Refuge.

Pitman, R.L. 2002. Mesoplodont whales *Mesoplodon* spp. Pages 738-742 in Perrin, W.F., B. Würsig, and J.G.M. Thewissen, eds. Encyclopedia of marine mammals. San Diego, California: Academic Press.

Rabalais, S.C. and N.N. Rabalais. 1980. The occurrence of sea turtles on the South Texas coast. Contributions in Marine Science 23:123-129.

Redfern, J.V., M.C. Ferguson, E.A. Becker, K.D. Hyrenbach, C. Good, J. Barlow, K. Kaschner, M.F. Baumgartner, K.A. Forney, L.T. Ballance, P. Fauchald, P. Halpin, T. Hamazaki, A.J. Pershing, S.S. Qian, A. Read, S.B. Reilly, L. Torres, and F. Werner. 2006. Techniques for cetacean-habitat modeling. Marine Ecology Progress Series 310:271-295.

Renaud, M.L., J.A. Carpenter, J.A. Williams, and S.A. Manzella-Tirpak. 1995. Activities of juvenile green turtles, *Chelonia mydas*, at a jettied pass in south Texas. Fishery Bulletin 93:586-593.

Rester, J. and R. Condrey. 1996. The occurrence of the hawksbill turtle, *Eretmochelys imbricata*, along the Louisiana coast. Gulf of Mexico Science 14(2):112-114.

Rhinehart, H.L., C.A. Manire, J.D. Buck, P. Cunningham-Smith, and D.R. Smith. 1999. Observations and rehabilitation of rough-toothed dolphins, *Steno bredanensis*, treated at Mote Marine Laboratory from two separate stranding events. Page 157 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Hawaii.

Rosman, I., G.S. Boland, L. Martin, and C. Chandler. 1987. Underwater sightings of sea turtles in the northern Gulf of Mexico. OCS Study MMS 87-0107. New Orleans, Louisiana: Minerals Management Service.

Rudloe, A., J. Rudloe, and L. Ogren. 1991. Occurrence of immature Kemp's ridley turtles, *Lepidochelys kempi*, in coastal waters of northwest Florida. Northeast Gulf Science 12(1):49-53.

Schmid, J.R., A.B. Bolten, K.A. Bjorndal, and W.J. Lindberg. 2002. Activity patterns of Kemp's ridley turtles, *Lepidochelys kempii*, in the coastal waters of the Cedar Keys, Florida. Marine Biology 140:215-228.

Schroeder, B.A. and N.B. Thompson. 1987. Distribution of the loggerhead turtle, *Caretta caretta*, and the leatherback turtle, *Dermochelys coriacea*, in the Cape Canaveral, Florida area: Results of aerial surveys. Pages 45-53 in Witzell, W.N., ed. Proceedings of the Cape Canaveral, Florida Sea Turtle Workshop. NOAA Technical Report NMFS 53.

Seber, G.A.F. 1982. The estimation of animal abundance and related parameters, 2d ed. London, England: Edward Arnald.

Seney, E.E. and J.A. Musick. 2005. Diet analysis of Kemp's ridley sea turtles *(Lepidochelys kempii)* in Virginia. Chelonian Conservation and Biology 4(4):864-871.

Shaver, D.J. and T. Wibbels. 2007. Head-starting the Kemp's ridley sea turtle. Pages 297-323 in Plotkin, P., ed. Biology and conservation of ridley sea turtles. Baltimore, Maryland: Johns Hopkins University Press.

Shoop, C.R. and R.D. Kenney. 1992. Seasonal distributions and abundances of loggerhead and leatherback sea turtles in waters of the northeastern United States. Herpetological Monographs 6:43-67.

Thomsen, F., F. Ugarte, and P.G.H. Evans, eds. 2005. Proceedings of the workshop on estimation of g(0) in line-transect surveys of cetaceans held at the European Cetacean Society's 18th Annual Conference, Vildmarkshotellet at Kolmården Djur Park, Kolmården, Sweden, 28th March 2004. European Cetacean Society Newsletter 44(Special Issue):1-46.

USFWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service). 1992. Recovery plan for the Kemp's ridley sea turtle (*Lepidochelys kempii*). St. Petersburg, Florida: National Marine Fisheries Service.

Wade, P.R. and R.P. Angliss. 1997. Guidelines for assessing marine mammal stocks. Report of the GAMMS (Guidelines for Assessing Marine Mammal Stocks) Workshop April 3-5, 1996, Seattle, Washington. NOAA Technical Memorandum NMFS-OPR-12:1-93.

Ward, J.A., G.H. Mitchell, A.M. Farak, and E.P. Keane. 2005. Beaked whale habitat characterization and prediction. NUWC-NPT Technical Report 11,548. Newport, Rhode Island: Naval Undersea Warfare Center Division.

Waring, G.T., E. Josephson, C.P. Fairfield, and K. Maze-Foley, eds. 2007. U.S. Atlantic and Gulf of Mexico marine mammal stock assessments -- 2006. NOAA Technical Memorandum NMFS-NE-201:1-378.

Waring, G.T., T. Hamazaki, D. Sheehan, G. Wood, and S. Baker. 2001. Characterization of beaked whale (Ziphiidae) and sperm whale (*Physeter macrocephalus*) summer habitat in shelf-edge and deeper waters off the northeast U.S. Marine Mammal Science 17(4):703-717.

Weber, M. 1995. Kemp's ridley sea turtle, *Lepidochelys kempii*. Pages 109-122 in Plotkin, P.T., ed. Status reviews of sea turtles listed under the Endangered Species Act of 1973. Silver Spring, Maryland: National Marine Fisheries Service.

Weller, D.W., A.J. Schiro, V.G. Cockcroft, and W. Ding. 1996. First account of a humpback whale (*Megaptera novaeangliae*) in Texas waters, with a re-evaluation of historical records from the Gulf of Mexico. Marine Mammal Science 12(1):133-137.

Weller, D.W., B. Würsig, S.K. Lynn, and A.J. Schiro. 2000. Preliminary findings on the occurrence and site fidelity of photo-identified sperm whales (*Physeter macrocephalus*) in the northern Gulf of Mexico. Gulf of Mexico Science 18(1):35-39.

Wells, R., C. Mainire, H. Rhinehart, D. Smith, A. Westgate, F. Townsend, T. Rowles, A. Hohn, and L. Hansen. 1999. Ranging patterns of rehabilitated rough-toothed dolphins, *Steno bredanensis*, released in the northeastern Gulf of Mexico. Page 199 in Abstracts, Thirteenth Biennial Conference on the Biology of Marine Mammals. 28 November-3 December 1999. Wailea, Hawaii.

Witherington, B. and S. Hirama. 2006. Sea turtles of the epi-pelagic sargassum drift community. Page 209 in Abstracts, Twenty-sixth Annual Symposium on Sea Turtle Biology and Conservation. 3-8 April 2006. Island of Crete, Greece.

Witherington, B.E. 1994. Flotsam, jetsam, post-hatchling loggerheads, and the advecting surface smorgasbord. Pages 166-168 in Bjorndal, K.A., A.B. Bolten, D.A. Johnson, and P.J. Eliazar, eds.

Proceedings of the Fourteenth Annual Symposium on Sea Turtle Biology and Conservation. NOAA Technical Memorandum NMFS-SEFSC-351.

Witzell, W.N. 1983. Synopsis of biological data on the hawksbill turtle *Eretmochelys imbricata* (Linnaeus, 1766). FAO Fisheries Synopsis 137. Rome, Italy: Food and Agriculture Organization of the United Nations.

Wood, S.N. 2006. Generalized additive models: An introduction with R. Boca Raton, Florida: Chapman & Hall/CRC.

Würsig, B., T.A. Jefferson, and D.J. Schmidly. 2000. The marine mammals of the Gulf of Mexico. College Station, Texas: Texas A&M University Press.

This page intentionally left blank

APPENDIX: SPATIAL MODELING OUTPUT

TABLE OF CONTENTS

This page intentionally left blank

This appendix contains the spatial modeling output for all species in the GOMEX study area for which density estimates were generated using spatial modeling. These are the data that were used to determine the model fit. Model output results are organized into three distinct sets of results for each species. They are as follows: (1) Detection function (results table and histogram); (2) RSM (GAMs table and two "smooth plots); and (3) variance estimation (results table and histogram). In cases where two separate models were generated (different seasons), there are two separate sets of model output. Sequence of the model output results provided below follow **Table A-1**.

- Sperm Whale (*Physeter macrocephalus*)

Table A-1. Detection function results for the sperm whale during summer, fall, and winter in the Gulf of Mexico study area.

Detection Function	
No. of observations	184
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.4370
SE	0.2711
Hazard Shape Parameter (Exponent)	
Estimate	1.3297
SE	0.3021
Average p	
Estimate	0.4500
SE	0.0585
CV (Coefficient of Variation)	0.1300
N in covered region	
Estimate	408.8661
SE	57.6493
CV	0.1500

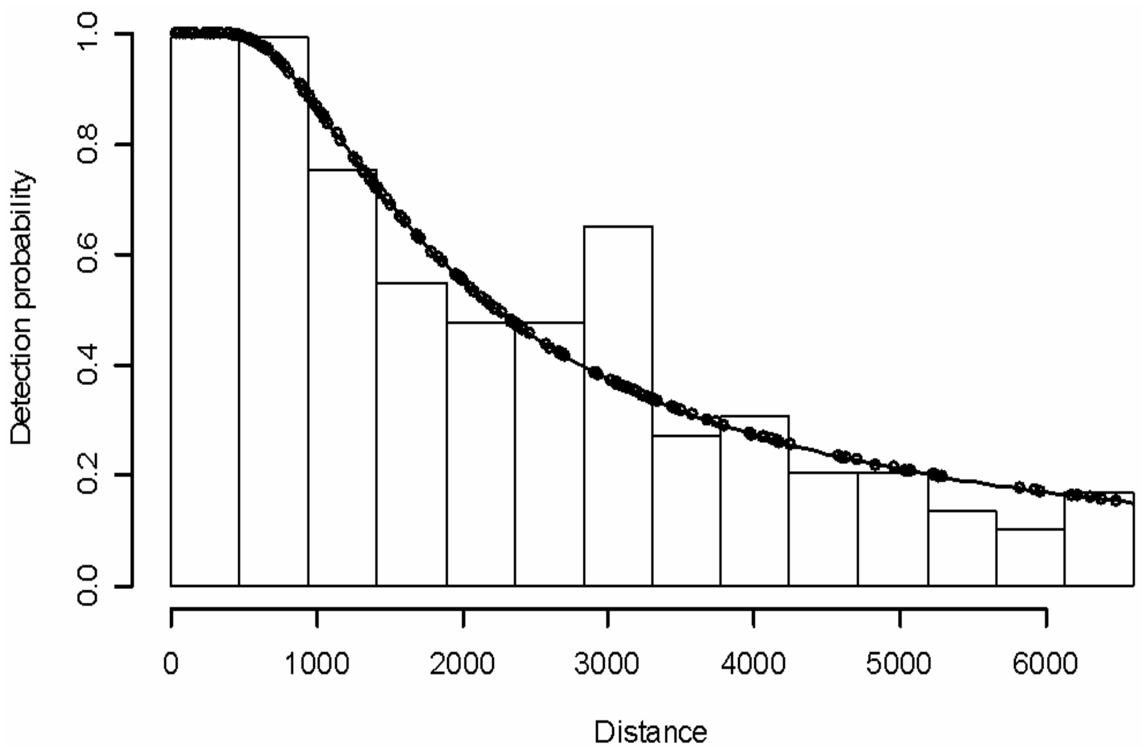


Figure A-1. Plot of the detection function for pooled sightings of the sperm whale during summer, fall, and winter in the Gulf of Mexico study area.

Table A-2. Response surface model (Generalized Additive Model) results for the sperm whale during summer, fall, and winter in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon,lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	17.547
Est. rank	29.000
F	4.655
p-value	1.04e-14
s(depth)	
Edf	6.997
Est. rank	9.000
F	9.490
p-value	4.16e-14
R-sq. (adj)	0.0598
n segments	138
Deviance explained	22%

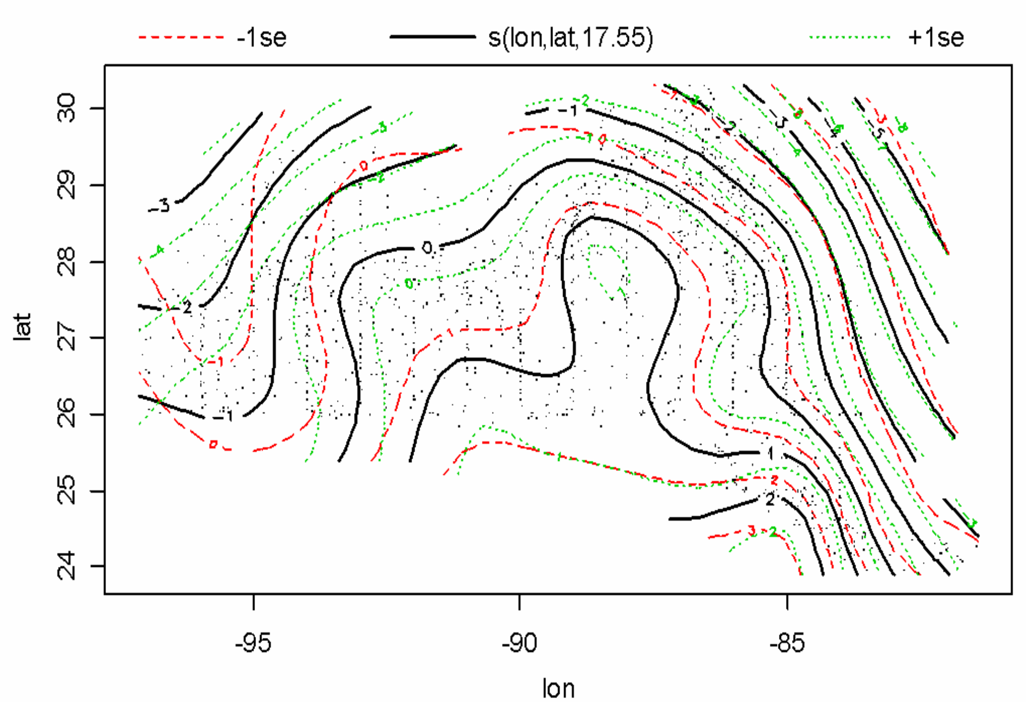


Figure A-2. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the sperm whale during summer, fall, and winter in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

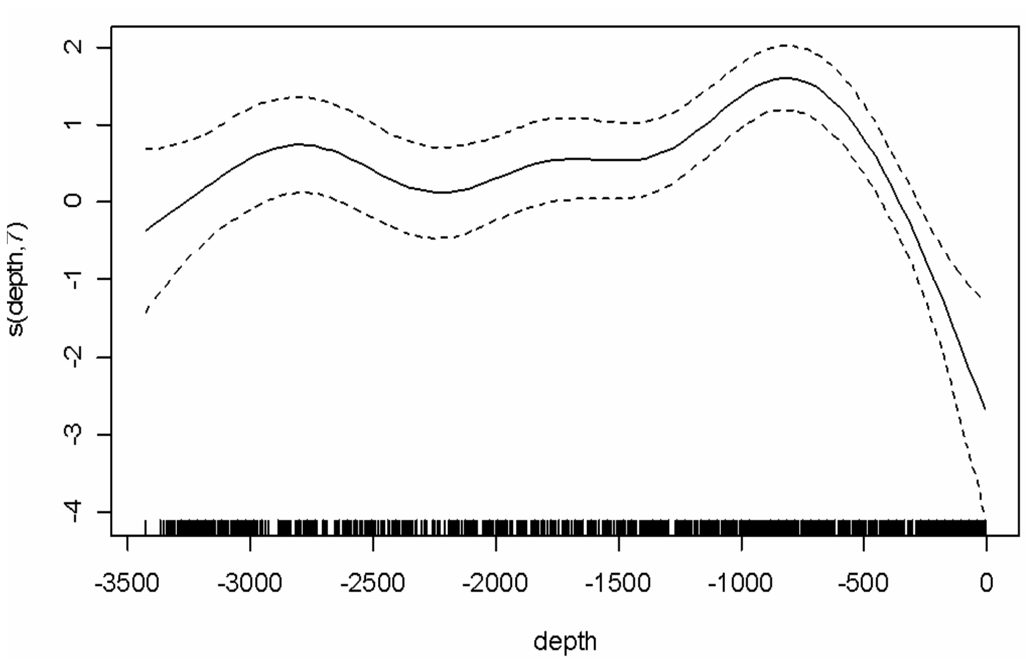


Figure A-3. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the sperm whale during summer, fall, and winter in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-3. Variance estimate model results for the sperm whale during summer, fall, and winter in the Gulf of Mexico study area.

Variance	
Legitimate values	493
Non-legitimate bootstrap replicates	6
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	771.2380 – 927.0584
Point estimate	851.4992
SE of bootstraps	40.2149
Est. CV for density surface model	0.0472
CV in detection probability	0.13
CV in overall estimate including density surface model AND detection probability	0.1383
Confidence interval incorporating detection function uncertainty	650.1791 , 1115.156

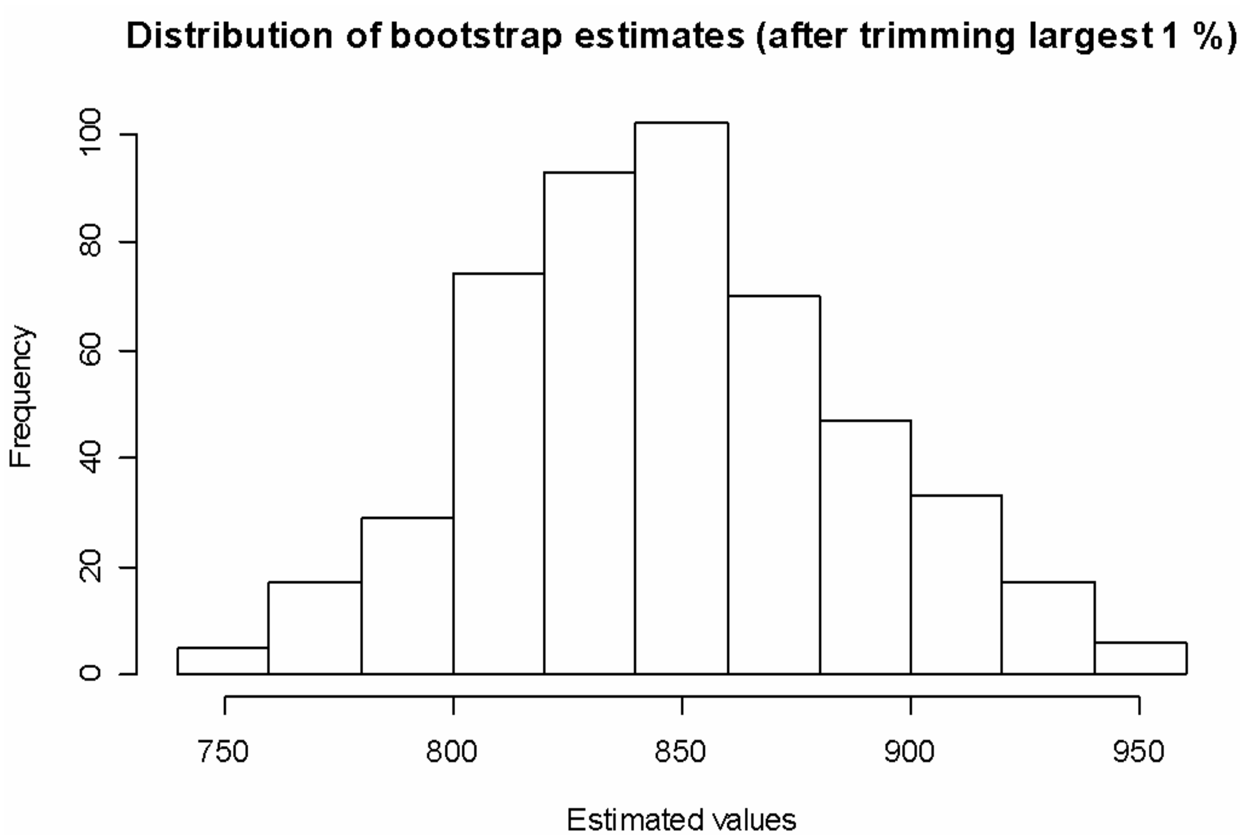


Figure A-4. Distribution of bootstrap estimates (after trimming largest 1%) for pooled sightings of the sperm whale during summer, fall, and winter in the Gulf of Mexico study area.

Table A-4. Detection function results for the sperm whale during spring in the Gulf of Mexico study area.

Detection Function	
No. of observations	137
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.3964
SE	0.2836
Hazard Shape Parameter (Exponent)	
Estimate	1.4992
SE	0.3307
Average p	
Estimate	0.3641
SE	0.0534
CV	0.1466
N in covered region	
Estimate	376.2958
SE	60.8174
CV	0.1616

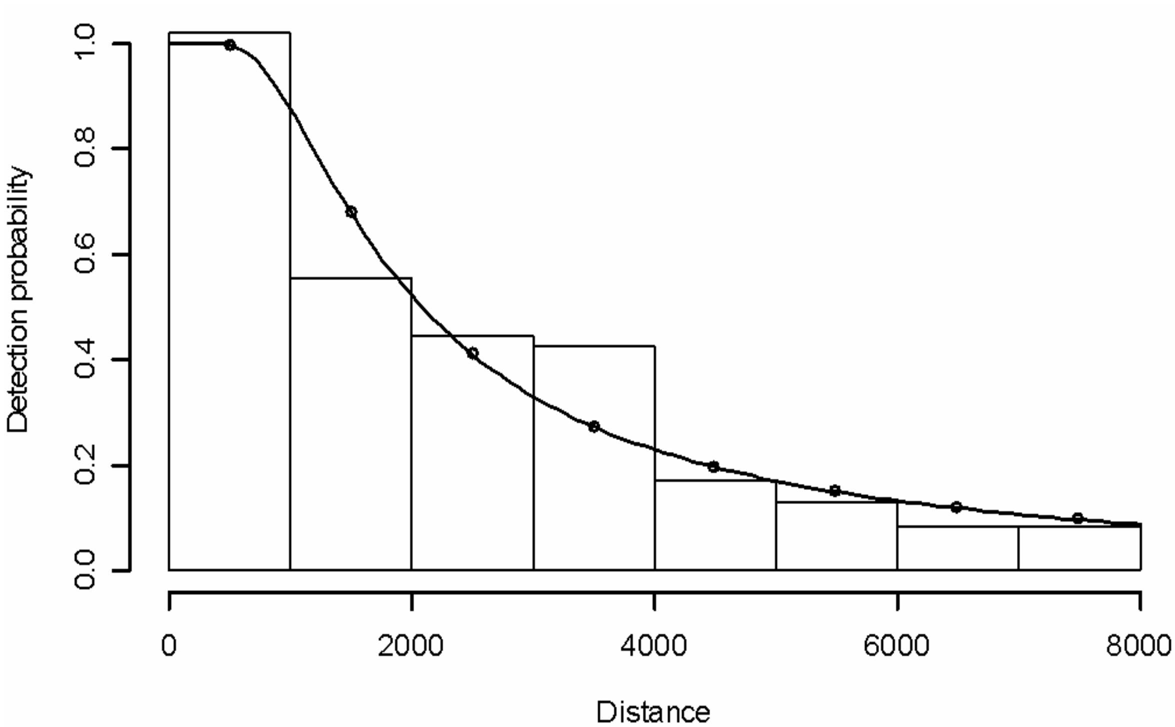


Figure A-5. Plot of the detection function for pooled sightings of the sperm whale during spring in the Gulf of Mexico study area.

Table A-5. Response surface model (Generalized Additive Model) results for the sperm whale during spring in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon) + s(lat) + s(depth) + s(SST) +
Approximate significance of smooth terms	
s(lon)	
Edf	6.808
Est. rank	9.000
F	8.703
p-value	1.25e-12
s(lat)	
Edf	8.497
Est. rank	9.000
F	7.696
p-value	5.71e-11
s(depth)	
Edf	9.000
Est. rank	9.000
F	5.301
p-value	4.45e-07
s(SST)	
Edf	7.877
Est. rank	9.000
F	5.046
p-value	1.14e-06
R-sq. (adj)	0.0952
n segments	101
Deviance explained	26.2%

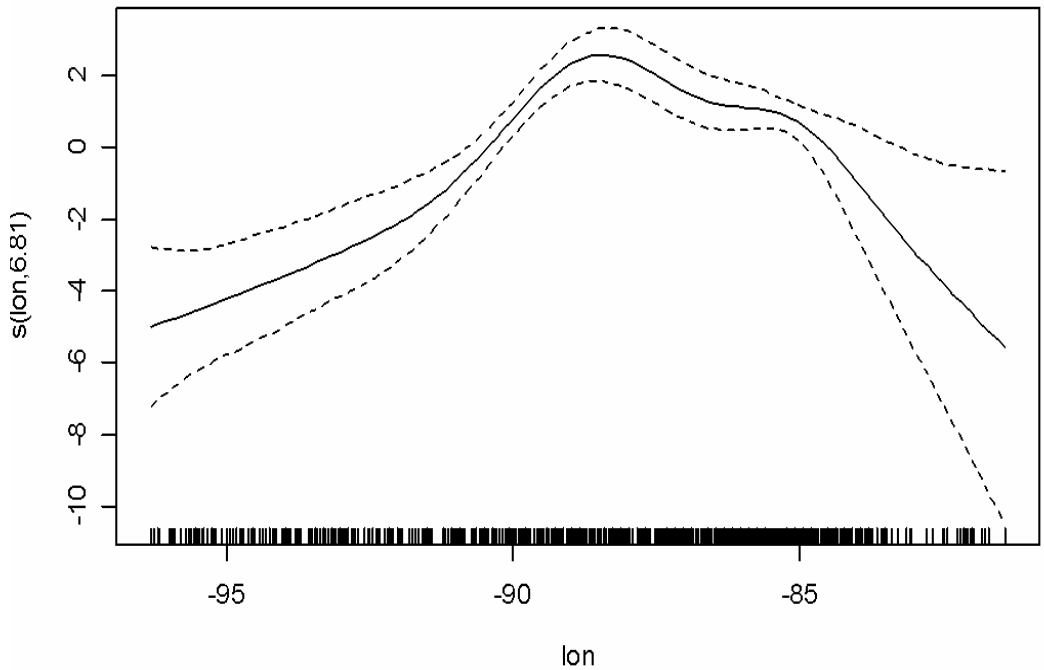


Figure A-6. Plot of the Generalized Additive Model smooth fit of the environmental covariate *longitude* selected for the sperm whale during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

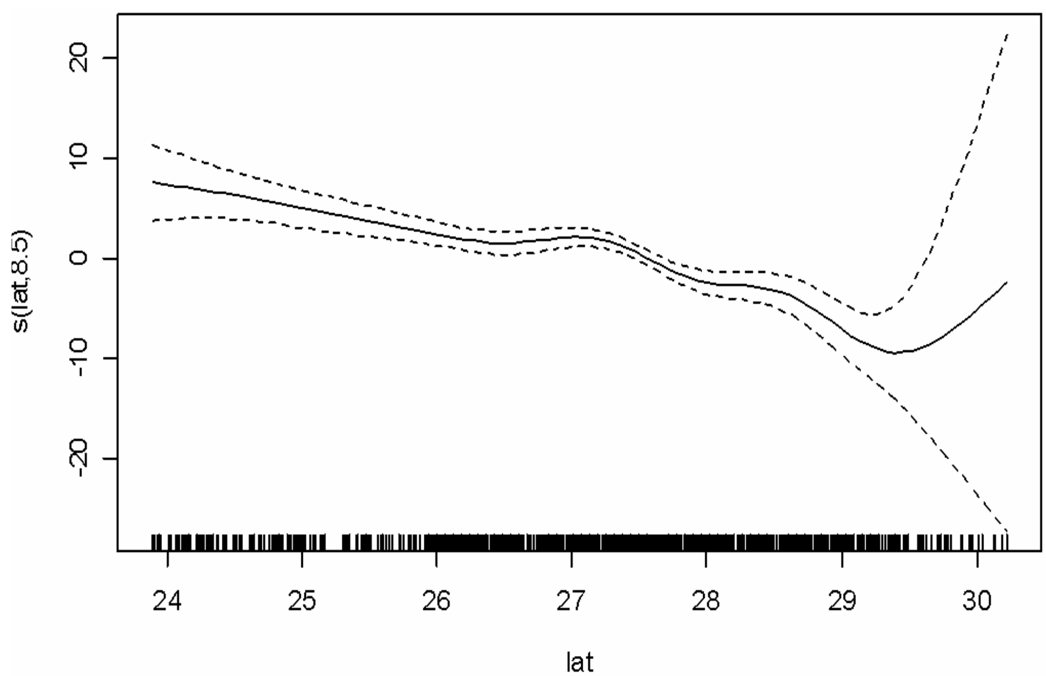


Figure A-7. Plot of the Generalized Additive Model smooth fit of the environmental covariate *latitude* selected for the sperm whale during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

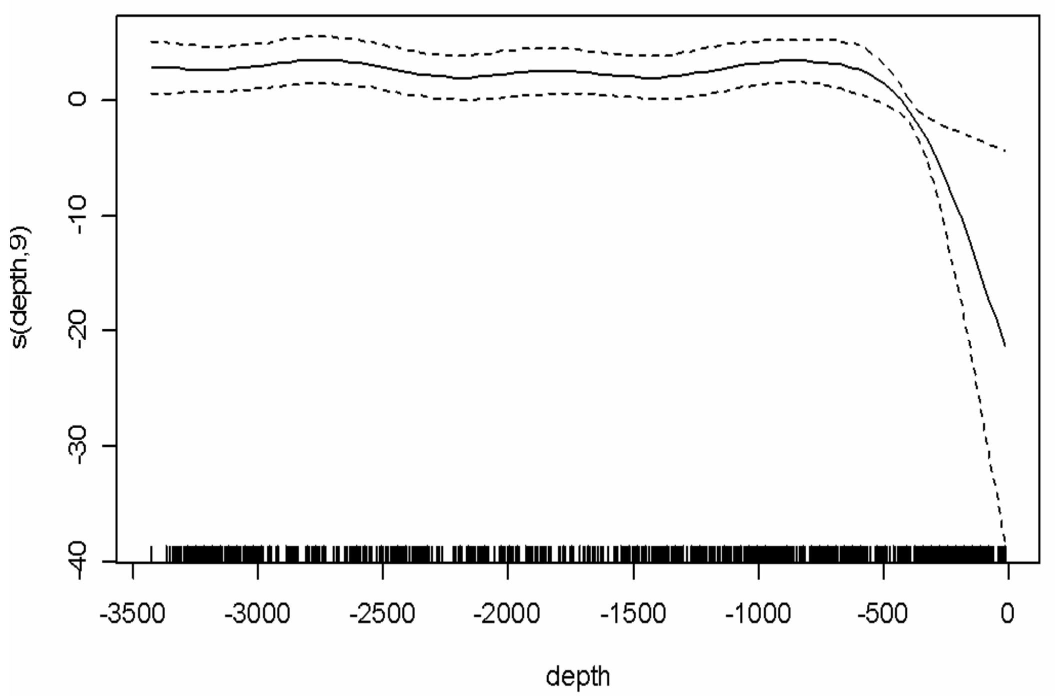


Figure A-8. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the sperm whale during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

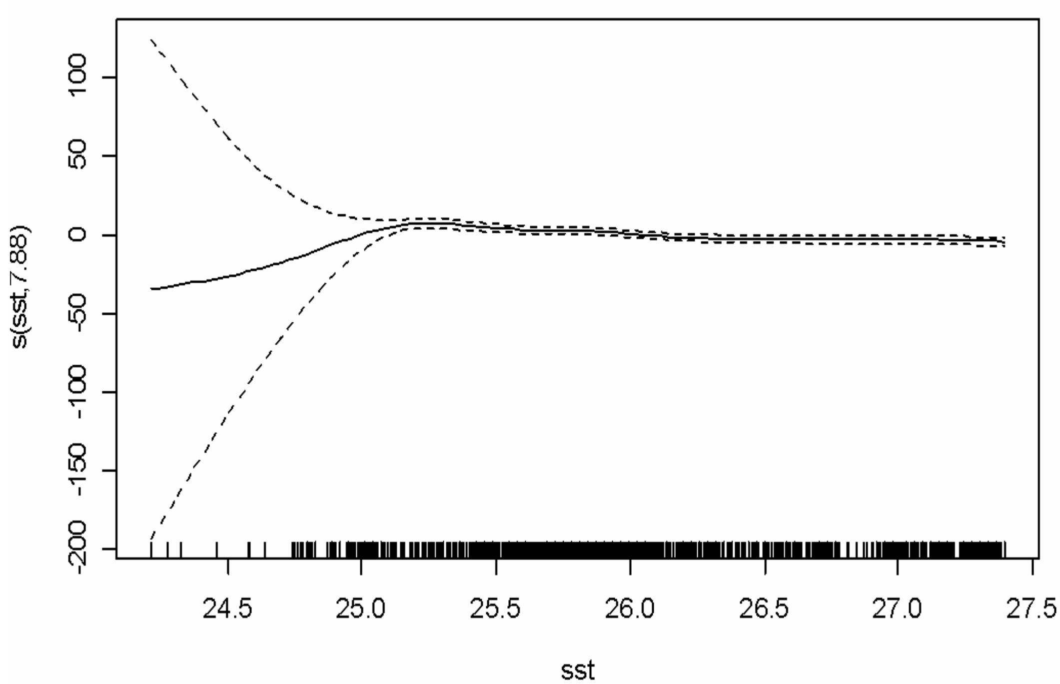


Figure A-9. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for the sperm whale during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-6. Variance estimate model results for the sperm whale during spring in the Gulf of Mexico study area.

