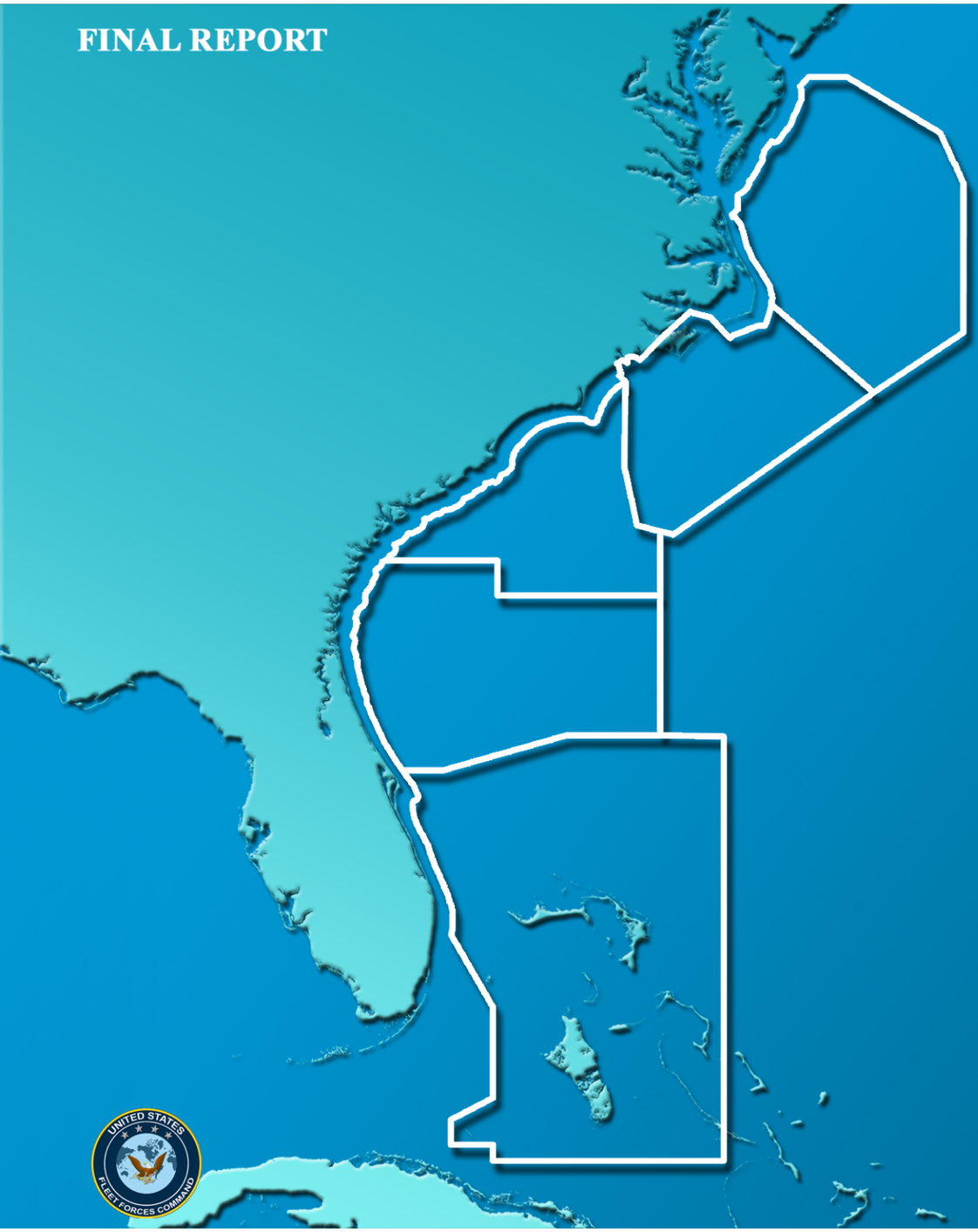
NAVY OPAREA DENSITY ESTIMATES (NODE) FOR THE SOUTHEAST OPAREAS: VACAPES, CHPT, JAX/CHASN, AND SOUTHEASTERN FLORIDA & AUTEC-ANDROS

FINAL REPORT

AUGUST 2007



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LIST OF ACRONYMS AND ABBREVIATIONS

θ	Angle
°	Degree(s)
%	Percent
AUTEC	Atlantic Undersea Test and Evaluation Center
AVHRR	Advanced Very High-Resolution Radiometer
BSS	Beaufort Sea State
C	Celsius
CHPT	Cherry Point
Chl *a*	Chlorophyll *a*
CREEM	Centre for Research into Ecological and Environmental Modelling
CV	Coefficient of Variation
DNA	Deoxyribonucleic Acid
DoN	Department of the Navy
DSM	Density Surface Model
EEZ	Exclusive Economic Zone
ESA	Endangered Species Act
EWS	Early Warning System
g(0)	Availability Bias
GAM	Generalized Additive Model
GCV	Generalized Cross Validation
GMI	Geo-Marine, Inc.
GOM	Gulf of Maine
GOMEX	Gulf of Mexico
IUCN-SSC	International Union for Conservation of Nature and Natural Resources–Species Survival Commission
IUSS	Integrated Undersea Surveillance System
JAX/CHASN	Jacksonville-Charleston
km	Kilometer(s)
km^2	Square Kilometer(s)
m	Meter(s)
MATS	Mid-Atlantic *Tursiops* Survey
mg/m^3	Milligram(s) Per Cubic Meter
min	Minute(s)
MMPA	Marine Mammal Protection Act
MRA	Marine Resources Assessment
N	North
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
NMFS-NEFSC	National Marine Fisheries Service-Northeast Fisheries Science Center
NOAA	National Oceanic and Atmospheric Administration
NODE	Navy OPAREA Density Estimate
OPAREA	Operating Area
PBR	Potential Biological Removal
PO.DAAC	Physical Oceanography Distributed Active Archive Center
PSD	Perpendicular Sighting Distance
RSM	Response Surface Model
S	South
SAR	Stock Assessment Report
SE	Southeast

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

SeaWiFS	Sea-Viewing Wide Field-of-View Sensor
sec	Second(s)
spp.	Species
SST	Sea Surface Temperature
UNOLS	University-National Oceanographic Laboratory System
U.S.	United States
VACAPES	Virginia Capes
VHF	Very High Frequency
W	West
yr	Year

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1.0 INTRODUCTION

The Department of the Navy (DoN) is committed to demonstrating environmental stewardship while executing its national defense mission. There is responsibility 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 United States (U.S.) Navy's Operating Areas (OPAREAs) are required. With few exceptions, these are generally lacking.

The U.S. Navy (Navy) Commander, Atlantic Fleet contracted Geo-Marine, Inc. (GMI) to prepare a Navy OPAREA Density Estimate (NODE) report for all marine mammals and sea turtles found in the OPAREAs of Virginia Capes (VACAPES), Cherry Point (CHPT), Jacksonville-Charleston (JAX/CHASN), and Southeastern Florida and the Atlantic Undersea Test and Evaluation Center (AUTEC)-Andros OPAREA (**Figure 1-1**). These OPAREAs, in addition to the oceanic waters (waters beyond the shelf break) of the Northeast (NE) Study Area (which encompass portions of the Narragansett Bay and Atlantic City OPAREAs), will be considered as one unit that is hereinafter referred to as the "Southeast study area." The AUTEC-Andros OPAREA is not included in the assessment, however, since no systematic survey effort is available. The goal of the 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.

This document represents the Navy's first comprehensive effort to provide density estimates in the Southeast (SE) study area. Previous NE and SE Marine Resources Assessments (MRAs) (DoN 2001; 2002b; 2002a; 2005b; 2007) for the aforementioned areas helped to serve as the foundation reference documents upon which this document is built upon. The density estimates are needed to assist in the determination of the potential impacts of military operations to marine mammal and sea turtle species and aid in the preparation of associated take permit authorizations and Section 7 Consultation.

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* – describes the methods and analytical mechanisms/decisions involved in deriving the density estimates;
- *Chapter 3: Density Estimates* – lists the species and provides relevant distributional ecology information; discusses caveats to density derivations for each species; and presents the density estimates in tabular form, as well as summary statements;
- *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 THE SOUTHEAST STUDY AREA

The SE study area is located in the western Atlantic Ocean off the southeastern coast of the U.S. (**Figure 1-1**). The SE study area encompasses 778,336 square kilometers (km^2) of the North Atlantic, Mid-Atlantic, and South Atlantic Bight. It ranges from the U.S./Canada border and is bounded to the south by the territorial waters of Cuba and to the west by the Key West Complex. The Narragansett Bay, Atlantic City, VACAPES, CHPT, and JAX/CHASN OPAREAs, as well as southeastern Florida, are all located within this region. The Narragansett Bay OPAREA is located offshore to the south of Massachusetts, Rhode Island, and Connecticut and extends down as far as the Delaware Bay (DoN 2005b). The Atlantic City OPAREA is a relatively small OPAREA found just off the coast of New Jersey and northern Maryland (DoN 2005b). The VACAPES OPAREA is located offshore of Delaware, Maryland, Virginia, and North Carolina (DoN 2001). The CHPT OPAREA extends from north of Cape Hatteras, North Carolina south to Cape Fear, North Carolina (DoN 2002a). The JAX/CHASN OPAREA extends from southern North Carolina to the Indian and Banana River Complex (DoN 2002b). This area encompasses several

dominant physiographic features, including submarine canyons and the Gulf Stream Current that warms the waters of the Mid-Atlantic Bight. A portion of this region that has received a tremendous amount of attention is the federally designated North Atlantic right whale (*Eubalaena glacialis*) critical habitat, which encompasses this highly endangered species' calving grounds off southern Georgia and NE Florida. This critical habitat is located in the JAX/CHASN OPAREA. Southeastern Florida and the AUTEC-Andros OPAREA extends from just north of Cape Canaveral south to West Palm Beach, Florida and eastward to just east of Eleuthera Island in The Bahamas (DoN 2007).

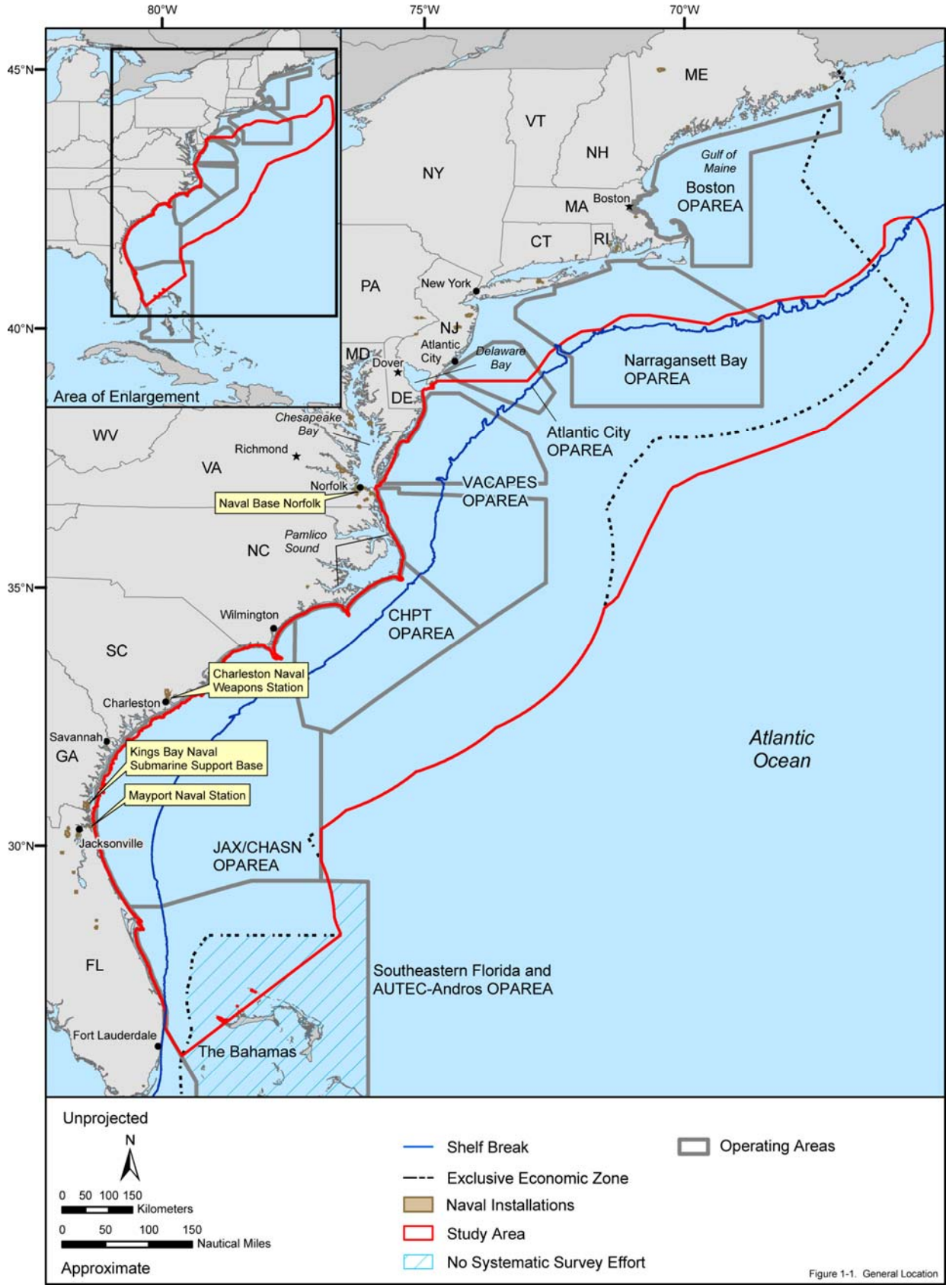

Figure 1-1. The Southeast study area located off the United States Atlantic Coast.

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2.0 METHODOLOGY

Density estimates for cetaceans were either modeled from data or derived from abundance estimates found in either the National Oceanic and Atmospheric Administration (NOAA) stock assessment report (SAR; Waring et al. 2007) or Mullin and Fulling (2003). **Section 2.4** describes the model-based approach, while **Section 2.8** discusses the process for literature-derived estimates. The approach for density estimation for sea turtles is presented in **Section 2.1.1.2.**

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, we used the model-based approach by constructing a model of animal density and applied that model to regions (and/or seasons) where sampling effort (i.e., 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 NE and SE study areas 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

Cetacean abundance in the southeastern U.S. was recently addressed by Mullin and Fulling (2003). Individual species density estimates were produced for those species with a sufficient number of sightings to create unique detection functions. Individual species density estimates for seasons lacking survey data were "predicted" using the density surface models (DSMs) presented in **Chapter 3**. Species with insufficient data were not analyzed using models. These species density estimates were either derived from the SAR and references within that document (i.e., Mullin and Fulling 2003) or other pertinent literature (**Section 2.8**).

2.1.1 Data Used

For this report, all analyses for cetaceans were based on data collected through the National Marine Fisheries Service-Northeast Fisheries Science Center (NMFS-NEFSC) and Southeast Fisheries Science Center (NMFS-SEFSC) shipboard and aerial surveys conducted from 1998 through 2005. **Section 2.2** provides details on the surveys.

2.1.1.1 Cetaceans

Only shipboard surveys were used to calculate the density estimates for cetaceans in the SE study area. Therefore, all models were based on the areas for which shipboard survey data existed. These areas included the SE OPAREAs and the waters of the NE OPAREAs between the shelf break and the U.S. Exclusive Economic Zone (EEZ).

When producing the cetacean density surfaces, all shipboard survey data from both the NE and SE were used and the surface created extended the entire U.S. Atlantic Coast. However, only data from the SE study area were used to generate the abundance estimates (see **Section 3.1.1**).

2.1.1.2 Sea Turtles

Density estimates for sea turtles were calculated using aerial survey data provided by the NMFS-NEFSC and the NMFS-SEFSC (see **Section 2.2** for more information) using data collected in Beaufort sea states (BSSs) ≤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 incorporated into the Hardshell Turtles category include green, hawksbill, and unidentified hardshell turtles were pooled together since the numbers of sightings for 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.

When producing the sea turtle density surface, all aerial survey data from both the NE and SE were used and the surface created extended the entire coastline. However, only data from the SE study area were used to generate the abundance estimates (see **Section 3.2.1**).

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 eight years be used to calculate potential biological removal (PBR).

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 and this is why these data were analyzed using spatial modeling techniques.

2.2 DESCRIPTION OF SURVEY EFFORT IN THE SOUTHEAST STUDY AREA

Shipboard and aerial line-transect surveys conducted by the NMFS in the SE 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 MRAs for each of the NE and SE OPAREAs (DoN 2001; 2002b; 2002a; 2005b; 2007). Areas of coverage by each type of survey are depicted in **Figures 2-1** and **2-2**.

Shipboard Surveys—Shipboard surveys were conducted on the NOAA Ship *Oregon II*, the NOAA Ship *Gordon Gunter* (formerly known as the *Relentless*), the NOAA Ship *Abel-J*, and the University-National Oceanographic Laboratory System (UNOLS) ship *Endeavor* (contracted by the NMFS-NEFSC). The purpose of these surveys was to collect data for estimation of the abundance of cetaceans in U.S. Atlantic waters south of Maryland in accordance with the MMPA. More information about the surveys can be found in **Table 2-1** and **Figure 2-1**.

Aerial Surveys—The aerial surveys (including the Mid-Atlantic *Tursiops* Surveys [MATS]) were all conducted by the NMFS-SEFSC and NMFS-NEFSC to assess the distribution and abundance of coastal bottlenose dolphins and other important cetacean and sea turtle species. MATS surveys were flown out to the 40 meter (m) isobath. As noted earlier, more information about the surveys can be found in **Table 2-2** and **Figure 2-2**. For detailed information concerning aerial surveys by the NMFS-NEFSC refer to Palka (2006).

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. Datasets of identical observation platforms (i.e., ship or plane) were combined regardless of year, season, or location for analysis. This was done provide a more comprehensive view of the overall distribution and relative density of cetaceans and sea turtles throughout the U.S. Atlantic Coast study areas.

Table 2-1. List of National Marine Fisheries Service (NMFS) shipboard survey information used for density estimation of cetaceans for the Southeast study area.

Dates	Source	Platform	Location	Strata covered
1998 06 July to 04 August (**Figure 2-1**)	NMFS-NEFSC (1998a)	RV *Abel-J* 98-01 Shipboard Survey	Virginia to Cape Cod, MA	Waters between the 100 meter (m) isobath and the eastern boundary of the Gulf Stream
1998 08 July to 17 August (**Figure 2-1**)	(Mullin 1999; Mullin and Fulling 2003)	R/V *Relentless* Cruise GU-98-01	Maryland to central Florida	10 m isobath to the boundary of the EEZ, approximately 200 nautical miles (NM) from the coast
1998 08 August and 06 September (**Figure 2-1**)	NMFS-NEFSC (1998a)	RV *Abel-J* 98-02 Shipboard Survey	Cape Cod, MA to Halifax, Nova Scotia	Waters between the 100 m isobath and the eastern boundary of the Gulf Stream
1999 28 July to 31 August (**Figure 2-1**)	NMFS-NEFSC (1999a)	RV *Abel-J* 99-02 Shipboard Survey	Muscungus Bay, ME to Grand Naman Island, Nova Scotia and eastward to Liverpool, Nova Scotia	Gulf of Maine (GOM), Georges Bank East
1999 4 August to 30 September (**Figure 2-1**)	NMFS-SEFSC (1999)	R/V *Oregon II* Cruise OT-99-05(236)	Cape Canaveral, FL to Delaware Bay	10 m isobath to approximately 185 km offshore
2002 10 February to 08 April (**Figure 2-1**)	Garrison et al. (2003a)	R/V *Gordon Gunter* Cruise GU-02-01	Cape Canaveral, FL to Delaware Bay	continental shelf and inner continental slope waters
2004 22 June to 19 August (**Figure 2-1**)	NMFS-SEFSC (1999)	R/V *Gordon Gunter* Cruise GU-04-03(028)	Maryland/Delaware border to southern Florida	50 m isobath the EEZ
2004 23 June to 12 July & 16 July to 04 August (**Figure 2-1**)	NMFS-NEFSC (2004a)	R/V *Endeavor* (UNOLS) EN-04-395 Shipboard Survey	Virginia to Cape Cod, MA	Mid-Atlantic, 100 m isobath to the Gulf Stream
2005 14 June to 16 August (**Figure 2-**1)	NMFS-SEFSC (2005)	R/V *Gordon Gunter* Cruise GU-05-03	Between Florida and New Jersey	Over continental shelf south of North Carolina and inner slope waters north of Cape Hatteras, NC

Table 2-2. List of National Marine Fisheries Service (NMFS) aerial survey information used for density estimation of sea turtles for the Southeast study area.