Variance	
Legitimate values	414
Non-legitimate bootstrap replicates	85
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	706.9897 – 949.6931
Point estimate	807.7282
SE of bootstraps	59.32685
Est. CV for density surface model	0.0734
CV in detection probability	0.1466
CV in overall estimate including density surface model AND detection probability	0.1639
Confidence interval incorporating detection function uncertainty	587.0105, 1111.436

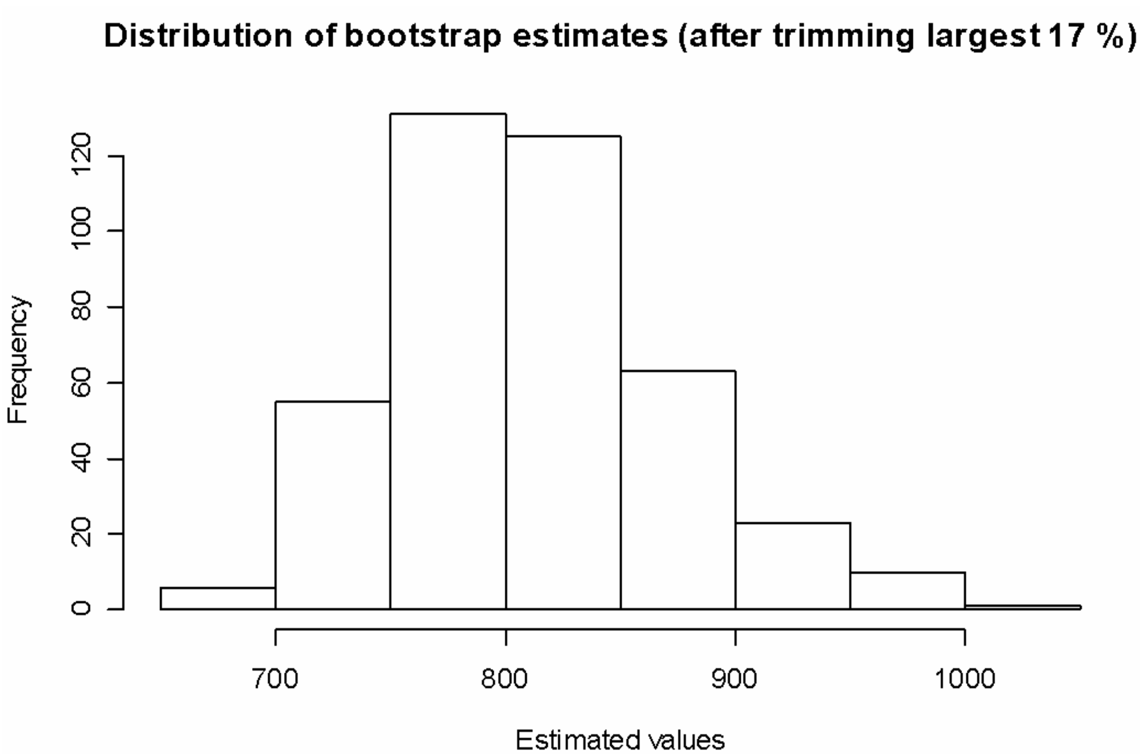


Figure A-10. Distribution of bootstrap estimates (after trimming largest 17%) for pooled sightings of the sperm whale during spring in the Gulf of Mexico study area.

➢ *Kogia* spp.

Table A-7. Detection function results for *Kogia* spp during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	82
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.4153
SE	0.1245
Average p	
Estimate	0.6154
SE	0.0572
CV	0.0929
N in covered region	
Estimate	133.2385
SE	15.3762
CV	0.1154

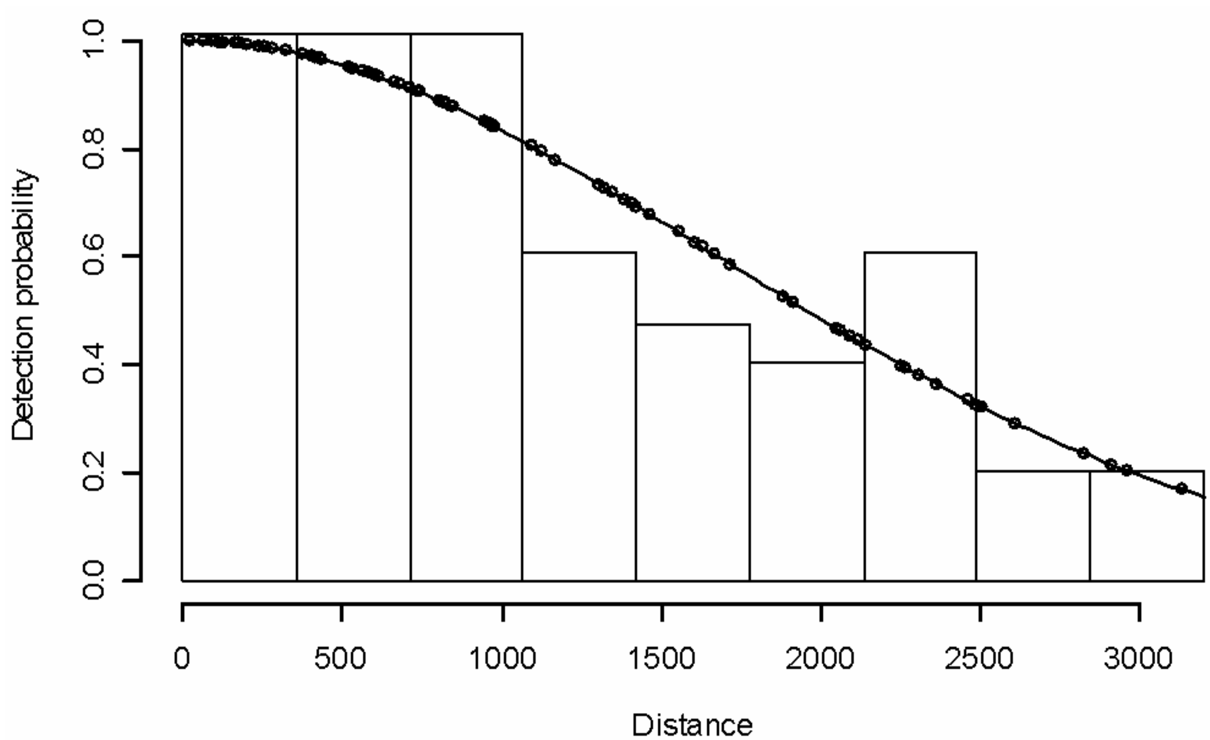


Figure A-11. Plot of the detection function for pooled sightings of *Kogia* spp. during all seasons in the Gulf of Mexico study area.

Table A-8. Response surface model (Generalized Additive Model) results for *Kogia* spp. during all seasons in the Gulf of Mexico study area.

Response Surface Model (Generalized Additive Model)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.287
Est. rank	25.000
F	6.014
p-value	<2e-16
s(depth)	
Edf	7.468
Est. rank	9.000
F	7.926
p-value	3.50e-11
R-sq. (adj)	0.0971
n segments	41
Deviance explained	41.6%

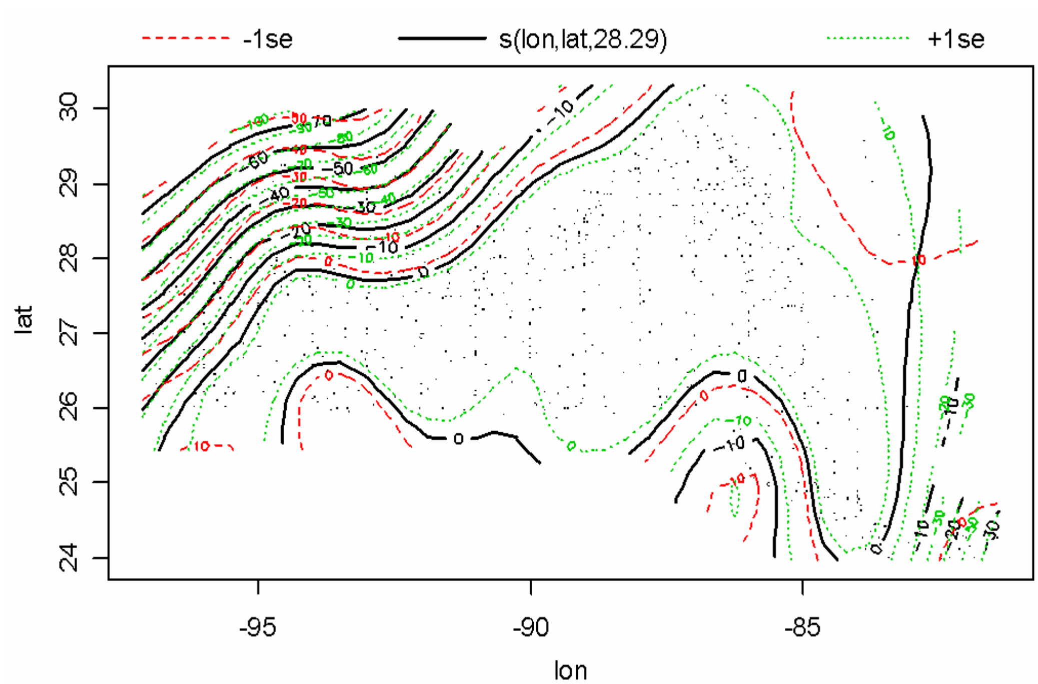


Figure A-12. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for *Kogia* spp. during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

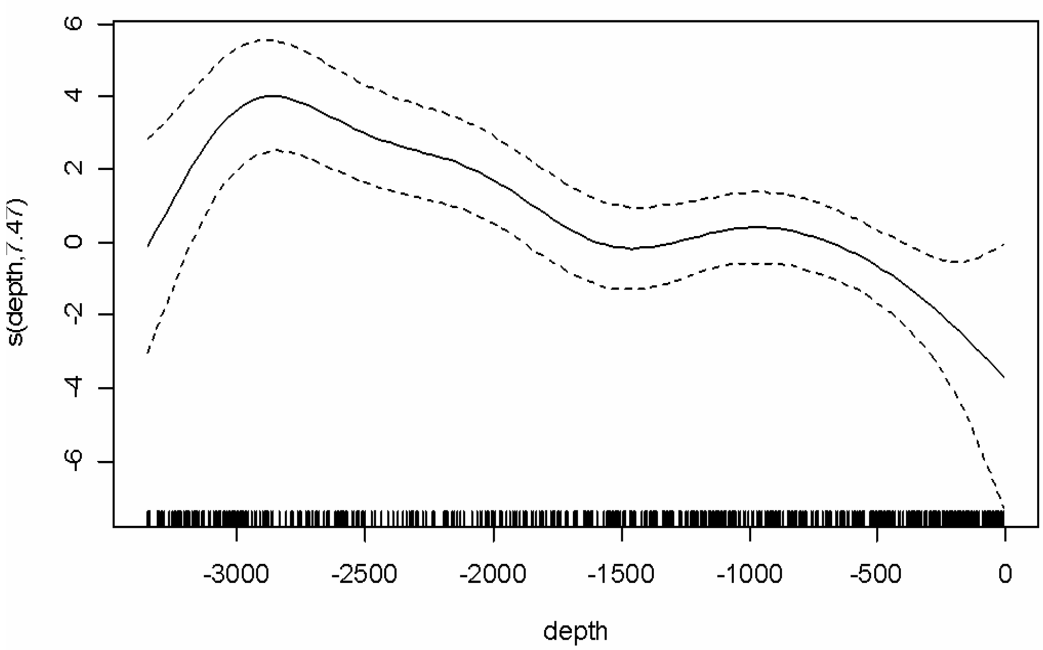


Figure A-13. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for *Kogia* spp. during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-9. Variance estimate model results for *Kogia* spp. during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	485
Non-legitimate bootstrap replicates	14
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	430.5754 – 568.6405
Point estimate	489.4183
SE of bootstraps	36.8083
Est. CV for density surface model	0.0752
CV in detection probability	0.0929
CV in overall estimate including density surface model AND detection probability	0.1195
Confidence interval incorporating detection function uncertainty	387.5297 , 618.0953

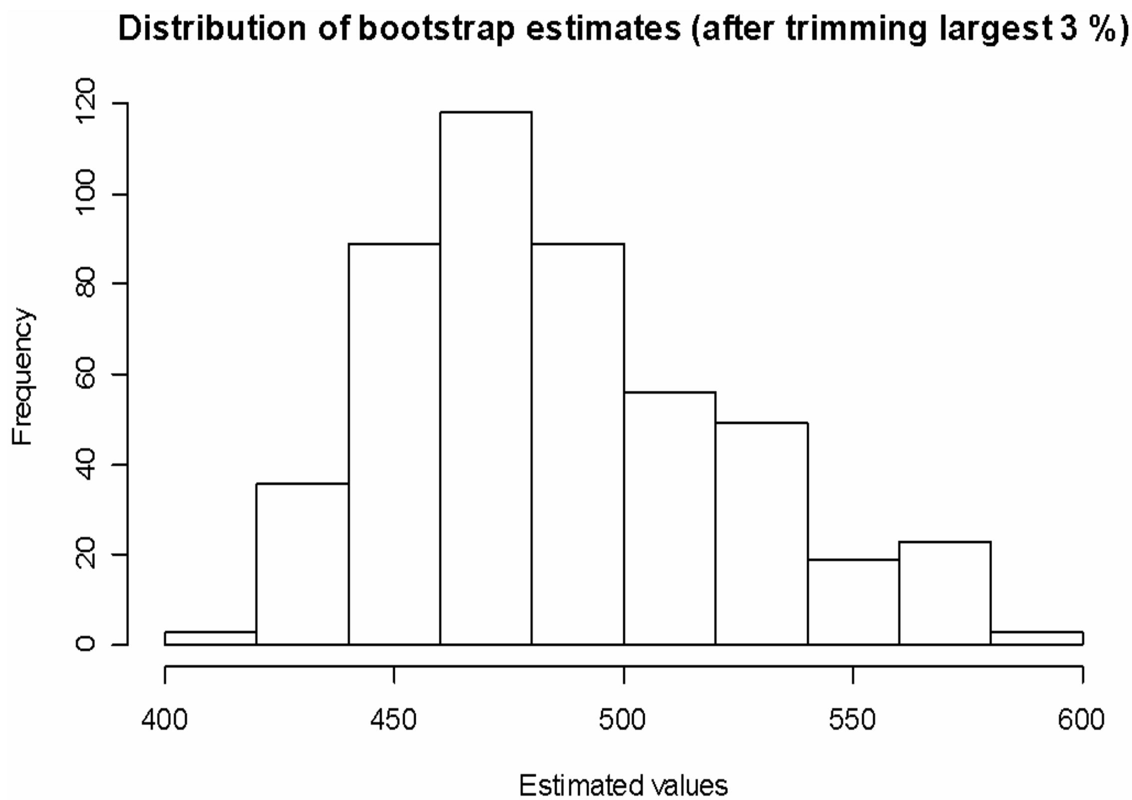


Figure A-14. Distribution of bootstrap estimates (after trimming largest 3%) for pooled sightings of *Kogia* spp. during all seasons in the Gulf of Mexico study area.

➢ Beaked Whales (Family Ziphiidae)

Table A-10. Detection function results for Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area.

Detection Function	
No. of observations	43
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.2542
SE	0.2460
Hazard Shape Parameter (Exponent)	
Estimate	2.3931
SE	0.6117
Average p	
Estimate	0.3217
SE	0.0543
CV	0.1687
N in covered region	
Estimate	133.6498
SE	28.1074
CV	0.2103

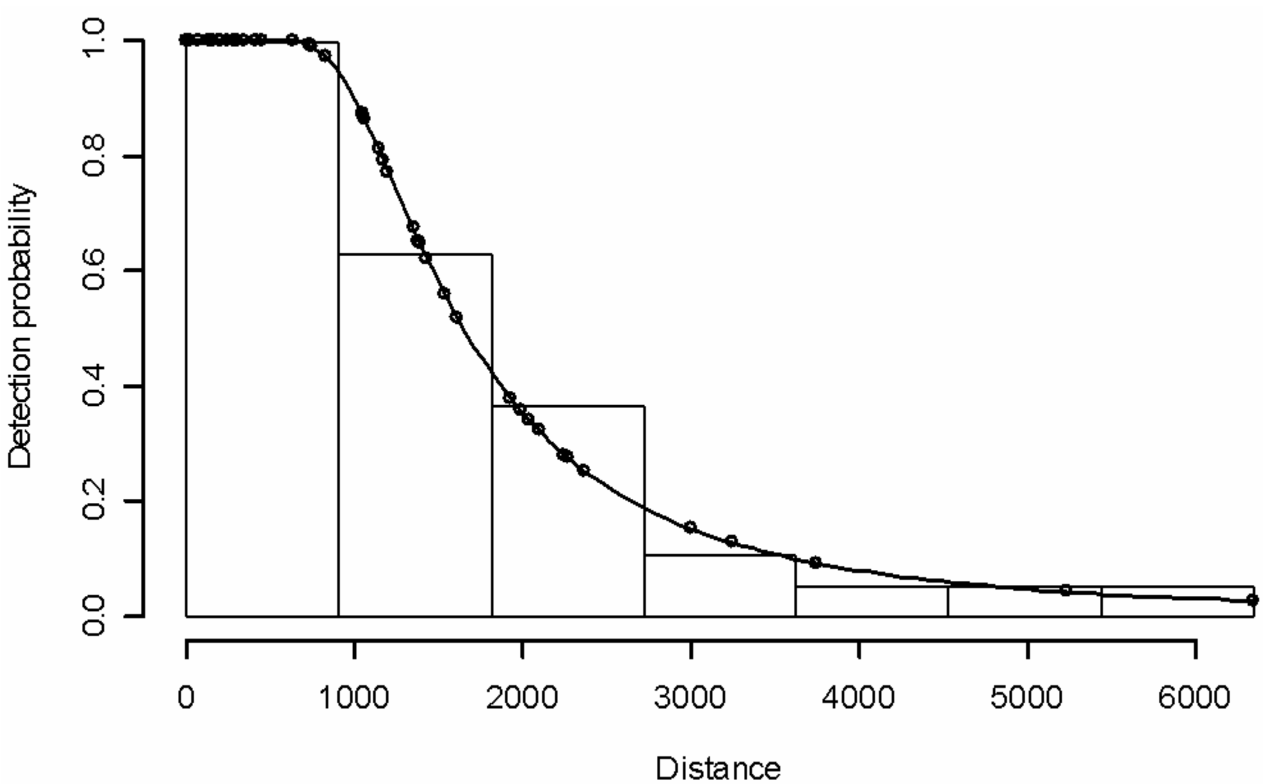


Figure A-15. Plot of the detection function for pooled sightings of Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area.

Table A-11. Response surface model (Generalized Additive Model) results for Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms		
s(lon,lat)		
	Edf	25.009
	Est. rank	28.000
	F	5.179
	p-value	9.03e-16
s(depth)		
	Edf	6.031
	Est. rank	9.000
	F	6.776
	p-value	2.39e-9
R-sq. (adj)		0.143
n segments		35
Deviance explained		36.5%

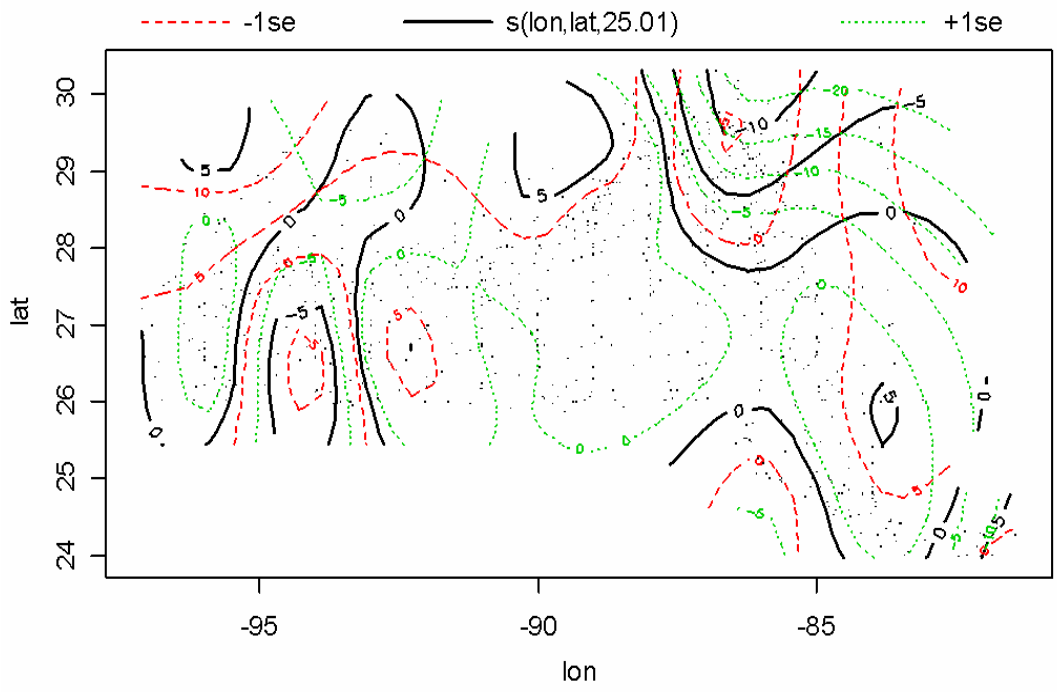


Figure A-16. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

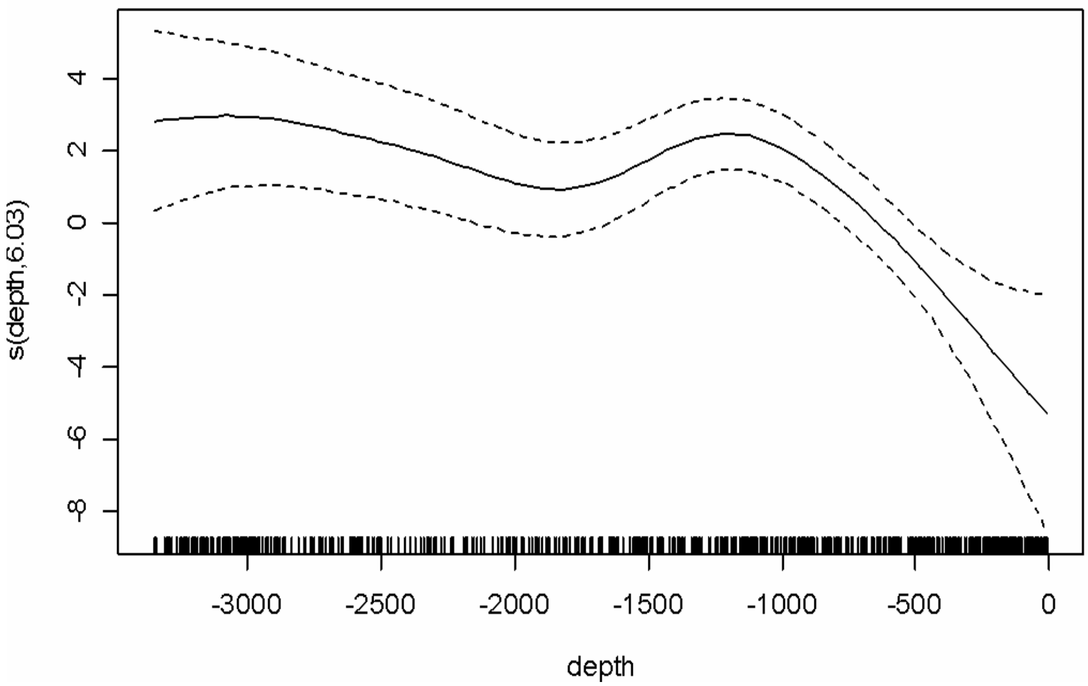


Figure A-17. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-12. Variance estimate model results for Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area.

Variance	
Legitimate values	489
Non-legitimate bootstrap replicates	10
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	270.7874 – 357.7519
Point estimate	310.348
SE of bootstraps	22.5433
Est. CV for density surface model	0.0726
CV in detection probability	0.1687
CV in overall estimate including density surface model AND detection probability	0.1837
Confidence interval incorporating detection function uncertainty	217.174 , 443.4964

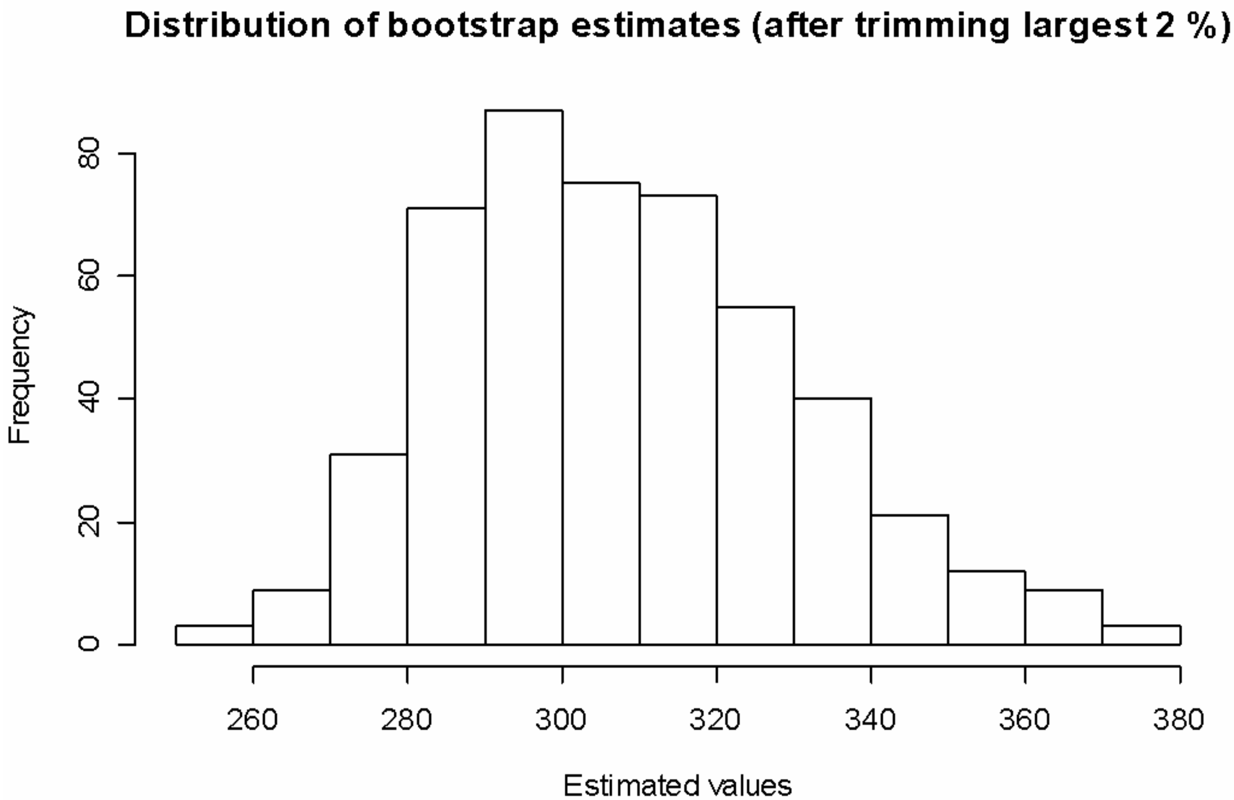


Figure A-18. Distribution of bootstrap estimates (after trimming largest 2%) for pooled sightings of Beaked Whales during summer, fall, and winter in the Gulf of Mexico study area.

Table A-13. Detection function results for Beaked Whales during spring in the Gulf of Mexico study area.

Detection Function	
No. of observations	29
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.1839
SE	0.1180
Average p	
Estimate	0.4395
SE	0.0498
CV	0.1132
N in covered region	
Estimate	65.9906
SE	11.8329
CV	0.1793

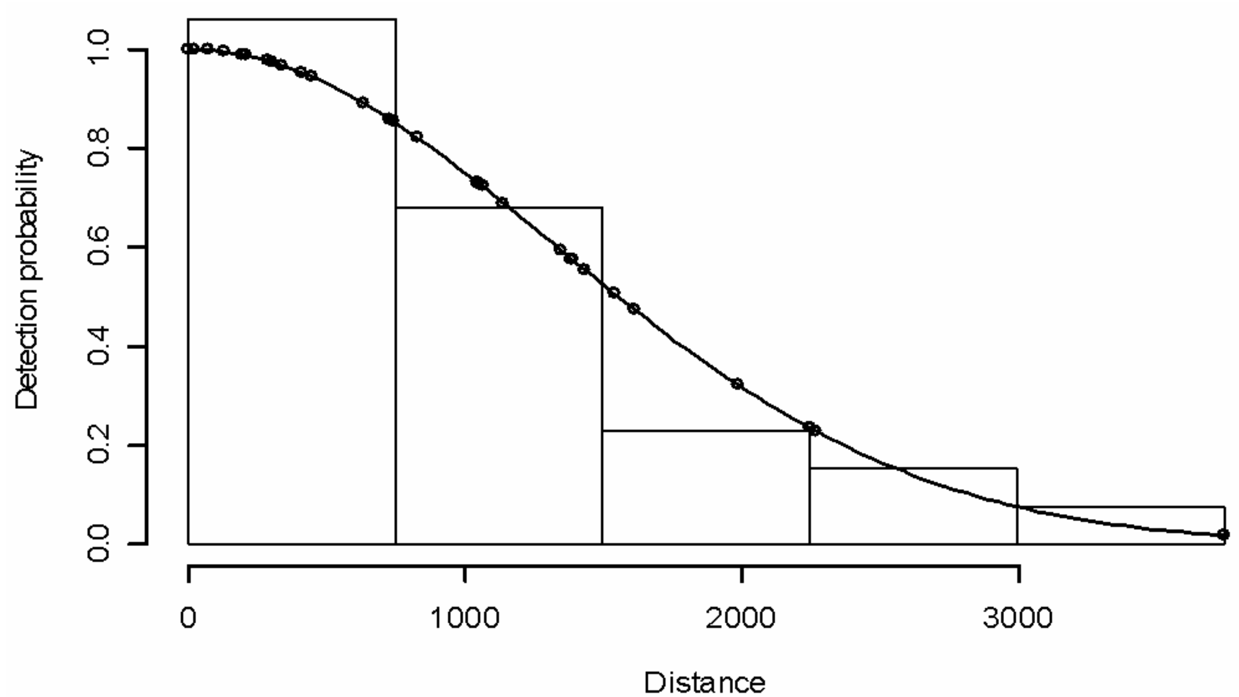


Figure A-19. Plot of the detection function for pooled sightings of Beaked Whales during spring in the Gulf of Mexico study area.

Table A-14. Response surface model (Generalized Additive Model) results for Beaked Whales during spring in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + s(chl *a*) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	26.816
Est. rank	29.000
F	4.992
p-value	9.59e-15
s(depth)	
Edf	4.433
Est. rank	9.000
F	4.653
p-value	6.33e-6
s(chl *a*)	
Edf	6.811
Est. rank	9.000
F	6.364
p-value	1.52e-8
R-sq. (adj)	0.198
n segments	25
Deviance explained	42.6%

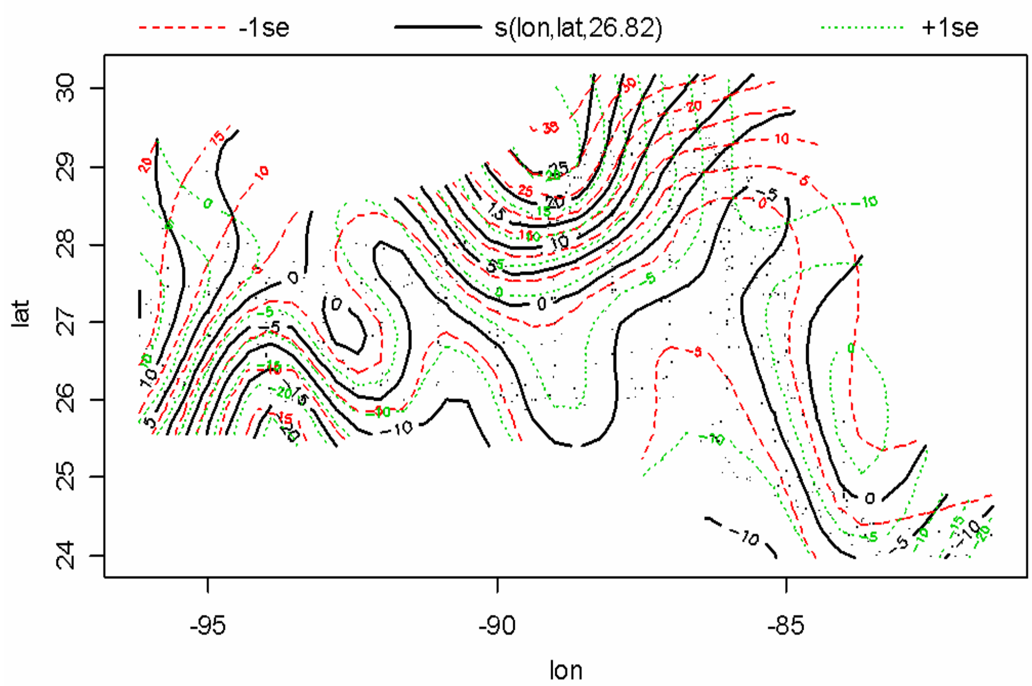


Figure A-20. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for Beaked Whales during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

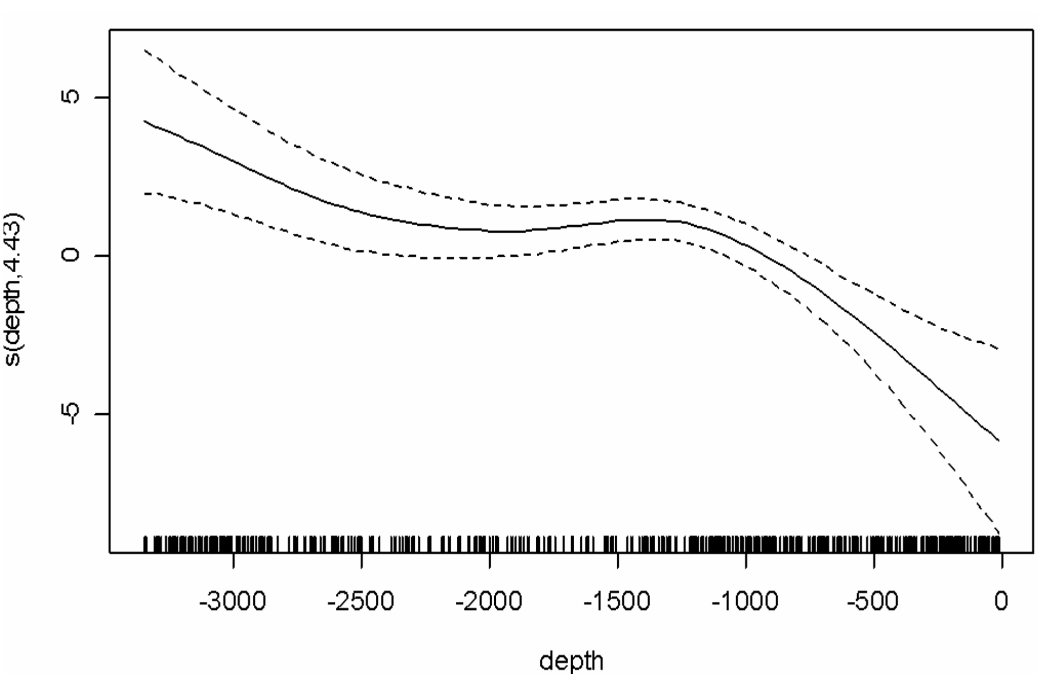


Figure A-21. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for Beaked Whales during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

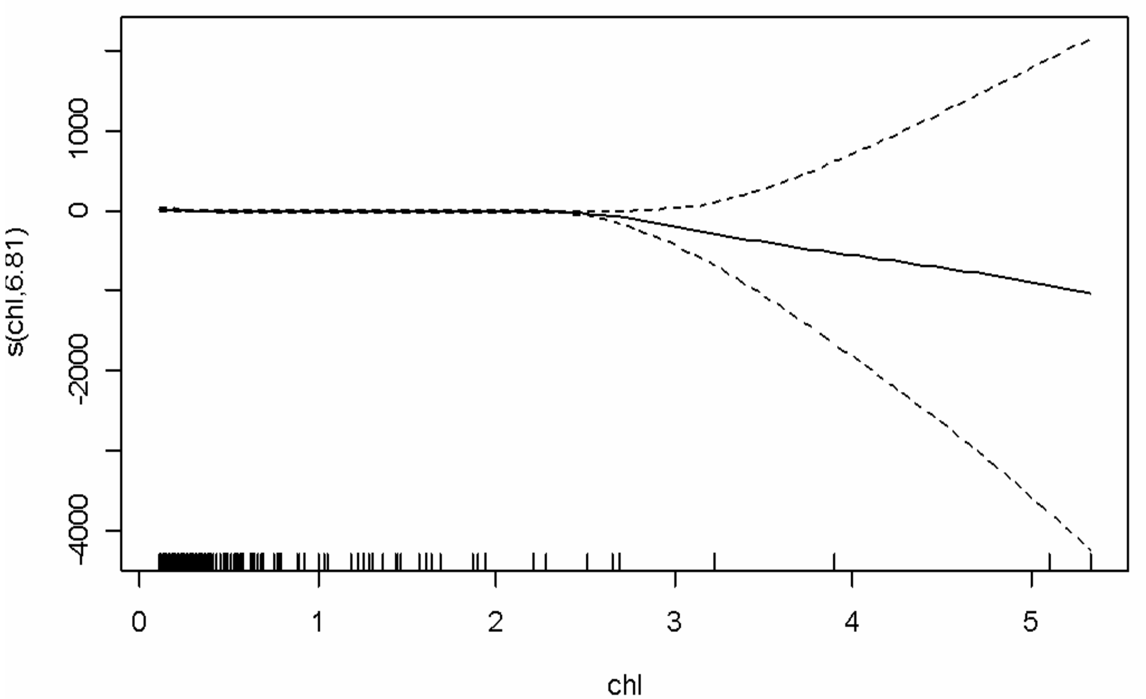


Figure A-22. Plot of the Generalized Additive Model smooth fit of the environmental covariate *chlorophyll* selected for Beaked Whales during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-15. Variance estimate model results for Beaked Whales during spring in the Gulf of Mexico study area.

Variance	
Legitimate values	407
Non-legitimate bootstrap replicates	92
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	398.6431 – 706.7035
Point estimate	491.9506
SE of bootstraps	81.777
Est. CV for density surface model	0.1662
CV in detection probability	0.1132
CV in overall estimate including density surface model AND detection probability	0.2011
Confidence interval incorporating detection function uncertainty	332.9696 , 726.8393

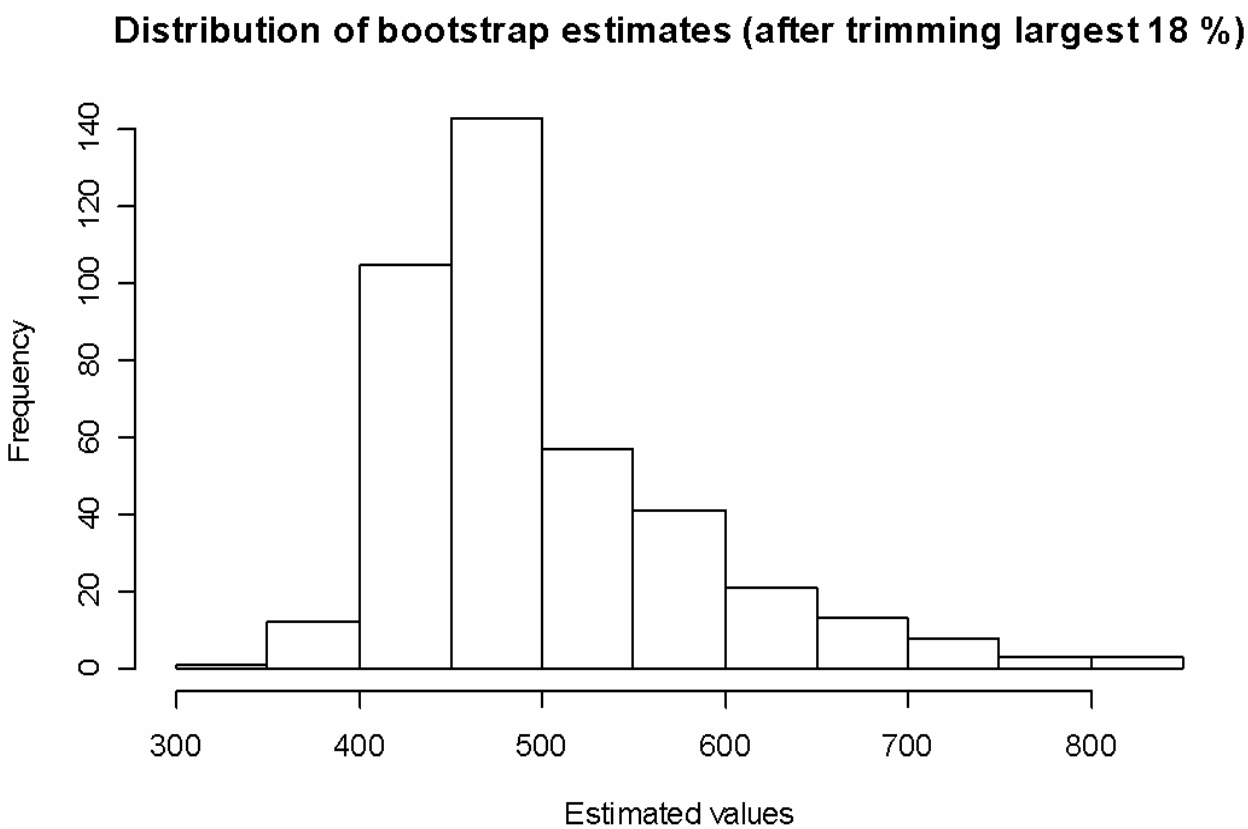


Figure A-23. Distribution of bootstrap estimates (after trimming largest 18%) for pooled sightings of Beaked Whales during spring in the Gulf of Mexico study area.

➢ Rough-toothed Dolphin (*Steno bredanensis*)

Table A-16. Detection function results for the rough-toothed dolphin during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	19
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.5856
SE	0.2904
Average p	
Estimate	0.5910
SE	0.1347
CV	0.2279
N in covered region	
Estimate	32.1470
SE	8.7143
CV	0.2711

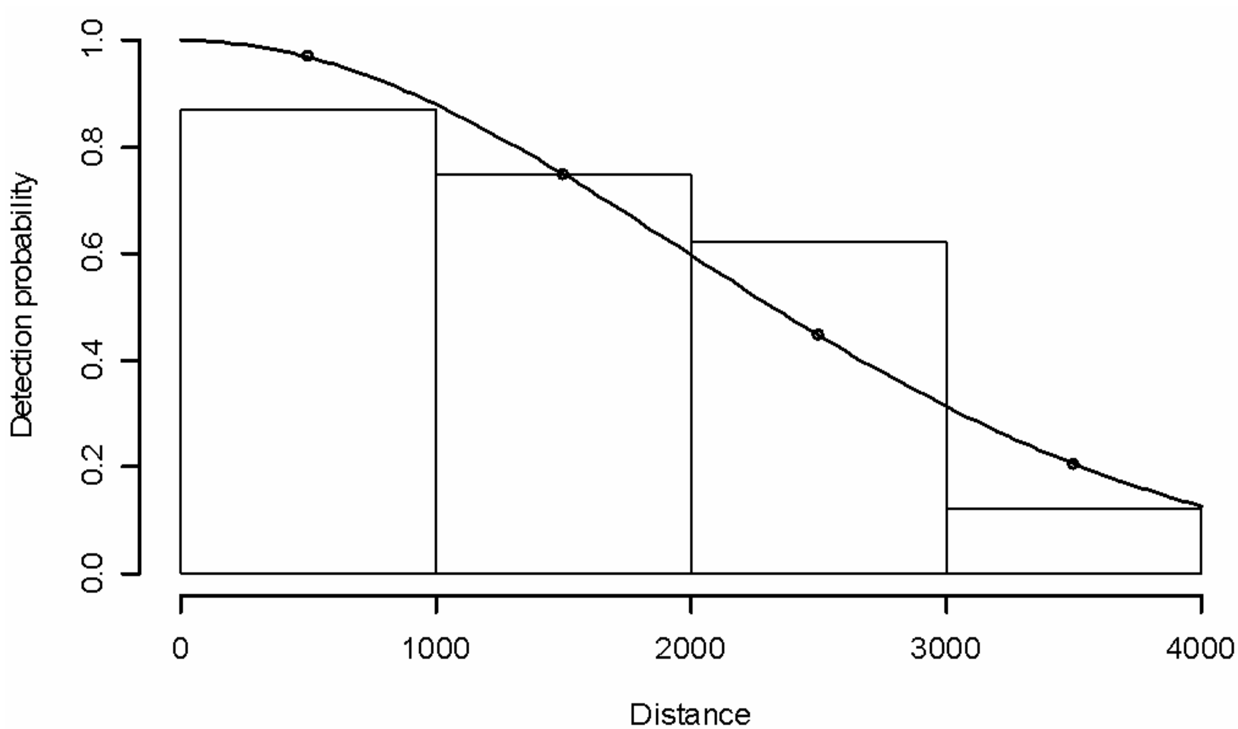


Figure A-24. Plot of the detection function for pooled sightings of the rough-toothed dolphin during all seasons in the Gulf of Mexico study area.

Table A-17. Response surface model (Generalized Additive Model) results for the rough-toothed dolphin during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.854
Est. rank	28.000
F	4.122
p-value	2.00e-11
s(depth)	
Edf	8.217
Est. rank	9.000
F	6.199
p-value	1.99e-08
R-sq. (adj)	0.0479
n segments	17
Deviance explained	32.2%

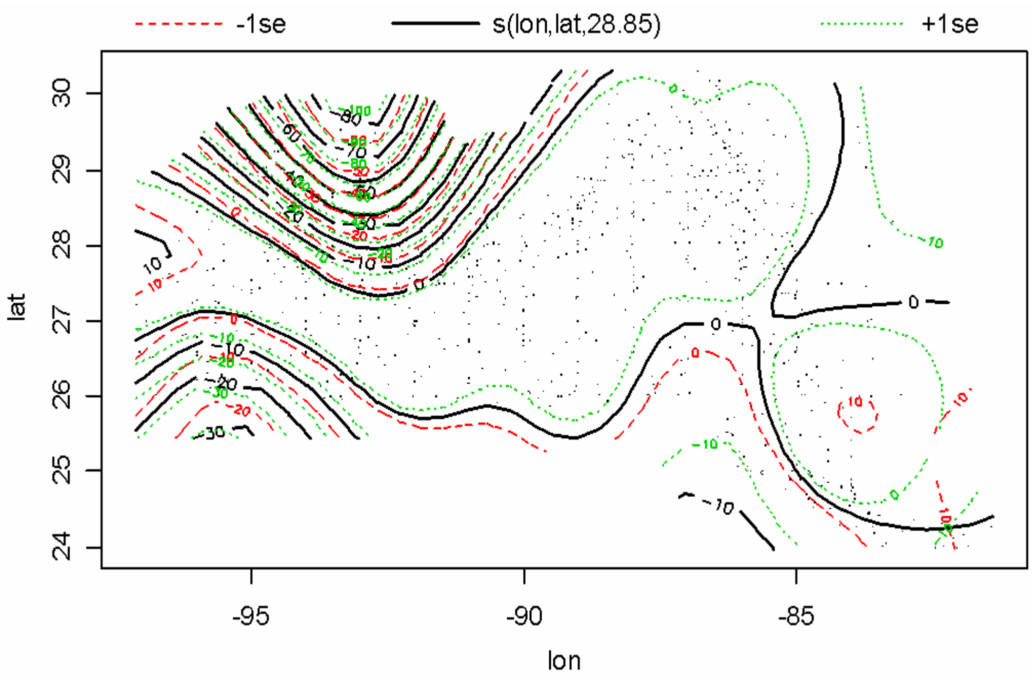


Figure A-25. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the rough-toothed dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

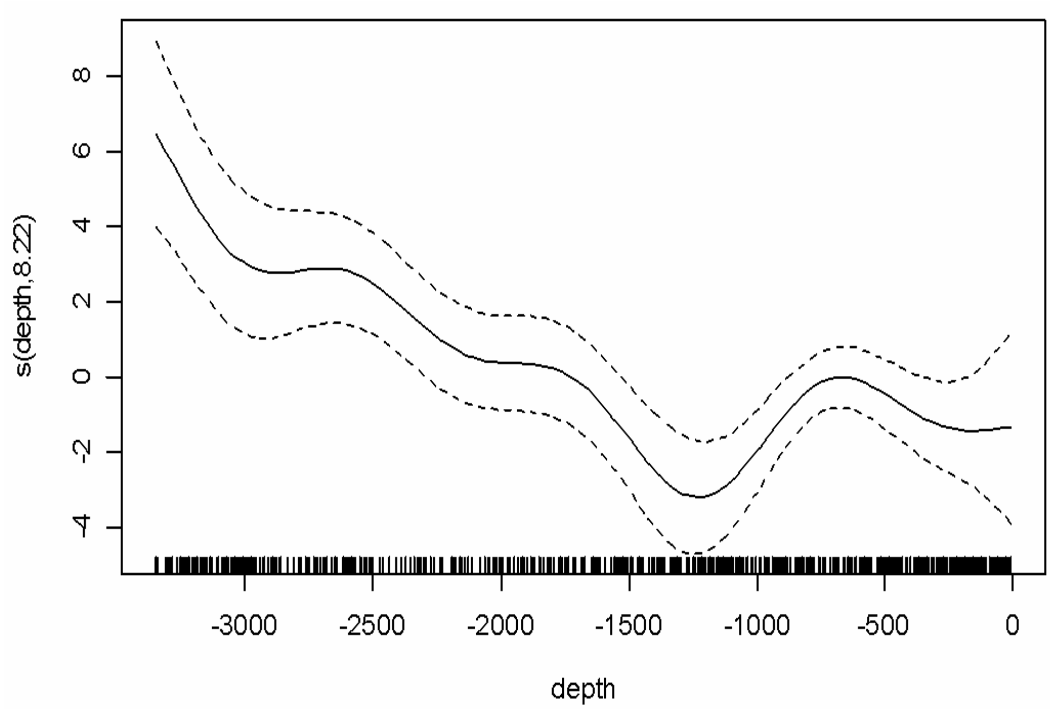


Figure A-26. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the rough-toothed dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-18. Variance estimate model results for the rough-toothed dolphin during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	440
Non-legitimate bootstrap replicates	59
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	1199.642 – 2704.252
Point estimate	1961.256
SE of bootstraps	382.0367
Est. CV for density surface model	0.1948
CV in detection probability	0.2279
CV in overall estimate including density surface model AND detection probability	0.2998
Confidence interval incorporating detection function uncertainty	1103.522 , 3485.681

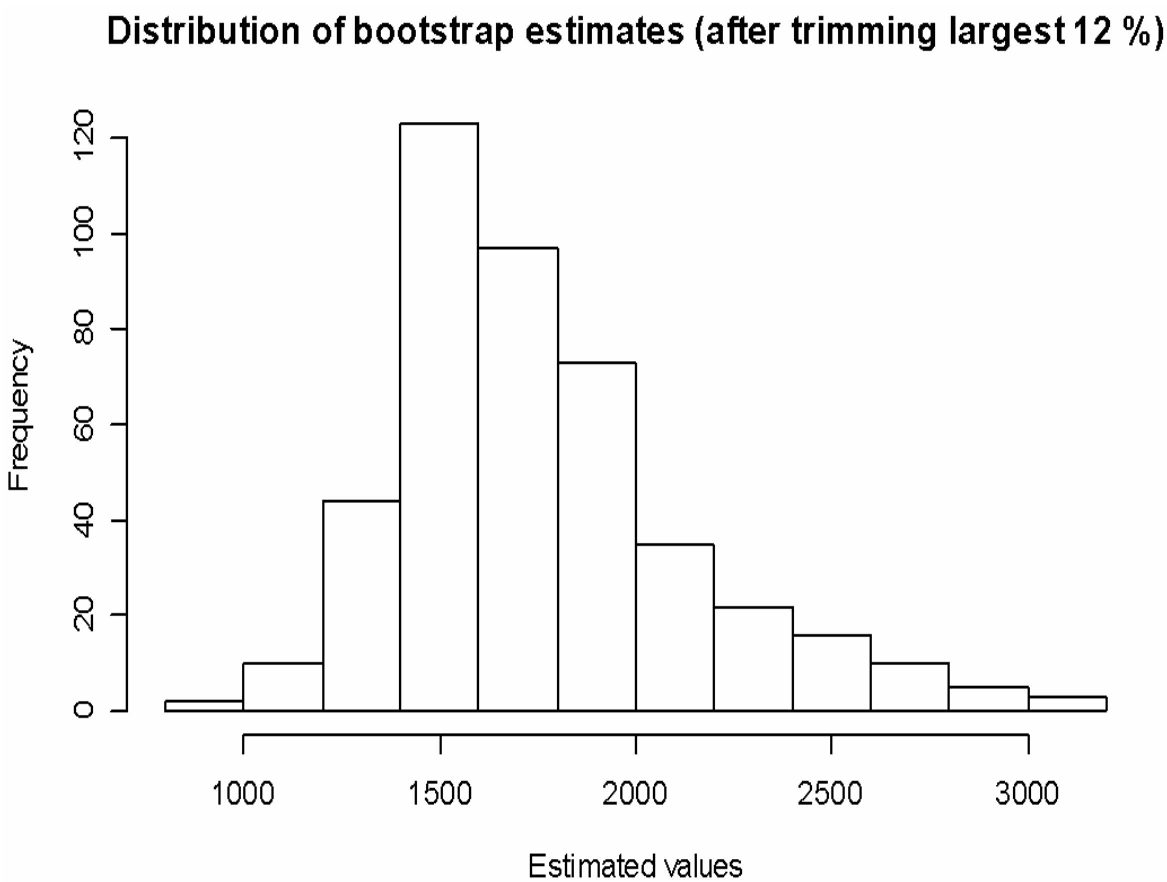


Figure A-27. Distribution of bootstrap estimates (after trimming largest 12%) for pooled sightings of the rough-toothed dolphin during all seasons in the Gulf of Mexico study area.