Dates	Source	Platform	Location	Strata covered
1998 18 July and 21 August (**Figure 2-2**)	NMFS-NEFSC (1998b)	NOAA Twin Otter Aerial Surveys	Cape Hatteras, NC to Cape Breton Island, Nova Scotia (with additional blocks in La Have/Emerald Basin and Emerald/Western Banks)	Nearshore waters from the coastline to the 73 m isobath
1999 10 to 29 August (**Figure 2-2**)	NMFS-NEFSC (1999b)	NOAA Twin Otter Aerial Surveys	Georges Bank north through the Gulf of Maine, south to Cape Breton Island, Nova Scotia	GOM, Georges Bank
2002 15 January to 28 February (**Figure 2-2**)	Garrison et al. (2003b)	NOAA Twin Otter	Georgia/Florida border to southern Delaware Bay	Shoreline to the 40 m isobath
2002 15 July to 31 August (**Figure 2-2**)	Garrison et al. (2003b)	NOAA Twin Otter	Sandy Hook, NJ to Vero Beach, FL	Shoreline to the 40 m isobath
2002 19 July and 16 August (**Figure 2-2**)	NMFS-NEFSC (2002)	NOAA Twin Otter Aerial Surveys	40 degrees (°) North (N) (just south of Long Island, NY) to the Bay of Fundy (just north of St. John, New Brunswick) and out to 64.5° West (W)	Mid-Atlantic, Georges Bank, GOM, and Scotian
2004 12 June to 12 July (**Figure 2-2**)	NMFS-NEFSC (2004b)	NOAA Twin Otter Aerial Surveys	State border between Virginia and North Carolina (36°N) to the Bay of Fundy (45°N) and from the US Atlantic shoreline to the entrance of the Gulf of St. Lawrence (58°W)	Mid-Atlantic, Georges Bank, GOM, and Scotian
2004 15 July to 31 August (**Figure 2-2**)	Josephson (2005)	NOAA Twin Otter	Sandy Hook, NJ to Cape Canaveral, FL	Shoreline to the 40 m isobath
2005 30 January to 09 March (**Figure 2-2**)	ASRG (2005)	NOAA Twin Otter	Chesapeake Bay to Cape Canaveral, FL	Shoreline to the 40 m isobath

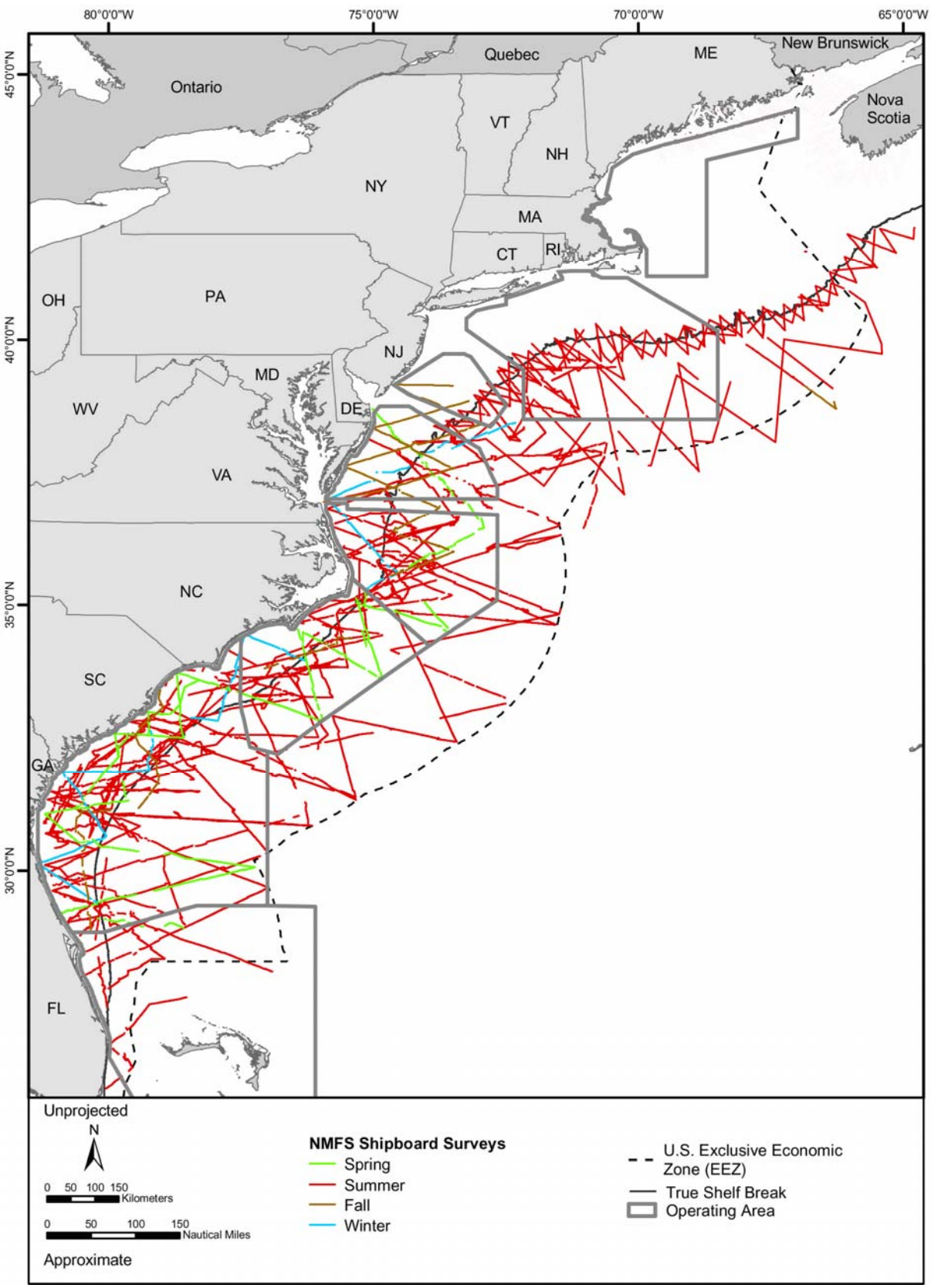

Figure 2-1. Shipboard survey effort conducted by the National Marine Fisheries Service (NMFS) in the Southeast study area.

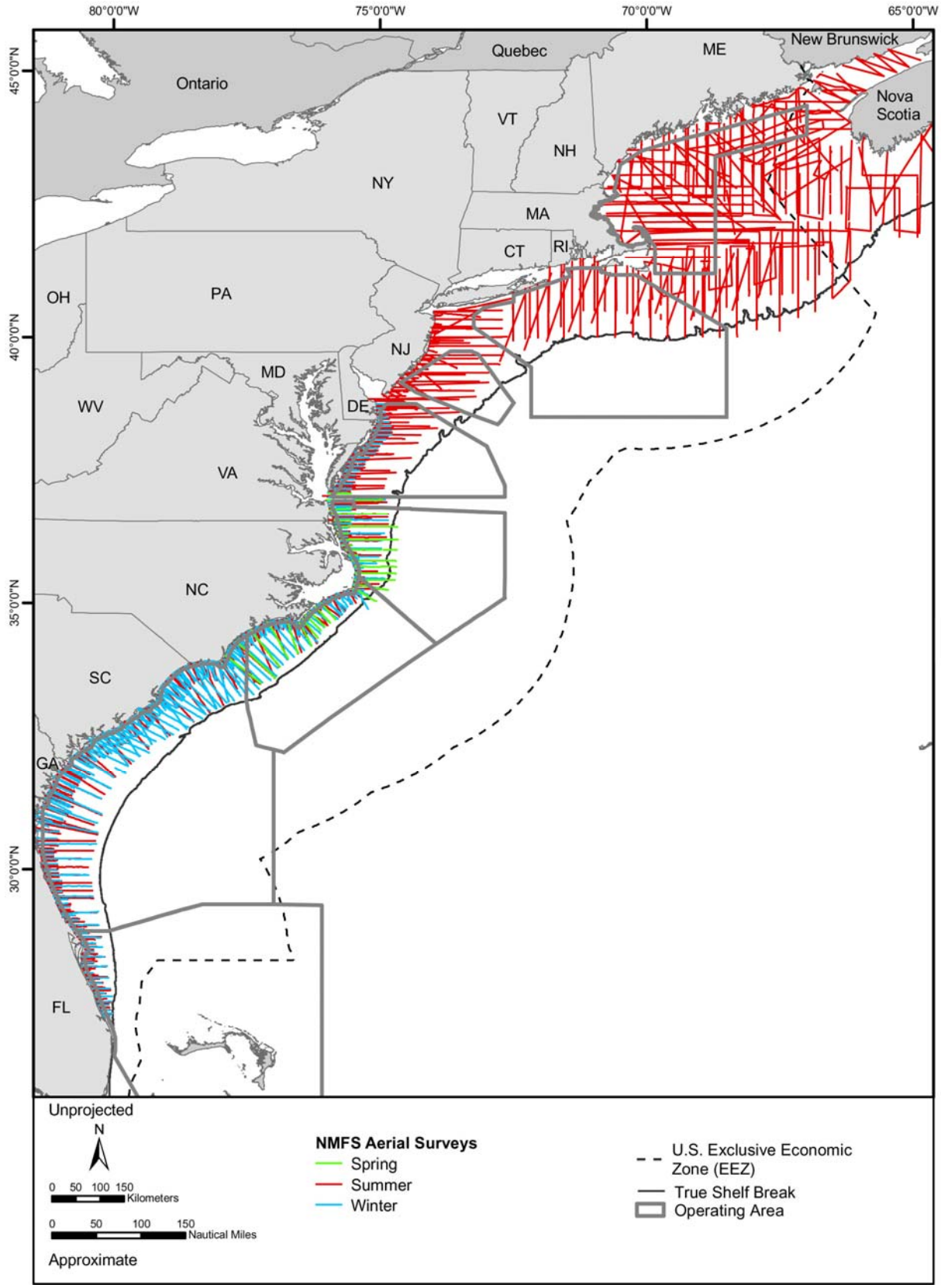

Figure 2-2. Aerial survey effort conducted by the National Marine Fisheries Service (NMFS) in the Southeast study area.

2.3.1 Preparation of the Sighting Data

During the NMFS-SEFSC and NMFS-NEFSC surveys, up to three separate species were 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 four groups of Beaked Whales, *Kogia* species (spp.), Pilot Whales, and Hardshell Turtles.

2.3.1.1 Seasonal Definitions

Since derived seasonal definitions based on sea surface temperature (SST) can be so disparate between the northern and southern portions of the U.S. Atlantic Coast, the seasons were instead based on three-month periods of time as follows:

- Winter—December, January, and February
- Spring—March, April, and May
- Summer—June, July, and August
- Fall—September, October, and November

2.3.1.2 Calculation of Survey Effort

Ship survey data provided by both the NMFS-NEFSC and the NMFS-SEFSC were collected as a series of latitude and longitude points every two minutes (min). 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 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 transect line. Each transect line was then used in density calculation of cetaceans in the NE study area shelf waters or sea turtles along the entire U.S. Atlantic Coast using the same methods as for shipboard observations.

Only “on-effort” portions of the tracklines conducted in BSSs ≤4 were used for analyses. “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.

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 2-3**). 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 degree [°] 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.

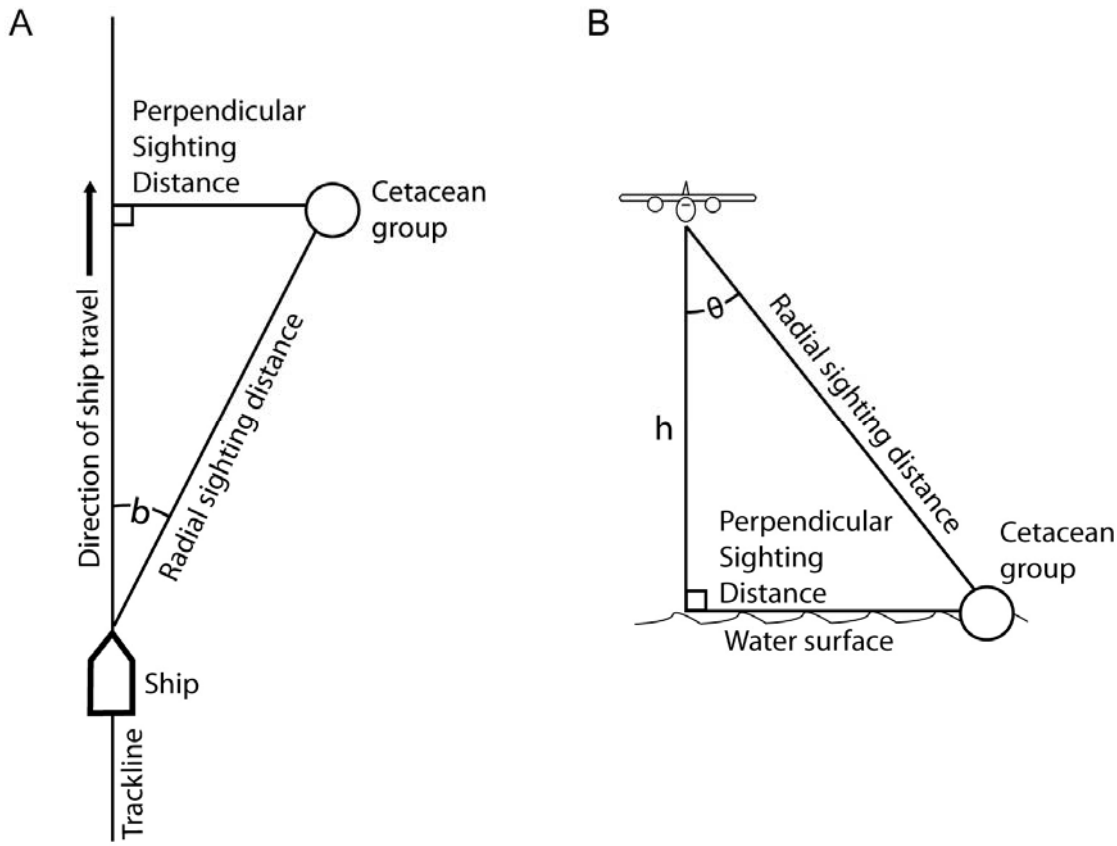

Figure 2-3. Diagram of perpendicular sighting distance and other sighting parameters for shipboard (A) and aerial (B) surveys (b and *θ* = angle between track-line and animal group, h = altitude).

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, bottom slope, distance of the sighting from the shelf break, latitude, longitude, SST, and chlorophyll *a* [chl *a*]) by fitting a generalized additive model (GAM; Wood 2006).

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

We combined all surveys conducted on like platforms (i.e. shipboard or aerial), regardless of season or location, to provide the greatest possible number of sightings. By combining surveys, we were able to increase the number of sightings for all species. When possible, 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, and unidentified turtles).

After fitting GAMs to the survey data, the resulting DSM is applied to a prediction grid superimposed upon the U.S. Atlantic Coast study areas. In this way, animal density can be predicted in regions of the U.S. Atlantic Coast study areas 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 largely only available for 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 (bottom depth, bottom slope, distance of the sighting from the shelf break, latitude, and longitude) for the models.

2.5 STEPS IN DENSITY SURFACE MODELING (DSM) OF LINE TRANSECT DATA

After all shipboard or aerial survey data were manipulated as described in **Section 2.8**, the following iterative steps were used to estimate the abundance, and subsequent density, of cetaceans and sea turtles in the U.S. Atlantic Coast study areas:

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, bottom slope, distance from shelf break, 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

<u>Estimating Bias - *g(0)*</u>

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, we 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 harbor porpoise). However, estimates of *g(0)* were not calculated during the surveys which our analyses were based. Furthermore, there are no *g(0)* estimates available for any species in the SE study area 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**).

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 kilometers (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, including 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). SST 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 along the U.S. Atlantic Coast (NASA 1998).

SST and Seasonal Delineation—Data from 1998 to 2005 for the U.S. Atlantic Coast study areas were extracted from the global SST dataset (NASA 2000). The pixel values were converted to SST values using the following function:

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

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 U.S. Atlantic Coast study areas were associated with a color spectrum grading from blue to red that represents cooler to warmer SST (°C), respectively.

Table 2-3. Range of estimates for *g(0)* for each cetacean species found in the Southeast 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.

g(0)	Location	Platform	Source
Threatened/Endangered Cetacean Species			
Right whale (*Eubalaena* spp.)			
0.29-1.00	U.S. Atlantic Coast	Shipboard	(Palka 2006)
0.19-0.29	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.95	U.S. West Coast	Aerial	(Forney et al. 1995)
Humpback (*Megaptera novaeangliae*)			
0.19-0.21	U.S. Atlantic Coast	Shipboard	(Palka 2005a)
0.90-1.00	U.S. West Coast	Shipboard	(Barlow 1995; Calambokidis and Barlow 2004)
0.95	U.S. West Coast	Aerial	(Forney et al. 1995)
0.26	Hawaii	Aerial	(Mobley et al. 2001)
Fin whale (*Balaenoptera physalus*)			
0.32-0.94	U.S. Atlantic Coast	Shipboard	(Blaylock et al. 1995; Palka 2006)
0.19-0.29	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.90-1.00	U.S. West Coast	Shipboard	(Barlow 1995, 2003b)
0.95-0.98	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.90-1.00	Hawaii	Shipboard	(Barlow 2003a)
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 2003b; 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 2003a, 2006)
0.32	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)
Non-Threatened/Non-Endangered Cetacean Species			
Minke whale (*Balaenoptera acutorostrata*)			
0.31-0.70	U.S. Atlantic Coast	Shipboard	(Blaylock et al. 1995; Palka 2006)
0.19-0.29	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.25-0.90	Eastern North Atlantic	Shipboard	(Butterworth and Borchers 1988; Øien 1990; Schweder et al. 1991; Schweder and Høst 1992; Schweder et al. 1992; Schweder et al. 1997; Skaug and Schweder 1999; Skaug et al. 2004)

Table 2-3. Continued.

g(0)	Location	Platform	Source
Non-Threatened/Non-Endangered Cetacean Species (*continued*)			
Minke whale (*Balaenoptera acutorostrata*) (*continued*)			
0.84	U.S. West Coast	Shipboard	(Barlow 1995, 2003b)
0.95-0.98	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.63-0.83	Antarctic	Shipboard	(Doi et al. 1982; IWC 1982, 1983)
***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, 2003b)
0.35	Hawaii	Shipboard	(Barlow 2003a, 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 2003b; Barlow et al. 2006)
0.23-0.45	Hawaii	Shipboard	(Barlow 2003a, 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, 2003b)
0.67-0.96	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 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 2003b)
0.77-1.0	Hawaii	Shipboard	(Barlow 2003a, 2006)
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 2003b)
0.76-1.00	Hawaii	Shipboard	(Barlow 2003a, 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, 2003b)
0.76-1.00	Hawaii	Shipboard	(Barlow 2003a, 2006)
Rough-toothed dolphin (*Steno bredanensis*)			
0.74-1.00	U.S. West Coast	Shipboard	(Barlow 2003b)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 2006)

Table 2-3. Continued.

g(0)	Location	Platform	Source
Non-Threatened/Non-Endangered Cetacean Species (*continued*)			
Common dolphin (*Delphinus* spp.)			
0.52-0.95	U.S. Atlantic Coast	Shipboard	(Palka 2005a; Palka 2006)
0.58-0.77	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.79-0.81	Eastern North Atlantic	Shipboard	(Cañadas et al. 2004)
0.77-1.0	U.S. West Coast	Shipboard	(Barlow 1995, 2003b)
0.67-0.96	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
White-sided dolphin (*Lagenorhynchus acutus and L. obliquidens*)			
0.27-0.38	U.S. Atlantic Coast	Shipboard	(Palka 2006)
0.58-0.77	U.S. Atlantic Coast	Aerial	(Palka 2005b)
0.77-1.00	U.S. West Coast	Shipboard	(Barlow 1995, 2003b)
0.67-0.96	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
Fraser's dolphin (*Lagenodelphis hosei*)			
0.76-1.00	Hawaii	Shipboard	(Barlow 2003a, 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, 2003b)
0.67-0.96	U.S. West Coast	Aerial	(Forney and Barlow 1993; Forney et al. 1995)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 2006)
False killer whale (*Pseudorca crassidens*)			
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 2006)
Pygmy killer whale (*Feresa attenuata*)			
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 2006)
Killer whale (*Orcinus orca*)			
0.90	U.S. West Coast	Shipboard	(Barlow 2003b)
Killer whale (*Orcinus orca*)			
0.95-0.98	U.S. West Coast	Aerial	(Forney et al. 1995)
0.90	Hawaii	Shipboard	(Barlow 2003a, 2006)
0.96	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)
Melon-headed whale (*Peponocephala electra*)			
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 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 2003b)
0.74-1.00	Hawaii	Shipboard	(Barlow 2003a, 2006)
0.93	Antarctic	Shipboard	(Kasamatsu and Joyce 1995)
Harbor porpoise (*Phocoena phocoena*)			
0.35-0.73	U.S. Atlantic Coast	Shipboard	(Palka 1995; Palka 1996; Palka 2006)
0.24-0.49	U.S. Atlantic Coast	Aerial	(Palka 2005b)

Table 2-3. Continued.

g(0)	Location	Platform	Source
Non-Threatened/Non-Endangered Cetacean Species (*continued*)			
Harbor porpoise (*Phocoena phocoena*) (*continued*)			
0.41-0.71	Eastern North Atlantic	Aerial	(Grünkorn et al. 2005)
0.08-0.85	U.S. West Coast	Aerial	(Barlow et al. 1988; Calambokidis et al. 1993a; Forney et al. 1995; Laake et al. 1997; Carretta et al. 2001; Carretta et al. 2007)
0.54-0.79	U.S. West Coast	Shipboard	(Calambokidis et al. 1993b; Barlow 1995; Carretta et al. 2001)

* 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 two spotted dolphin species

Chl *a*—Pixel data for the study area and vicinity from 1998 to 2005 were extracted and converted to chl *a* values using MATLAB® and the following function:

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

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 centroid of each grid cell using 30 arc second bathymetry data (Smith and Sandwell 1997; NOAA 1999; 2001). 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 a 3 km coastline buffer and the EEZ, extending from the U.S./Canada border to approximately Cape Canaveral, Florida. 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, slope, distance from the shelf break, 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 MATLAB. The gridded output was smoothed via linear interpolation and plotted using a color scale to visualize the model results. On-effort sightings were overlaid on the density surface for visual reference and comparison. Total density estimates based on the DSM were compared to published density values to ground truth that the model was within reason.

2.7 DENSITY SURFACE MODEL SELECTION

One hundred fifty-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 the GCV score) were evaluated for the following criteria: significance of each

smooth variable; total deviance explained; GCV score; and density estimate. Lower GCV scores indicate a better fit of the DSM. If a variable in the model was determined to not be significant, the variable was excluded and the model 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 density surface model 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 marine mammal 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 quantiles 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 DSM. However, these data were: not available for all cruises; were not available for all cells of the prediction grid (which covers the entire U.S. Atlantic Coast); and would require extensive post-processing time. Instead, our 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.

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, and distance from shore, sea surface height, and prey resources. While these additional variables would certainly improve our density estimates, the purpose of this project was to estimate densities, and not to generate comprehensive habitat models. Due to time constraints, we were unable to fully investigate all potential environmental and biological variables that may influence animal distribution. Our 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 SE study area. Our approach is the first attempt to model animal densities in the SE 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

For several species, there were not enough sightings to be able to produce a density surface using the program DISTANCE. Two general approaches were adopted during these instances to derive density estimates and are described below.

2.8.1 Published Literature

When a density surface could not be generated for a given species or species group based on the shipboard surveys for the waters of the SE study area and those of the NE OPAREAs study area that lie beyond the shelf break, density estimates derived from 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. The species or species groups for which this approach was used include: Clymene dolphin, *Kogia* spp., harbor porpoise, and pantropical spotted dolphin. On occasion, if a density estimate could not be derived from the abundance estimate in the SAR, it was possible to derive one from the abundance estimate for that species from Mullin and Fulling (2003) instead. The minke whale and the rough-toothed dolphin both fall into this latter category.

2.8.2 Exception to the Rule

The North Atlantic right whale was the primary species needing the SAR-derived approach. The approach for handling right whales was to take the abundance estimate of 396 animals (NARWC 2006) and divide that among the four different quartiles from the occurrence polygons found in the NE MRA (DoN 2005b). This was under the assumptions that: 1) 75% of the population was found in the NE OPAREAs study area during spring, summer, and fall and that 50% of the population remained there during the winter; and 2) that each quartile represented 25% of the population found in the area at a given time. Therefore, given these assumptions, density estimates were derived for each season by dividing the number of animals assumed to be in each of the quartile regions by the total area (km^2) of that quartile. The density estimates from Hain and Kenney (2005c; 2005b; 2005a) were used for each of the three SE OPAREAs of

VACAPES, CHPT, and JAX/CHASN (the VACAPES density estimates were extended up to approximately the New York/New Jersey border).

Additionally, the humpback whale estimates were based on the Gulf of Maine (GOM) SAR estimate of 902 animals and is the only abundance estimate which is appropriate to use for the SE OPAREAs. This estimate was seasonally partitioned along the U.S. Atlantic coast considering the species migration patterns to and from the calving grounds in the Caribbean. The partitions were: 100% of the whales in fall and spring, 50% of the whales in winter, and 0% whales in summer.

2.8.3 No Estimates Provided

For some species or species groups, there was no density estimate available or it was not possible to derive one based on the available abundance estimates. In these instances, none were supplied.

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3.0 DENSITY ESTIMATES

There are 40 marine mammal species with occurrence records in the SE study area: 35 cetacean species, 4 pinniped species, and 1 sirenian species (DoN 2001; 2002c; 2002b). Due to lack of sufficient survey data, only thirteen species and three species groups (*Kogia* spp., Beaked Whales, and Pilot Whales) of the 35 cetacean species are covered within this report and have abundance/density estimates provided (**Table 3-1**). This is due to: 1) the lack of sufficient observations of the remaining species during the surveys conducted by the NMFS-NEFSC and the NMFS-SEFSC used to develop the density and abundance estimates for this report, and 2) the lack of an abundance estimate from which to derive a density estimate either from the SAR or the literature.

Density estimates for cetaceans were either modeled from data or derived from abundance estimates found in either the NOAA SAR (Waring et al. 2007) or Mullin and Fulling (2003). **Section 2.4** describes the model-based approach, while **Section 2.8** discusses the process for literature-derived estimates. Density/abundance estimates for the North Atlantic right whale were derived in consultation with Dr. Robert Kenney (University of Rhode Island).