➢ Bottlenose Dolphin (*Tursiops truncatus)*

Table A-19. Detection function results for the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area.

Detection Function	
No. of observations	283
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.1415
SE	0.2413
Hazard Shape Parameter (Exponent)	
Estimate	1.2046
SE	0.1419
Average p	
Estimate	0.2478
SE	0.0303
CV	0.1225
N in covered region	
Estimate	1142.1754
SE	151.7608
CV	0.1329

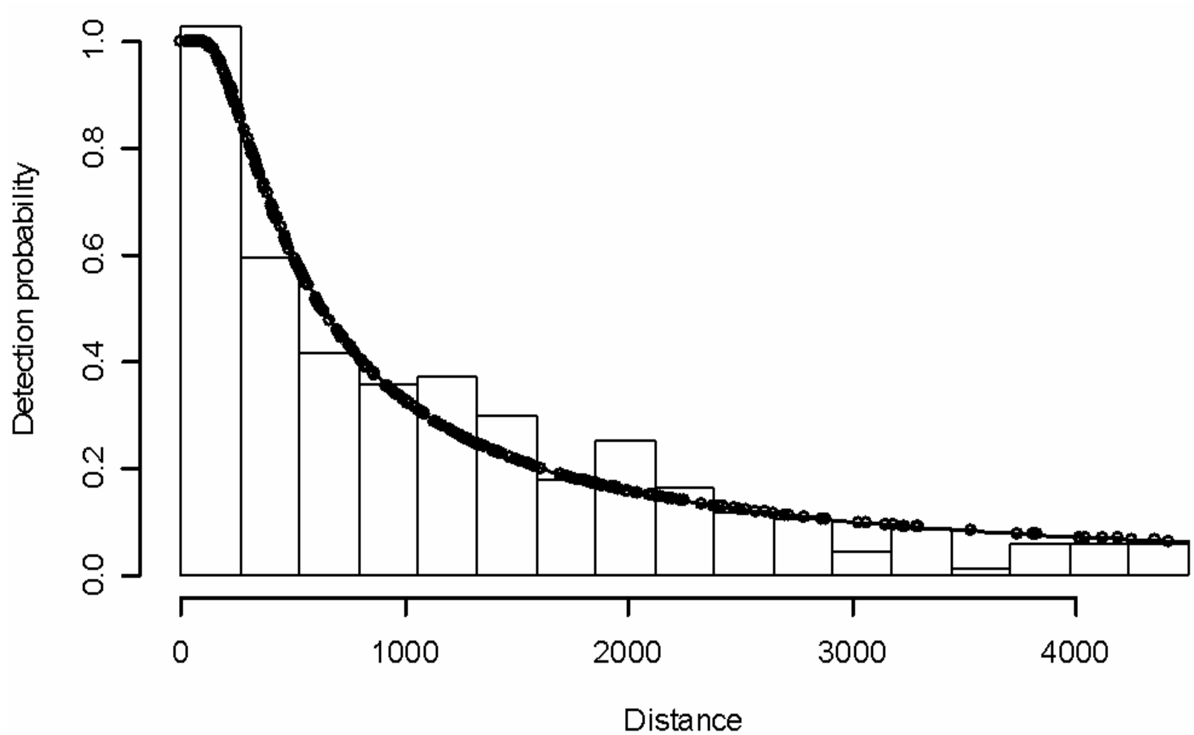


Figure A-28. Plot of the detection function for pooled sightings of the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area.

Table A-20. Response surface model (Generalized Additive Model) results for the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.999
Est. rank	29.000
F	19.826
p-value	<2e-16
s(depth)	
Edf	7.041
Est. rank	7.000
F	9.685
p-value	6.71e-12
R-sq. (adj)	0.158
n segments	198
Deviance explained	42.3%

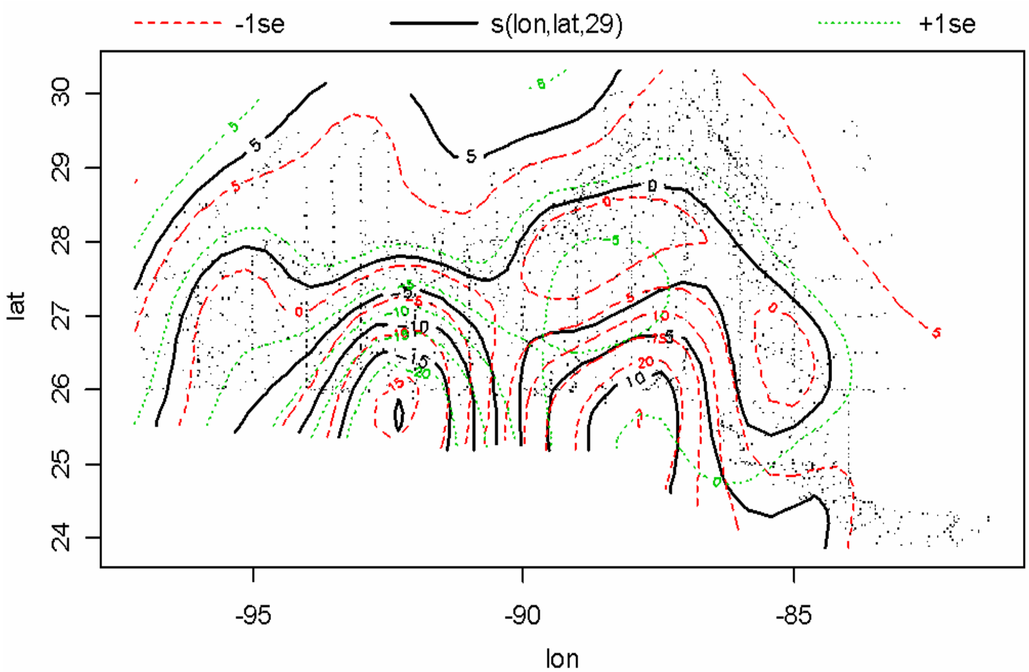


Figure A-29. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

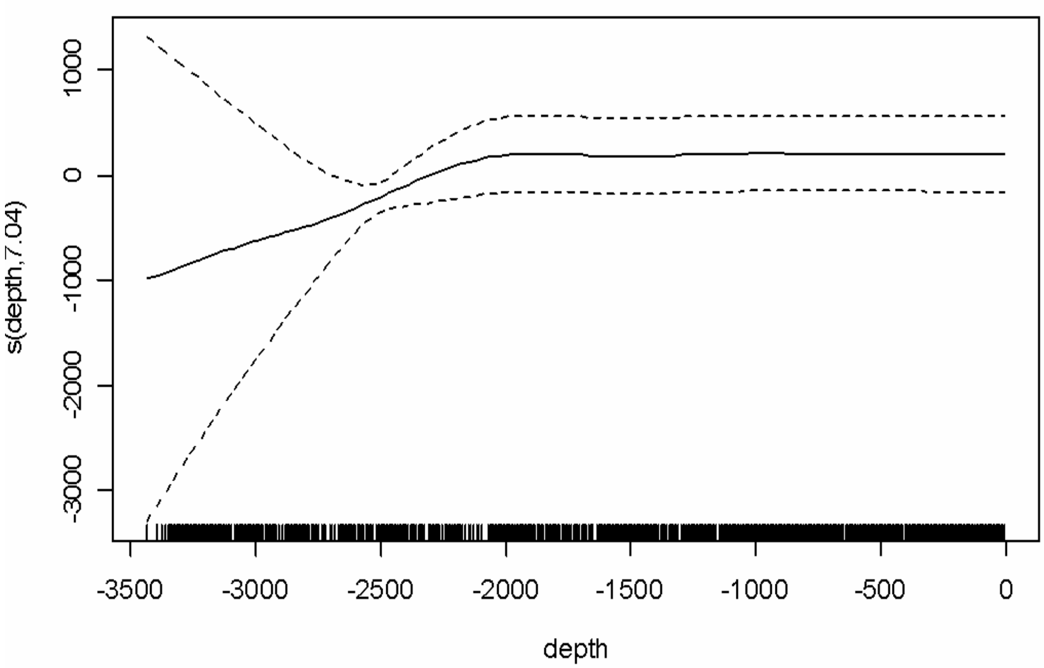


Figure A-30. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-21. Variance estimate model results for the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area.

Variance	
Legitimate values	472
Non-legitimate bootstrap replicates	27
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	39588.04 – 83775.47
Point estimate	49509.06
SE of bootstraps	10604.94
Est. CV for density surface model	0.2142
CV in detection probability	0.1225
CV in overall estimate including density surface model AND detection probability	0.2467
Confidence interval incorporating detection function uncertainty	30743.63 , 79728.63

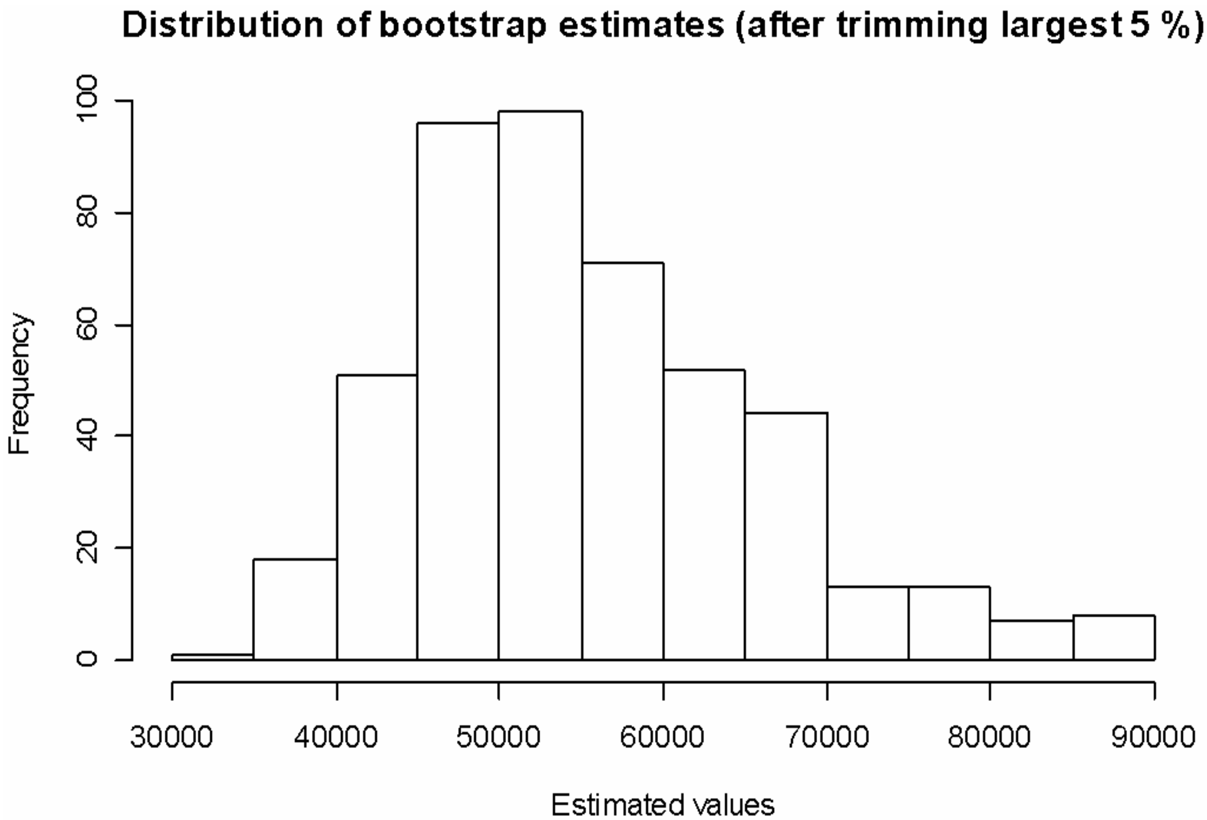


Figure A-31. Distribution of bootstrap estimates (after trimming largest 5%) for pooled sightings of the bottlenose dolphin during fall, winter, and spring in the Gulf of Mexico study area.

Table A-22. Detection function results for the bottlenose dolphin during summer in the Gulf of Mexico study area.

Detection Function	
No. of observations	157
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.1683
SE	0.3223
Hazard Shape Parameter (Exponent)	
Estimate	1.2052
SE	0.2116
Average p	
Estimate	0.3165
SE	0.0510
CV	0.1611
N in covered region	
Estimate	496.0907
SE	86.3491
CV	0.1741

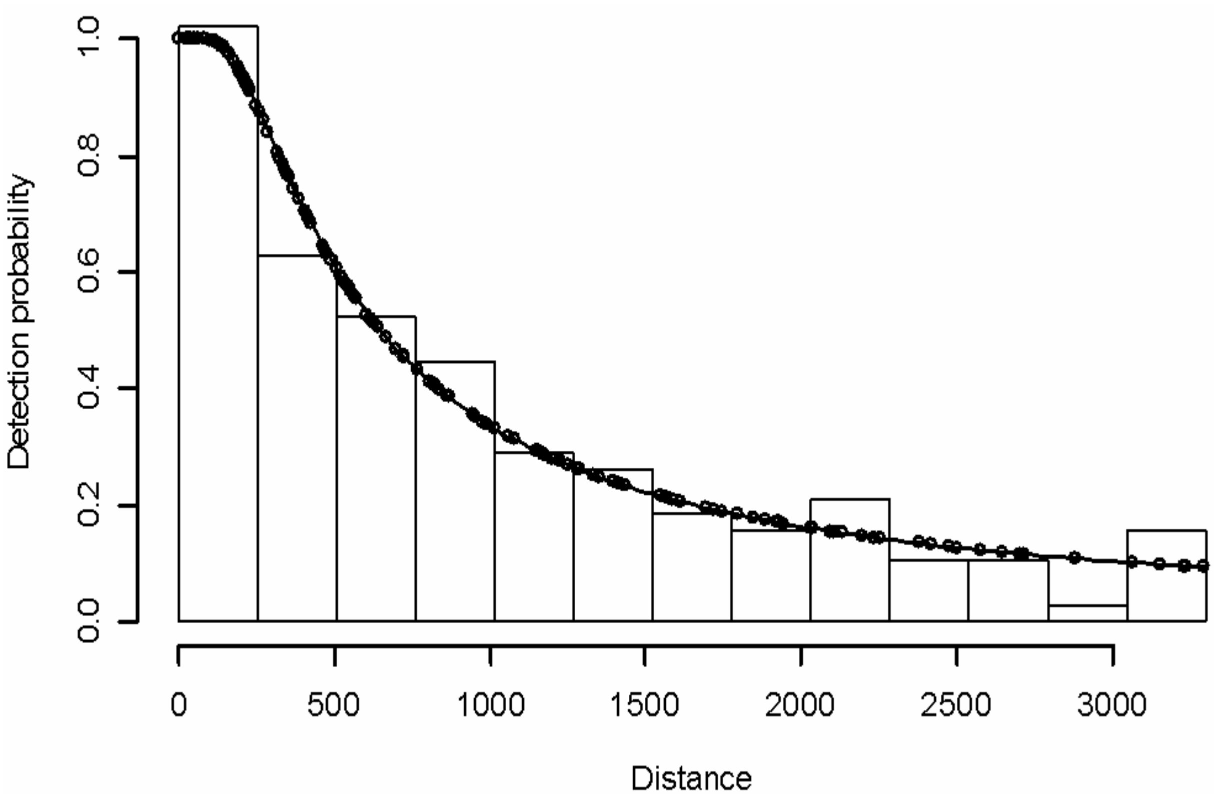


Figure A-32. Plot of the detection function for pooled sightings of the bottlenose dolphin during summer in the Gulf of Mexico study area.

Table A-23. Response surface model (Generalized Additive Model) results for the bottlenose dolphin during summer in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.44
Est. rank	29.000
F	6.694
p-value	<2e-16
R-sq. (adj)	0.085
n segments	124
Deviance explained	29.3%

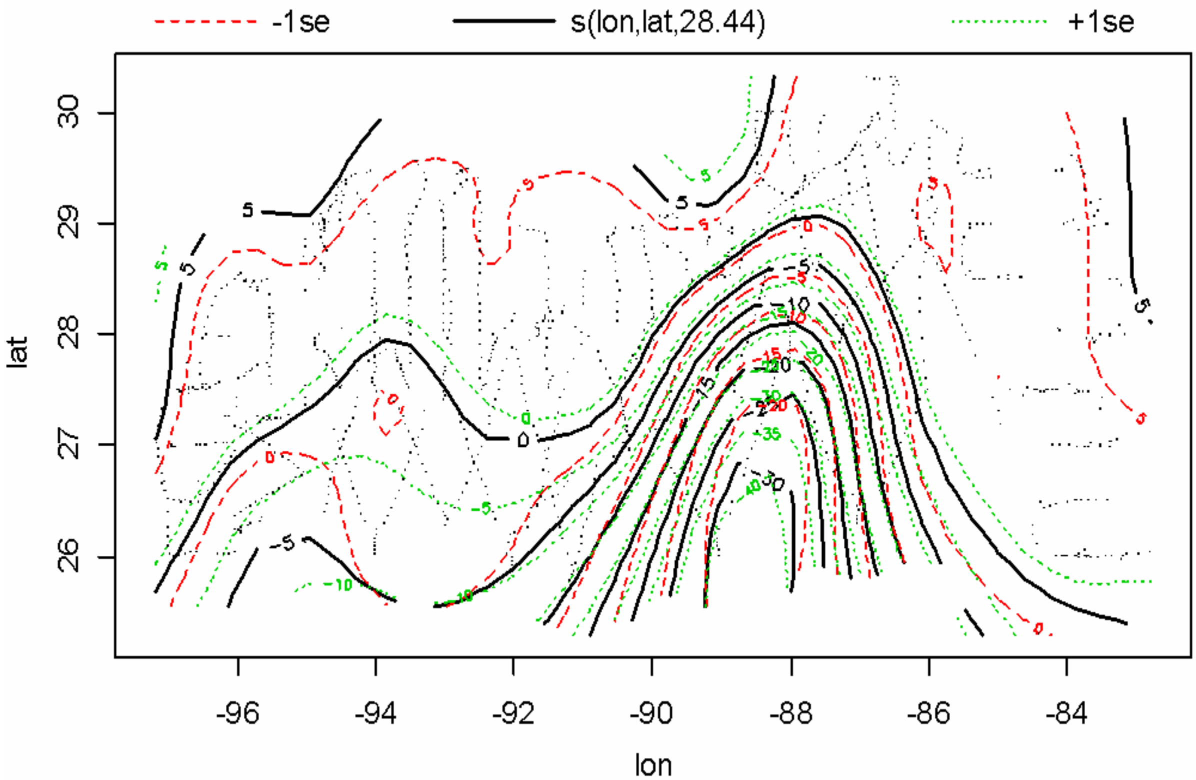


Figure A-33. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the bottlenose dolphin during summer in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

Table A-24. Variance estimate model results for the bottlenose dolphin during summer in the Gulf of Mexico study area.

Variance	
Legitimate values	499
Non-legitimate bootstrap replicates	0
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	32019.21 – 54052.75
Point estimate	39597.86
SE of bootstraps	5828.727
Est. CV for density surface model	0.1472
CV in detection probability	0.1611
CV in overall estimate including density surface model AND detection probability	0.2182
Confidence interval incorporating detection function uncertainty	25947.40 , 60429.6

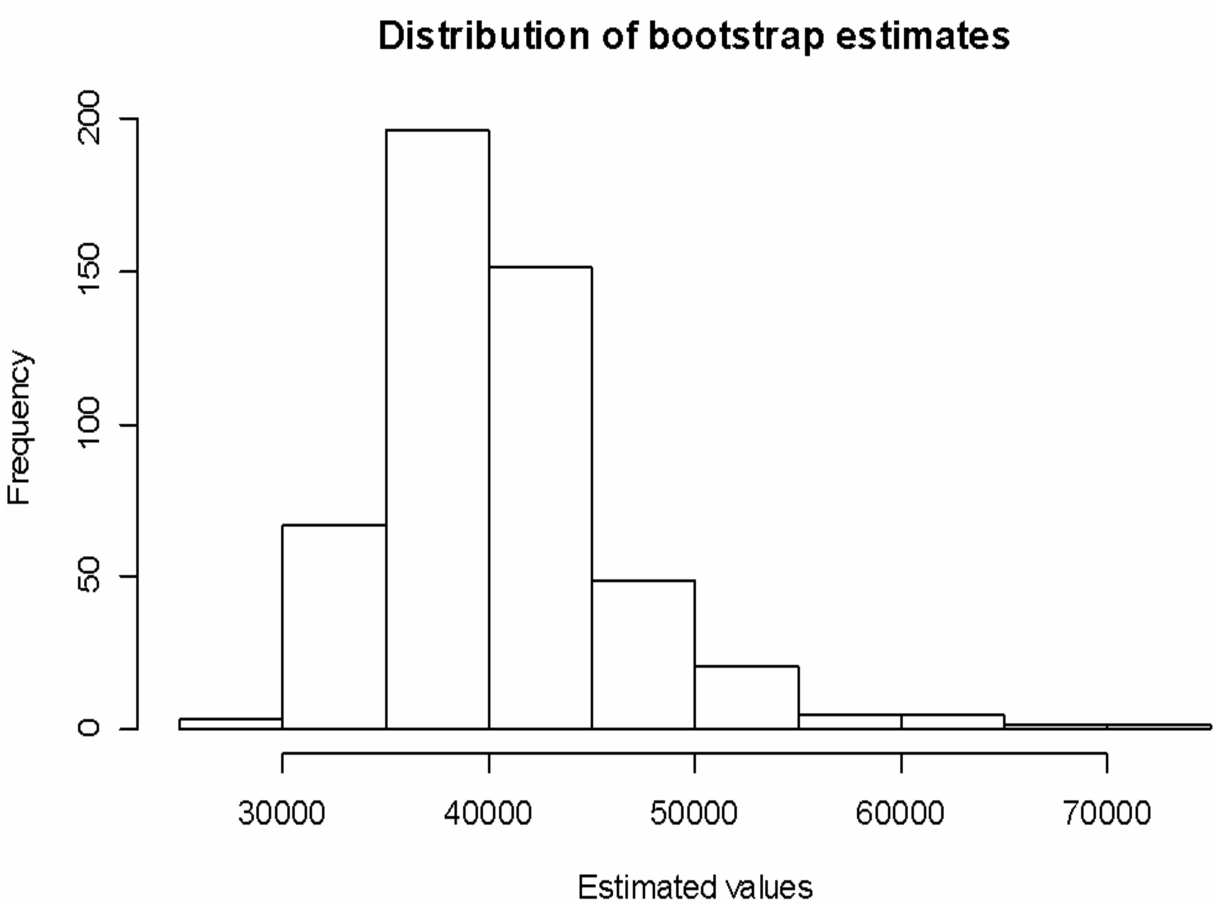


Figure A-34. Distribution of bootstrap estimates for pooled sightings of the bottlenose dolphin during summer in the Gulf of Mexico study area.

➢ <u>Pantropical Spotted Dolphin (</u>*Stenella attenuata*)

Table A-25. Detection function results for the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area.

Detection Function	
No. of observations	297
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.4478
SE	0.3060
Hazard Shape Parameter (Exponent)	
Estimate	1.0337
SE	0.1583
Average p	
Estimate	0.3507
SE	0.0478
CV	0.1364
N in covered region	
Estimate	846.9537
SE	122.1524
CV	0.1442

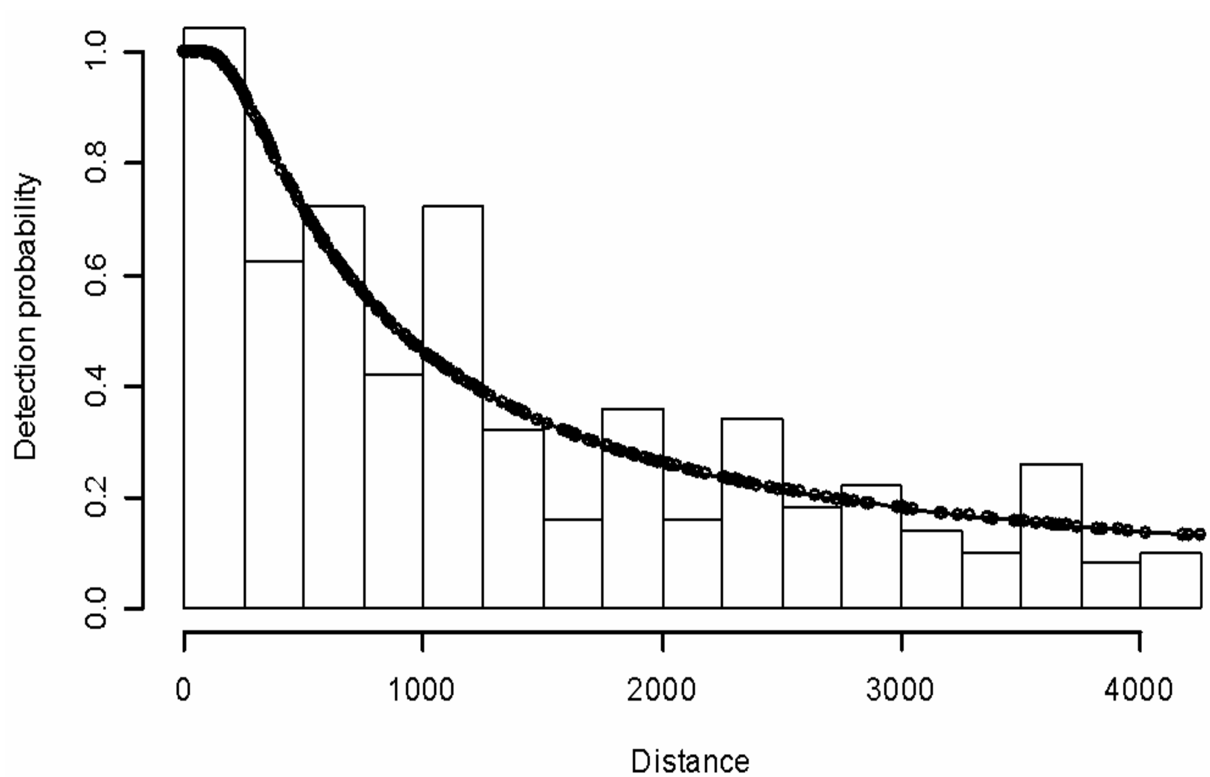


Figure A-35. Plot of the detection function for pooled sightings of the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area.

Table A-26. Response surface model (Generalized Additive Model) results for the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	17.619
Est. rank	29.000
F	4.776
p-value	1.27e-15
s(depth)	
Edf	7.614
Est. rank	9.000
F	11.015
p-value	<2e-16
R-sq. (adj)	0.0514
n segments	236
Deviance explained	20.2%

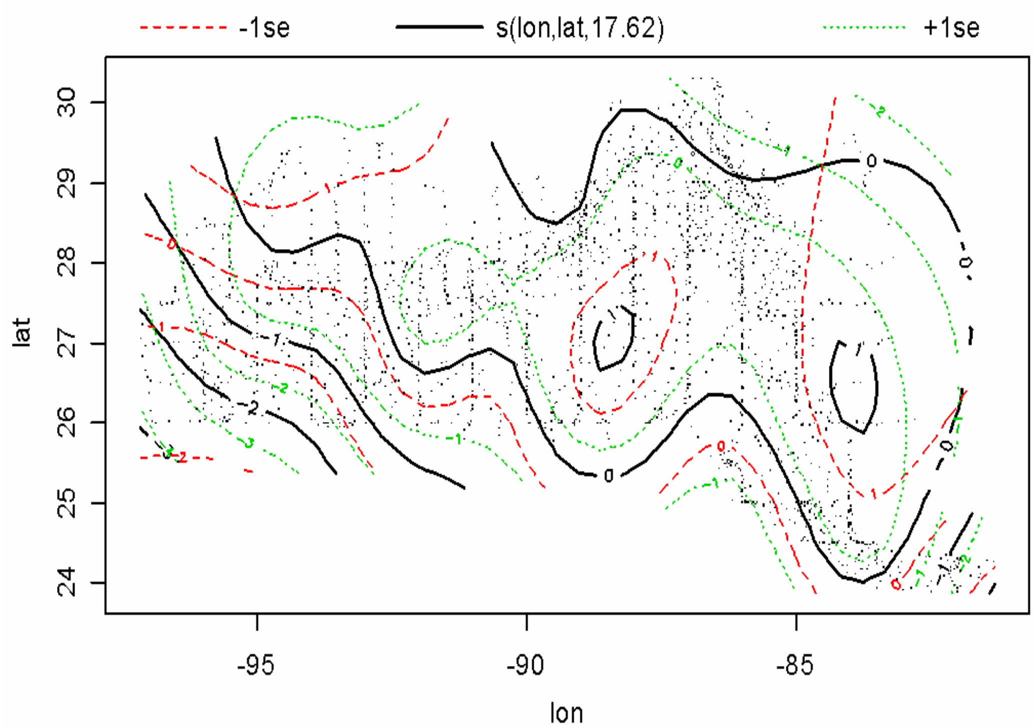


Figure A-36. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

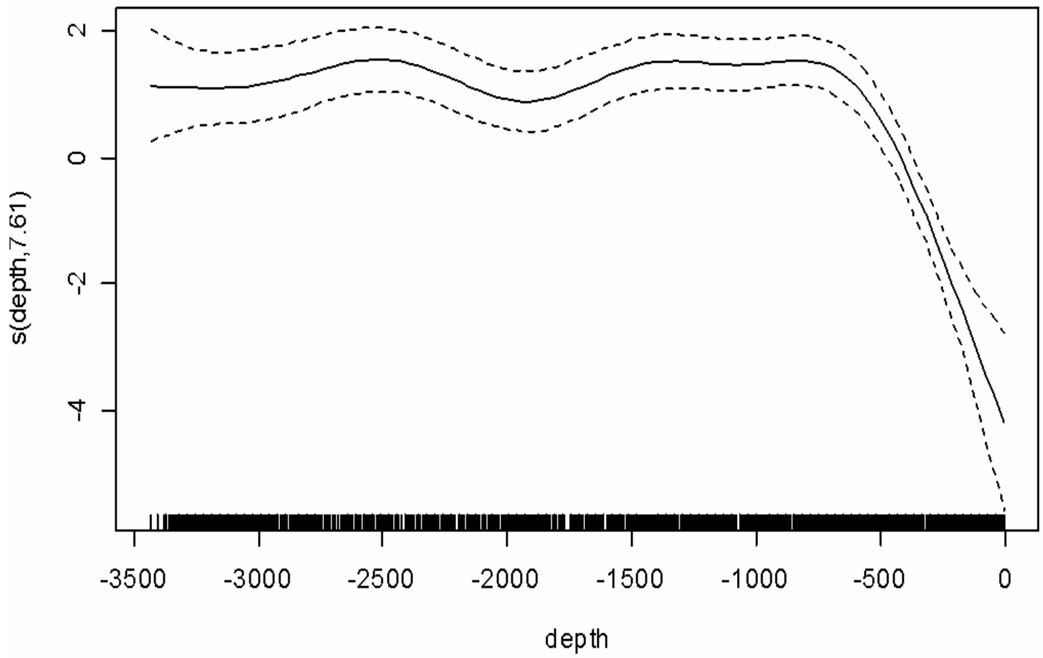


Figure A-37. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-27. Variance estimate model results for the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area.