There are 11 cetacean species with documented or expected occurrence in the SE study area for which abundance/density estimates are not available (See **Table 3.1**)

There are also five sea turtle species with occurrence records within the SE study area (DoN 2001; 2002c; 2002b); three species and one species group are addressed within this report (see **Table 3-1**). Again, this is due to (1) the lack of sufficient sightings in the survey data to do density estimate calculations for individual species, and (2) the unavailability of an abundance estimate in the SAR or the literature from which to derive a density estimate.

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 marine mammal species and groups, as well as the sea turtle species presented in this report, their status, habitat preferences, distribution, behavior and life history, and information on acoustics and hearing, please refer to (DoN 2001; 2002c; 2002b). In addition to the basic habitat preference and distribution information, the abundance estimates and density surfaces are provided here as well. The results of the models used to generate the abundance estimates and the density surfaces for each species are contained in the **Appendix**. A summary of the abundance estimates (model-based or literature-derived) for each species considered in this report can be found in **Tables 3.2** and **3.3**.

This section begins with those species with model-based density estimates (**Section 2.4**), followed by those with SAR-derived estimates (**Section 2.8**), ending with those cetacean species listed in the SAR that could occur in the SE study area and have literature-derived estimates (**Section 2.8**).

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 Southeast study area for which density estimates are provided. Naming convention matches that used by the National Marine Fisheries Service.

Threatened/Endangered Cetacean Species	
Blue whale[5]	*Balaenoptera musculus*
North Atlantic right whale[2]	*Eubalaena glacialis*
Humpback whale[2]	*Megaptera novaeangliae*
Sei whale[5]	*Balaenoptera borealis*
Fin whale[1]	*Balaenoptera physalus*
Sperm whale[1]	*Physeter macrocephalus*
Non-Threatened/Non-Endangered Cetacean Species	
Bryde's whale[5]	*Balaenoptera brydei/edeni*
Minke whale[4]	*Balaenoptera acutorostrata*
***Kogia* spp.**[3]	
Pygmy sperm whale	*Kogia breviceps*
Dwarf sperm whale	*Kogia sima*
Beaked Whales[1]	
Cuvier's beaked whale	*Ziphius cavirostris*
True's beaked whale	*Mesoplodon mirus*
Gervais' beaked whale	*Mesoplodon europaeus*
Sowerby's beaked whale	*Mesoplodon bidens*
Blainville's beaked whale	*Mesoplodon densirostris*
Rough-toothed dolphin[4]	*Steno bredanensis*
Bottlenose dolphin[1]	*Tursiops truncatus*
Pantropical spotted dolphin[3]	*Stenella attenuata*
Atlantic spotted dolphin[1]	*Stenella frontalis*
Spinner dolphin[5]	*Stenella longirostris*
Clymene dolphin[3]	*Stenella clymene*
Striped dolphin[1]	*Stenella coeruleoalba*
Common dolphin[1]	*Delphinus delphis*
Fraser's dolphin[5]	*Lagenodelphis hosei*
Atlantic white-sided dolphin[5]	*Lagenorhynchus acutus*
Harbor porpoise[5]	*Phocoena phocoena*
Risso's dolphin[1]	*Grampus griseus*
Killer whale[5]	*Orcinus orca*
Pygmy killer whale[5]	*Feresa attenuata*
False killer whale[5]	*Pseudorca crassidens*
Melon-headed whale[5]	*Peponocephala electra*
Pilot Whales[1]	
Long-finned pilot whale	*Globicephala melas*
Short-finned pilot whale	*Globicephala macrorhynchus*
Sea Turtles	
Kemp's ridley turtle[1]	*Lepidochelys kempii*
Leatherback turtle[1]	*Dermochelys coriacea*
Loggerhead turtle[1]	*Caretta caretta*
Hardshell Turtles[1]	
Green turtle	*Chelonia mydas*
Hawksbill turtle	*Eretmochelys imbricata*
Kemp's ridley turtle	*Lepidochelys kempii*
Loggerhead turtle	*Caretta caretta*
Unidentified hardshell turtles	(does not include Leatherback)

[1] Indicates species for which density estimates were derived through spatial modeling of the NMFS survey data
[2] Density estimates derived (see **Section 2.8** for an explanation on how these estimates were derived)
[3] Estimates taken from the SAR (Waring et al. 2007)
[4] Estimates taken from Mullin and Fulling (2003)
[5] No density estimate was provided

Table 3-2. Seasonal estimates of abundance for cetaceans and sea turtles in the Southeast study area. Both model-based and literature-derived estimates are presented. Literature-derived estimates are the "best" estimates of abundance from either Waring et al. (2007) or Mullin and Fulling (2003).

Species/Species Group	Spring	Summer	Fall	Winter
Model-Derived Abundance Estimates				
Fin whale (*Balaenoptera physalus*)	114	114	114	114
Sperm whale (*Physeter macrocephalus*)	1,827	2,068	1,827	1,827
Beaked Whales (Family Ziphiidae)	1,054	1,145	1,054	1,054
Bottlenose dolphin (*Tursiops truncatus*)	67,125	67,311	67,125	67,125
Atlantic spotted dolphin (*Stenella frontalis*)	67,018	67,018	67,018	67,018
Striped dolphin (*Stenella coeruleoalba*)	59,882	59,882	59,882	59,882
Common dolphin (*Delphinus delphis*)	29,416	29,416	29,416	29,416
Risso's dolphin (*Grampus griseus*)	13,835	13,835	13,835	13,835
Pilot Whales (*Globicephala* spp.)	16,332	17,295	16,332	16,332
Leatherback turtle (*Dermochelys coriacea*)	1,710	3,323	1,710	1,710
Kemp's ridley turtle (*Lepidochelys kempii*)	1,890	1,890	1,890	1,890
Loggerhead turtle (*Caretta caretta*)	11,268	11,672	11,268	11,268
Hardshell Turtles	5,956	7,747	5,956	5,956
Literature-Derived Abundance Estimates				
North Atlantic Right Whale (*Eubalaena glacialis*)[1]	See **Tables 3-3** and **3-13** below			
Humpback whale (*Megaptera novaeangliae*)[1]	902	0	902	451
Minke whale (*Balaenoptera acutorostrata*)[3]	20	20	20	20
Kogia spp.[2]	395	395	395	395
Rough-toothed dolphin (*Steno bredanensis*)[3]	274	274	274	274
Pantropical spotted dolphin (*Stenella attenuata*)[2]	4,439	4,439	4,439	4,439
Clymene dolphin (*Stenella clymene*)[2]	6,086	6,086	6,086	6,086
Species for Which Abundance Estimates Are Not Available				
Blue whale (*Balaenoptera musculus*)	No estimate available			
Sei whale (*Balaenoptera borealis*)	No estimate available			
Bryde's whale (*Balaenoptera brydei/edeni*)	No estimate available			
Killer whale (*Orcinus orca*)	No estimate available			
Pygmy killer whale (*Feresa attenuata*)	No estimate available			
False killer whale (*Pseudorca crassidens*)	No estimate available			
Melon-headed Whale (*Peponocephala electra*)	No estimate available			
Spinner dolphin (*Stenella longirostris*)	No estimate available			
Fraser's dolphin (*Lagenodelphis hosei*)	No estimate available			
Atlantic white-sided dolphin (*Lagenorhynchus acutus*)	No estimate available			
Harbor porpoise (*Phocoena phocoena*)	No estimate available			

[1] Please refer to **Section 2.8** of the Methodology for an explanation on how these estimates were derived
[2] Estimates taken from the NOAA SAR (Waring et al. 2007)
[3] Estimates taken from Mullin and Fulling (2003)

Table 3-3. Monthly estimates of abundance for the North Atlantic right whale based on the occurrence polygons from the Northeast Operating Area Marine Resources Assessment (DoN 2005) and density estimates for this species produced by Hain and Kenney (2005c; 2005b; 2005a).

North Atlantic Right Whale (*Eubalaena glacialis*)*	
Time Period	**Abundance Estimate**
January	90
February	112
March	112
April	46
May	9
June	9
July & August	5
September	5
October & November	11
December	112

* Please refer to **Section 2.8** of the Methodology for an explanation on how these estimates were derived.

3.1 MARINE MAMMALS

All marine mammal species are afforded protection by the MMPA. Six of the twenty-seven marine mammal species/species groups considered in this report are listed as endangered under the ESA: the North Atlantic right, humpback, fin, sei, blue, and sperm whales. 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. In this section, individual species with density estimates are addressed first and are followed by the species as listed in **Table 3-1**.

3.1.1 Species with Model-Based Density Estimates

➢ Fin Whale *(Balaenoptera physalus)*

Distribution and habitat preferences:

- The fin whale is the most common whale species acoustically detected with Navy deepwater hydrophone arrays in the North Atlantic (Clark 1995; Clark and Gagnon 2004). The overall range in the western North Atlantic extends from the Gulf of Mexico (GOMEX)/Caribbean north to Greenland (Gambell 1985; NMFS 2006a). Fin whales are common in waters of the EEZ, principally north of Cape Hatteras (CETAP 1982; Hain et al. 1992; Waring et al. 2007).

- As a species, the fin whale is believed to follow the typical baleen whale migratory pattern, with a population shift north to summer feeding grounds and south to winter breeding grounds; however, the location and extent of the wintering grounds are poorly known (Aguilar 2002). Fin whales have been seen feeding as far south as the coast of Virginia (Hain et al. 1992).

- Hain et al. (1992) suggested that based on stranding data, calving in the western North Atlantic takes place during winter near Cape Hatteras; however, (Clark and Gagnon 2004) noted that fin whales in the North Atlantic do not appear to have specific breeding areas. Additionally, as noted by Waring et al. (2007), the popular notion that entire fin whale populations make distinct annual migrations like some other mysticetes has questionable support in the data, since in the North Pacific, year-round monitoring of fin whale calls found no evidence for large-scale migratory movements (Watkins et al. 2000).

- Fin whales in the U.S. Atlantic occur in waters over the continental shelf and shelf break (Hain et al. 1992; Waring et al. 2007). There is a strong preference for shelf breaks, seamounts or other areas where food resources are concentrated (e.g., Kenney and Winn 1987; Hain et al. 1992; Clark and Gagnon 2004). The fin whale appears to be scarce in offshore slope and Gulf Stream waters (CETAP 1982; Waring et al. 1992).

Table 3-4. Density surface model results for the fin whale by season. These are abundance estimates for the fin whale in the Southeast study area.

Season	Abundance
Spring	114
Summer	114
Fall	114
Winter	114

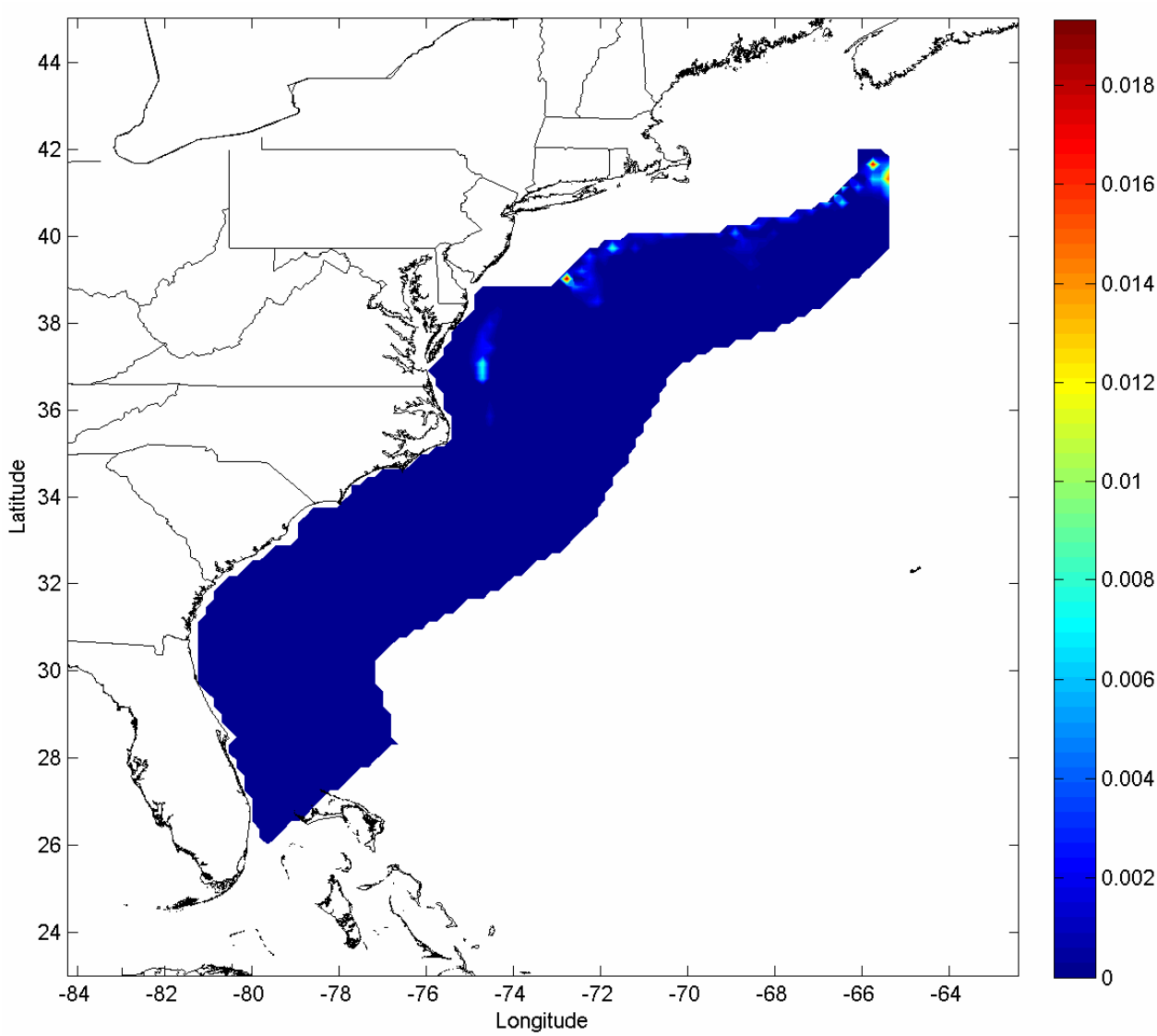

Figure 3-1. Density surface for the fin whale during all seasons off the United States Atlantic Coast.

➢ Sperm Whale (*Physeter macrocephalus*)

Distribution and habitat preferences

- Sperm whales off the U.S. Atlantic Coast occur over the shelf break, continental slope, and into deeper waters (CETAP Schmidly 1981; 1982; Kenney and Winn 1987; Waring et al. 1993; Waring et al. 2001; Waring et al. 2007).

- Sperm whales appear to have a distinct seasonal distribution in waters off the U.S. Atlantic Coast (CETAP 1982; Scott and Sadove 1997; Waring et al. 2007). In winter, they are sighted primarily east and NE of Cape Hatteras. In spring, distribution shifts northward to off Delaware and Virginia and is widespread throughout the central Mid-Atlantic Bight and southern Georges Bank. In summer, the distribution is similar but now also includes the area east and north of Georges Bank and into the NE Channel region, as well as the continental shelf (inshore of the 100 m isobath) south of New England. In the fall, sperm whale occurrence south of New England on the

continental shelf is at its highest level, and there remains a continental shelf break occurrence in the Mid-Atlantic Bight.

- Sperm whales off the U.S. Atlantic Coast are found in regions of pronounced horizontal temperature gradients, such as along the edges of the Gulf Stream and warm-core rings (Fritts et al. 1983; Waring et al. 1993; Griffin 1999); these are areas of increased productivity. The Gulf Stream is an important influence on sperm whale distribution in the western North Atlantic Ocean (e.g., Townsend 1935; Waring et al. 1993; Griffin 1999; NMFS 2006b).

Table 3-5. Density surface model results for the sperm whale by season. These are abundance estimates for the sperm whale in the Southeast study area.

Season	Abundance
Spring	1,827
Summer	2,068
Fall	1,827
Winter	1,827

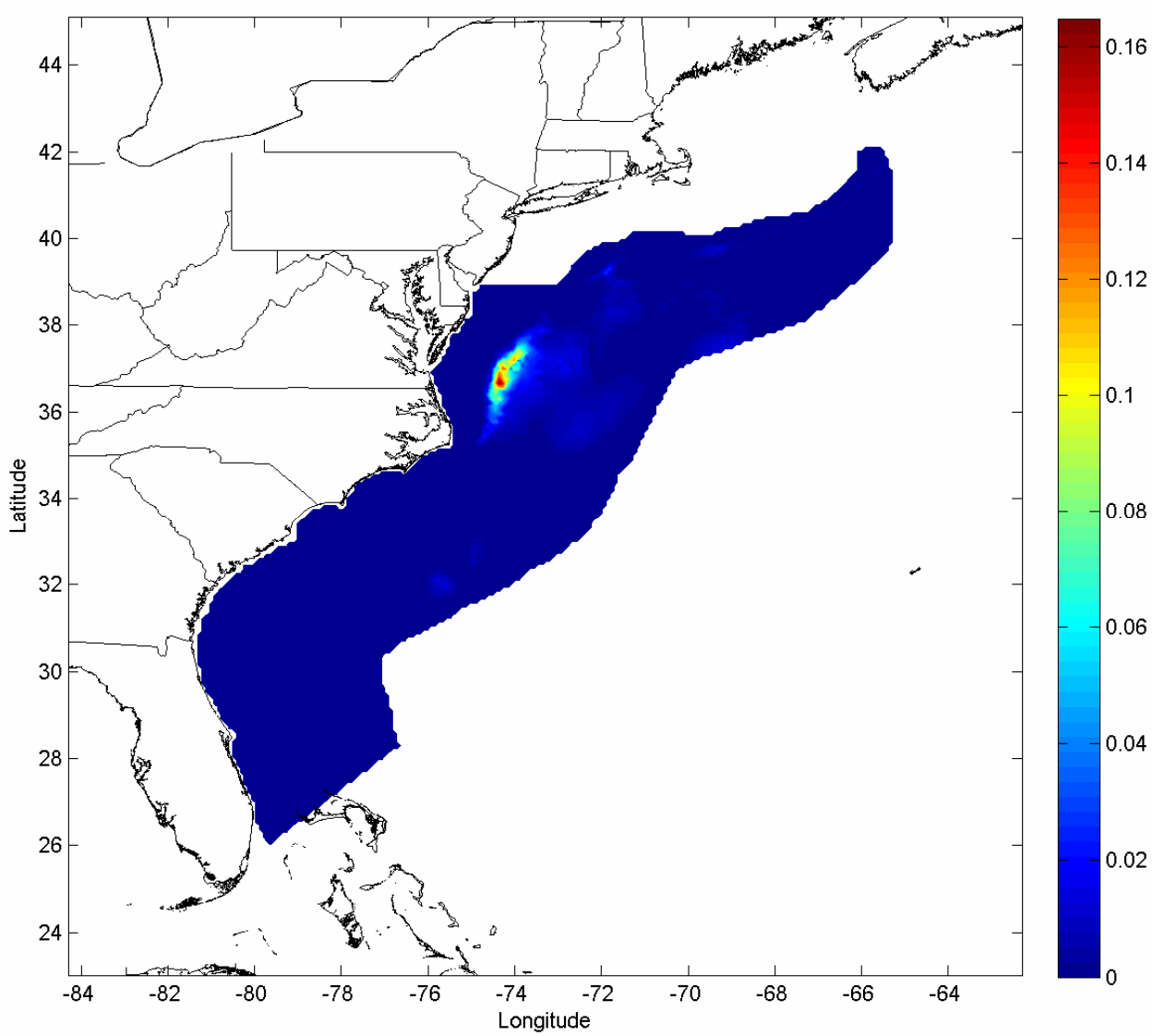

Figure 3-2. Density surface for the sperm whale during the summer off the United States Atlantic Coast.

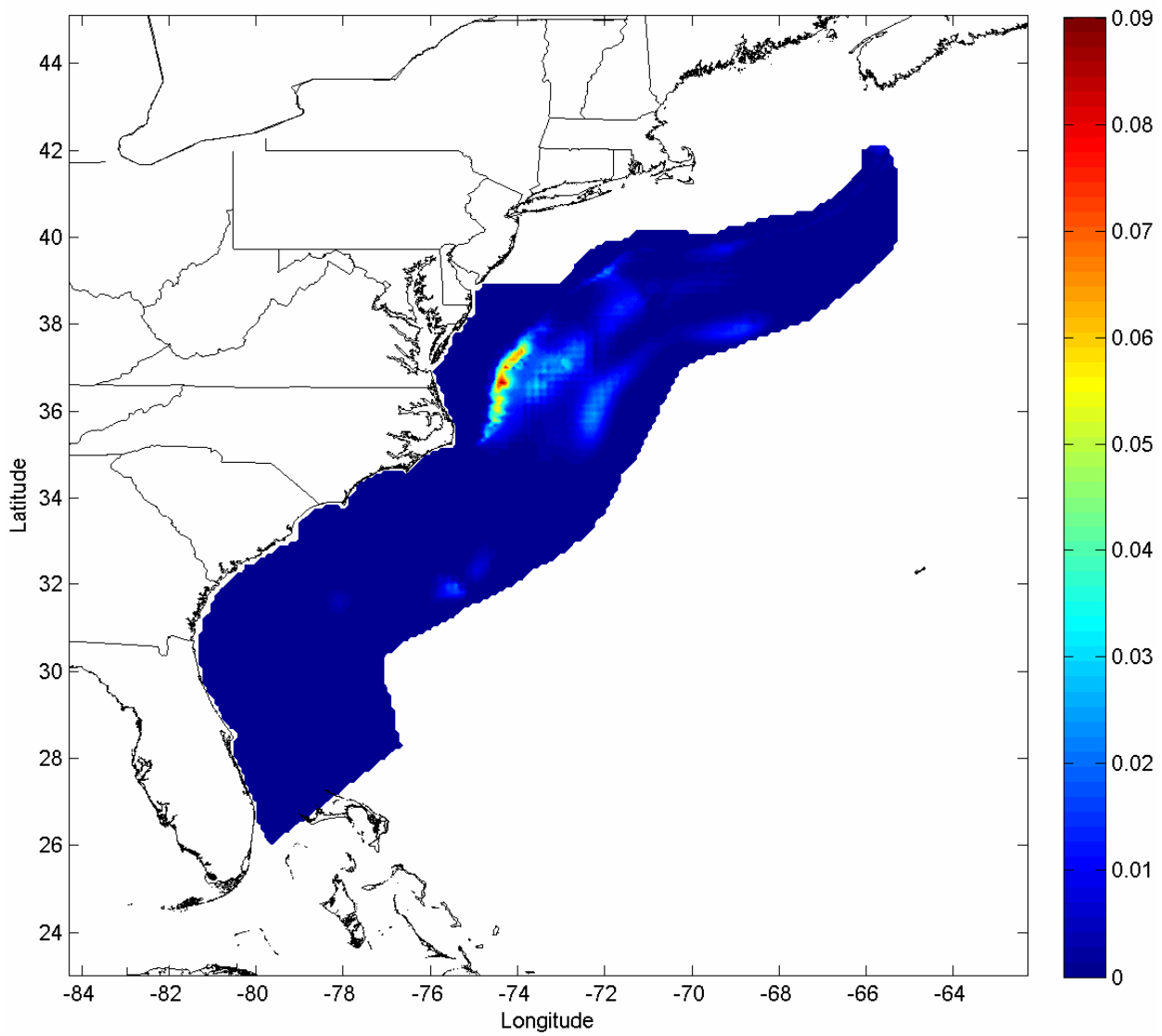

Figure 3-3. Density surface for the sperm whale during fall, winter, and spring off the United States Atlantic Coast.