Variance	
Legitimate values	492
Non-legitimate bootstrap replicates	7
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	63515.44 – 97977.24
Point estimate	81033.84
SE of bootstraps	8676.435
Est. CV for density surface model	0.1071
CV in detection probability	0.1364
CV in overall estimate including density surface model AND detection probability	0.1734
Confidence interval incorporating detection function uncertainty	57826.53 , 113554.9

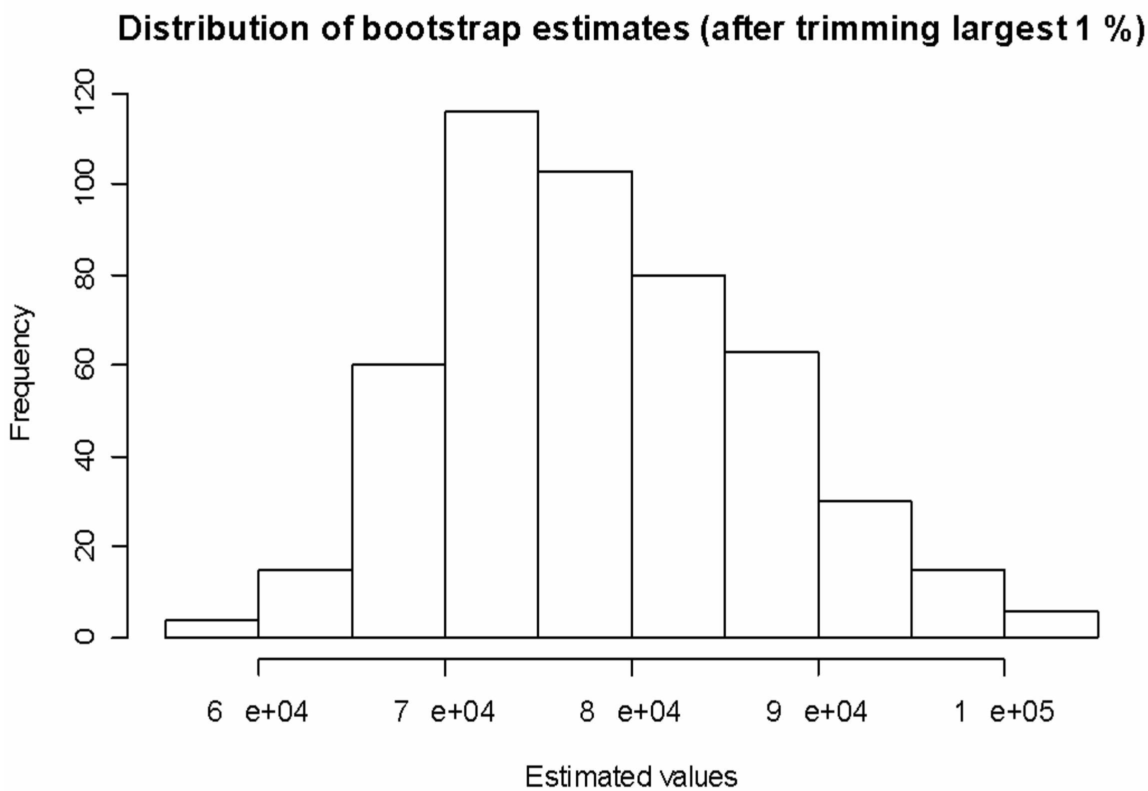


Figure A-38. Distribution of bootstrap estimates (after trimming largest 1%) for pooled sightings of the pantropical spotted dolphin during summer, fall, and winter in the Gulf of Mexico study area.

Table A-28. Detection function results for the pantropical spotted dolphin during spring in the Gulf of Mexico study area.

Detection Function	
No. of observations	245
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.2178
SE	0.3428
Hazard Shape Parameter (Exponent)	
Estimate	1.0318
SE	0.1544
Average p	
Estimate	0.3005
SE	0.0473
CV	0.1574
N in covered region	
Estimate	815.2193
SE	135.4789
CV	0.1662

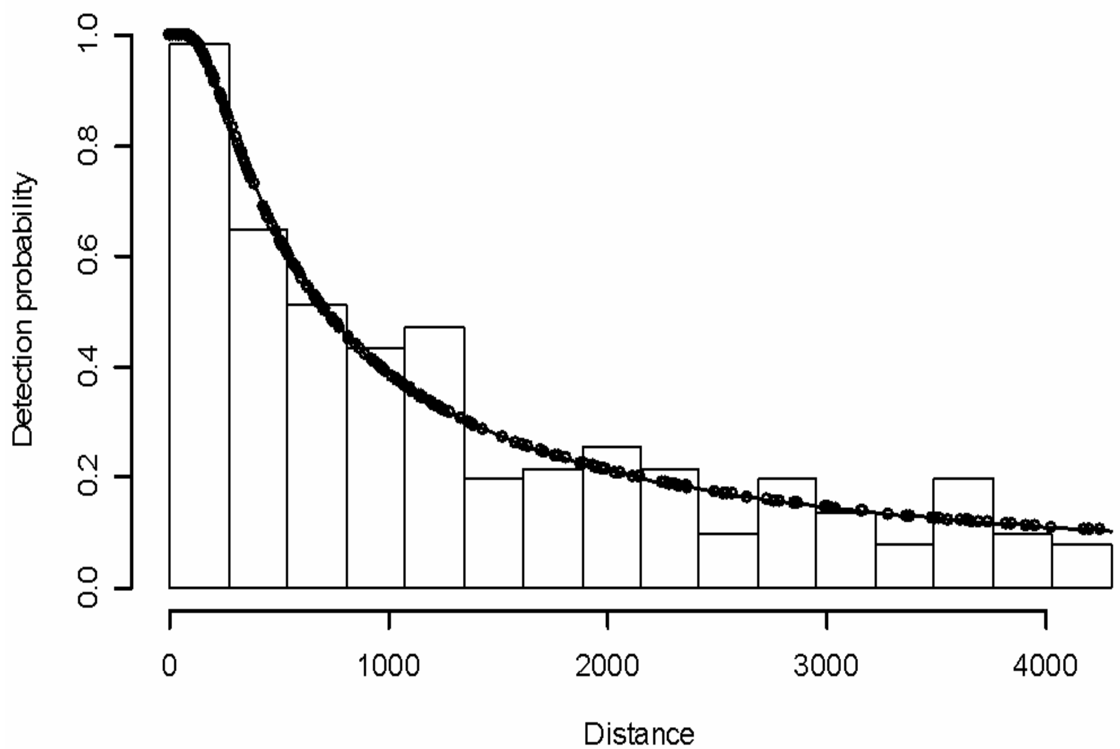


Figure A-39. Plot of the detection function for pooled sightings of the pantropical spotted dolphin during spring in the Gulf of Mexico study area.

Table A-29. Response surface model (Generalized Additive Model) results for the pantropical spotted dolphin during spring in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + s(SST) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.734
Est. rank	29.000
F	5.422
p-value	<2e-16
s(depth)	
Edf	8.460
Est. rank	9.000
F	6.255
p-value	9.79e-9
s(SST)	
Edf	5.755
Est. rank	9.000
F	4.243
p-value	1.86e-5
R-sq. (adj)	0.0804
n segments	196
Deviance explained	21%

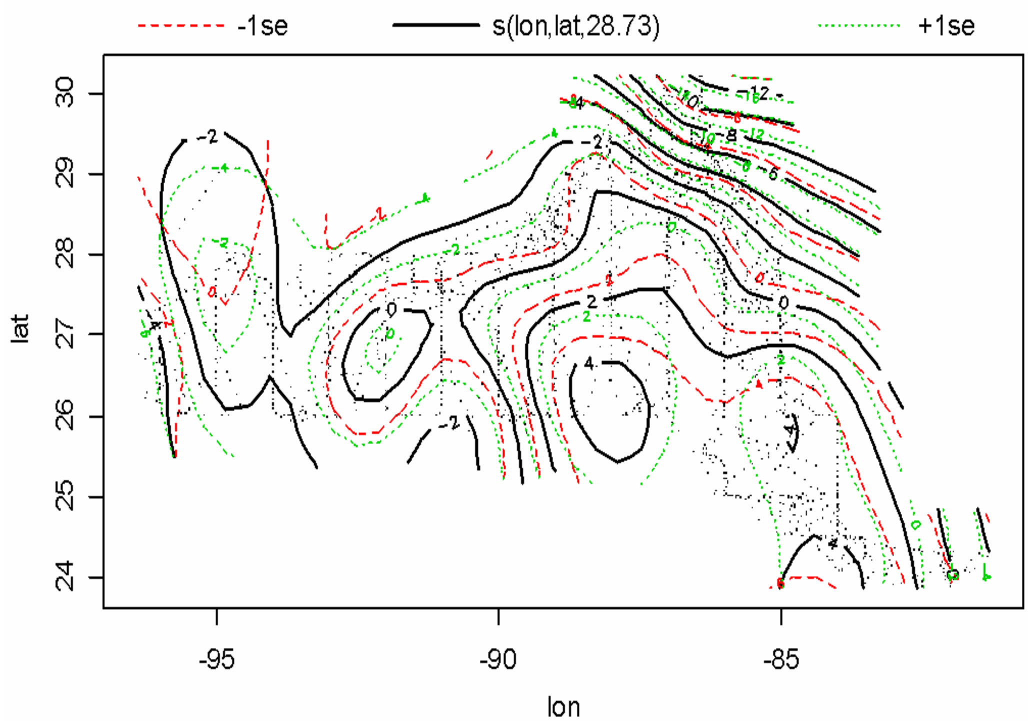


Figure A-40. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates longitude and *latitude* selected for the pantropical spotted dolphin during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

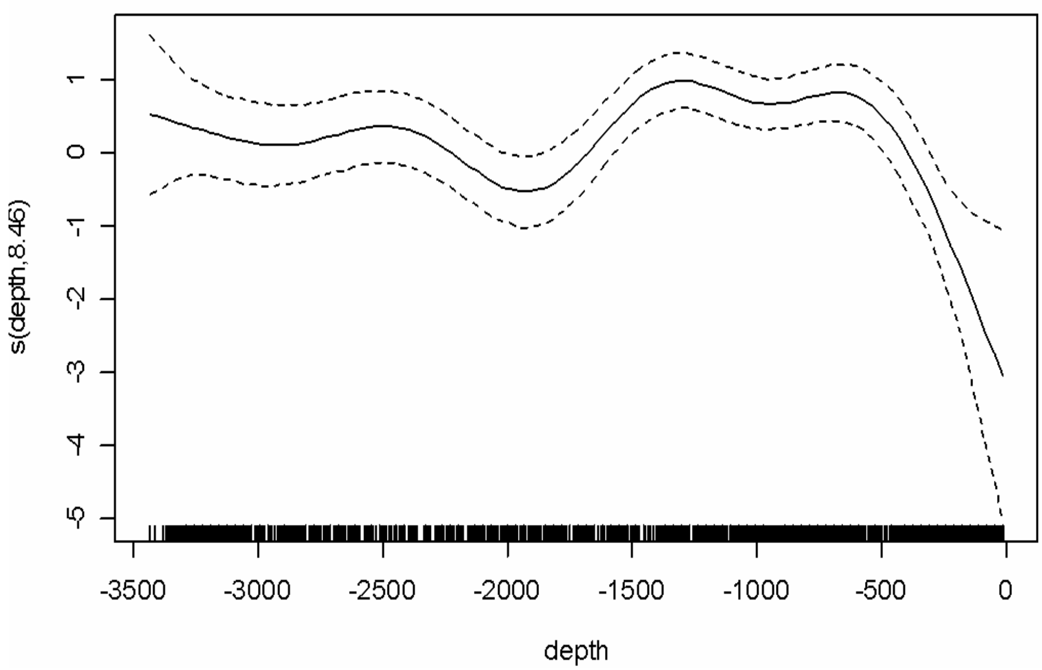


Figure A-41. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the pantropical spotted dolphin during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

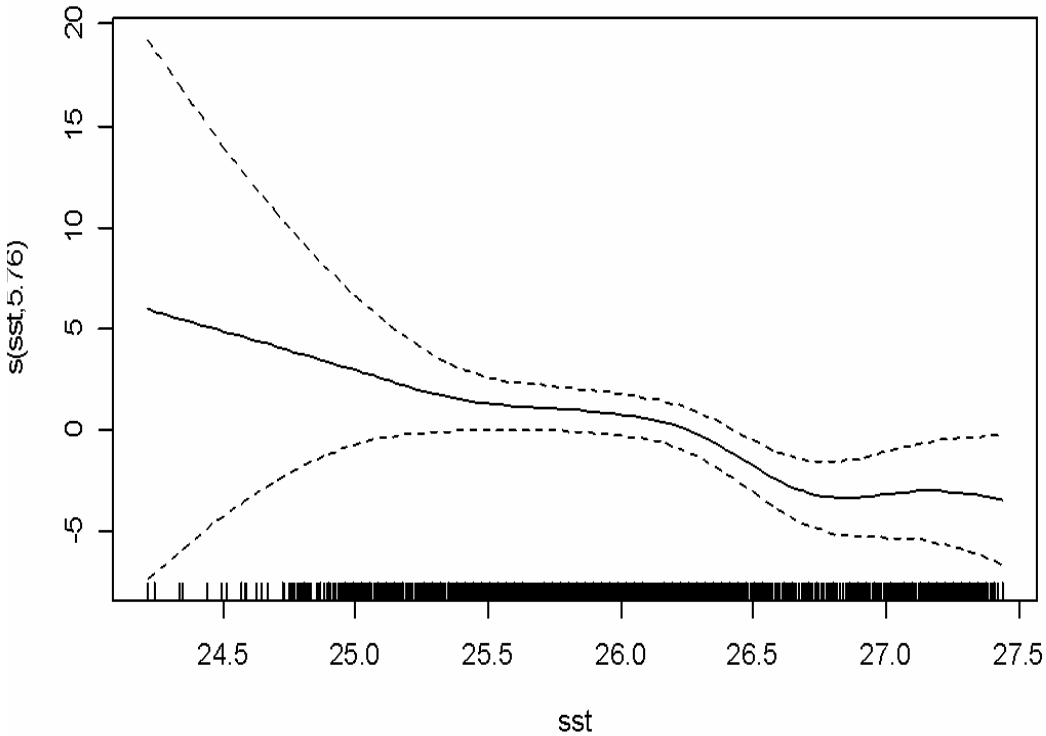


Figure A-42. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for the pantropical spotted dolphin during spring in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-30. Variance estimate model results for the pantropical spotted dolphin during spring in the Gulf of Mexico study area.

Variance	
Legitimate values	444
Non-legitimate bootstrap replicates	55
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	74233.67 - 153981.59
Point estimate	102173.8
SE of bootstraps	19923.44
Est. CV for density surface model	0.195
CV in detection probability	0.1574
CV in overall estimate including density surface model AND detection probability	0.2506
Confidence interval incorporating detection function uncertainty	62992.23 , 165726.7

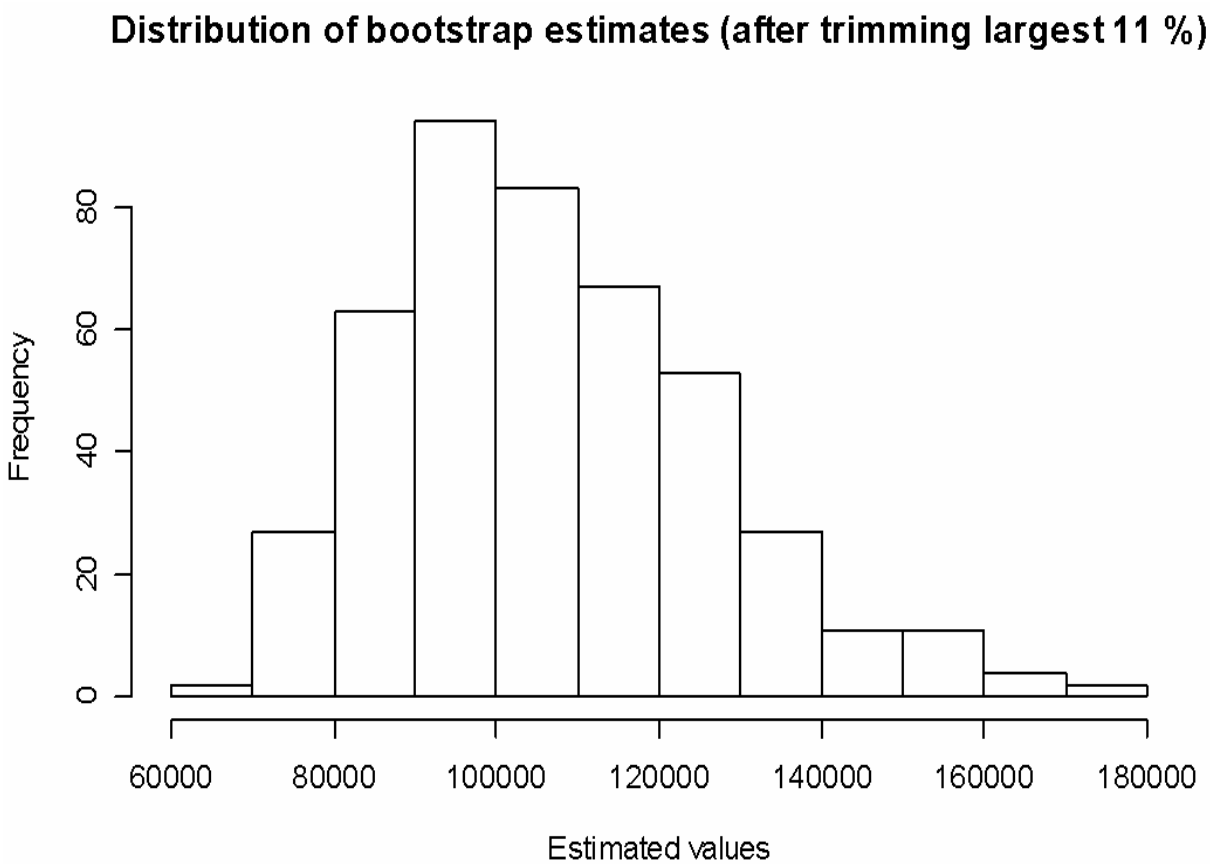


Figure A-43. Distribution of bootstrap estimates (after trimming largest 11%) for pooled sightings of the pantropical spotted dolphin during spring in the Gulf of Mexico study area.

➢ Atlantic Spotted Dolphin (*Stenella frontalis*)

Table A-31. Detection function results for the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	94
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.8094
SE	0.3781
Hazard Shape Parameter (Exponent)	
Estimate	1.3632
SE	0.3733
Average p	
Estimate	0.4240
SE	0.0810
CV	0.1911
N in covered region	
Estimate	221.6937
SE	45.7897
CV	0.2065

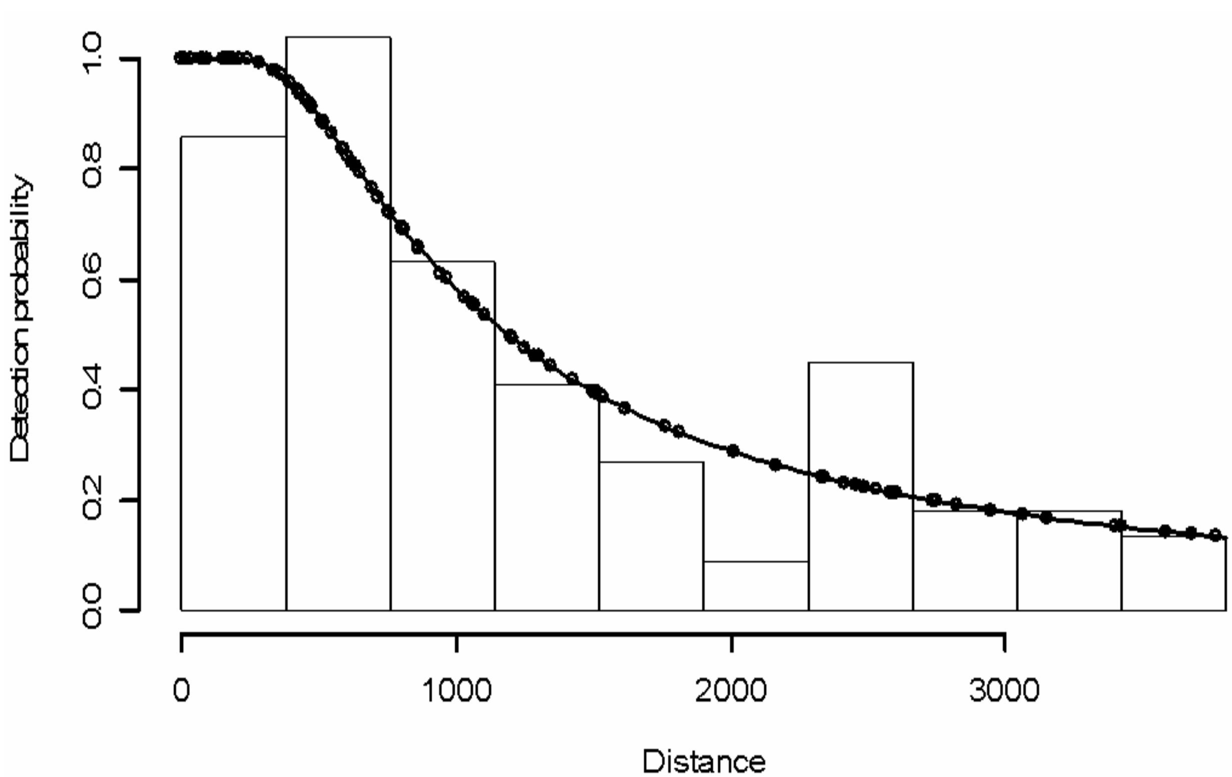


Figure A-44. Plot of the detection function for pooled sightings of the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area.

Table A-32. Response surface model (Generalized Additive Model) results for the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.849
Est. rank	27.000
F	6.214
p-value	<2e-16
s(depth)	
Edf	1.003
Est. rank	2.000
F	30.257
p-value	2.36e-13
R-sq. (adj)	0.5
n segments	52
Deviance explained	69%

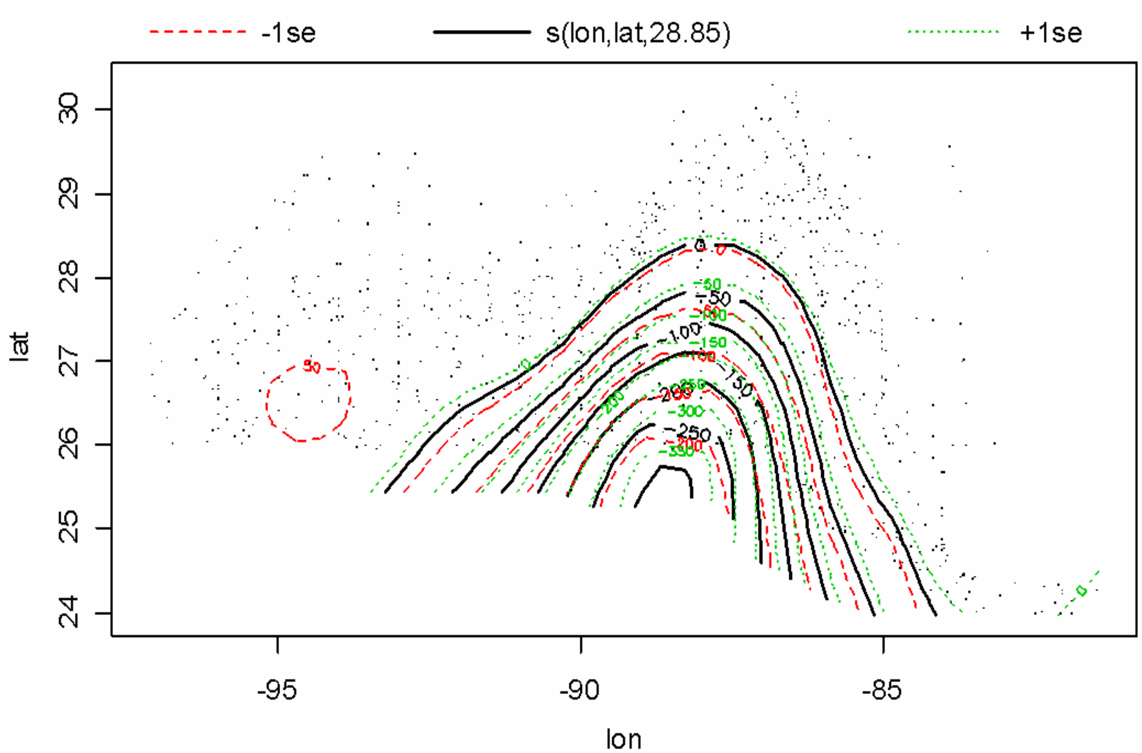


Figure A-45. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

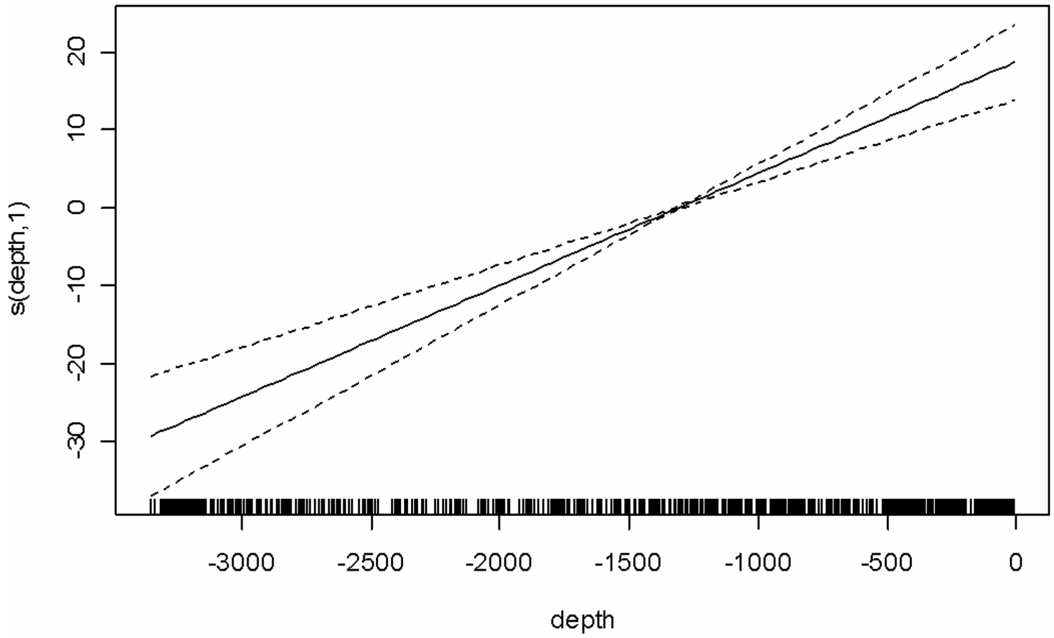


Figure A-46. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-33. Variance estimate model results for the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	407
Non-legitimate bootstrap replicates	92
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	21910.15 – 101801.04
Point estimate	32226.52
SE of bootstraps	21228.95
Est. CV for density surface model	0.6587
CV in detection probability	0.1911
CV in overall estimate including density surface model AND detection probability	0.6859
Confidence interval incorporating detection function uncertainty	9542.15 , 108838

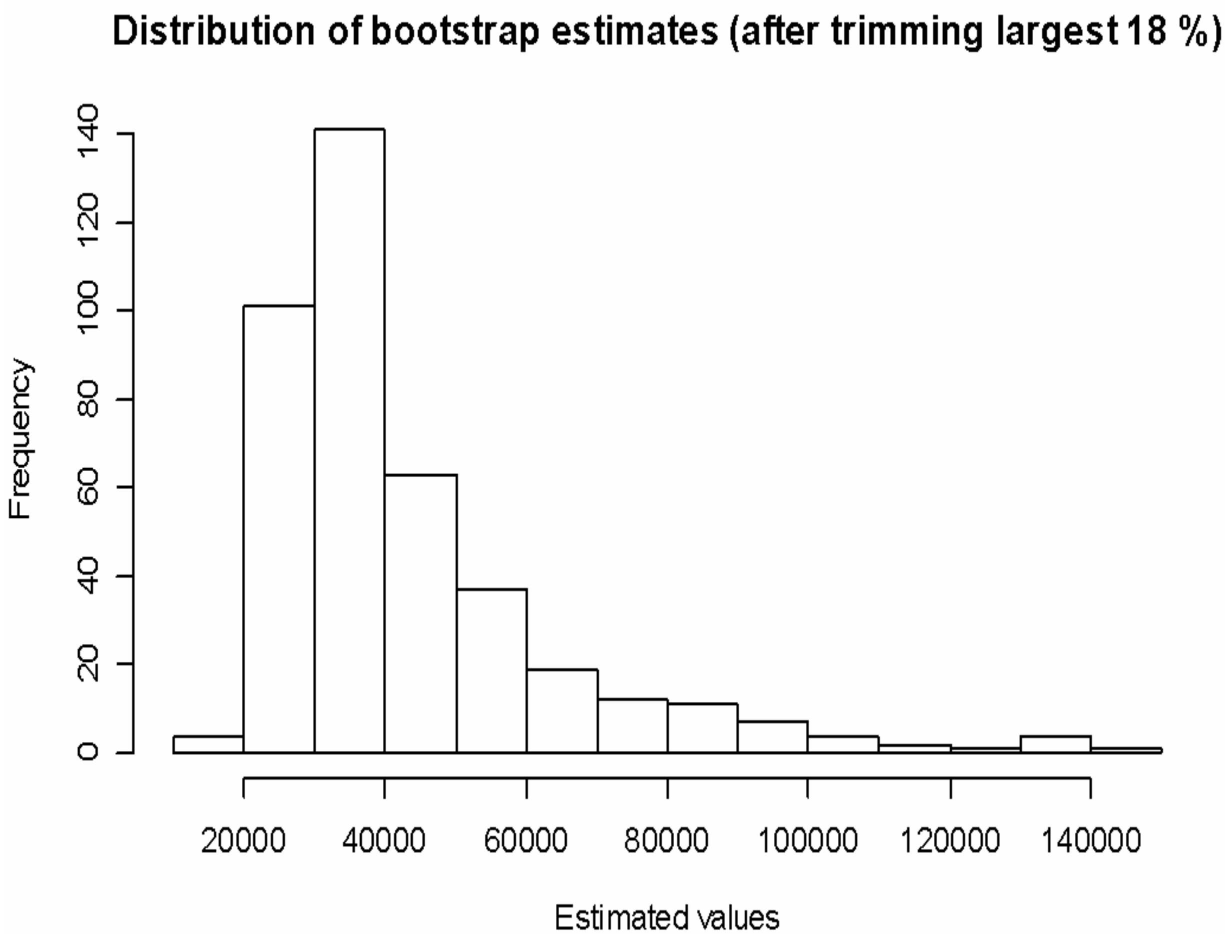


Figure A-47. Distribution of bootstrap estimates (after trimming largest 18%) for pooled sightings of the Atlantic spotted dolphin during all seasons in the Gulf of Mexico study area.