- Beaked Whales (Family Ziphiidae)

  The beaked whales category encompasses species belonging to the Family Ziphiidae occurring in the SE study area; these are the Cuvier's beaked whale, True's beaked whale, Gervais' beaked whale, Sowerby's beaked whale, Blainville's beaked whale, and extralimital occurrences of the northern bottlenose whale.

  Distribution and habitat preferences

  - The Cuvier's beaked whale is the most widely distributed beaked whale species (MacLeod et al. 2006). It has been reported from Massachusetts and Rhode Island south to the Florida Keys (MacLeod et al. 2006). 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). Sowerby's

and True's beaked whales are the most northerly species (MacLeod 2000). The Sowerby's beaked whale appears to occur primarily between Labrador and New England (MacLeod 2000). The majority of records for True's beaked whale in the North Atlantic are strandings occurring between New Jersey and Maryland (MacLeod 2000), though there are records in the SE study area (DoN 2007).

- World-wide, beaked whales normally inhabit continental slope and deep oceanic waters (>200 m) (Waring et al. 2001; Pitman 2002; MacLeod et al. 2004; Ferguson et al. 2006a; MacLeod and Mitchell 2006). Beaked whales are only occasionally reported in more shallow waters (Pitman 2002).

- As noted by MacLeod and D'Amico (2006), in many locales, occurrence patterns have been linked to physical features, in particular, the continental slope, canyons, and escarpments.

- Beaked whale abundance off the U.S. Atlantic Coast may be highest in association with the Gulf Stream and the warm-core rings it develops (Waring et al. 1992). In summer, the continental shelf break off the northeastern U.S. is primary habitat (Waring et al. 2001). The continental shelf margins from Cape Hatteras to southern Nova Scotia were recently identified as known key areas for beaked whales, in a global review by MacLeod and Mitchell (2006).

Table 3-6. Density surface model results for beaked whales by season. These are abundance estimates for beaked whales in the Southeast study area. (shipboard)

Season	Abundance
Spring	1,054
Summer	1,145
Fall	1,054
Winter	1,054

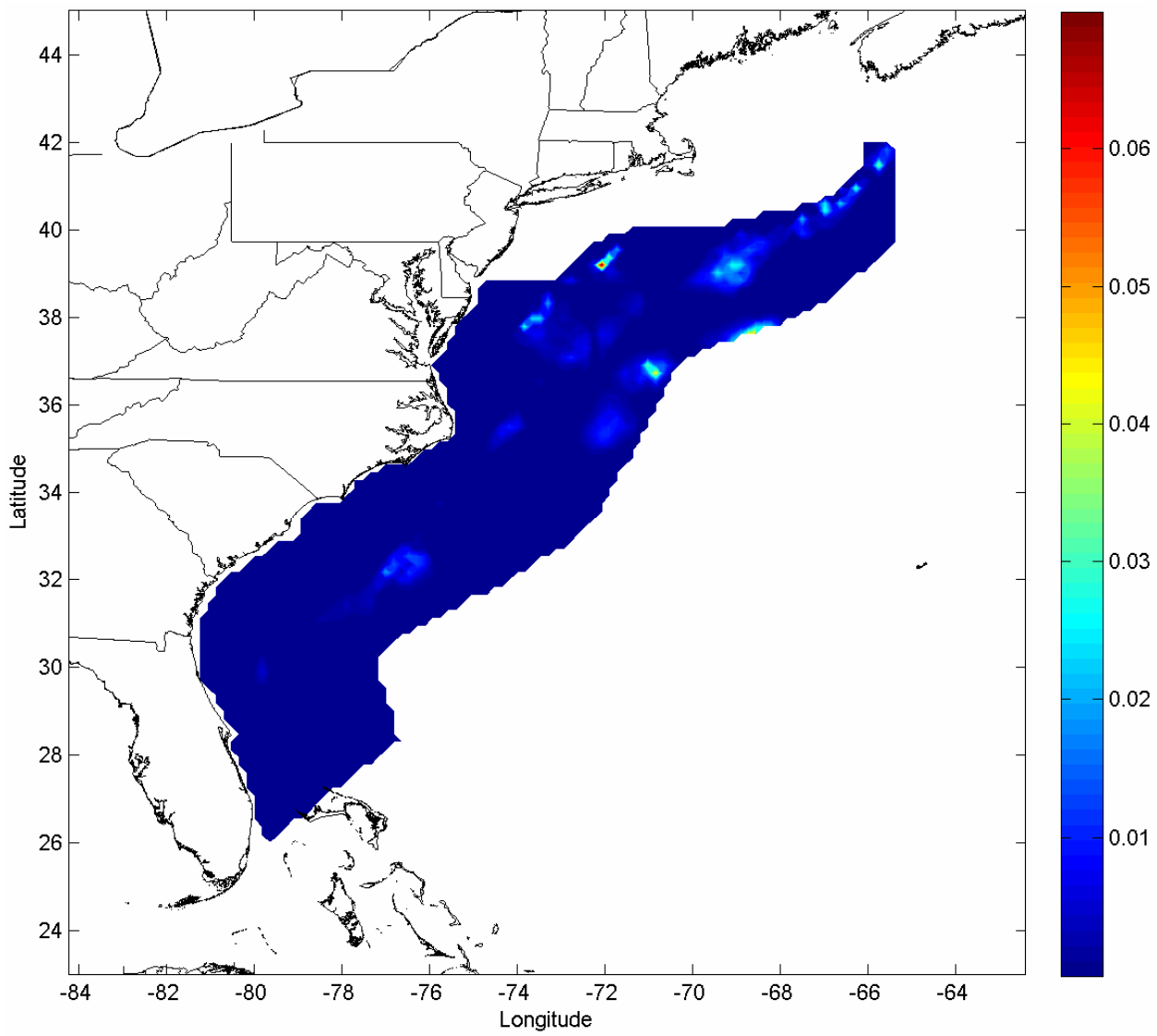

Figure 3-4. Density surface for beaked whales during fall, winter, and spring off the United States Atlantic Coast.

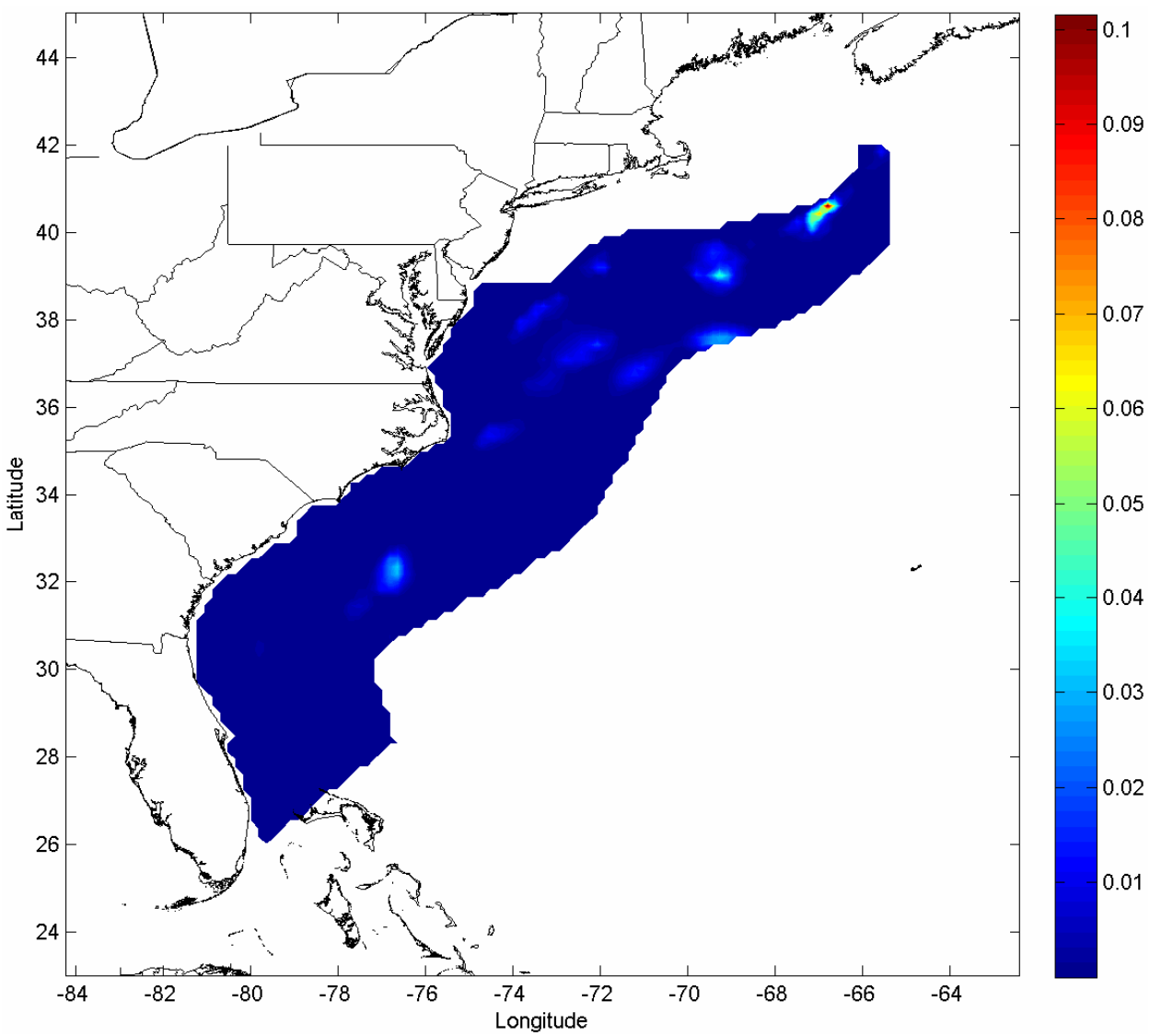

Figure 3-5. Density surface for beaked whales during summer off the United States Atlantic Coast.

➢ Bottlenose Dolphin (*Tursiops truncatus*)

The category for bottlenose dolphins includes both the coastal (nearshore) and the offshore morphotypes (forms) that are recognized in the western North Atlantic (Waring et al. 2007).

Distribution and habitat preferences

- Bottlenose dolphins off the U.S. Atlantic Coast are frequently found over the continental shelf and especially along the shelf break (Kenney 1990; Mullin and Fulling 2003). They occasionally move up rivers and may also be found in very deep waters (Caldwell and Caldwell 1972; Kenney 1990; R.S. Wells et al. 1999; Gannon 2003).

- Seasonally, bottlenose dolphins occur over the outer continental shelf and inner slope waters as far north as Georges Bank (CETAP 1982; Kenney 1990; Waring et al. 2007). The nearshore waters of the Outer Banks are known to serve as winter habitat for coastal bottlenose dolphins (Read et al. 2003; Torres et al. 2005).

- The coastal morphotype stock in the western North Atlantic is most often found within 7.5 km of the coast (approximately >25 m in bottom depth), although occurrences much further offshore are known (Torres et al. 2003; Waring et al. 2007). The coastal morphotype of bottlenose dolphin (comprised of seven management units) is continuously distributed along the Atlantic coast south of Long Island. Communities of coastal bottlenose dolphins occur in coastal embayments and estuaries along the western Atlantic coast, and may exhibit either resident or migratory patterns in these areas (Waring et al. 2007).

- Currently, a single western North Atlantic offshore stock is recognized seaward of 34 km from the U.S. coastline, in waters with a bottom depth greater than 34 m (Torres et al. 2003; Waring et al. 2007). The coastal ecotype stock shows a temperature-limited distribution, occurs in significantly warmer waters than the offshore stock, and has a distinct northern boundary (Kenney 1990; Waring et al. 2007).

- The coastal morphotype stock shows a temperature-limited distribution, occurs in significantly warmer waters than the offshore stock, and has a distinct northern boundary (Kenney 1990). Although a critical temperature limit for the stock has not been defined, recent winter aerial surveys reported a lack of sightings north of Chesapeake Bay, corresponding to water temperatures less than 9.5°C (Waring et al. 2007). Water temperature may directly affect movements by acting as a thermal barrier to coastal bottlenose dolphin movement (Barco et al. 1999; Torres et al. 2005). Alternatively, water temperature may indirectly affect movements by directly affecting prey movements (Barco et al. 1999; Wells and Scott 1999).

- North of Cape Hatteras, there is clear separation of the two morphotypes relative to bathymetry during the summer. Bottlenose dolphins concentrated close to shore are of the coastal morphotype, while those in waters >40 m in bottom depth are from the offshore morphotype (Garrison et al. 2003b).

- During winter months and south of Cape Hatteras, the range of the coastal and offshore morphotypes overlaps to some degree. Over the continental shelf south of Cape Hatteras, the two morphotypes overlap spatially, though the probability of encountering the offshore morphotype increases with increasing depth, though there is significant spatial overlap (Waring et al. 2007). It should be noted that the offshore morphotype has been sampled as close as 7.3 km from shore in waters with a bottom depth of 13 m (Garrison et al. 2003b).

Table 3-7. Density surface model results for the bottlenose dolphin by season. These are abundance estimates for the bottlenose dolphin in the Southeast study area.

Season	Abundance
Spring	67,125
Summer	67,311
Fall	67,125
Winter	67,125

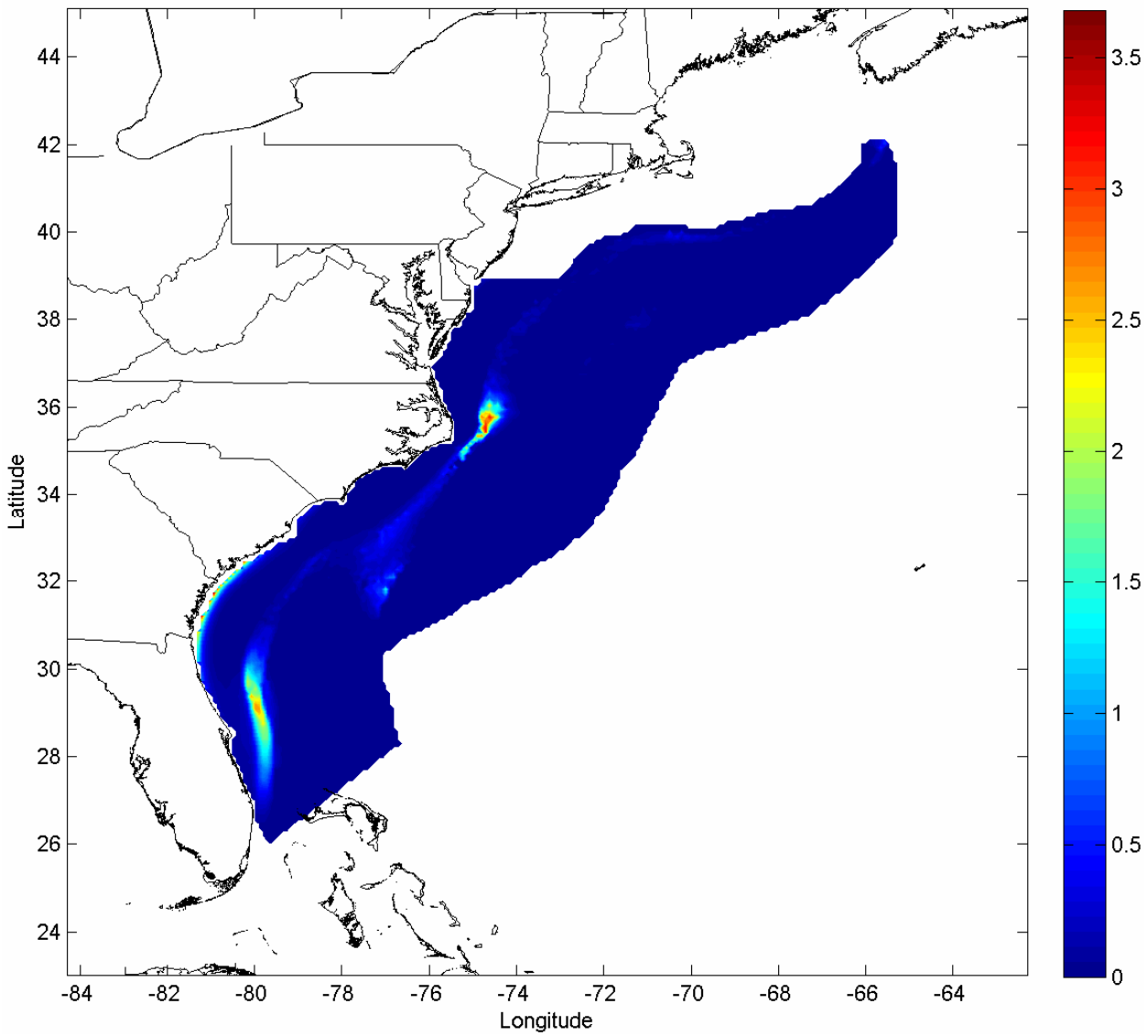

Figure 3-6. Density surface for the bottlenose dolphin during fall, winter, and spring off the United States Atlantic Coast.

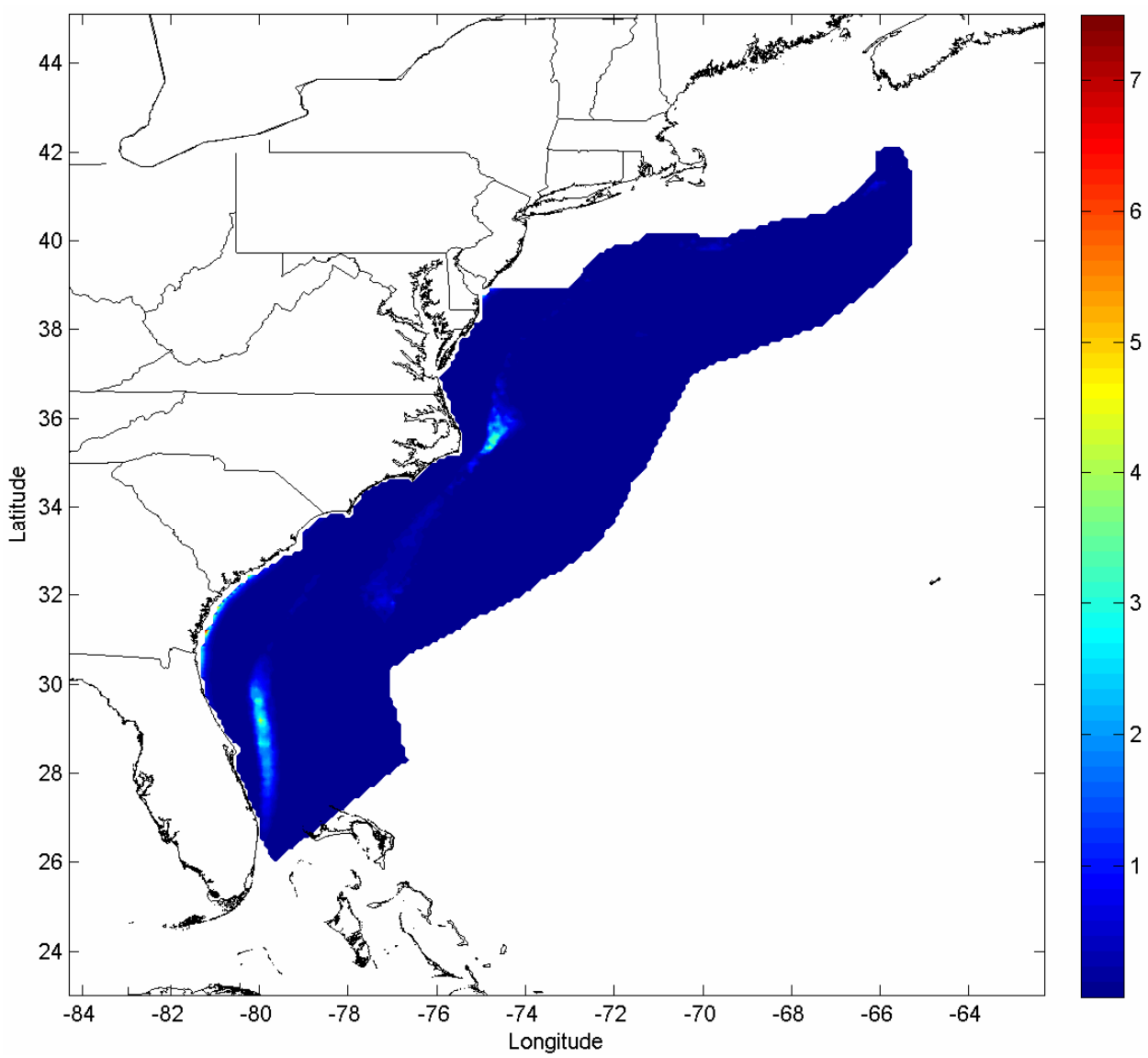

Figure 3-7. Density surface for the bottlenose dolphin during summer off the United States Atlantic Coast.

- Atlantic Spotted Dolphin (*Stenella frontalis*)

  It should be noted that two distinct morphotypes of the Atlantic spotted dolphin are described for the western North Atlantic: a larger, more heavily spotted form found in waters over the continental shelf, and a smaller, less spotted form found in oceanic waters (Perrin 2002a; Mullin and Fulling 2003).

  Distribution and habitat preferences

  - Atlantic spotted dolphins are endemic to warm-temperate and tropical Atlantic waters from approximately 45º North (N) to 35º South (S); in the western North Atlantic Ocean, this translates to waters from northern New England to Venezuela, including the GOMEX and the Caribbean Sea (Perrin et al. 1987).

- The Atlantic spotted dolphin typically occurs over the continental shelf inshore of or near the 185 m isobath, usually at least 8 to 20 km offshore (Perrin 2002a). Bottlenose dolphins are thought to occupy more coastal waters than spotted dolphins in nearshore habitats.

- In the SE study area, Atlantic spotted dolphins regularly occur in waters over the continental shelf and slope (Payne et al. 1984; Mullin and Fulling 2003). Atlantic spotted dolphins have been observed close to shore in waters with a bottom depth as shallow as 13 m (e.g., Sutherland and May 1977; Mullin and Fulling 2003) and as deep as 2,524 m (Mullin and Fulling 2003).

- Along the northeastern U.S., Waring et al. (1992) found that stenellids (members of the genus *Stenella*) were distributed along the Gulf Stream's northern wall. *Stenella* sightings also occurred within the Gulf Stream (Waring et al. 1992; Mullin and Fulling 2003), which is consistent with the oceanic distribution of this genus and its preference for warm water.

Table 3-8. Density surface model results for the Atlantic spotted dolphin by season. These are abundance estimates for the Atlantic spotted dolphin in the Southeast study area.

Season	Abundance
Spring	67,018
Summer	67,018
Fall	67,018
Winter	67,018

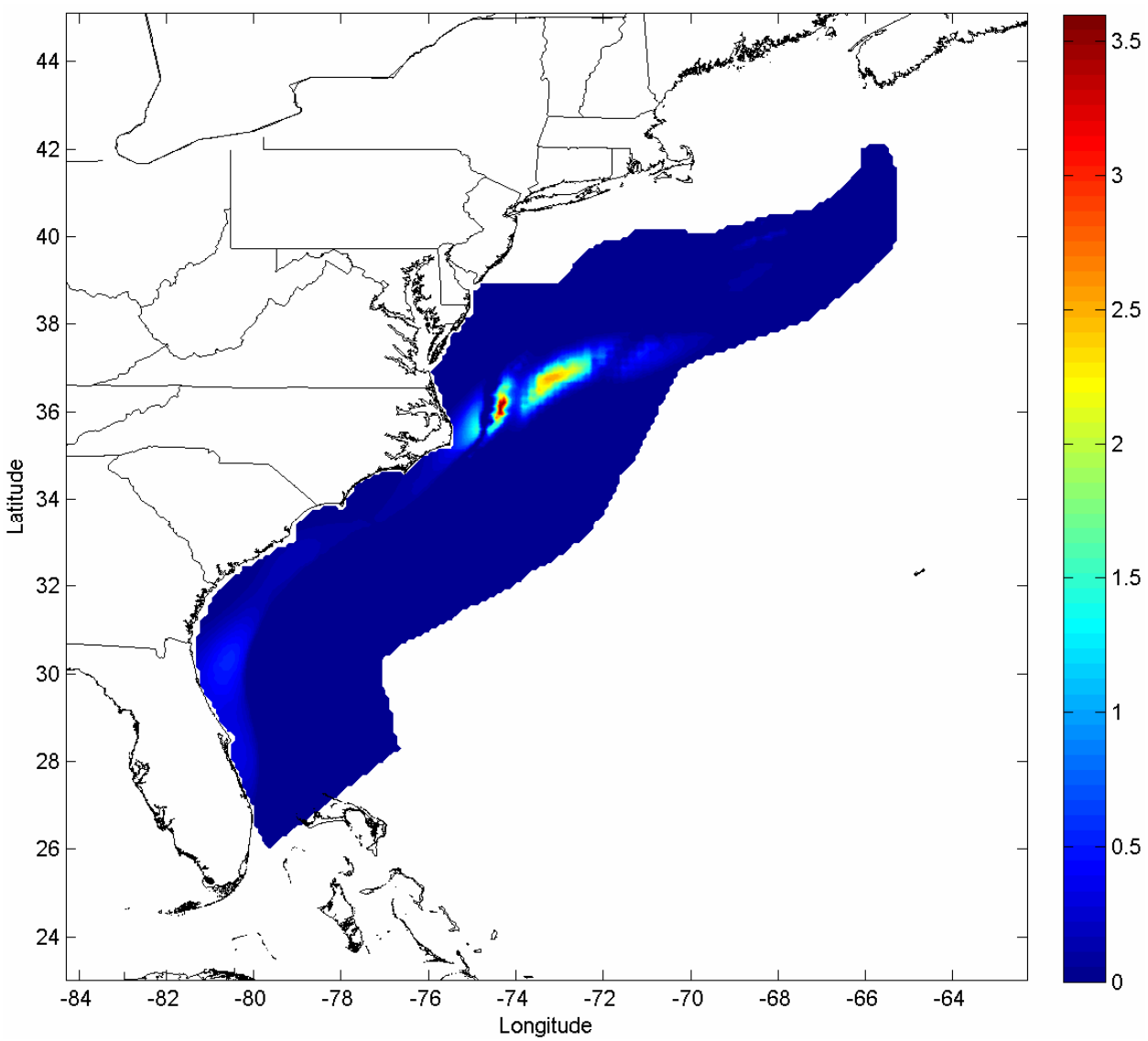

Figure 3-8. Density surface for the Atlantic spotted dolphin during all seasons off the United States Atlantic Coast.

- Striped Dolphin (*Stenella coeruleoalba*)

Distribution and habitat preferences

- Striped dolphins have a worldwide distribution in deep and cool temperate to tropical zones.
- In the western North Atlantic, striped dolphins are generally distributed along the continental shelf break from Cape Hatteras to the southern margin of Georges Bank, as well as offshore over the continental slope and continental rise in the mid-Atlantic region (CETAP 1982; Mullin and Fulling 2003). Striped dolphins are known to associate with the Gulf Stream's northern wall and warm-core ring features (Waring et al. 1992).

Table 3-9. Density surface model results for the striped dolphin by season. These are abundance estimates for the striped dolphin in the Southeast study area.

Season	Abundance
Spring	59,882
Summer	59,882
Fall	59,882
Winter	59,882

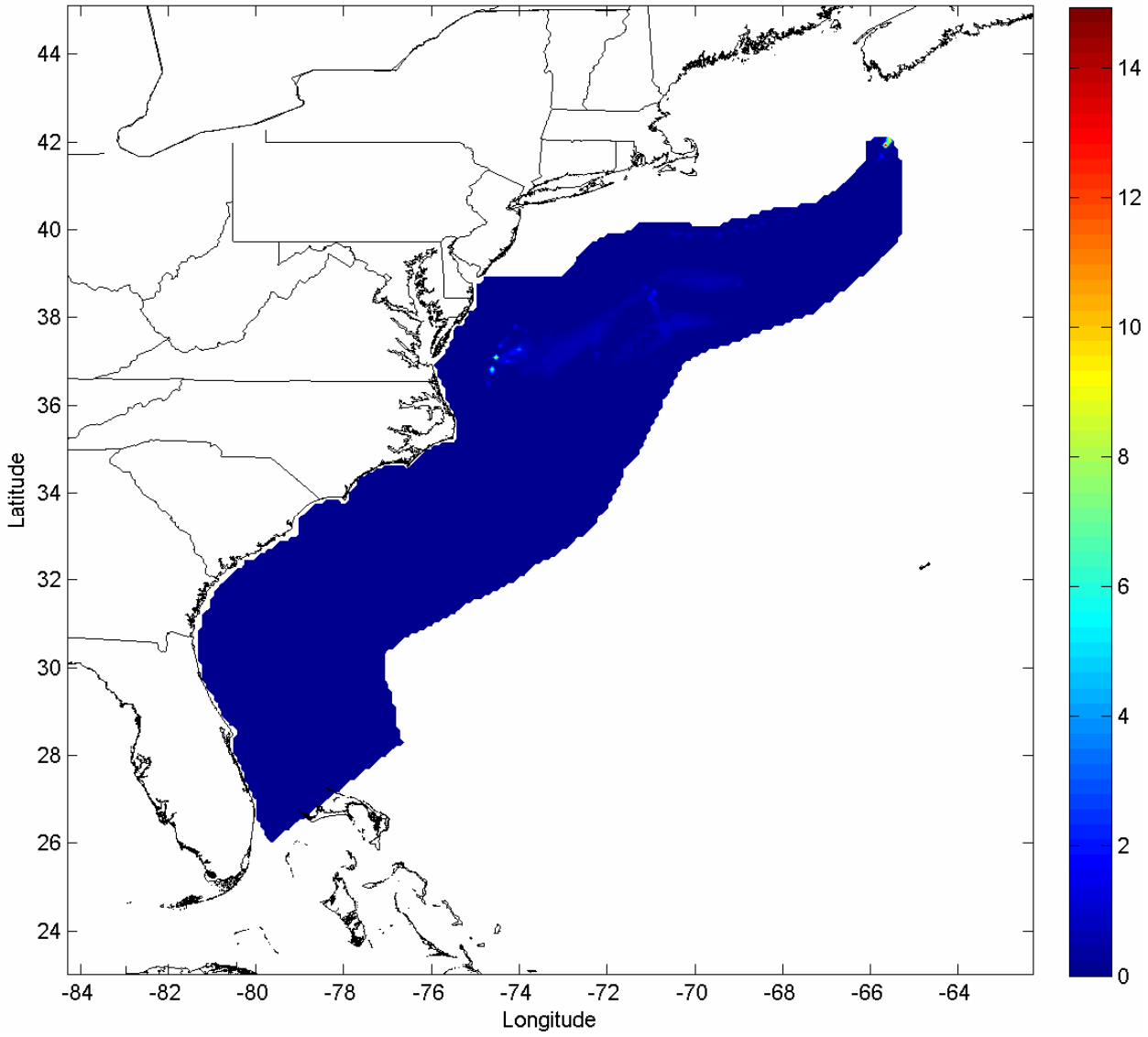

Figure 3-9. Density surface for the striped dolphin during all seasons off the United States Atlantic Coast.

➢ Common Dolphin (*Delphinus delphis*)

Distribution and habitat preferences

- Common dolphins occur from Newfoundland to Florida in the western Atlantic (Perrin 2002b), although this species more commonly occurs in temperate, cooler waters in the northwestern Atlantic (Waring and Palka 2002). Common dolphins are abundant within a broad band paralleling the continental slope from 35°N to the NE peak of Georges Bank.

- Along the U.S. Atlantic Coast, common dolphins typically occur in temperate waters on the continental shelf between the 100 and 200 m isobaths, but can be found in association with the Gulf Stream (CETAP 1982; Selzer and Payne 1988; Waring and Palka 2002).

- Distribution is primarily along the edge of the continental shelf south of 40°N in spring and north of this latitude in fall (Selzer and Payne 1988).

- Common dolphins are less common south of Cape Hatteras; however, sightings have been reported as far south as eastern Florida (Gaskin 1992). Occurrences south of Cape Hatteras should be considered questionable, although there are old records of occurrence off Florida (DoN 2007). Historically, common dolphins frequented the northeastern Florida coast but for unknown reasons have been conspicuously absent since the early 1960s (Caldwell et al. 1971; Leatherwood et al. 1976). Jefferson and Schiro (1997) speculated that this may be a result of population or distributional fluctuations.

Table 3-10. Density surface model results for the common dolphin by season. These are abundance estimates for the common dolphin in the Southeast study area.

Season	Abundance
Spring	29,416
Summer	29,416
Fall	29,416
Winter	29,416

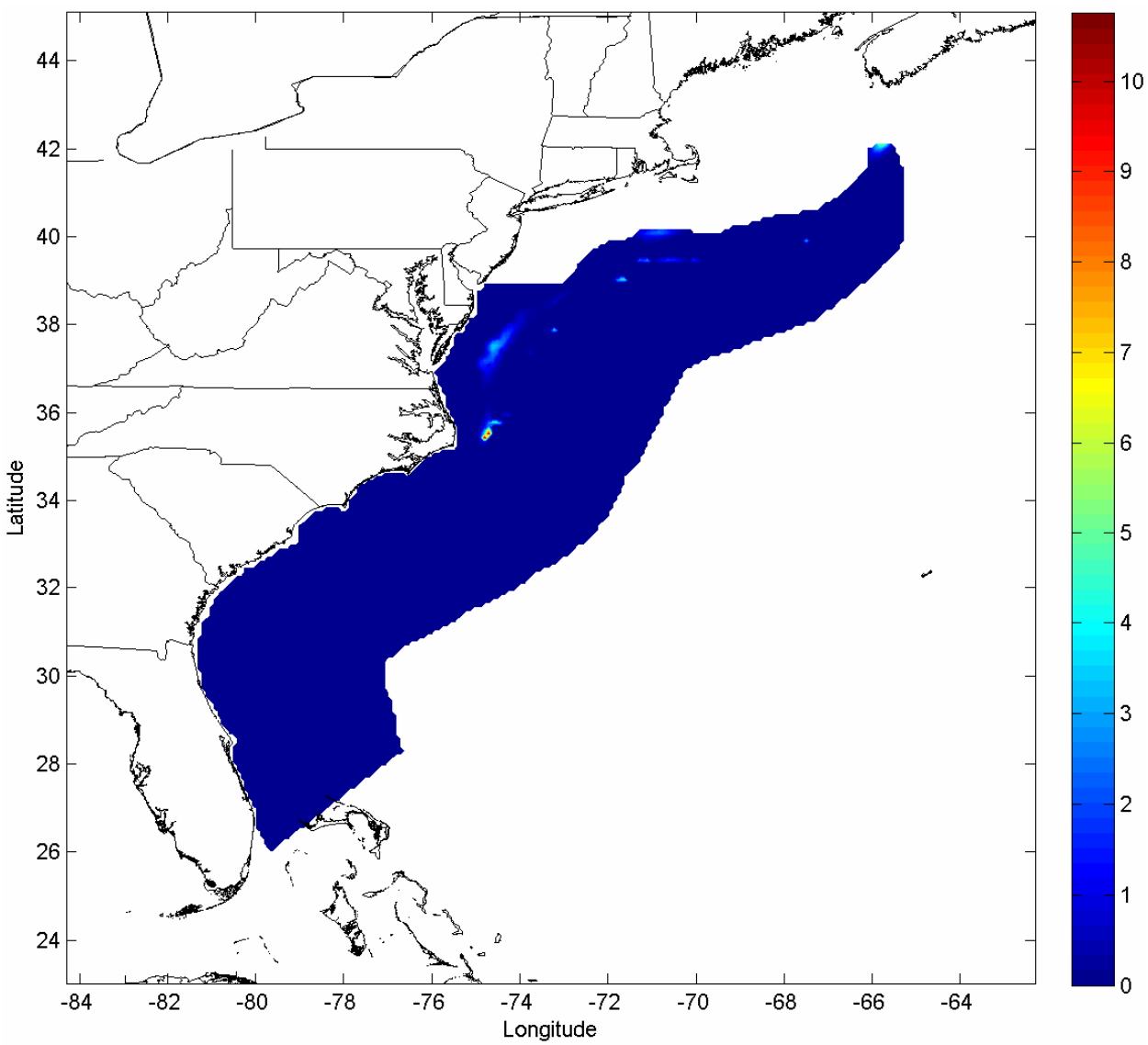

Figure 3-10. Density surface for the common dolphin during all seasons off the United States Atlantic Coast.

➢ Risso's Dolphin (*Grampus griseus*)

Distribution and habitat preferences

- In the western North Atlantic, Risso's dolphins are found from Florida to eastern Newfoundland (Leatherwood et al. 1976; Baird and Stacey 1991).

- Several studies have noted that Risso's dolphins are found primarily offshore, along the continental shelf break, and over the slope (CETAP 1982; Green et al. 1992; Baumgartner 1997; Davis et al. 1998; Mignucci-Giannoni 1998; Kruse et al. 1999). Baumgartner (1997) hypothesized that the fidelity of Risso's dolphins on the steeper portions of the upper continental slope in the GOMEX is most likely the result of cephalopod prey distribution in the same area. Mullin and Fulling (2003) reported sightings over the continental shelf, south of Cape Hatteras, and in waters seaward of the slope, with a bottom depth as shallow as 44 m and as deep as 4,755 m.

- Along the U.S. Atlantic Coast between Cape Hatteras and George's Bank, individuals were distributed along the northern wall of the Gulf Stream and associated with warm-core rings (Waring et al. 1992).

- In general, Risso's dolphins occupy the mid-Atlantic continental shelf year-round (Payne et al. 1984). They are distributed along the continental shelf break from Cape Hatteras north to Georges Bank from March through December (CETAP 1982; Payne et al. 1984). This range extends seaward in the mid-Atlantic Bight from December through February (Payne et al. 1984).

Table 3-11. Density surface model results for the Risso's dolphin by season. These are abundance estimates for the Risso's dolphin in the Southeast study area.

Season	Abundance
Spring	13,835
Summer	13,835
Fall	13,835
Winter	13,835

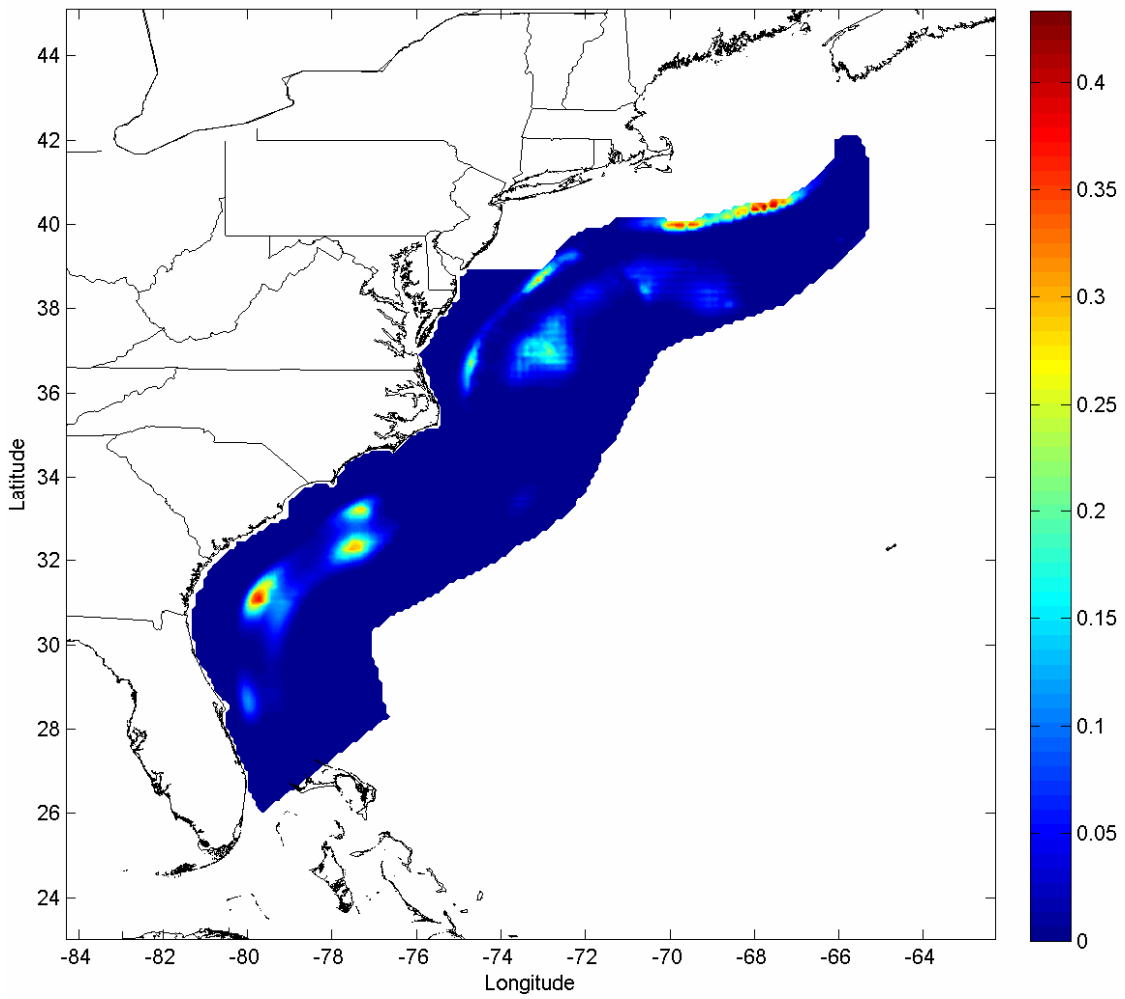

Figure 3-11. Density surface for the Risso's dolphin during all seasons off the United States Atlantic Coast.

- Pilot Whales (*Globicephala* spp.)

The long-finned pilot whale (*Globicephala melas*) and the short-finned pilot whale (*Globicephala macrorhynchus*) comprise this category. These species can be difficult to distinguish from one another in the field.

Distribution and habitat preferences

- The long-finned pilot is considered to occur from Canada to Cape Hatteras, though strandings have been recorded as far south as South Carolina (Waring et al. 2007). The short-finned pilot whale usually does not range north of 50°N or south of 40°S; they are common south of Cape Hatteras (Caldwell and Golley 1965; Irvine et al. 1979), however, stranding as far north as Rhode Island are known.

- The apparent ranges of the two pilot whale species overlap in shelf/shelf-edge and slope waters of the northeastern U.S. between 35°N and 38° to 39°N (New Jersey to Cape Hatteras, North Carolina) (Payne and Heinemann 1993).

- 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). Pilot whales are also associated with the Gulf Stream north wall and thermal fronts along the continental shelf break (Waring et al. 1992; Waring et al. 2007).

- Pilot whales (*Globicephala* sp.) are distributed principally along the continental shelf break off the NE U.S. coast in winter and early spring, (CETAP 1982; Waring et al. 1990; Payne and Heinemann 1993; Abend and Smith 1999; Waring et al. 2007). In late spring, pilot whales move onto Georges Bank and into the GOM and more northern waters, and remain in these areas through late fall (CETAP 1982; Payne and Heinemann 1993; Waring et al. 2007).

- Short-finned pilot whales are widely distributed seaward of the shelf break off the southeastern U.S. (Mullin and Fulling 2003).

Table 3-12. Density surface model results for pilot whales by season. These are abundance estimates for pilot whales in the Southeast study area.

Season	Abundance
Spring	16,332
Summer	17,295
Fall	16,332
Winter	16,332

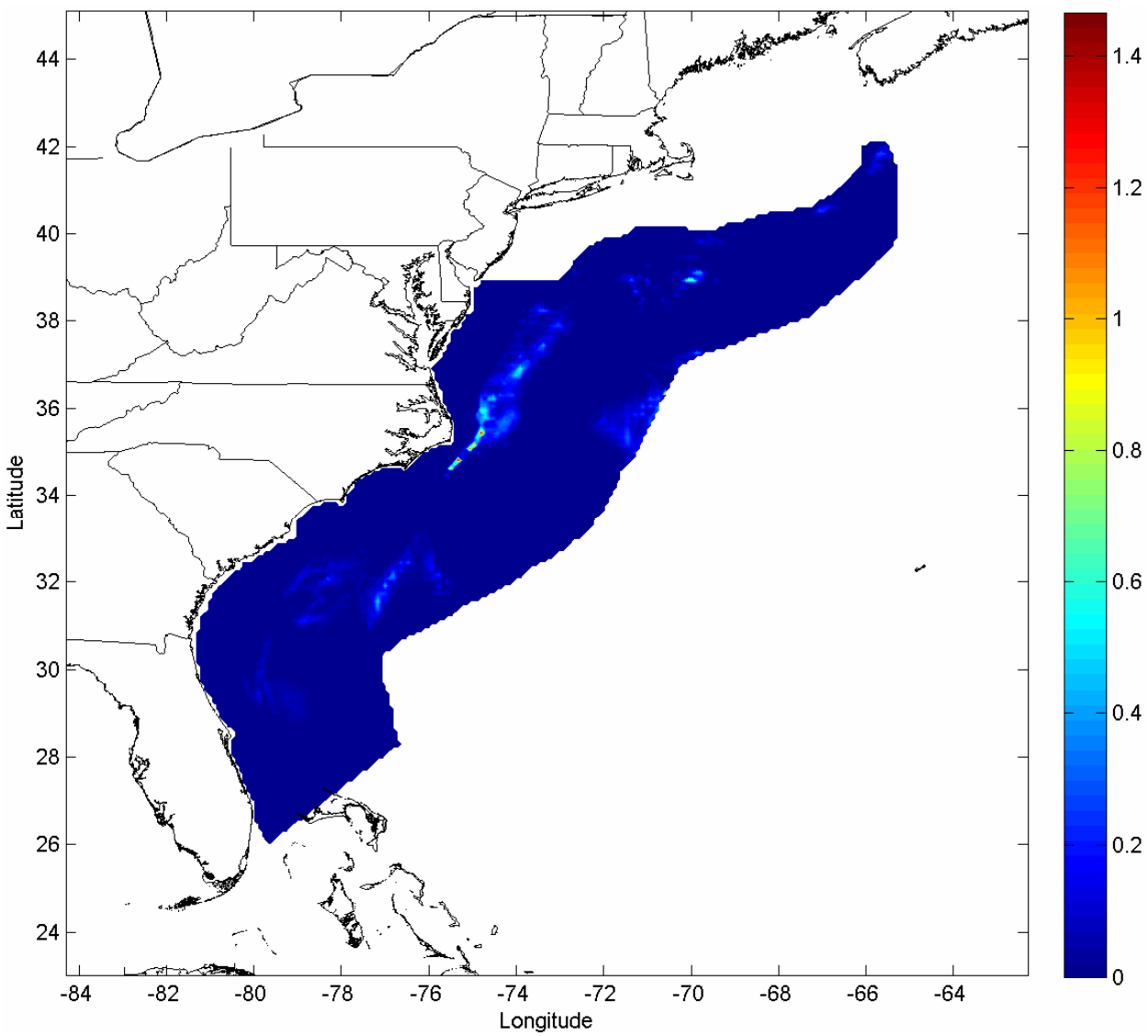

Figure 3-12. Density surface for pilot whales during summer off the United States Atlantic Coast.