➢ Striped Dolphin *(Stenella coeruleoalba)*

Table A-34. Detection function results for the striped dolphin during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	38
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.0028
SE	0.8097
Hazard Shape Parameter (Exponent)	
Estimate	1.3103
SE	0.6447
Average p	
Estimate	0.3583
SE	0.1398
CV	0.3900
N in covered region	
Estimate	106.0485
SE	43.5967
CV	0.4111

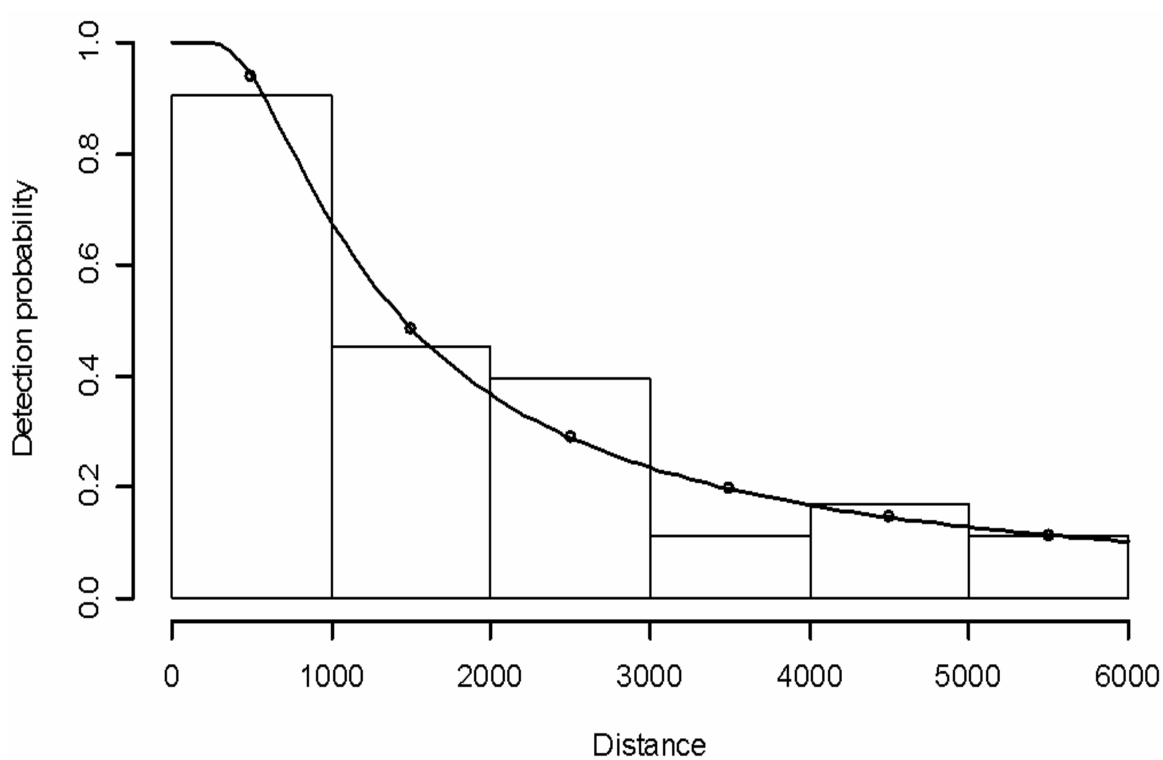


Figure A-48. Plot of the detection function for pooled sightings of the striped dolphin during all seasons in the Gulf of Mexico study area.

Table A-35. Response surface model (Generalized Additive Model) results for the striped dolphin during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon) + s(lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon)	
Edf	9.00
Est. rank	9.000
F	11.698
p-value	<2e-16
s(lat)	
Edf	5.699
Est. rank	9.000
F	6.689
p-value	3.25e-09
s(depth)	
Edf	8.031
Est. rank	9.000
F	12.647
p-value	<2e-16
R-sq. (adj)	0.105
n segments	34
Deviance explained	33.9%

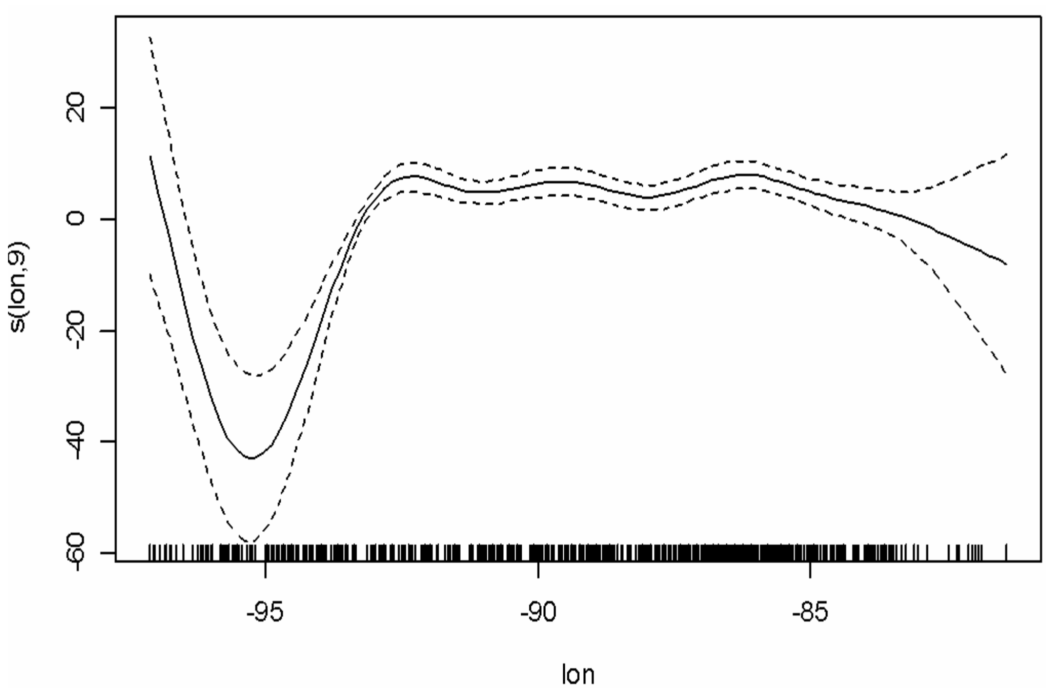


Figure A-49. Plot of the Generalized Additive Model smooth fit of the environmental covariate *longitude* selected for the striped dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

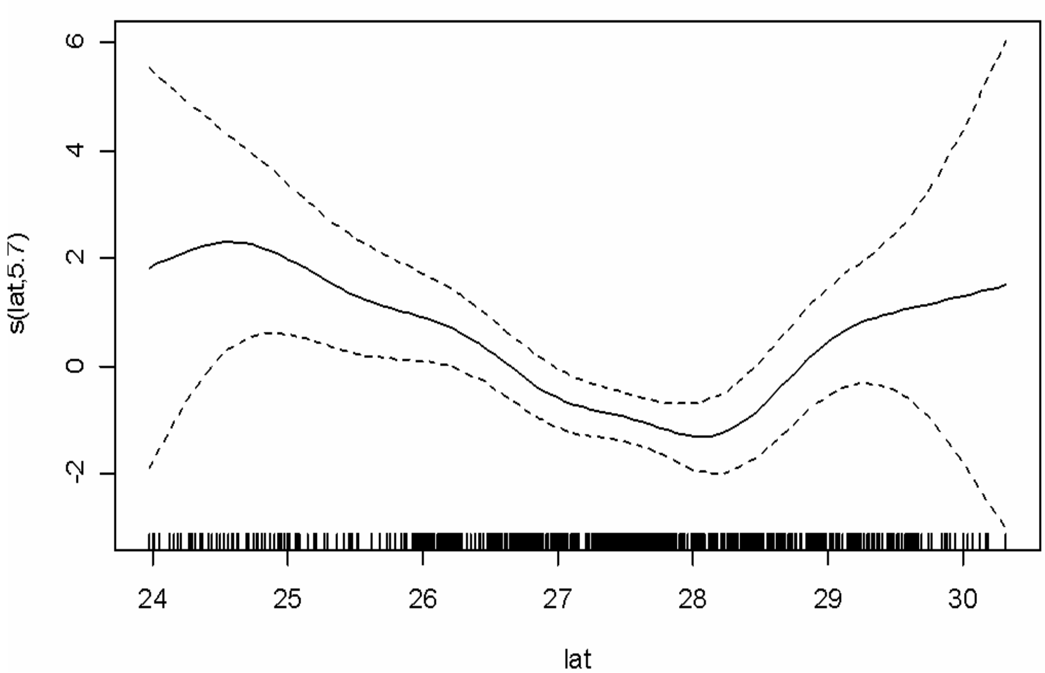


Figure A-50. Plot of the Generalized Additive Model smooth fit of the environmental covariate *latitude* selected for the striped dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

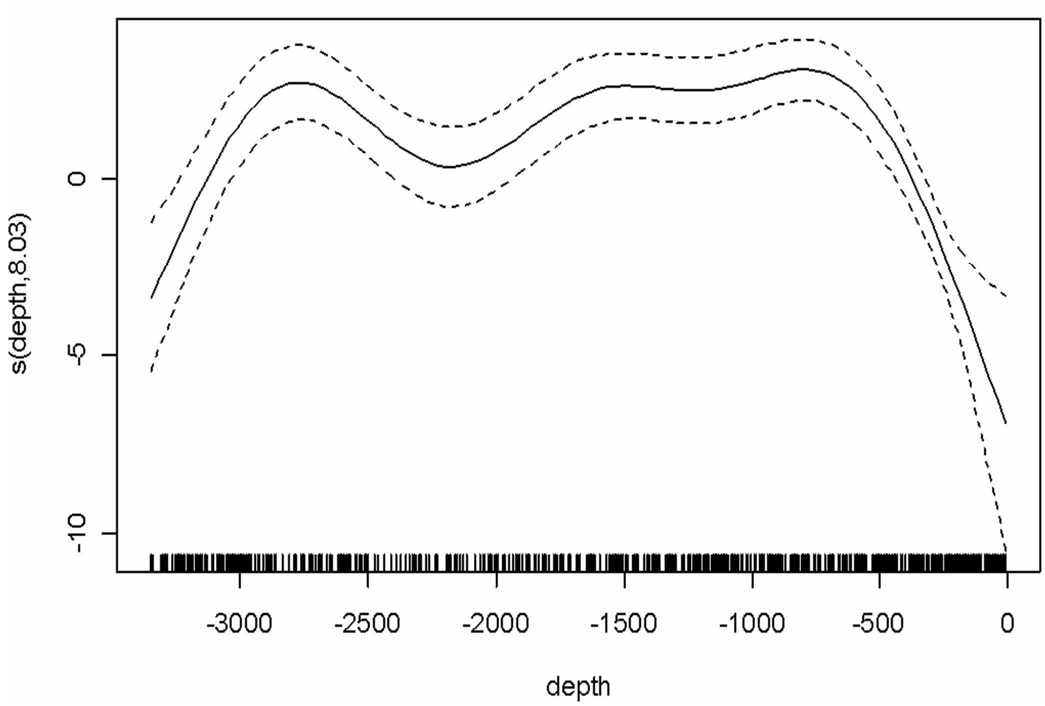


Figure A-51. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the striped dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-36. Variance estimate model results for the striped dolphin during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	468
Non-legitimate bootstrap replicates	31
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	2774.651 – 6890.732
Point estimate	4389.186
SE of bootstraps	1023.977
Est. CV for density surface model	0.2333
CV in detection probability	0.39
CV in overall estimate including density surface model AND detection probability	0.4545
Confidence interval incorporating detection function uncertainty	1877.326 , 10261.91

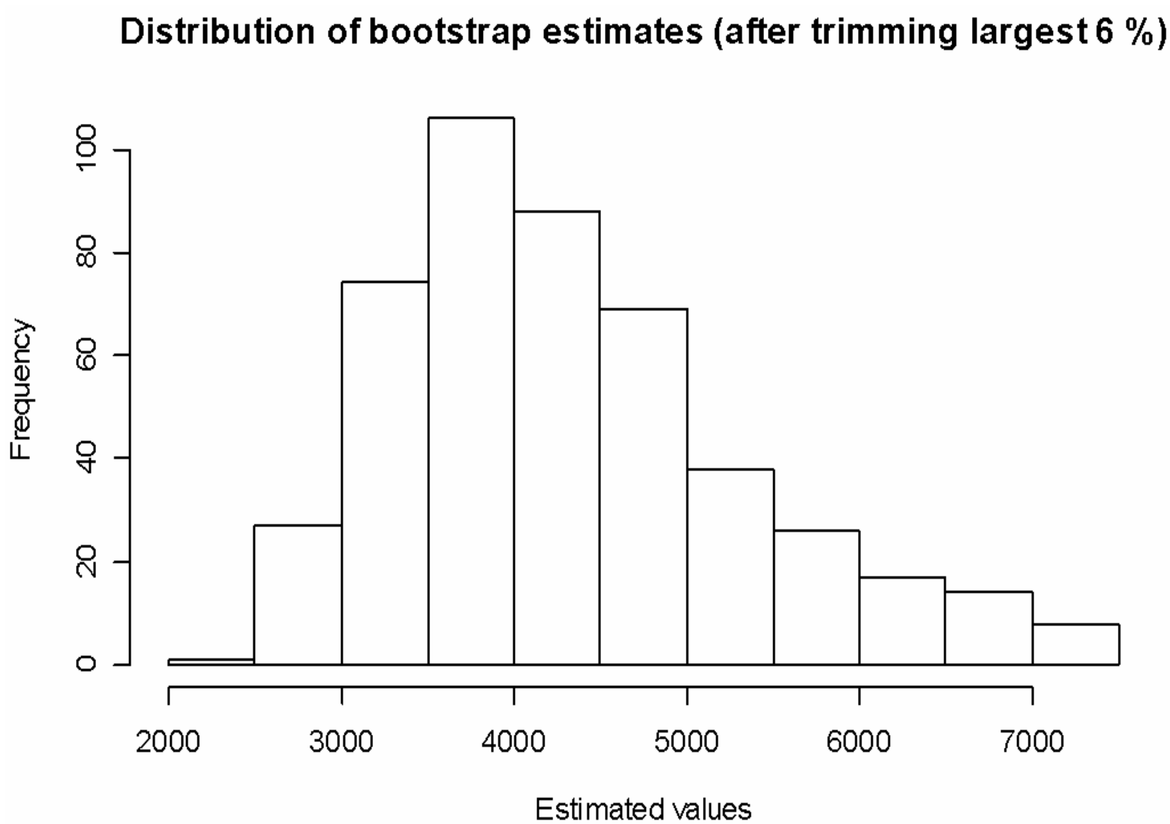


Figure A-52. Distribution of bootstrap estimates (after trimming largest 6%) for pooled sightings of the striped dolphin during all seasons in the Gulf of Mexico study area.

➢ Spinner Dolphin (*Stenella longirostris*)

Table A-37. Detection function results for the spinner dolphin during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	25
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.8889
SE	0.1689
Average p	
Estimate	0.5067
SE	0.0769
CV	0.1518
N in covered region	
Estimate	49.3367
SE	10.2045
CV	0.2068

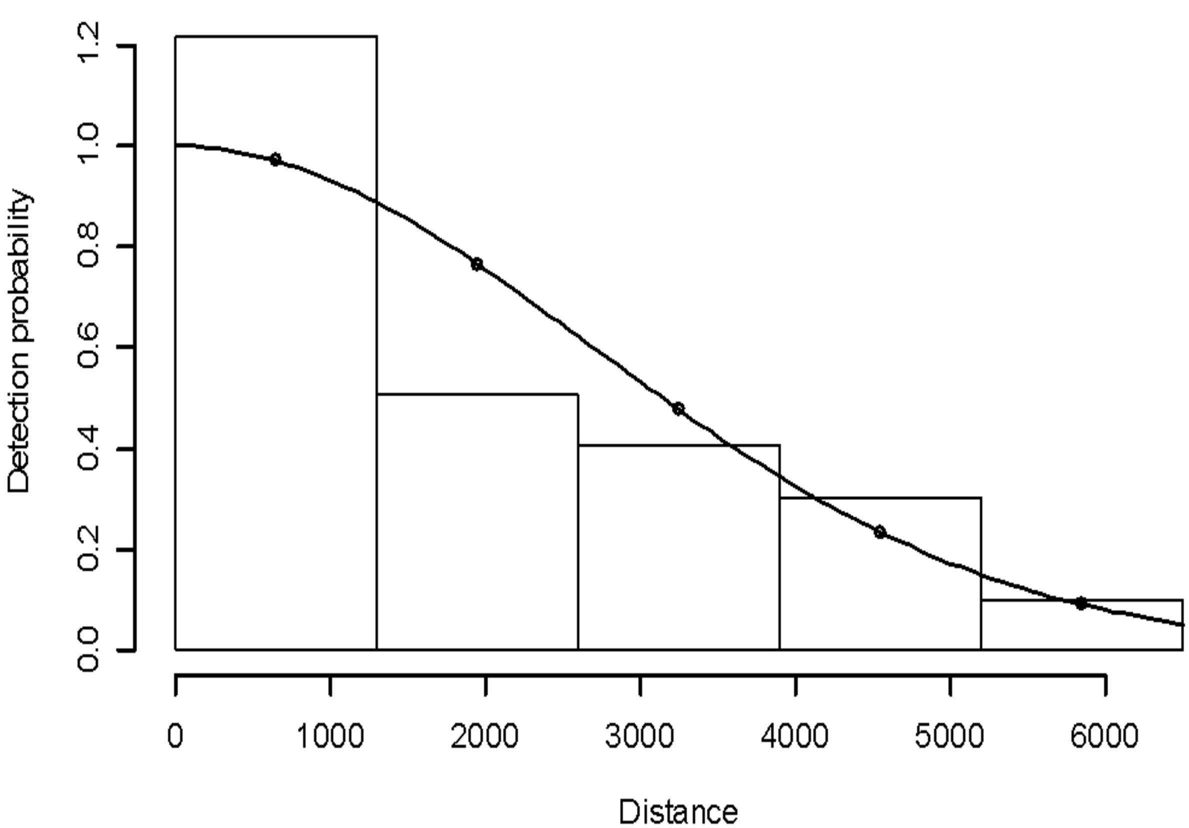


Figure A-53. Plot of the detection function for pooled sightings of the spinner dolphin during all seasons in the Gulf of Mexico study area.

Table A-38. Response surface model (Generalized Additive Model) results for the spinner dolphin during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	25.677
Est. rank	17.000
F	6.933
p-value	1.30e-15
s(depth)	
Edf	8.986
Est. rank	8.000
F	11.079
p-value	8.99e-15
R-sq. (adj)	0.312
n segments	23
Deviance explained	57%

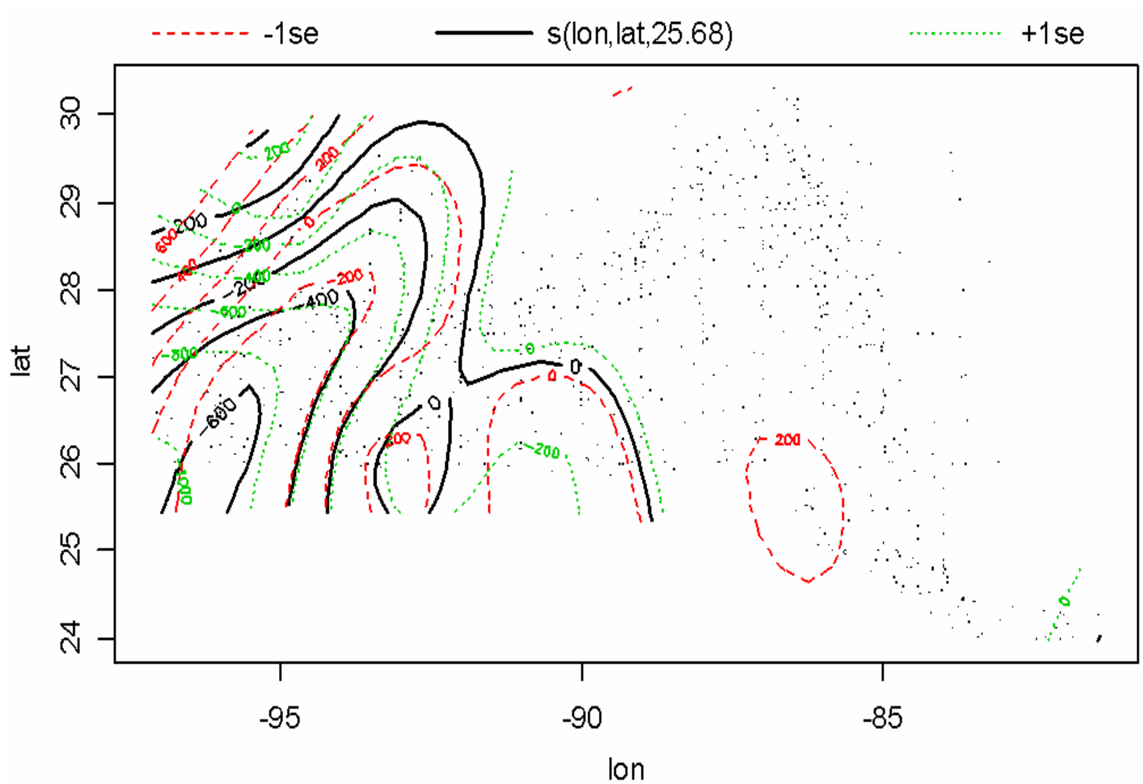


Figure A-54. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the spinner dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

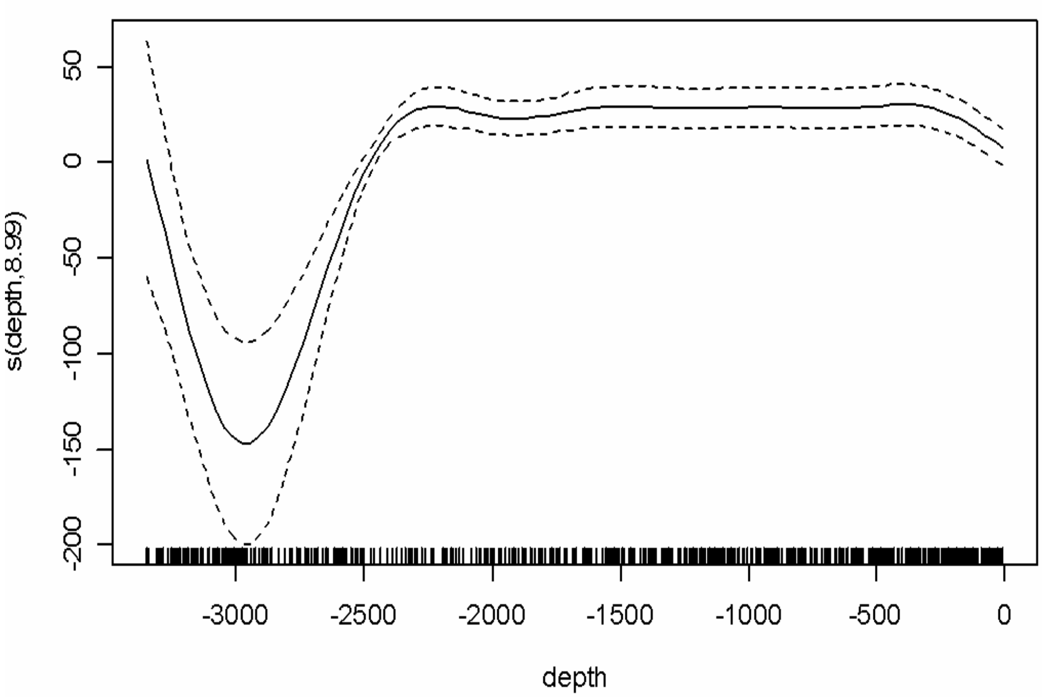


Figure A-55. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the striped dolphins during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-39. Variance estimate model results for the spinner dolphin during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	377
Non-legitimate bootstrap replicates	122
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	4596.141 – 3.863271e09
Point estimate	10265.88
SE of bootstraps	1576433981
Est. CV for density surface model	153560.5
CV in detection probability	0.1518
CV in overall estimate including density surface model AND detection probability	153560.5
Confidence interval incorporating detection function uncertainty	0.7102589 , 148380100

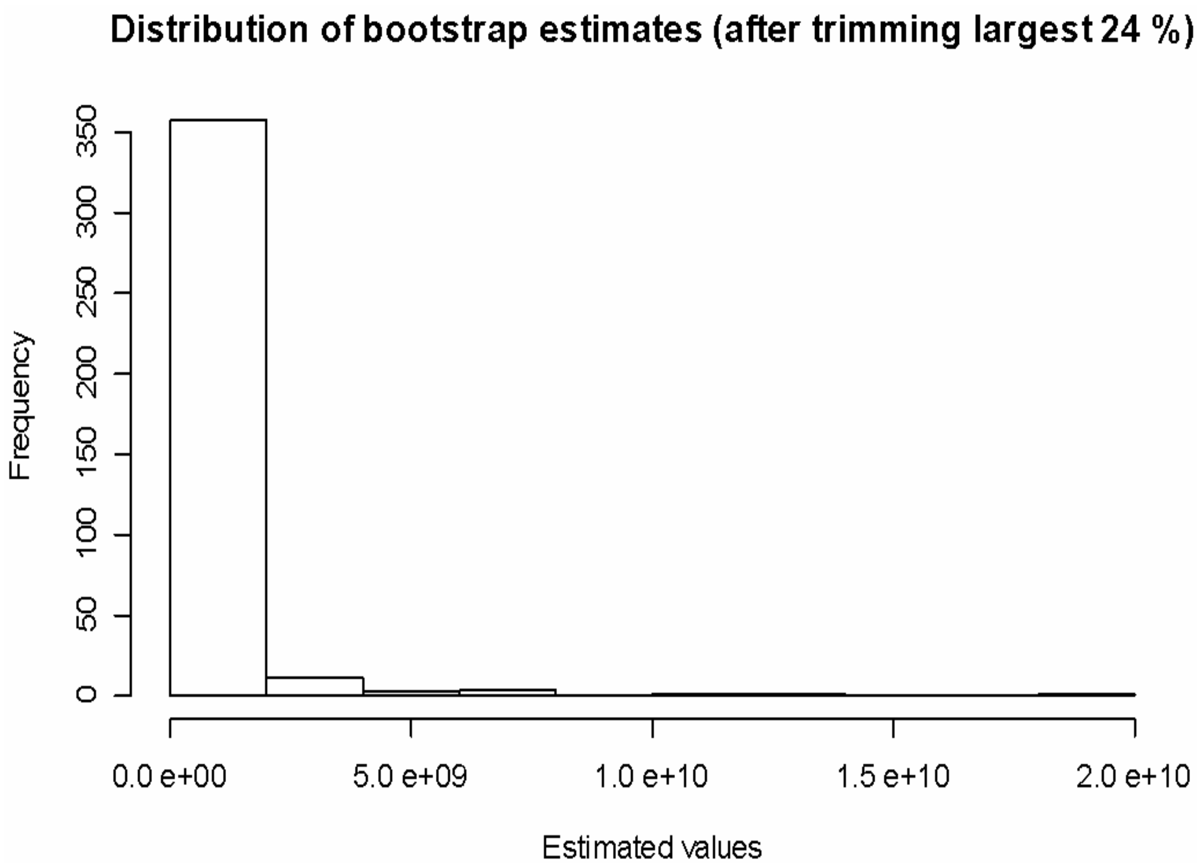


Figure A-56. Distribution of bootstrap estimates (after trimming largest 24%) for pooled sightings of the spinner dolphin during all seasons in the Gulf of Mexico study area.