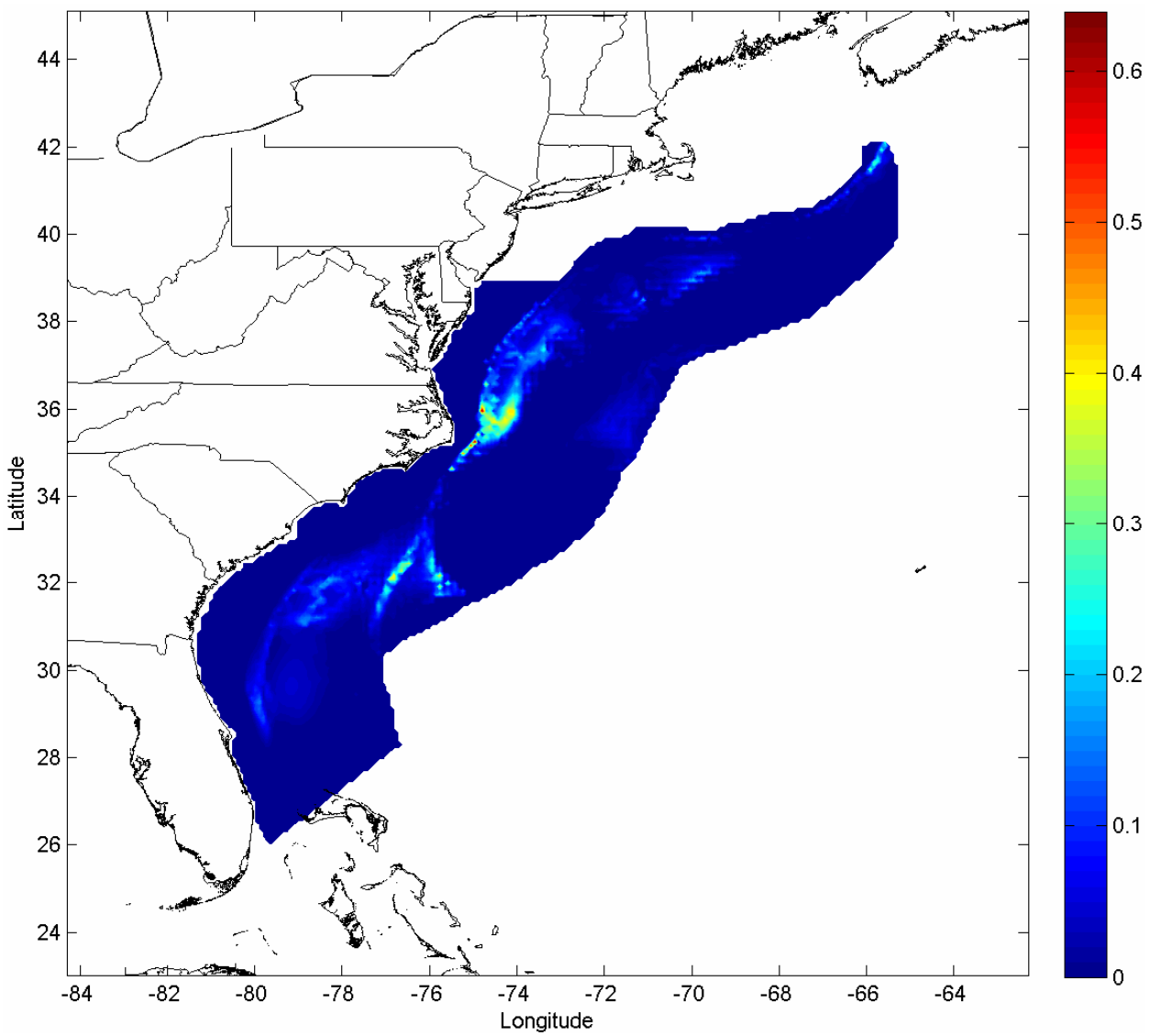

Figure 3-13. Density surface for pilot whales during fall, winter, and spring off the United States Atlantic Coast.

3.1.2 Species with Stock Assessment Report (SAR)-Derived Density Estimates

- North Atlantic Right Whale *(Eubalaena glacialis)*

Density and Abundance Estimate

The North Atlantic right whale was the primary species needing the SAR-derived approach. The approach for handling right whales was to take the abundance estimate of 396 animals (NARWC 2006) and divide that among the four different quartiles from the occurrence polygons found in the NE MRA (DoN 2005b). This was under the assumptions that: 1) 75% of the population was found in the NE OPAREAs study area during spring, summer, and fall and that 50% of the population remained there during the winter; and 2) that each quartile represented 25% of the population found in the area at a given time. Therefore, given these assumptions, density estimates were derived for each season by dividing the number of animals assumed to be in each of the quartile regions by the total area (km^2) of that quartile. The density estimates from Hain and Kenney (2005c; 2005b; 2005a) were used

for each of the three SE OPAREAs of VACAPES, CHPT, and JAX/CHASN (the VACAPES density estimates were extended up to approximately the New York/New Jersey border).

Distribution and habitat preferences

- North Atlantic right whales are found primarily in continental shelf waters between Florida and Nova Scotia (Winn et al. 1986). Although primarily found in waters over the continental shelf, tagging data indicate that individuals also move into deeper waters (Mate et al. 1997). Knowlton et al. (2002) determined that 94% of all right whale sightings and 80% of tagged animal sightings occurred within 30 nautical miles (NM) (56 km) of land. This corresponds to 80% of all sightings within waters with a bottom depth of 90 ft (27 m), with 71% of all sightings in waters with a bottom depth within 60 ft (18 m) of water (Knowlton et al. 2002).

- Right whales may be found in coastal waters off North Carolina, Georgia, and northern Florida from November through March (Winn et al. 1986). The waters off Georgia and northern Florida are the only known calving ground for western North Atlantic right whales; these waters are designated as a critical habitat (NMFS 1994). During the winter, most right whales leave the feeding grounds for either the calving grounds or unknown habitats.

- Right whales in winter calving grounds are most-often found in nearshore regions within cooler sea surface temperatures inshore of a mid-shelf front (Kraus et al. 1993; Ward 1999). High whale densities can extend more northerly than the current defined boundary of the calving critical habitat in response to interannual variability in regional SST distribution (Garrison 2007). During January and February, there is a possible southward shift in whale distribution toward warmer SSTs in the region monitored by the Early Warning System (EWS). However, in the relatively warmer and southernmost survey zone (nearshore waters of Florida), right whales concentrate in the northern, cooler portion (Keller et al. 2006). Warm Gulf Stream waters appear to represent a thermal limit (both southward and eastward) for right whales (Keller et al. 2006).

Table 3-13. Monthly and bi-monthly estimates of abundance for the North Atlantic right whale based on density estimates for this species produced by Hain and Kenney (2005c; 2005b; 2005a).

Time Period	Abundance
January	90
February	112
March	112
April	46
May	9
June	9
July & August	5
September	5
October & November	11
December	112

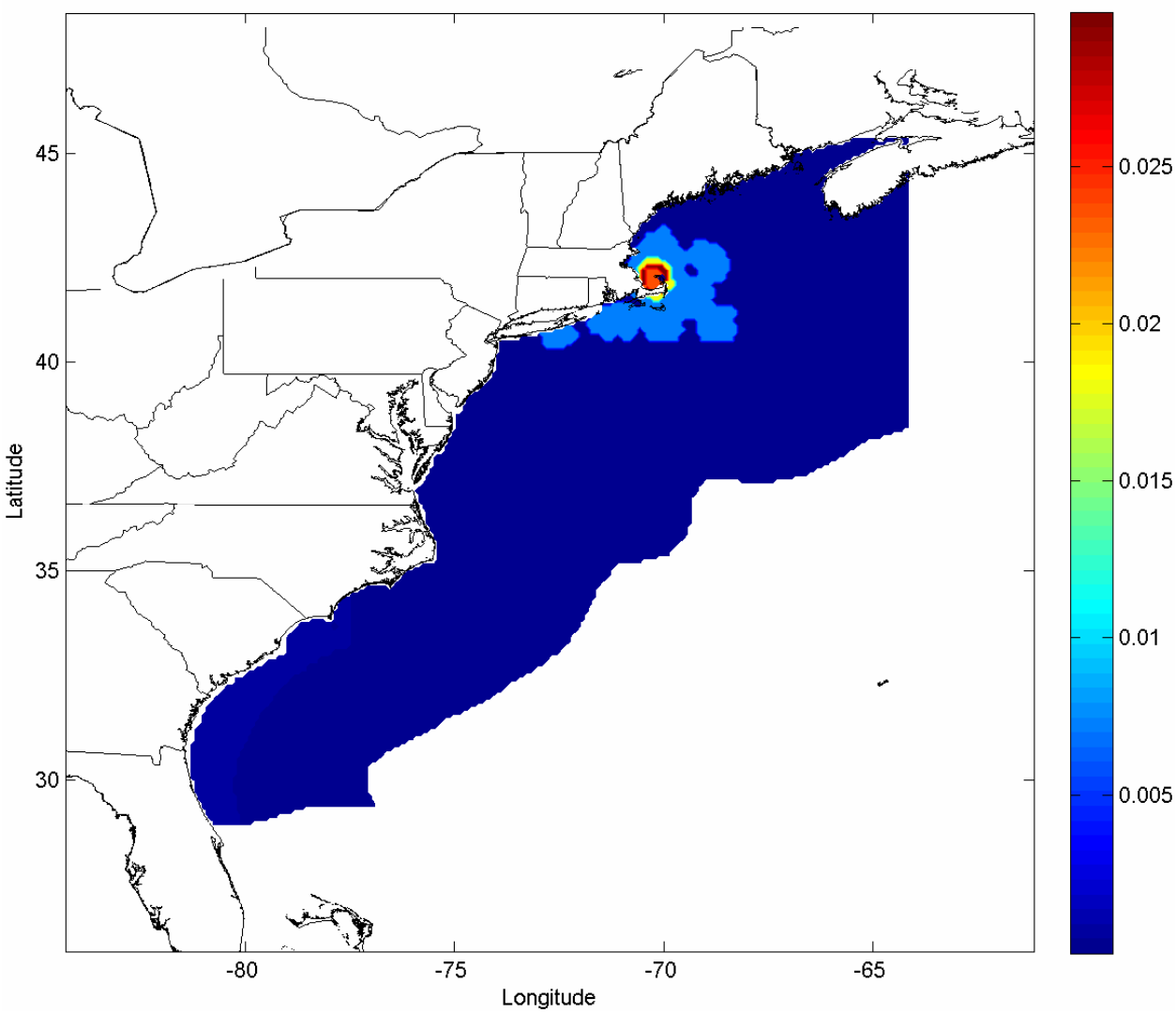

Figure 3-14. Atlantic density surface of the North Atlantic right whale for January based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

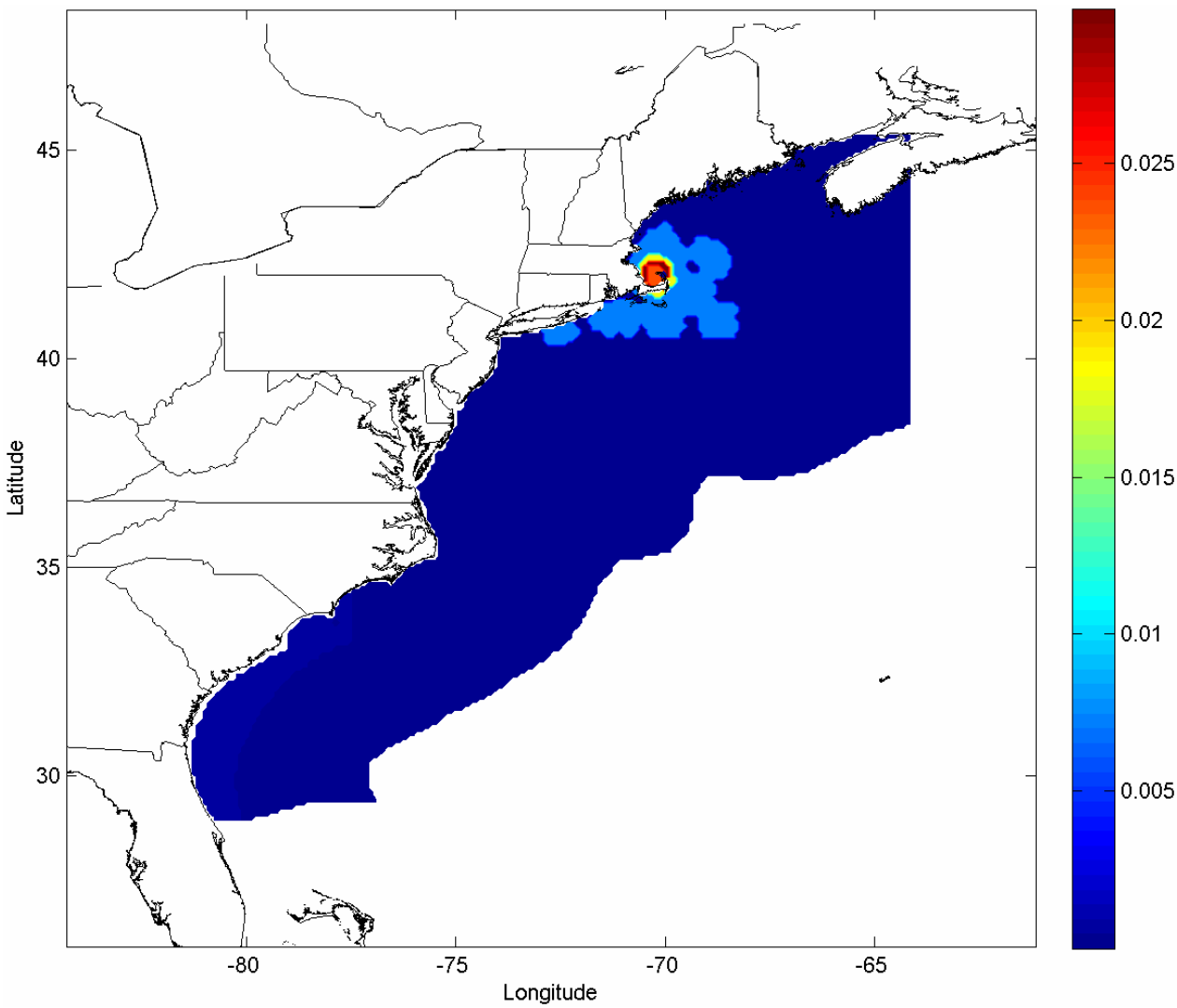

Figure 3-15. Atlantic density surface of the North Atlantic right whale for February based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers. comm., April 2007).

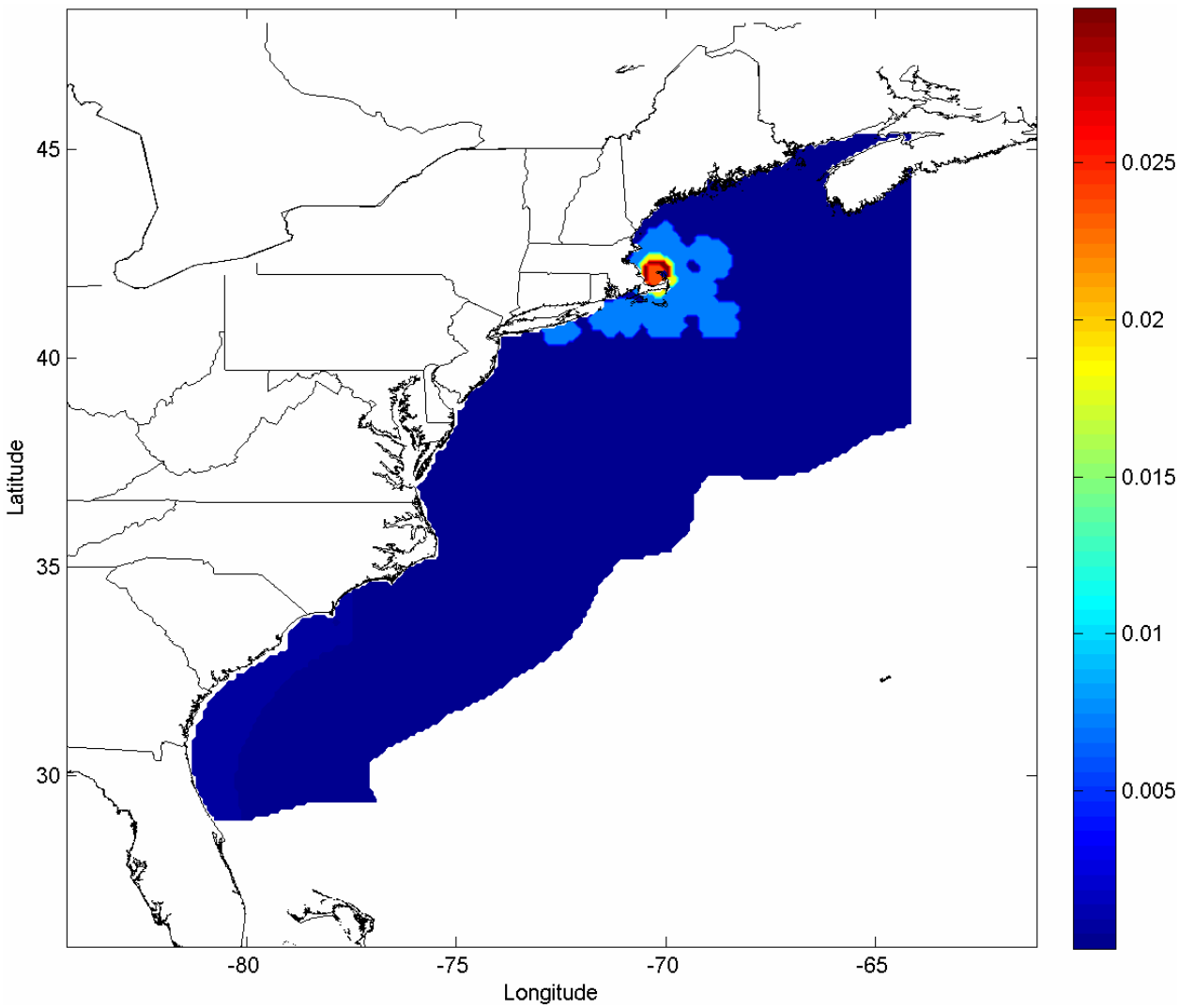

Figure 3-16. Atlantic density surface of the North Atlantic right whale for March based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers. comm. ,April 2007).

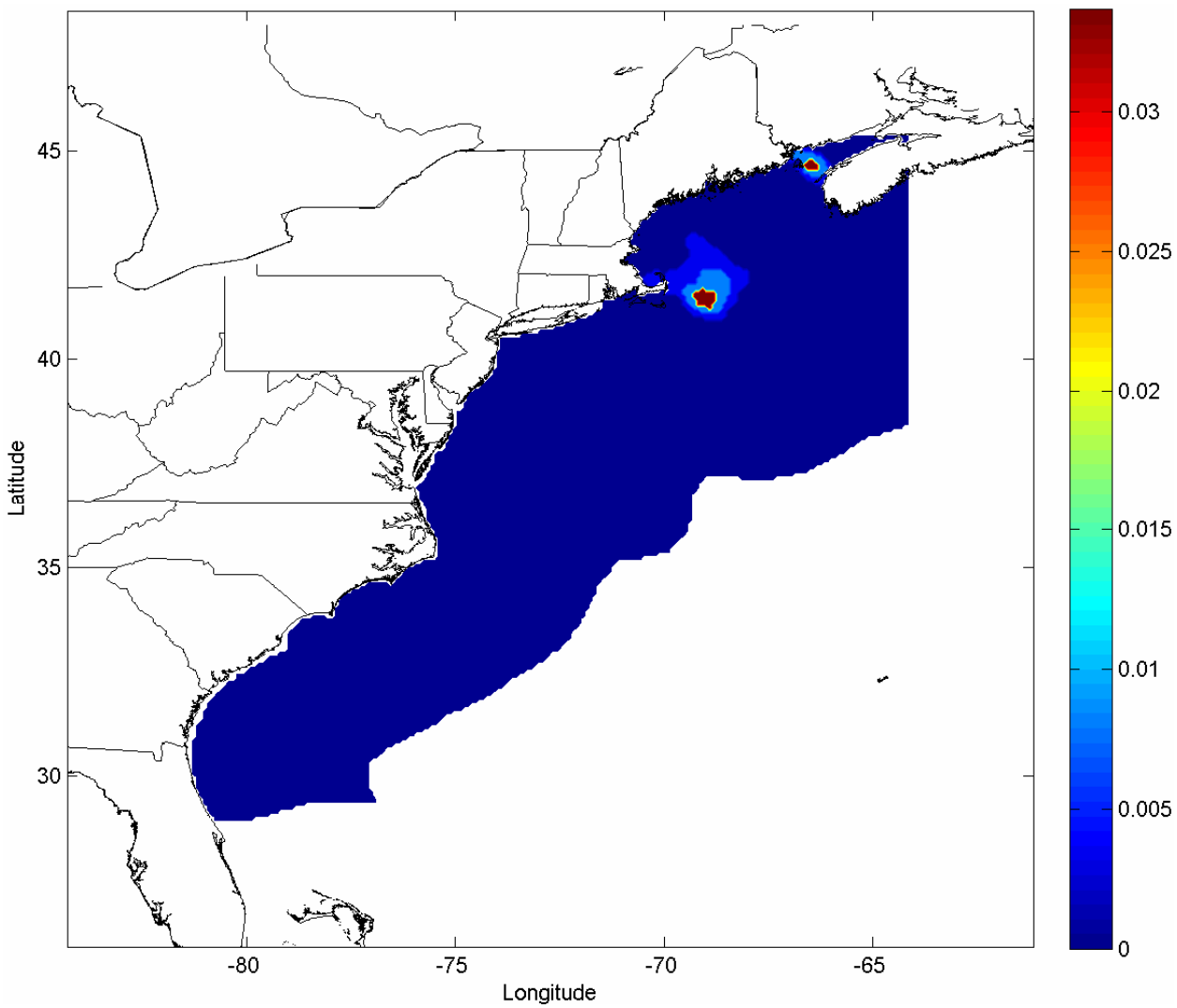

Figure 3-17. Atlantic density surface of the North Atlantic right whale for April based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