➢ Risso's Dolphin (*Grampus griseus*)

Table A-40. Detection function results for the Risso's dolphin during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	91
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.1085
SE	0.3033
Hazard Shape Parameter (Exponent)	
Estimate	1.5587
SE	0.3634
Average p	
Estimate	0.3774
SE	0.0634
CV	0.1680
N in covered region	
Estimate	241.1234
SE	45.1469
CV	0.1872

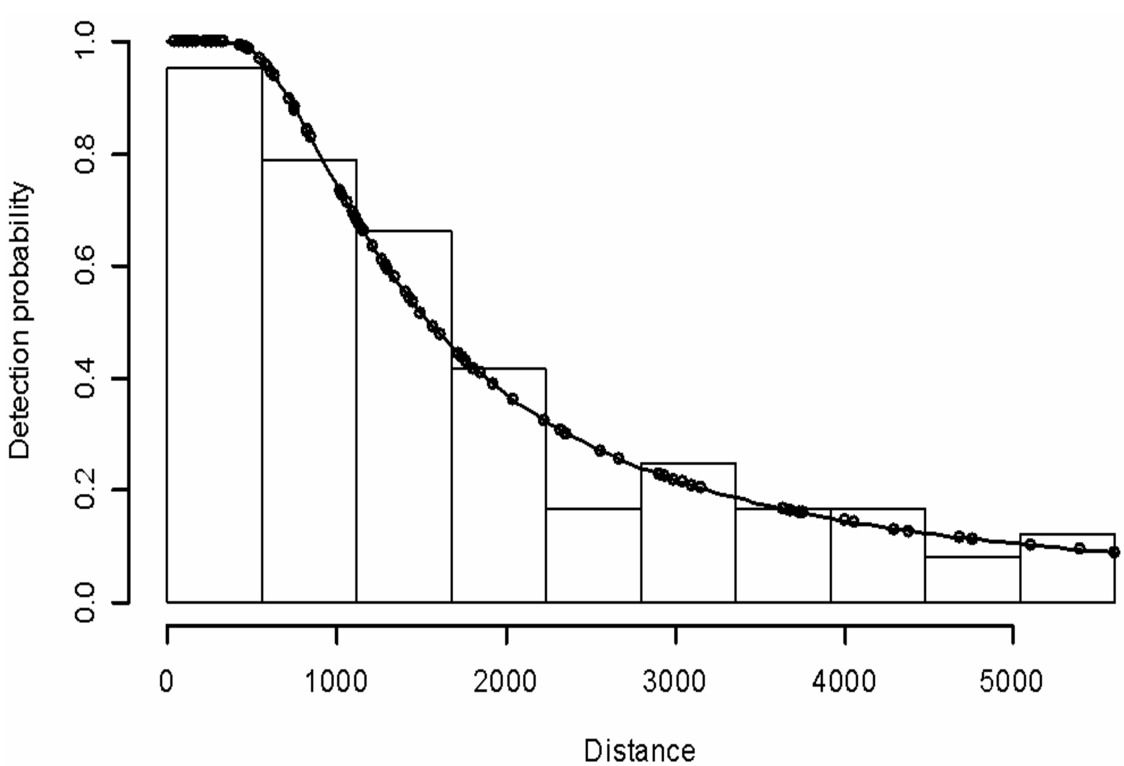


Figure A-57. Plot of the detection function for pooled sightings of the Risso's dolphin during all seasons in the Gulf of Mexico study area.

Table A-41. Response surface model (Generalized Additive Model) results for the Risso's dolphin during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	13.673
Est. rank	28.000
F	3.476
p-value	7.40e-09
s(depth)	
Edf	8.998
Est. rank	9.000
F	5.465
p-value	2.85e-07
R-sq. (adj)	0.103
n segments	68
Deviance explained	24.9%

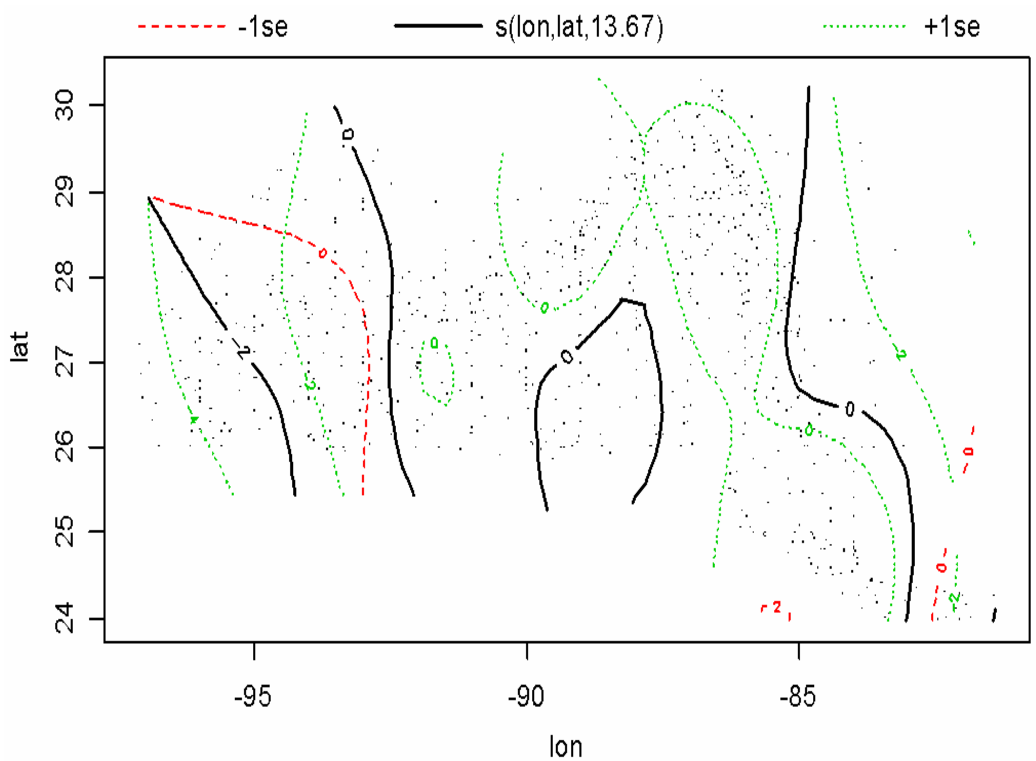


Figure A-58. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the Risso's dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

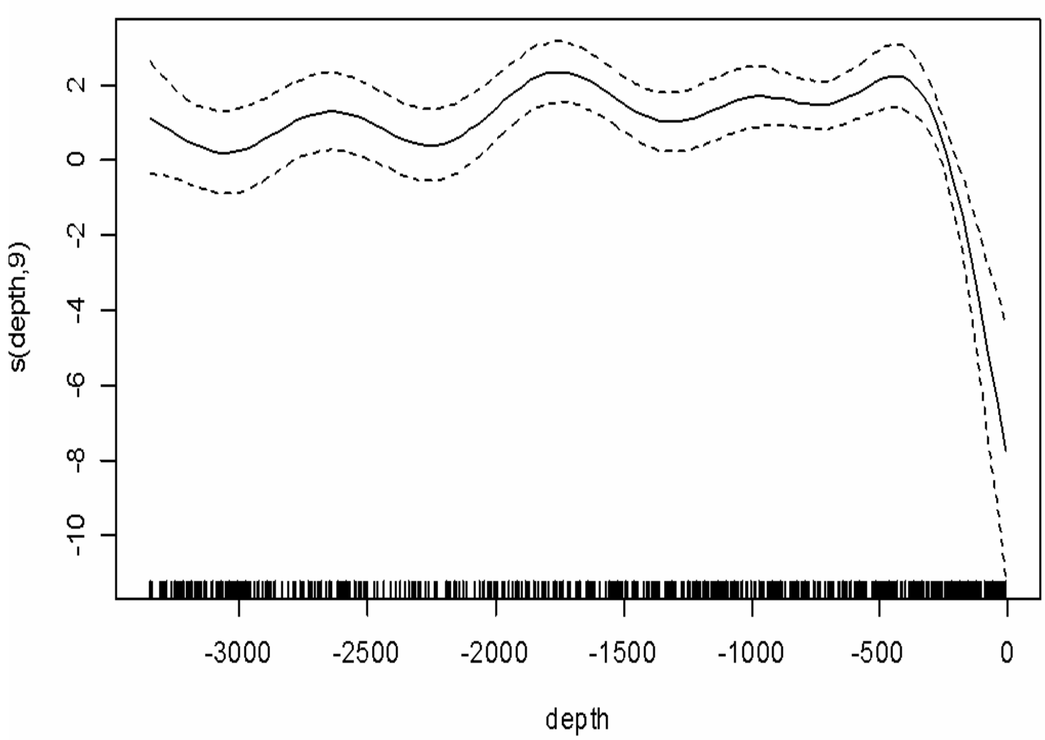


Figure A-59. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the Risso's dolphin during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-42. Variance estimate model results for the Risso's dolphin during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	481
Non-legitimate bootstrap replicates	18
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	1518.482 – 2570.416
Point estimate	1975.562
SE of bootstraps	265.0342
Est. CV for density surface model	0.1342
CV in detection probability	0.168
CV in overall estimate including density surface model AND detection probability	0.215
Confidence interval incorporating detection function uncertainty	1302.461 , 2996.516

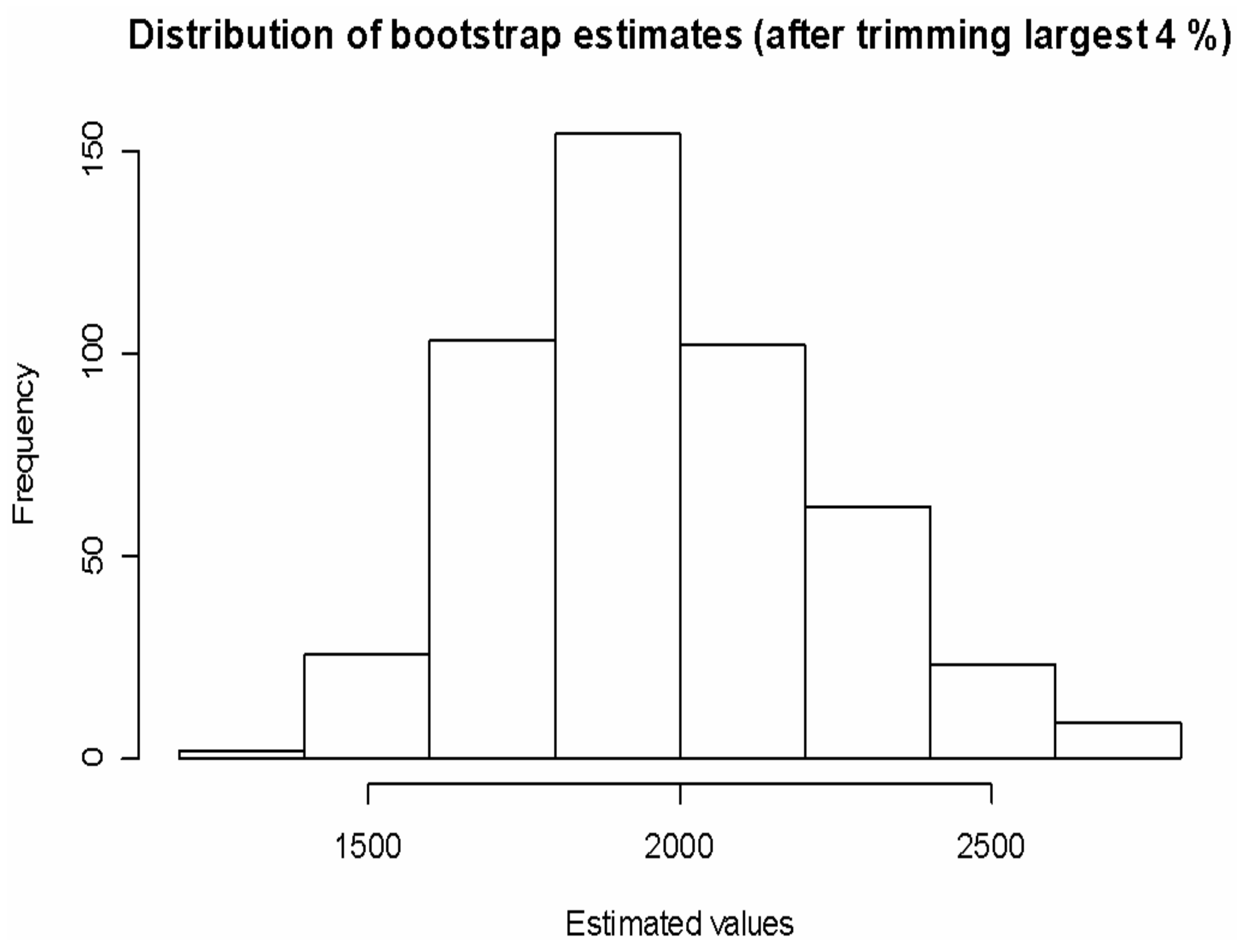


Figure A-60. Distribution of bootstrap estimates (after trimming largest 4%) for pooled sightings of the Risso's dolphin during all seasons in the Gulf of Mexico study area.

➢ Leatherback Turtle (*Dermochelys coriacea*)

Table A-43. Detection function results for the leatherback turtle during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	98
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.1475
SE	0.0733
Average p	
Estimate	0.4296
SE	0.0304
CV	0.0708
N in covered region	
Estimate	228.1309
SE	23.7465
CV	0.1041

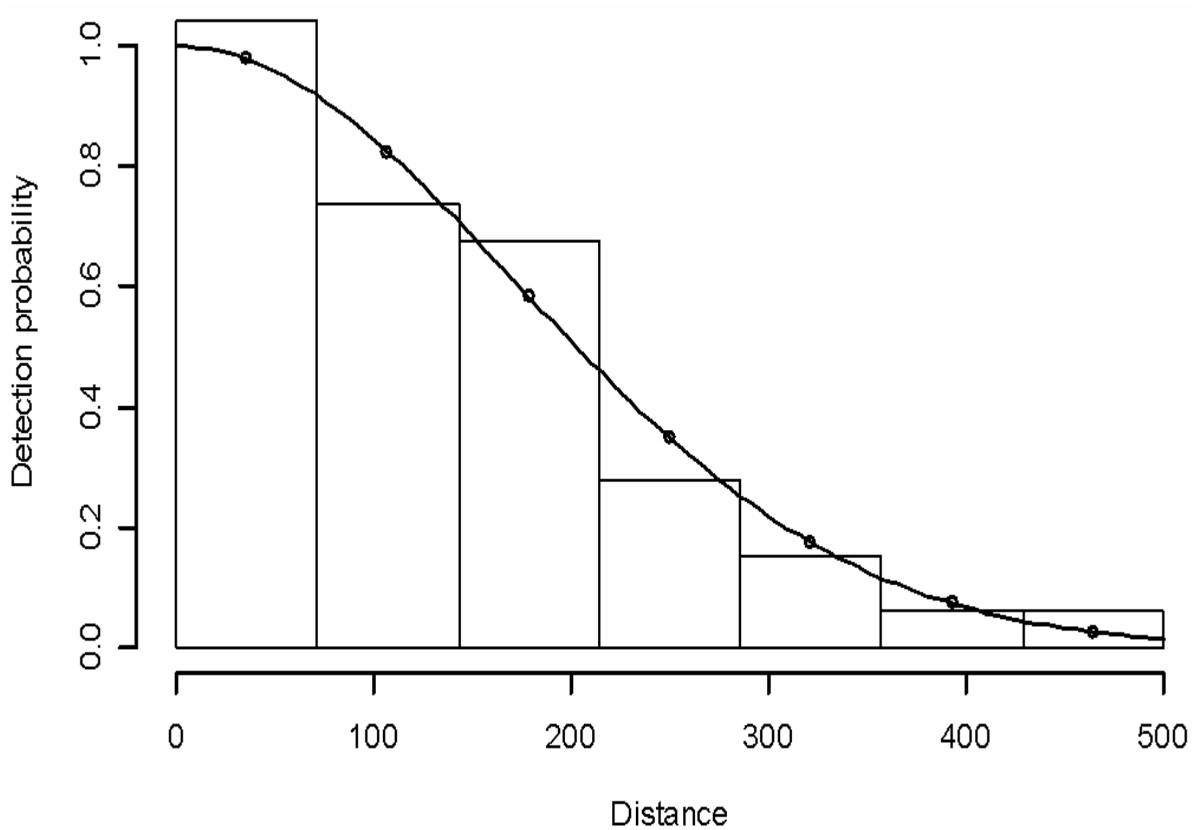


Figure A-61. Plot of the detection function for pooled sightings of the leatherback turtle during all seasons in the Gulf of Mexico study area.

Table A-44. Response surface model (Generalized Additive Model) results for the leatherback turtle during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + s(SST) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	28.870
Est. rank	27.000
F	5.066
p-value	7.75e-16
s(depth)	
Edf	1.004
Est. rank	3.000
F	5.361
p-value	1.13e-03
s(SST)	
Edf	6.185
Est. rank	9.000
F	5.401
p-value	2.56e-07
R-sq. (adj)	0.061
n segments	82
Deviance explained	24.7%

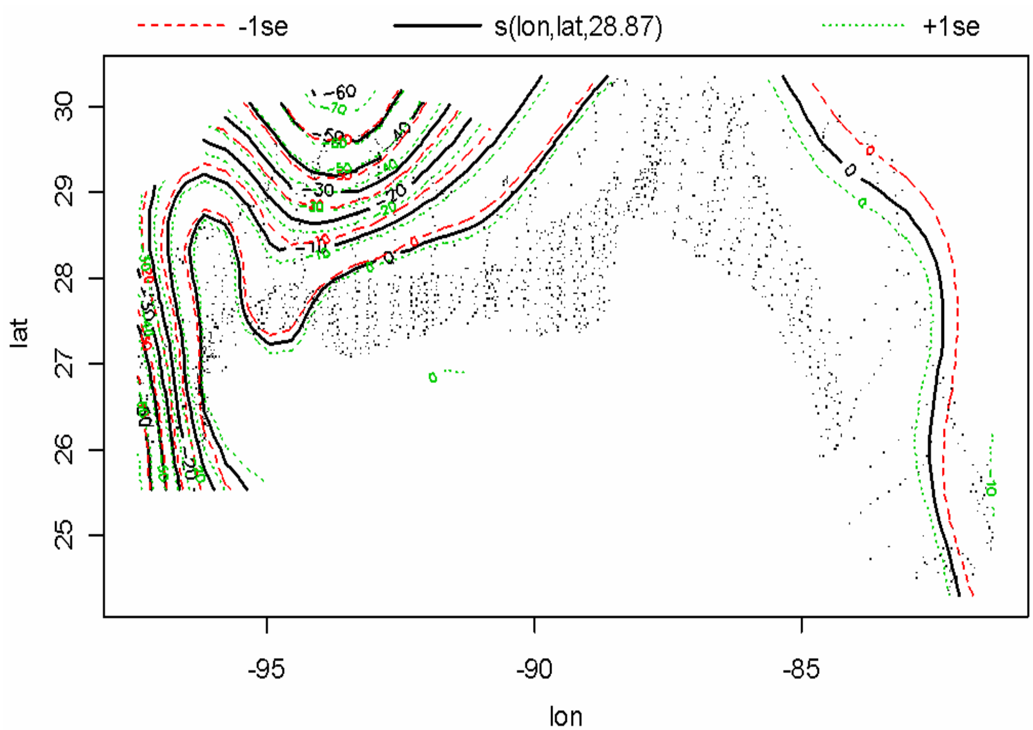


Figure A-62. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the leatherback turtle during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

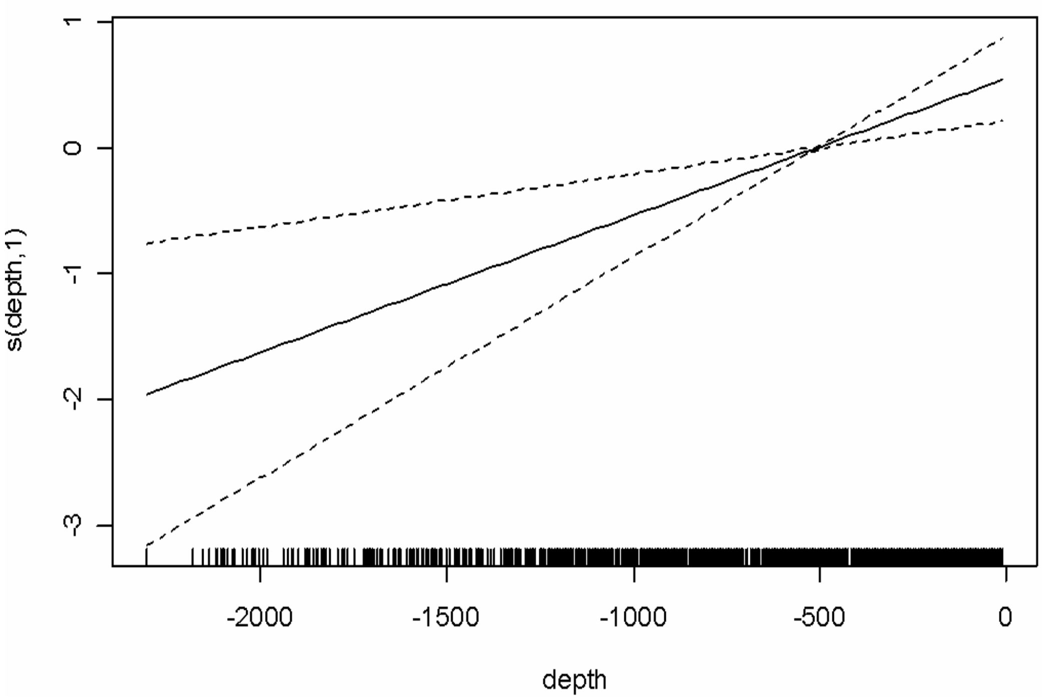


Figure A-63. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the leatherback turtle during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

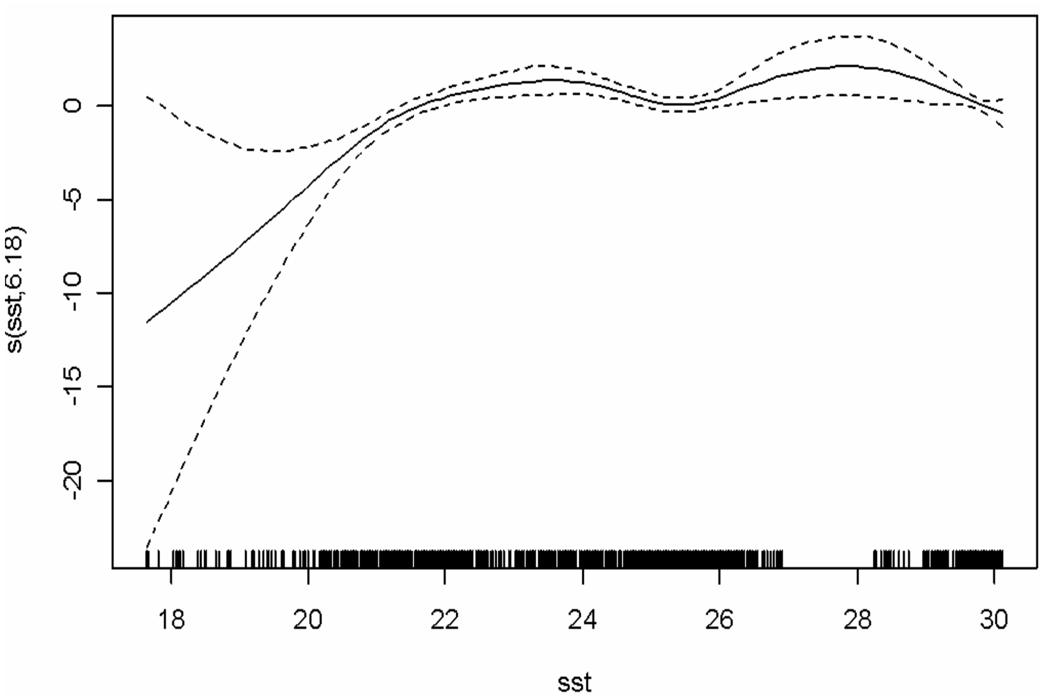


Figure A-64. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for the leatherback turtle during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-45. Variance estimate model results for the leatherback turtle during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	476
Non-legitimate bootstrap replicates	23
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	1354.750 – 1616.061
Point estimate	1468.062
SE of bootstraps	67.1842
Est. CV for density surface model	0.0458
CV in detection probability	0.0708
CV in overall estimate including density surface model AND detection probability	0.0843
Confidence interval incorporating detection function uncertainty	1244.809 , 1731.356

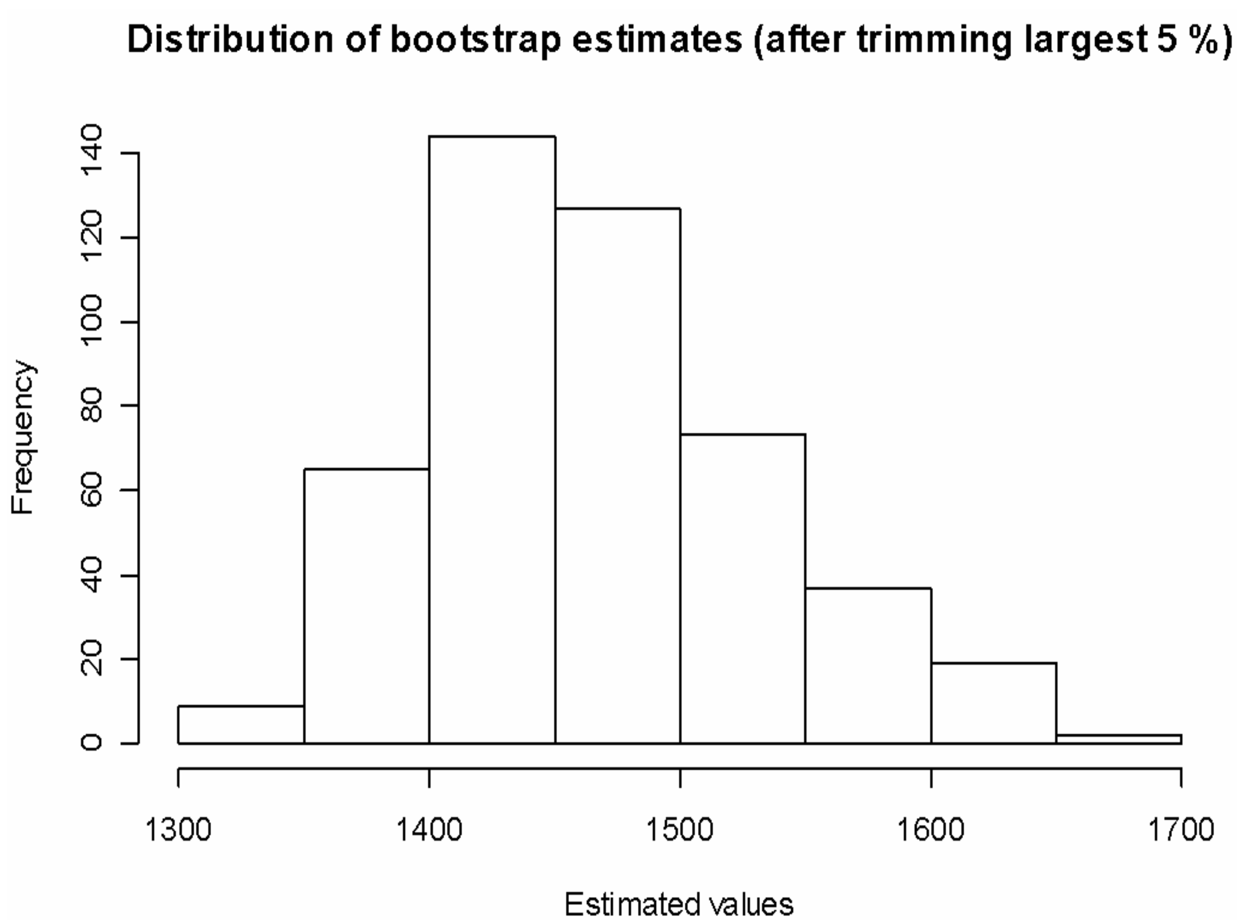


Figure A-65. Distribution of bootstrap estimates (after trimming largest 5%) for pooled sightings of the leatherback turtle during all seasons in the Gulf of Mexico study area.