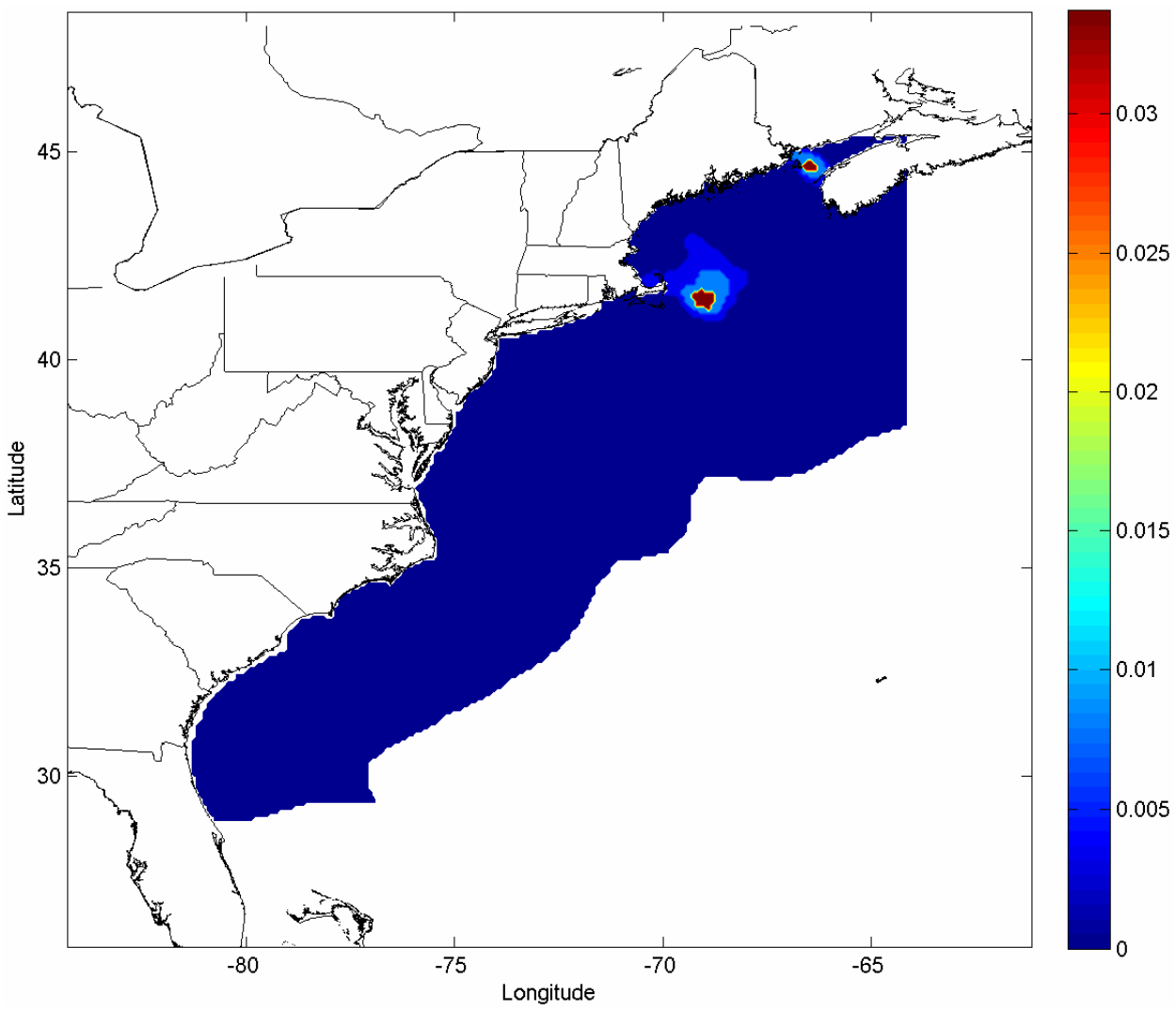

Figure 3-18. Atlantic density surface of the North Atlantic right whale for May based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

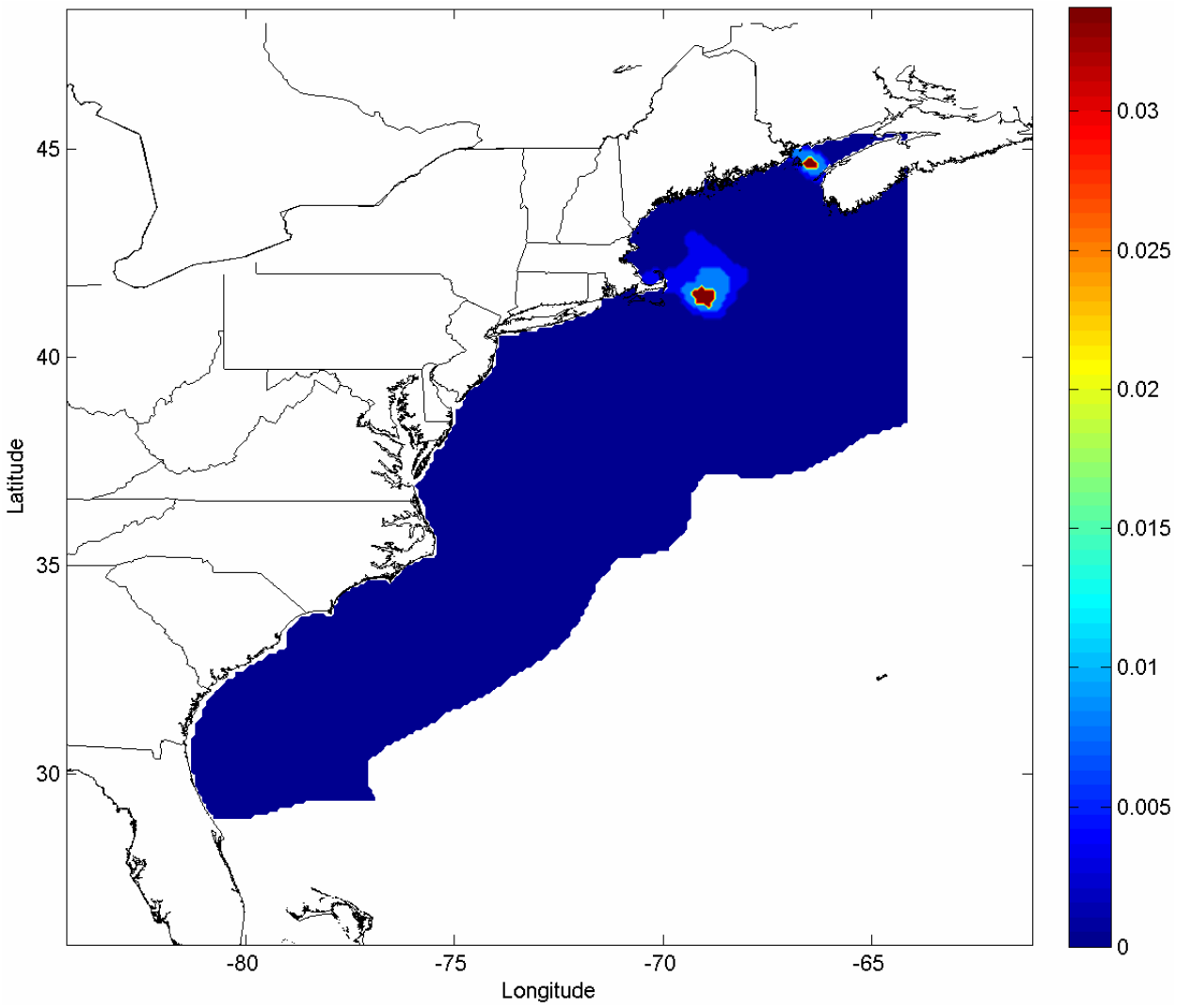

Figure 3-19. Atlantic density surface of the North Atlantic right whale for June based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

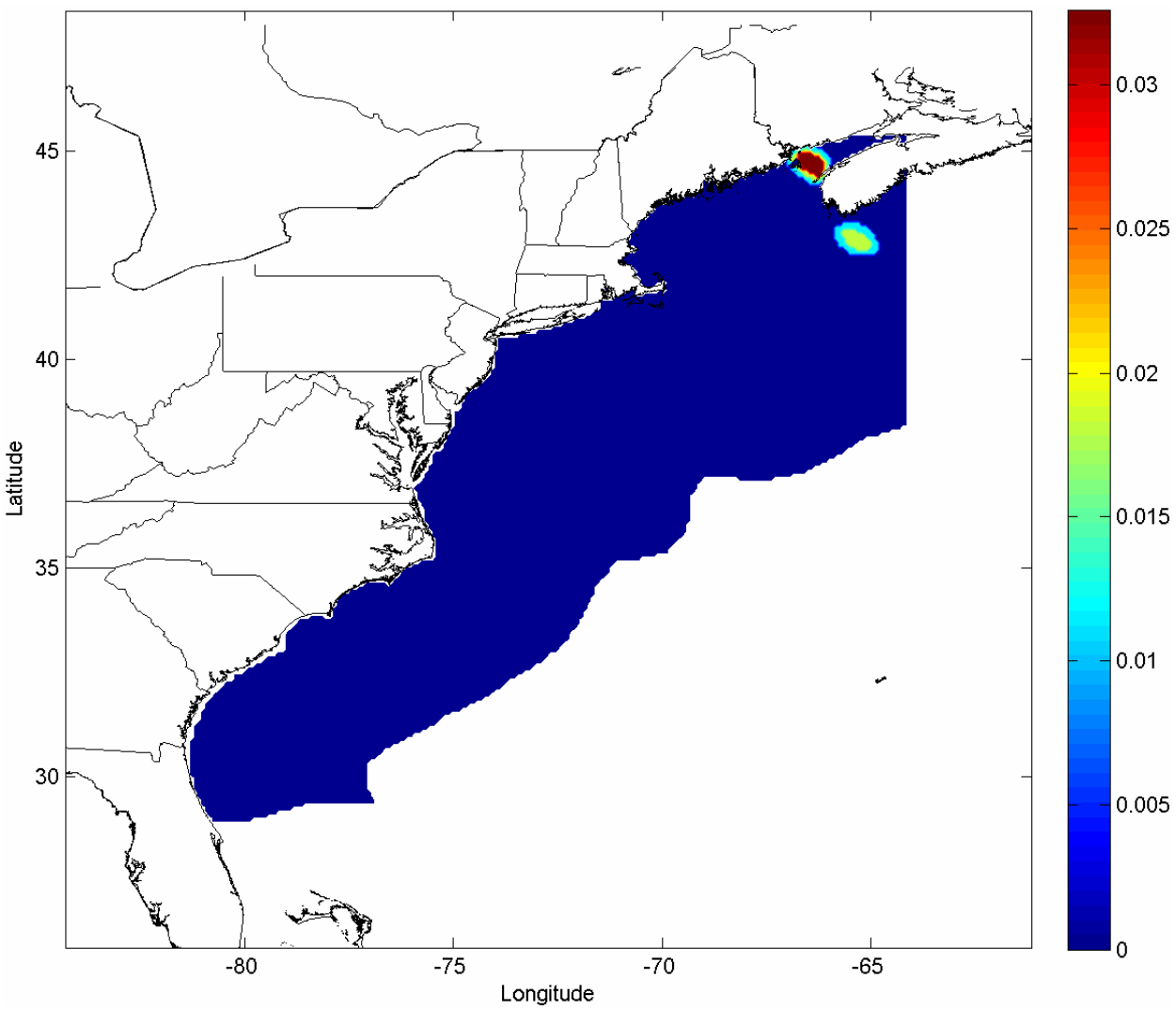

Figure 3-20. Atlantic density surface of the North Atlantic right whale for July and August based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

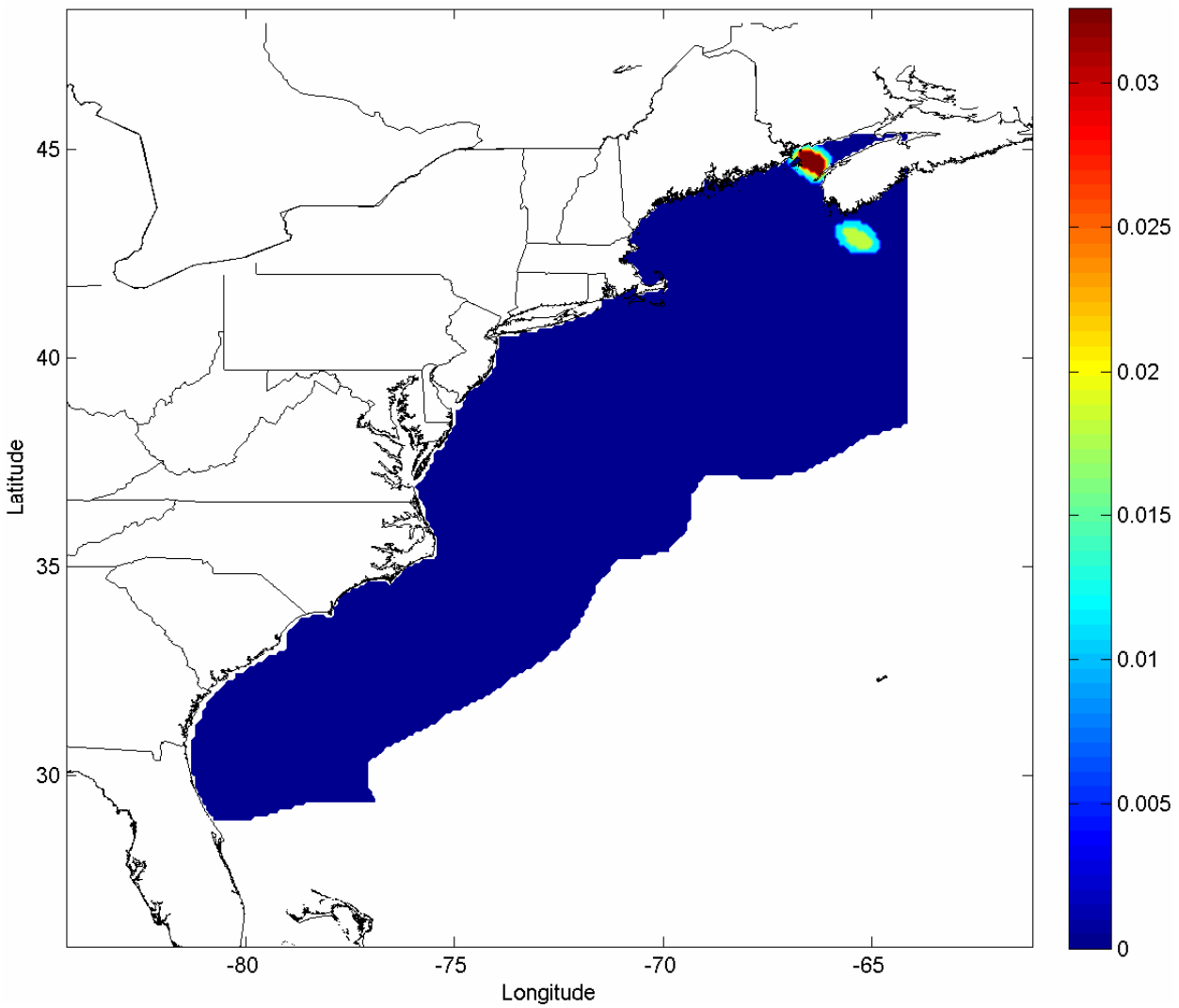

Figure 3-21. Atlantic density surface of the North Atlantic right whale for September based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

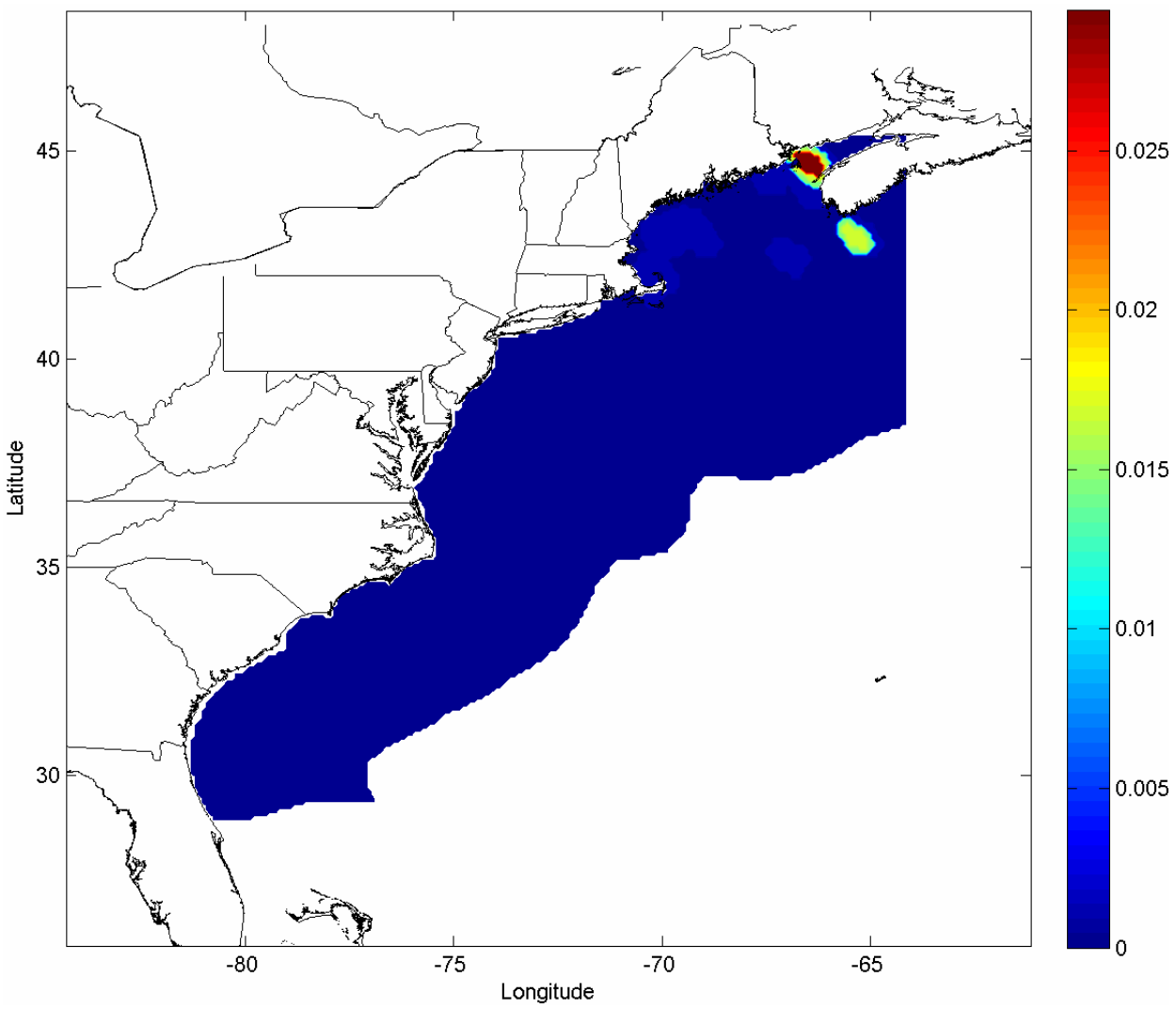

Figure 3-22. Atlantic density surface of the North Atlantic right whale for October and November based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

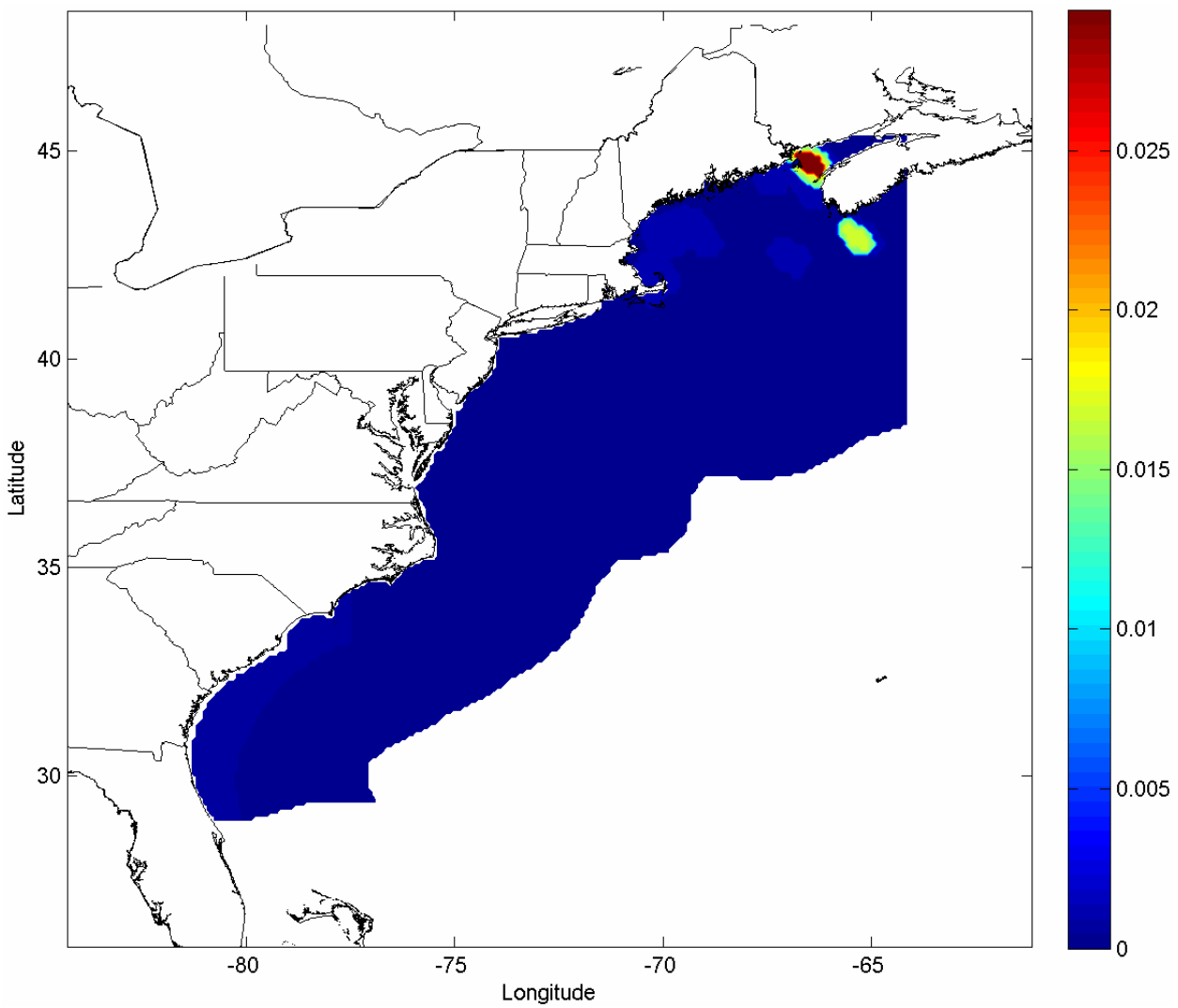

Figure 3-23. Atlantic density surface of the North Atlantic right whale for December based on Southeast Marine Resource Assessment polygons (DoN 2001; 2002c; 2002b) and Dr. Robert Kenney (Kenney, R., University of Rhode Island, pers, comm., April 2007).

➢ Humpback Whale (*Megaptera novaeangliae*)

Density and Abundance Estimate

The humpback whale estimates were based on the GOM SAR estimate of 902 animals and is the only abundance estimate which is appropriate to use for the SE OPAREAs. This estimate was seasonally partitioned along the U.S. Atlantic coast considering the species migration patterns to and from the calving grounds in the Caribbean. The partitions were: 100% of the whales in fall and spring, 50% of the whales in winter, and 0% whales in summer.

Distribution and habitat preferences

- The largest numbers of humpbacks occur off the northeastern U.S. from mid-April to mid-November on the feeding grounds (NMFS 1991). The GOM is one of the principal summer feeding grounds for humpback whales in the North Atlantic.

- During the winter, most of the North Atlantic population of humpback whales is believed to migrate south to calving grounds in the West Indies region; however, sightings are still made during this time of the year off the northeastern U.S. Humpbacks may be found along the continental shelf from the southern GOM to Virginia during this time of year (Whitehead and Moore 1982; Stevick et al. 2003).