➢ Loggerhead Turtle (*Caretta caretta*)

Table A-46. Detection function results for the loggerhead turtle during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	349
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.3764
SE	0.0700
Average p	
Estimate	0.6340
SE	0.0317
CV	0.0500
N in covered region	
Estimate	550.4974
SE	32.8138
CV	0.0596

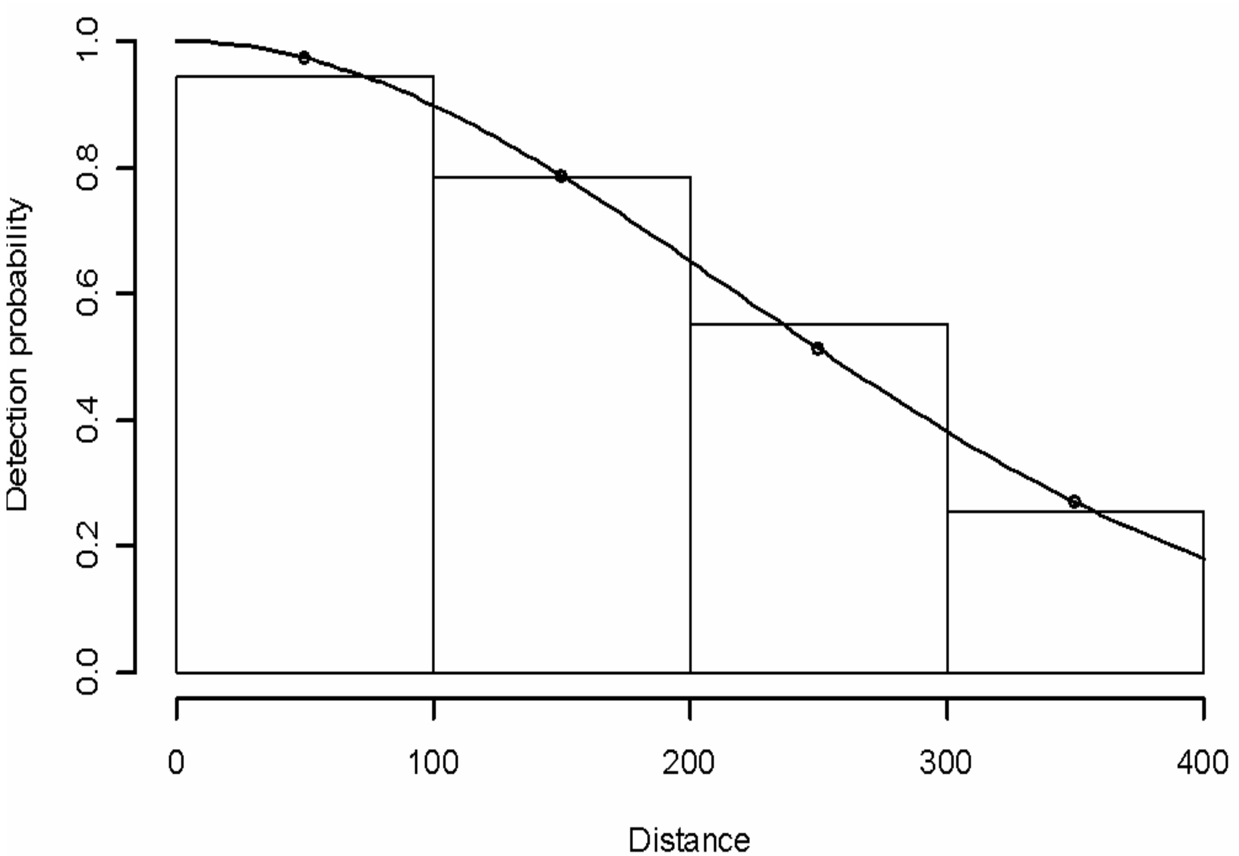


Figure A-66. Plot of the detection function for pooled sightings of the loggerhead turtle during all seasons in the Gulf of Mexico study area.

Table A-47. Response surface model (Generalized Additive Model) results for the loggerhead turtle during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon, lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	25.912
Est. rank	29.000
F	21.410
p-value	<2e-16
s(depth)	
Edf	7.352
Est. rank	9.000
F	9.858
p-value	5.63e-15
R-sq. (adj)	0.32
n segments	230
Deviance explained	51.8%

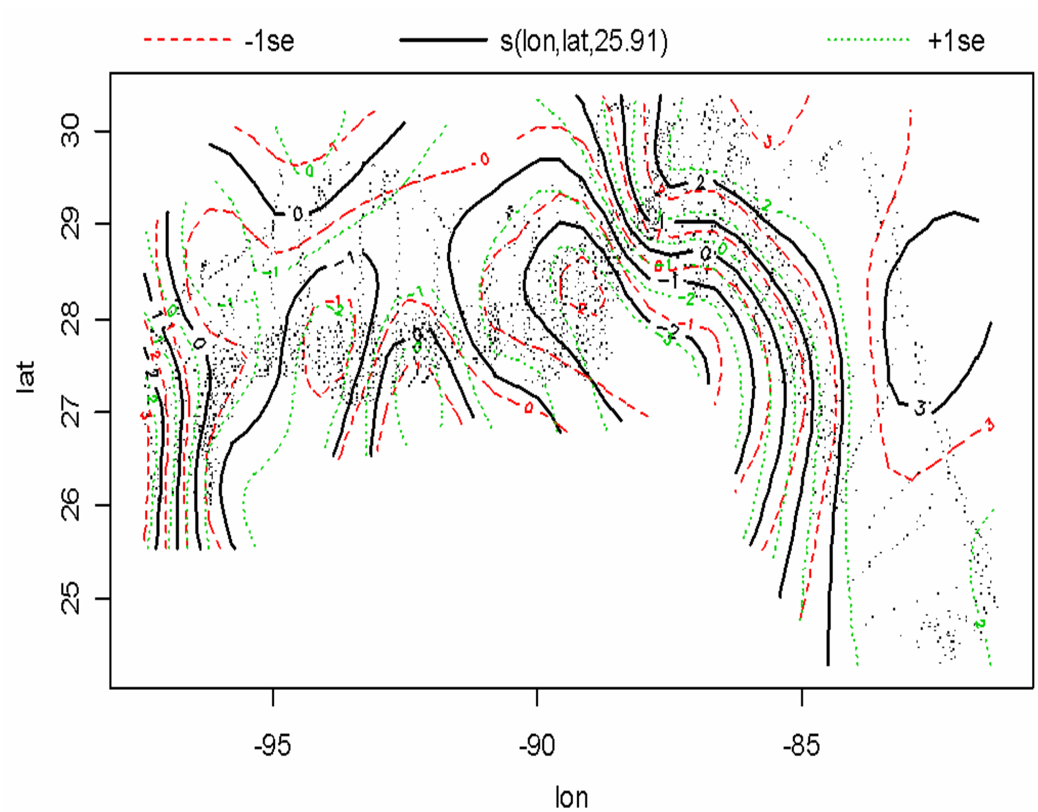


Figure A-67. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the loggerhead turtle during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

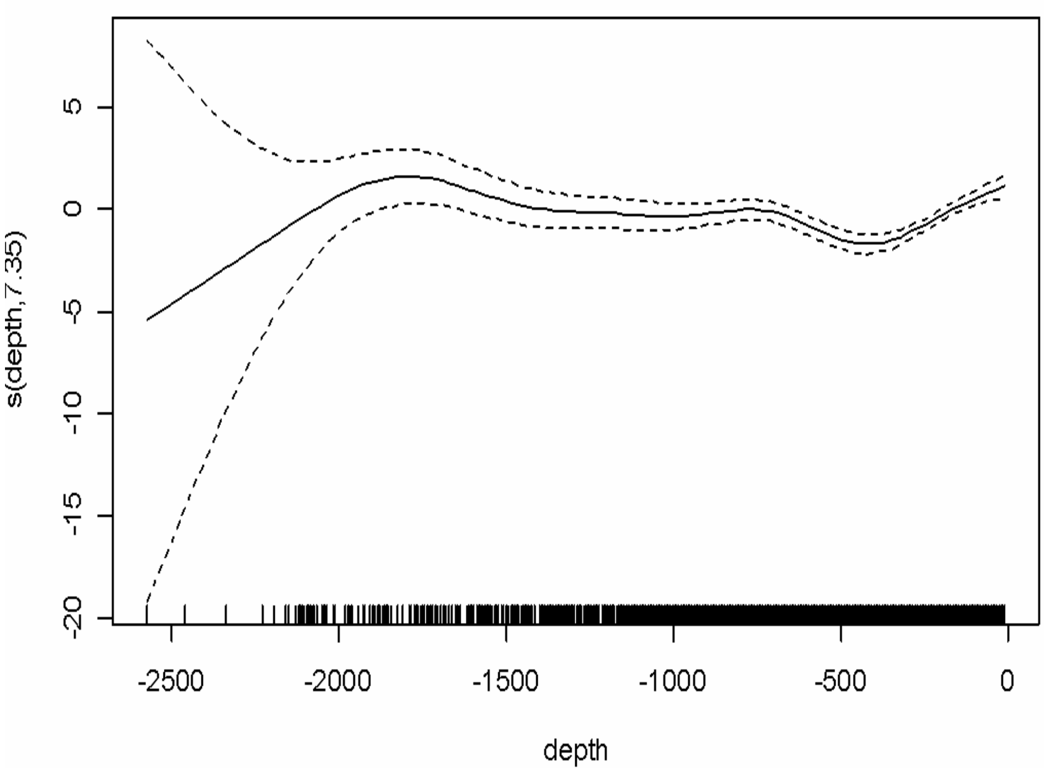


Figure A-68. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the loggerhead turtle during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-48. Variance estimate model results for the loggerhead turtle during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	494
Non-legitimate bootstrap replicates	5
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	8490.661 – 9310.519
Point estimate	8866.92
SE of bootstraps	219.9901
Est. CV for density surface model	0.0248
CV in detection probability	0.05
CV in overall estimate including density surface model AND detection probability	0.0559
Confidence interval incorporating detection function uncertainty	7948.128 , 9891.924

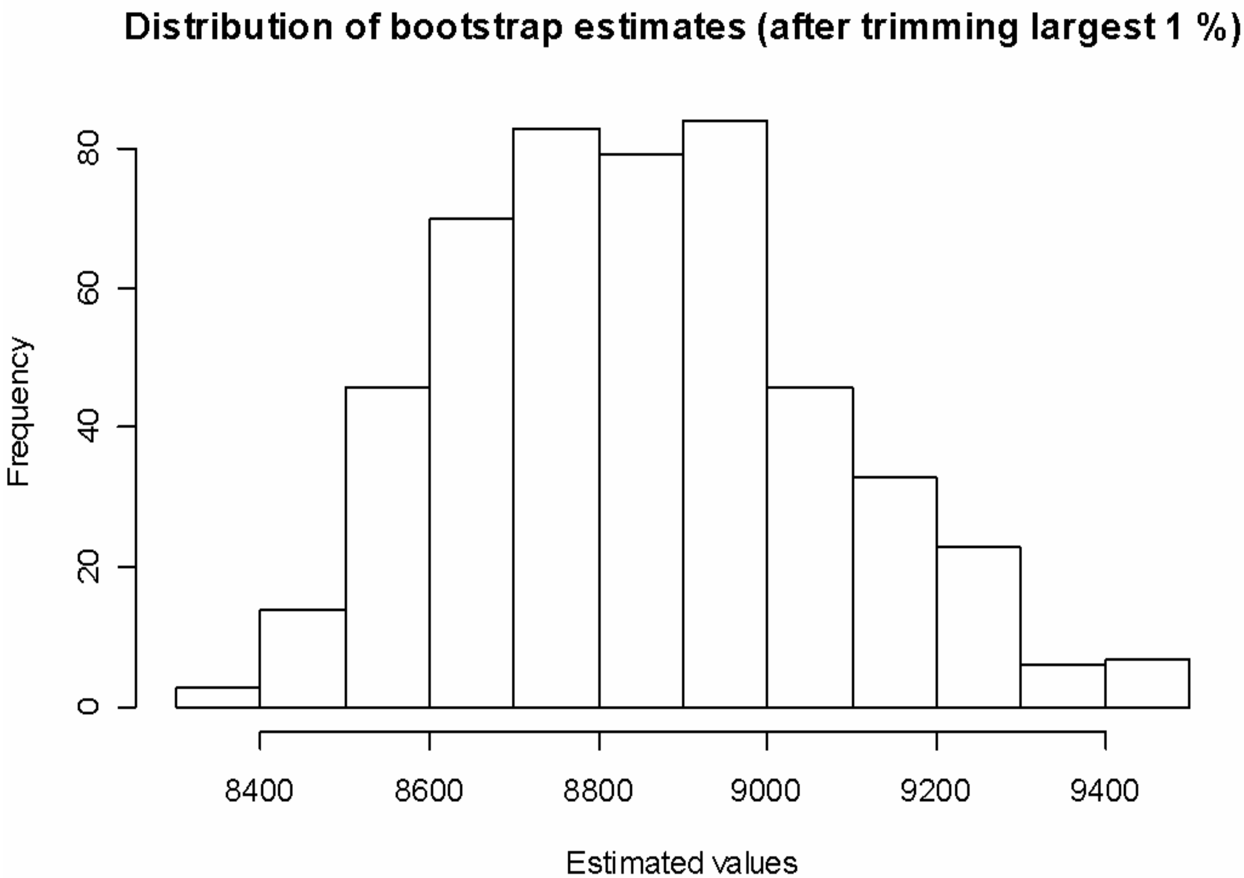


Figure A-69. Distribution of bootstrap estimates (after trimming largest 1%) for pooled sightings of the loggerhead turtle during all seasons in the Gulf of Mexico study area.

➢ Hardshell Turtles

Table A-49. Detection function results for Hardshell Turtles during all seasons in the Gulf of Mexico study area.

Detection Function	
No. of observations	347
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.4828
SE	0.0703
Hazard Shape Parameter (Exponent)	
Estimate	3.8661
SE	0.9037
Average p	
Estimate	0.6965
SE	0.0309
CV	0.0444
N in covered region	
Estimate	498.2260
SE	26.5611
CV	0.0533

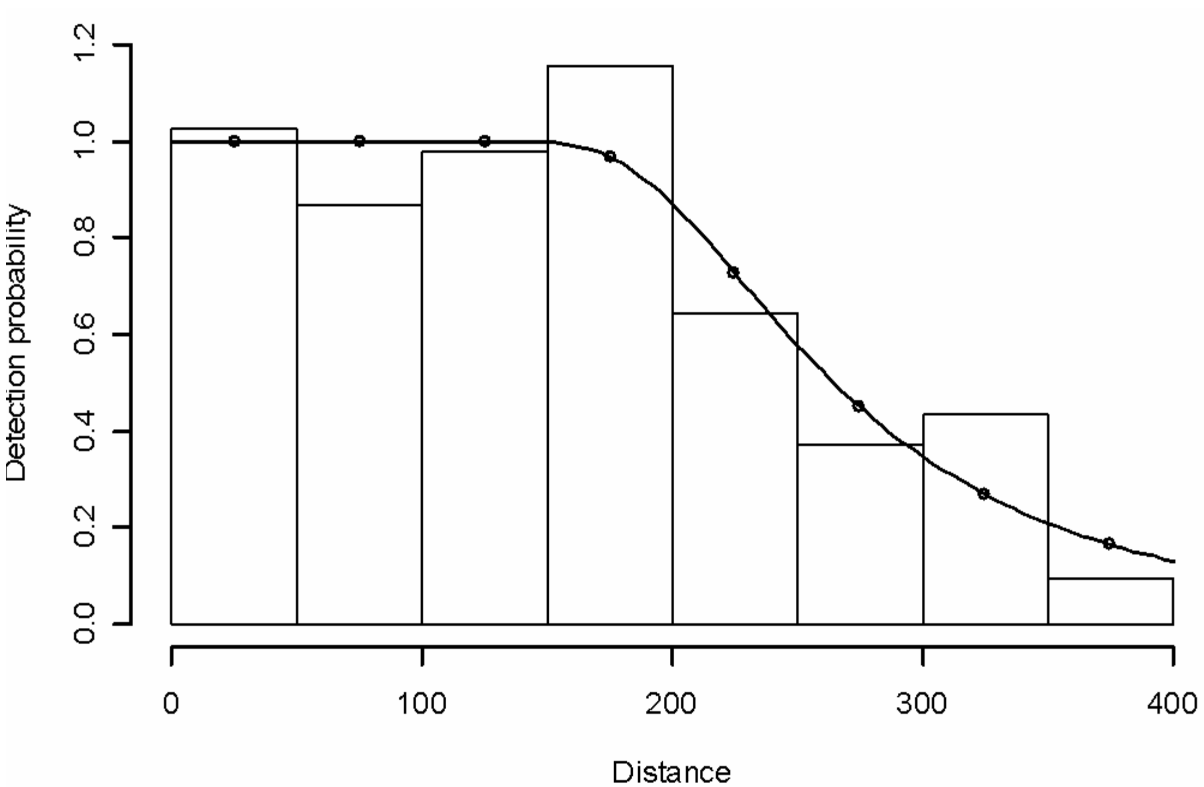


Figure A-70. Plot of the detection function for pooled sightings of Hardshell Turtles during all seasons in the Gulf of Mexico study area.

Table A-50. Response surface model (Generalized Additive Model) results for Hardshell Turtles during all seasons in the Gulf of Mexico study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon) + s(lat) + s(depth) + offset(off.set)
Approximate significance of smooth terms	
s(lon)	
Edf	7.961
Est. rank	9.000
F	48.26
p-value	<2e-16
s(lat)	
Edf	9.000
Est. rank	9.000
F	67.56
p-value	<2e-16
s(depth)	
Edf	8.960
Est. rank	3.000
F	27.93
p-value	<2e-16
R-sq. (adj)	0.428
n segments	163
Deviance explained	75.1%

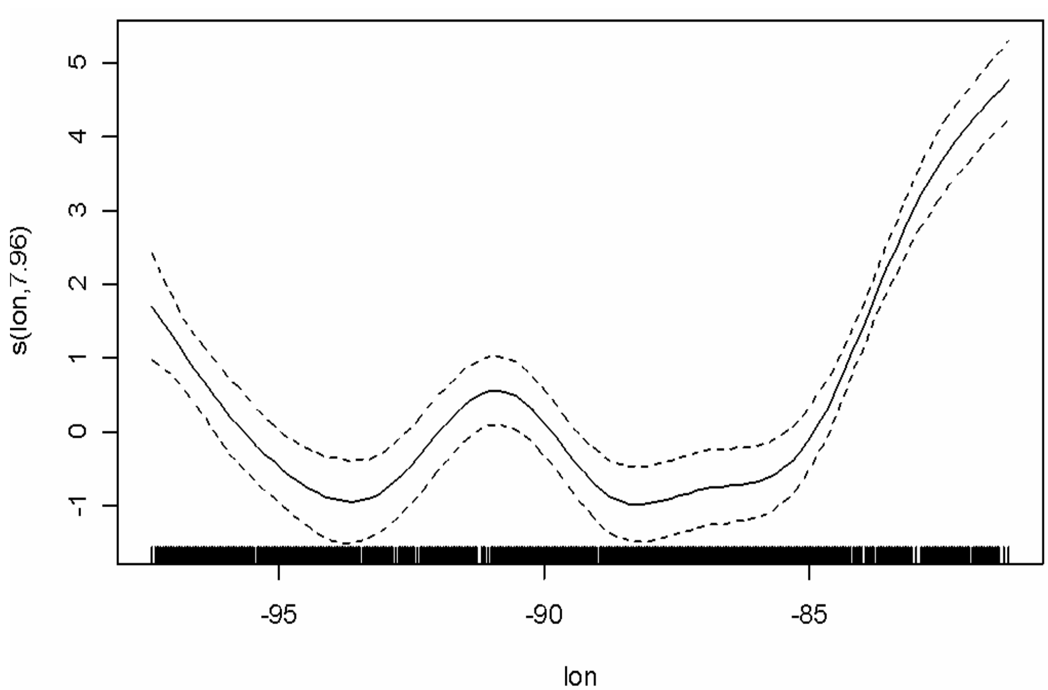


Figure A-71. Plot of the Generalized Additive Model smooth fit of the environmental covariate longitude selected for Hardshell Turtles during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

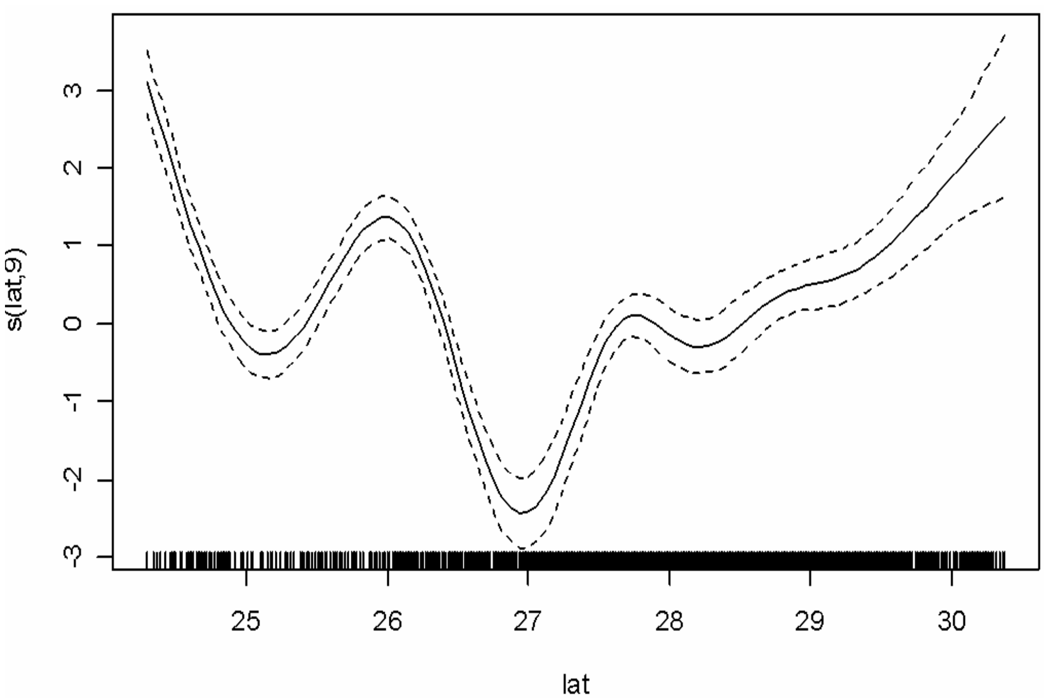


Figure A-72. Plot of the Generalized Additive Model smooth fit of the environmental covariate *latitude* selected for Hardshell Turtles during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

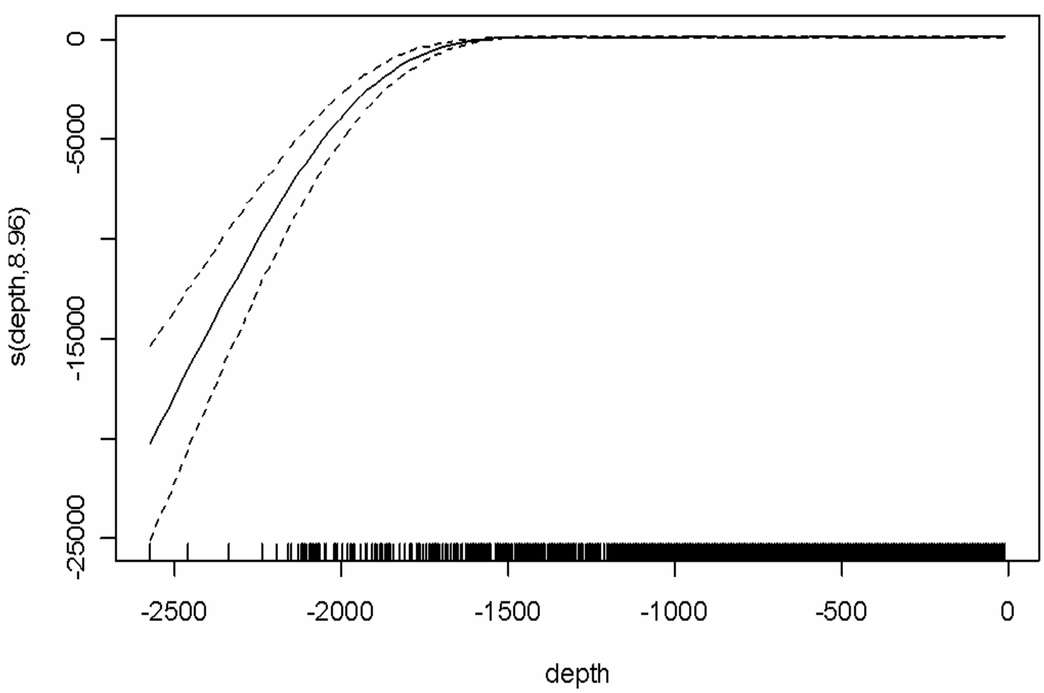


Figure A-73. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for Hardshell Turtles during all seasons in the Gulf of Mexico study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-51. Variance estimate model results for Hardshell Turtles during all seasons in the Gulf of Mexico study area.

Variance	
Legitimate values	470
Non-legitimate bootstrap replicates	29
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	12134.09 – 14158.49
Point estimate	13061.97
SE of bootstraps	523.2538
Est. CV for density surface model	0.0401
CV in detection probability	0.0444
CV in overall estimate including density surface model AND detection probability	0.0598
Confidence interval incorporating detection function uncertainty	11619.27 , 14683.79

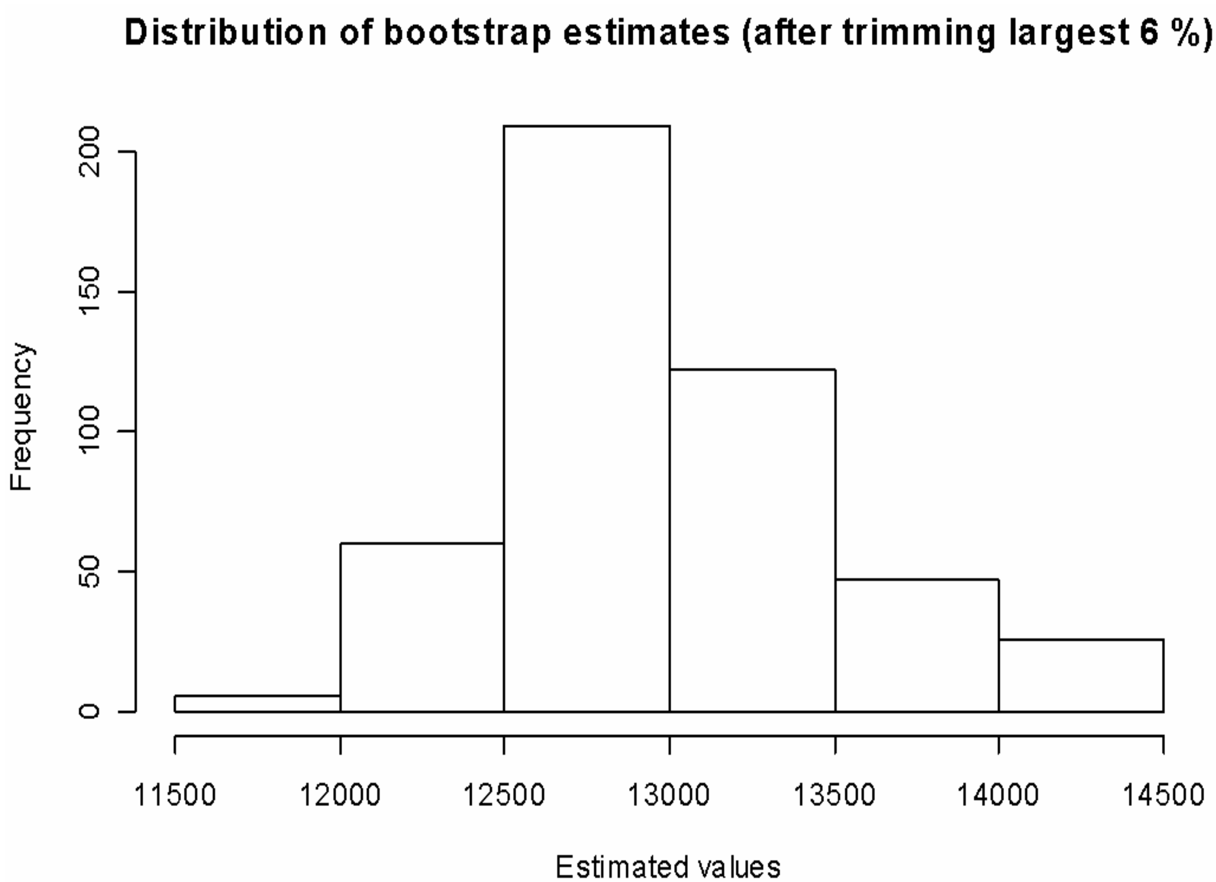


Figure A-74. Distribution of bootstrap estimates (after trimming largest 6%) for pooled sightings of Hardshell Turtles during all seasons in the Gulf of Mexico study area.