- There has been an increasing occurrence of humpbacks, which appear to be primarily juveniles, during the winter along the U.S. Atlantic Coast, from Florida north to Virginia (Clapham et al. 1993; Swingle et al. 1993; Wiley et al. 1995; Laerm et al. 1997; Barco et al. 2002) (Pitchford 2006-pers comm.). Strandings of humpbacks (mainly juveniles) in this area have also increased in recent years (Wiley et al. 1995). These occurrences are not fully understood. They might be due to shifts in distribution, increases in sighting effort, or habitat that is becoming increasingly important for juveniles (Waring et al. 2007). Sighting histories of mature humpback whales suggest that the mid-Atlantic area contains a greater percentage of mature animals than is represented by strandings (Barco et al. 2002). It has recently been proposed that the mid-Atlantic region primarily represents a supplemental winter feeding ground, which is also an area of mixing of humpback whales from different feeding stocks (Barco et al. 2002).

- Exact migratory routes are not known; however, it is presumed that whales travel more direct routes in deeper, offshore waters since large numbers of humpback whales are not observed close to shore during this time (Smith et al. 1999; Reeves et al. 2004). Historical whaling records also suggest a significant abundance of humpback whales throughout deep waters off southeastern Florida (Townsend 1935).

- Although humpback whales typically travel over deep, oceanic waters during migration, their feeding and breeding habitats are mostly in shallow, coastal waters over continental shelves (CETAP 1982; Payne et al. 1990a; Payne et al. 1990b; Clapham and Mead 1999; Hamazaki 2002).

Table 3-14. Abundance estimates for the humpback whale by season in the Southeast study area.

Season	Abundance
Spring	902
Summer	0
Fall	902
Winter	451

➢ Minke Whale (*Balaenoptera acutorostrata*)

Distribution and habitat preferences

- Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 1993); they are less common in the tropics than in cooler waters. This species is most abundant in New England waters rather than the mid-Atlantic U.S. (Hamazaki 2002; Waring et al. 2007). Minke whales are only occasionally found, and on a widely-scattered basis, in the mid-Atlantic area (CETAP 1982). The southernmost sighting in recent NMFS surveys was of one individual offshore of the mouth of Chesapeake Bay in waters with a bottom depth of 3,475 m (Mullin and Fulling 2003).

- There appears to be a strong seasonal component to minke whale distribution in waters off the northeastern coast of the U.S. Spring and summer are times of relatively widespread and common occurrence; minke whales are most abundant in New England waters during this time of

year (Waring et al. 2007). During the winter months (November through March), minke whales are known to occur in the southwestern region of the North Atlantic including the area from Bermuda to the West Indies (Mitchell 1991). The winter distribution in the southern part of the western North Atlantic is supported by acoustics data (Clark 1995; Clark and Gagnon 2004).

- Off eastern North America, the minke whale generally prefers waters over the continental shelf, including inshore bays and estuaries, and slope waters (Mitchell and Kozicki 1975; Waring and Palka 2002; Waring et al. 2007).

- Based on whaling catches and surveys worldwide, there is also a deep-ocean component to the minke whale's distribution (Slijper et al. 1964; CETAP 1982; Horwood 1990; Mitchell 1991; Waring et al. 2007).

Density and abundance estimates

- The only abundance estimate provided in the SAR (Waring et al. 2007) for minke whale pertained to the east coast of Canada. Rather than assume an estimate of zero for the study area, an abundance estimate for minke whales was obtained from Mullin and Fulling (2003). The abundance estimate provided in that document was 20 animals and for the purpose of this report, that estimate is being applied to the entire SE study area and across all seasons.

➢ *Kogia* spp.

There are two *Kogia* species: pygmy sperm whale (*Kogia breviceps*) and dwarf sperm whale (*Kogia sima*).

Distribution and habitat preferences

- In the western North Atlantic Ocean, *Kogia* are known to occur as far north as the northern Gulf of St. Lawrence, Quebec, Canada (Measures et al. 2004).

- 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; Fulling and Fertl 2003; MacLeod et al. 2004; Baird 2005). Sightings over the continental shelf are known from the nearby GOMEX (Fulling and Fertl 2003). Mullin and Fulling (2003) reported sighting *Kogia* spp. in waters with a bottom depth of 766 to 4,079 m.

Density and abundance estimates

- The abundance estimate for *Kogia* was obtained from the SAR (Waring et al. 2007). The "best" estimate provided for this species group was 395 animals. For the purpose of this report, this estimate was applied to the entire SE study area and across all seasons.

➢ Rough-toothed Dolphin *(Steno bredanensis)*

Distribution and habitat preferences

- Rough-toothed dolphins occur in warm-temperate and tropical waters of all major oceans, rarely ranging north of 40ºN or south of 35ºS (Miyazaki and Perrin 1994). In most areas where the species is known to occur, individuals are infrequently encountered (Jefferson 2002b).

- The rough-toothed dolphin is generally regarded as a deepwater species, though it can occur in waters with variable bottom depths. For example, in the nearby GOMEX, the rough-toothed dolphin occurs primarily over the deeper waters off the continental shelf (Davis et al. 1998; Mullin et al. 2004) though off the Florida Panhandle, this species can be found over the continental shelf

(R. Wells et al. 1999; Fulling et al. 2003; Mullin et al. 2004). Four stranded rough-toothed dolphins (three with satellite-linked transmitters) were rehabilitated and released in 1998 off the Gulf Coast of Florida (R. Wells et al. 1999). Bottom depth at tracking locations of these individuals averaged 195 m off the Florida Panhandle (R. Wells et al. 1999).

- Stranded and rehabilitated individuals were released with tags off the Atlantic Coast of Florida in March 2005. These rough-toothed dolphins moved within the Gulf Stream and parallel to the continental shelf off Florida, Georgia, and South Carolina, in waters with a bottom depth of 400 to 800 m. They later moved NE into waters with a bottom depth greater than 4,000 m (Manire and Wells 2005).

- In April 2005, two dolphins from the March 2005 mass stranding in the Florida Keys were released by the Marine Animal Rescue Society off Miami, one with a satellite-linked transmitter (Wells, R.S., Mote Marine Laboratory, pers. comm., 29 January 2007). The tagged animal moved north as far as Charleston, South Carolina, before returning to the Miami area, remaining in relatively shallow waters (Wells, R.S., Mote Marine Laboratory, pers. comm., 29 January 2007).

- 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.S., 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.S., Mote Marine Laboratory, pers. comm., 29 January 2007). The last signal placed them NE of the Lesser Antilles (Wells, R.S., Mote Marine Laboratory, pers. comm., 29 January 2007).

- When compared to individuals tagged and released in the northeastern GOMEX in 1998, rough-toothed dolphins tagged and released off the Atlantic coast of Florida in 2005 demonstrated a preference for cooler (and deeper) waters (Manire and Wells 2005). The Gulf dolphins remained in waters with an average SST of 25°C. The individuals from the Atlantic remained in waters that averaged 19°C.

Density and abundance estimates

- No abundance estimates have been provided in the SAR (Waring et al. 2007) for the rough-toothed dolphin along the east coast of U.S. Instead of assuming no occurrence for this species in the study area, an abundance estimate for rough-toothed dolphin was obtained from Mullin and Fulling (2003). The abundance estimate provided in that document was 274 animals and for the purpose of this report, that estimate is being applied to the entire SE study area and across all seasons.

➢ Pantropical Spotted Dolphin (*Stenella attenuata*)

Distribution and habitat preferences

- Pantropical spotted dolphins are primarily seen between the 40° latitudes (Perrin 2001), though occurrence records are known as far north as Massachusetts in the western North Atlantic Ocean. Mullin and Fulling (2003) reported sighting pantropical spotted dolphins primarily in the southern portion of their U.S. mid/south-Atlantic study area (i.e., Blake Plateau).

- This species shows a preference for waters beyond the continental shelf break (e.g., Davis et al. 1998; Baumgartner et al. 2001; Moreno et al. 2005). Mullin and Fulling (2003) found pantropical spotted dolphins in waters with a bottom depth ranging from 598 to 5,030 m.

- Off the U.S. Atlantic Coast, there are *Stenella* sightings associated with the Gulf Stream (Waring et al. 1992; Mullin and Fulling 2003).

Density and abundance estimates

- The abundance estimate for the pantropical spotted dolphin was obtained from the SAR (Waring et al. 2007). The "best" estimate provided for the species group was 4,439 animals. For the purpose of this report, this estimate was applied to the entire SE study area and across all seasons.

➢ Clymene Dolphin (*Stenella clymene*)

Distribution and habitat preferences

- The Clymene dolphin is endemic to the tropical and warm temperate waters of the Atlantic Ocean (Jefferson 2002a). Off the U.S. Atlantic Coast, the Clymene dolphin occurs from New Jersey to Florida (Fertl et al. 2003). Mullin and Fulling (2003) reported that sightings of Clymene dolphins were primarily in offshore waters east of Cape Hatteras over the continental slope.

- Clymene dolphins are considered to have an exclusively oceanic distribution, with a mean bottom depth of 1,870 m and as far offshore as the 4,500 m isobath (Fertl et al. 2003).

- The Clymene dolphin is biogeographically influenced by the warm waters of the Gulf Stream (Fertl et al. 2003; Mullin and Fulling 2003).

Density and abundance estimates

- The "best" estimate of abundance for this species, as listed in the SAR, is 6,086 animals (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 SE study area and across all seasons.

3.1.3 Species for Which Density Estimates Are Not Available

For some species or species groups, there was no density estimate available at all or it was not possible to derive one based on the available abundance estimates.

➢ Blue Whale *(Balaenoptera musculus)*

Distribution and habitat preferences

- Stranding and sighting data suggest that the blue whale's original Atlantic range extended south to Florida, the GOMEX, the Cape Verde Islands, and the Caribbean Sea (Yochem and Leatherwood 1985).

- Blue whales rarely occur in the EEZ and the GOM from August to October, which may represent the limits of their feeding range (CETAP 1982; Wenzel et al. 1988). Researchers using Navy-integrated undersea surveillance system (IUSS) resources have more recently been able to detect blue whales throughout the open Atlantic south to at least The Bahamas (Clark 1995; Clark and Gagnon 2004).

- Blue whales in the Atlantic are primarily found in deeper, offshore waters and are rare in shallower, shelf waters (Wenzel et al. 1988).

Density and abundance estimates

- As noted in the NOAA SAR (Waring et al. 2007), there is insufficient data to estimate abundance of the blue whale off the U.S. Atlantic Coast. Therefore, density estimates for this species could not be generated.

➢ Sei Whale *(Balaenoptera borealis)*

Distribution and habitat preferences

- Sei whales are found primarily in cold temperate to subpolar latitudes rather than in the tropics or near the poles (Horwood 1987). Sei whales spend the summer months feeding in the subpolar higher latitudes and return to the lower latitudes to calve in the winter. For the most part, the location of winter breeding areas for the species remains a mystery (Rice 1998; Perry et al. 1999).

- In the western North Atlantic Ocean, the Nova Scotia Stock of the sei whale occurs primarily from Georges Bank north to Davis Strait (NE Canada, between Greenland and Baffin Island) (NE Canada, between Greenland and Baffin Island; Perry et al. 1999; Waring et al. 2007) but may be distributed as far south as North Carolina (NMFS 1998).

- The hypothesis is that the Nova Scotia stock moves from spring feeding grounds on or near Georges Bank, to the Scotian Shelf in June and July, eastward to perhaps Newfoundland and the Grand Banks in late summer, then back to the Scotian Shelf in fall, and offshore and south in winter (Mitchell and Chapman 1977).

- Sei whales are not common in U.S. waters (NMFS 1998); peak abundance here occurs from winter through spring (mid-March through mid-June), primarily around the edges of Georges Bank (CETAP 1982; Stimpert et al. 2003).

- Sei whales are known for occasional irruptive occurrences in areas followed by disappearances for sometimes decades (Horwood 1987; Schilling et al. 1992; Clapham et al. 1997; Gregr et al. 2005).

- The sei whale prefers regions of steep bathymetric relief, such as the continental shelf break, canyons, or basins situated between banks and ledges (Kenney and Winn 1987; Schilling et al. 1992; Gregr and Trites 2001; Best and Lockyer 2002). These areas are often the location of persistent hydrographic features, which may be important factors in concentrating prey, especially copepods.

- On the feeding grounds, the distribution is largely associated with oceanic frontal systems (Horwood 1987). Characteristics of preferred breeding grounds are unknown. Horwood (1987) noted that sei whales prefer oceanic waters and are rarely found in marginal seas; historical whaling catches were usually from deepwater, and land station catches were usually taken from along or just off the edges of the continental shelf.

Density and abundance estimates

- Despite the fact that sei whales may occur as far south as the study area, they were not recorded during NMFS surveys. Also, as noted in the NOAA SAR (Waring et al. 2007), the age of the data precludes the use of the available data to estimate abundance of the sei whale off the U.S. Atlantic Coast (see Wade and Angliss 1997 for discussion of age of data issues). Therefore, density estimates for this species could not be generated.

- Bryde's Whale *(Balaenoptera brydei/edeni)*

Distribution and habitat preferences

- Bryde's whales are found in subtropical and tropical waters and generally do not range north or south of 40° in either hemisphere (Jefferson et al. 1993). Bryde's whales are more restricted to tropical and subtropical waters than other rorquals.

- Bryde's whales are found in many offshore and nearshore regions. In the nearby GOMEX, all Bryde's whale sightings have been near the shelf break in DeSoto Canyon (Davis et al. 2002). In other locales, Bryde's whales are sometimes seen very close to shore and even inside enclosed bays (Best et al. 1984).

Density and abundance estimates

- This species is not listed in the NOAA SAR (Waring et al. 2007), though there are occurrence records in the SE study area. There is insufficient data to estimate abundance of the blue whale off the U.S. Atlantic Coast; therefore, density estimates for this species could not be generated.

- Killer Whale *(Orcinus orca)*

Distribution and habitat preferences

- Killer whale occurrence in the western North Atlantic is unpredictable (e.g., Katona et al. 1988; Waring et al. 2007), though (Katona et al. 1988) reported a regular occurrence south of 35ºN (Katona et al. 1988).

- Globally, killer whales can be found in the open sea, as well as in coastal areas (Dahlheim and Heyning 1999). In the western North Atlantic, they are primarily found along the shelf break and farther offshore (Katona et al. 1988; Mitchell and Reeves 1988).

- Killer whales in the western North Atlantic do occur in fishing areas, perhaps coincident with tuna, in warm seasons (e.g., Katona et al. 1988; Waring et al. 2007).

Density and abundance estimates

- As noted in the NOAA SAR (Waring et al. 2007), there is insufficient data to estimate abundance of the killer whale off the U.S. Atlantic Coast. Therefore, density estimates for this species could not be generated.

- Pygmy Killer Whale *(Feresa attenuata)*

Distribution and habitat preferences

- Pygmy killer whales have a worldwide distribution in tropical and subtropical waters, generally not ranging north of 40ºN or south of 35ºS (Jefferson et al. 1993). There are few confirmed records of this species in the western North Atlantic (Caldwell and Caldwell 1971; Ross and Leatherwood 1994).

- Pygmy killer whales generally occupy offshore habitats. In the nearby northern GOMEX, this species is found primarily in deeper waters off the continental shelf out to waters over the abyssal plain (Davis and Fargion 1996; Davis et al. 2000).

Density and abundance estimates

- As noted in the NOAA SAR (Waring et al. 2007), there is insufficient data to estimate abundance of the pygmy killer whale off the U.S. Atlantic Coast. Therefore, density estimates for this species could not be generated.

➢ False Killer Whale *(Pseudorca crassidens)*

Distribution and habitat preferences

- False killer whales are found in tropical and temperate waters, generally between 50°S and 50°N latitude with a few records north of 50°N in the Pacific and the Atlantic (Baird et al. 1989; Odell and McClune 1999).

- This species is found primarily in oceanic and offshore areas. Most sightings in the nearby GOMEX have been made in oceanic waters with a bottom depth greater than 200 m, although there are some sightings in waters over the continental shelf (Davis and Fargion 1996).

Density and abundance estimates

- As noted in the NOAA SAR (Waring et al. 2007), there is insufficient data to estimate abundance of the false killer whale off the U.S. Atlantic Coast. Therefore, density estimates for this species could not be generated.

➢ Melon-headed Whale *(Peponocephala electra)*

Distribution and habitat preferences

- Melon-headed whales are found worldwide in deep subtropical and tropical waters. There are very few records of melon-headed whales in the North Atlantic (Jefferson and Barros 1997).

- Melon-headed whales are most often found in offshore waters. Most sightings in the GOMEX have been well beyond the continental shelf break (Mullin et al. 1994; Davis and Fargion 1996; Davis et al. 2000; Mullin and Fulling 2004; Mullin et al. 2004). MacLeod et al. (2004) reported sighting three groups of melon-headed whales in the Bahamas in waters with bottom depths ranging from 512 to 646 m.

Density and abundance estimates

- As noted in the NOAA SAR (Waring et al. 2007), there is insufficient data to estimate abundance of the melon-headed whale off the U.S. Atlantic Coast. Therefore, density estimates for this species could not be generated.

➢ Spinner Dolphin (*Stenella longirostris*)

Distribution and habitat preferences

- Spinner dolphin distribution is along most of the U.S. Atlantic Coast, primarily in offshore waters (CETAP 1982; Waring et al. 1992; Waring et al. 2007).

- Spinner dolphins have been sighted within the Gulf Stream, which is consistent with the oceanic distribution and warm-water preference of this genus (Waring et al. 1992).

- Oceanic populations, such as those in the eastern tropical Pacific, are often found in waters with a shallow thermocline (Au and Perryman 1985; Reilly 1990). The thermocline concentrates pelagic organisms in and above it; spinner dolphins feed on this aggregation of prey.

Density and abundance estimates

- As noted in the NOAA SAR (Waring et al. 2007), there is insufficient data to estimate abundance of the spinner dolphin off the U.S. Atlantic Coast. Therefore, density estimates for this species could not be generated.

➢ Fraser's Dolphin *(Lagenodelphis hosei)*

Distribution and habitat preferences

- Fraser's dolphins are found in subtropical and tropical waters around the world, typically between 30ºN and 30ºS (Jefferson et al. 1993). Few records are available from the Atlantic Ocean (Leatherwood et al. 1993; Watkins et al. 1994). Strandings in temperate areas are considered extralimital and usually are associated with anomalously warm water temperatures (Perrin et al. 1994).

- Fraser's dolphins are an oceanic species. In the nearby GOMEX, Fraser's dolphins occur well beyond the outer edge of the continental shelf and over the abyssal plain (Leatherwood et al. 1993).

Density and abundance estimates

- This species is not addressed in the NOAA SAR (Waring et al. 2007), though there are occurrence records in the SE study area. There is insufficient data to estimate abundance of the Fraser's dolphin off the U.S. Atlantic Coast; therefore, density estimates for this species could not be generated.

➢ Atlantic White-sided Dolphin *(Lagenorhynchus acutus)*

Distribution and habitat preferences

- The Atlantic white-sided dolphin inhabits waters from central West Greenland to North Carolina (about 35°N) (Waring et al. 2007). In the western North Atlantic, the Atlantic white-sided is most common over the continental shelf from Hudson Canyon north to the GOM (Palka et al. 1997). Virginia and North Carolina represent the southern edge of the range (Testaverde and Mead 1980). Data indicate seasonal shifts in distribution, perhaps a reflection of an inshore/offshore movement (CETAP 1982; Payne et al. 1990a; Northridge et al. 1997).

- This species is found primarily in continental shelf waters inshore of the 100 m depth contour however, they can also be found in slope waters (CETAP 1982; Selzer and Payne 1988; Mate et al. 1994).

Density and abundance estimates

- This species is not addressed in the NOAA SAR (Waring et al. 2007), though there are occurrence records in the SE study area. There is insufficient data to estimate abundance of the Atlantic white-sided dolphin off the U.S. Atlantic Coast; therefore, density estimates for this species could not be generated.

- Harbor Porpoise *(Phocoena phocoena)*

Distribution and habitat preferences

- Harbor porpoises occur in subpolar to cool-temperate waters in the North Atlantic and Pacific (Read 1999). Off the northeastern U.S., harbor porpoise distribution is strongly concentrated in the GOM/Georges Bank region, with more scattered occurrences to the mid-Atlantic (CETAP 1982; Northridge 1996). Stranding data indicate that the southern limit is northern Florida (Polacheck 1995; Read 1999).

- Mid-Atlantic (into North Carolina waters) porpoise occurrence is from December through May, based on bycatch data (Waring et al. 2007).. Data indicate that only juvenile harbor porpoises are present in nearshore waters of the mid-Atlantic during this time (Cox et al. 1998). Harbor porpoises are not tied to shallow, nearshore waters during winter, as evidenced by a harbor porpoise caught in a pelagic drift net off North Carolina (Read et al. 1996).

Density and abundance estimates

- This species is known to occur in the SE study area; however, its abundance in this region is not addressed in the NOAA SAR (Waring et al. 2007). There is insufficient data to estimate abundance of the harbor porpoise in the SE study area; therefore, density estimates for this species could not be generated.

3.2 SEA TURTLES

Along the continental shelf of the U.S. Atlantic coast, four sea turtle species (leatherback, loggerhead, Kemp's ridley, hawksbill and green) migrate seasonally from offshore and warmer southern waters far into northern latitudes each summer (Morreale 2005). Nesting is also documented for beaches bordering the SE study area.

A notable distinction is the increasing proportion of small and apparently young individuals along a northward gradient (Morreale and Standora 2005). This pattern is evident in loggerheads and greens, and is 'starkly obvious' in Kemp's ridleys (Morreale and Standora 2005). In North Carolina and Virginia, the proportion of breeding adult loggerheads in bays and estuaries is smaller than in Georgia and Florida, with most individuals classified as medium-sized juveniles. For Kemp's ridley, most individuals throughout the range are immature, but the latitudinal gradient still exists (Morreale and Standora 2005). In southern and mid-Atlantic states (Florida, Georgia, South Carolina, Virginia), a few larger individuals are reported, but the vast majority are small (Morreale and Standora 2005). In the northeastern waters of New York and Massachusetts, only small-sized Kemp's ridleys are documented.

All sea turtle species are listed as threatened or endangered under the ESA. 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 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, and unidentified hardshell turtles were pooled together since the numbers of sightings for 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.

When producing the sea turtle density surface, all aerial survey data from both the NE and SE study areas were used and the surface created extended the entire coastline, as depicted in **Figures 3-24** through **3-30**. However, only data from the SE study area were used to generate the abundance estimates contained in **Tables 3-15** through **3-18** (see **Section 3.2.1**).

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. The leatherback turtle is distributed circumglobally in tropical, subtropical, and warm-temperate waters throughout the year and into cooler temperate waters during warmer months (NMFS and USFWS 1992; James et al. 2005). The leatherback often undertakes extensive migrations following depth contours for thousands of kilometers (Morreale et al. 1996; Hughes et al. 1998). Adult leatherback turtles forage in temperate and subpolar regions in all oceans and migrate to tropical nesting beaches between 30°N and 20°S. Female leatherbacks nest from the southeastern United States to southern Brazil in the western Atlantic (The SWOT Team 2007a).

- 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. 1995b).

- 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.

- Survey data indicate that leatherback migration starts with the northward movement of individuals along the SE coast of the U.S. in the late winter/early spring. In February and March, most leatherbacks along the U.S. Atlantic Coast are found in the waters off NE Florida. By April and May leatherbacks begin to occur in large numbers off the coasts of Georgia and the Carolinas (NMFS 1995; NMFS 2000). In late spring/early summer, leatherbacks begin to appear off the mid-Atlantic and New England coasts, while by late summer/early fall, many will have traveled as far north as the waters off eastern Canada (CETAP 1982; Shoop and Kenney 1992; Thompson et al. 2001).

Table 3-15. Density surface model results for the leatherback turtle by season. These are abundance estimates for the leatherback turtle in the Southeast study area.

Season	Abundance
Spring	2,042
Summer	3,773
Fall	2,042
Winter	2,042

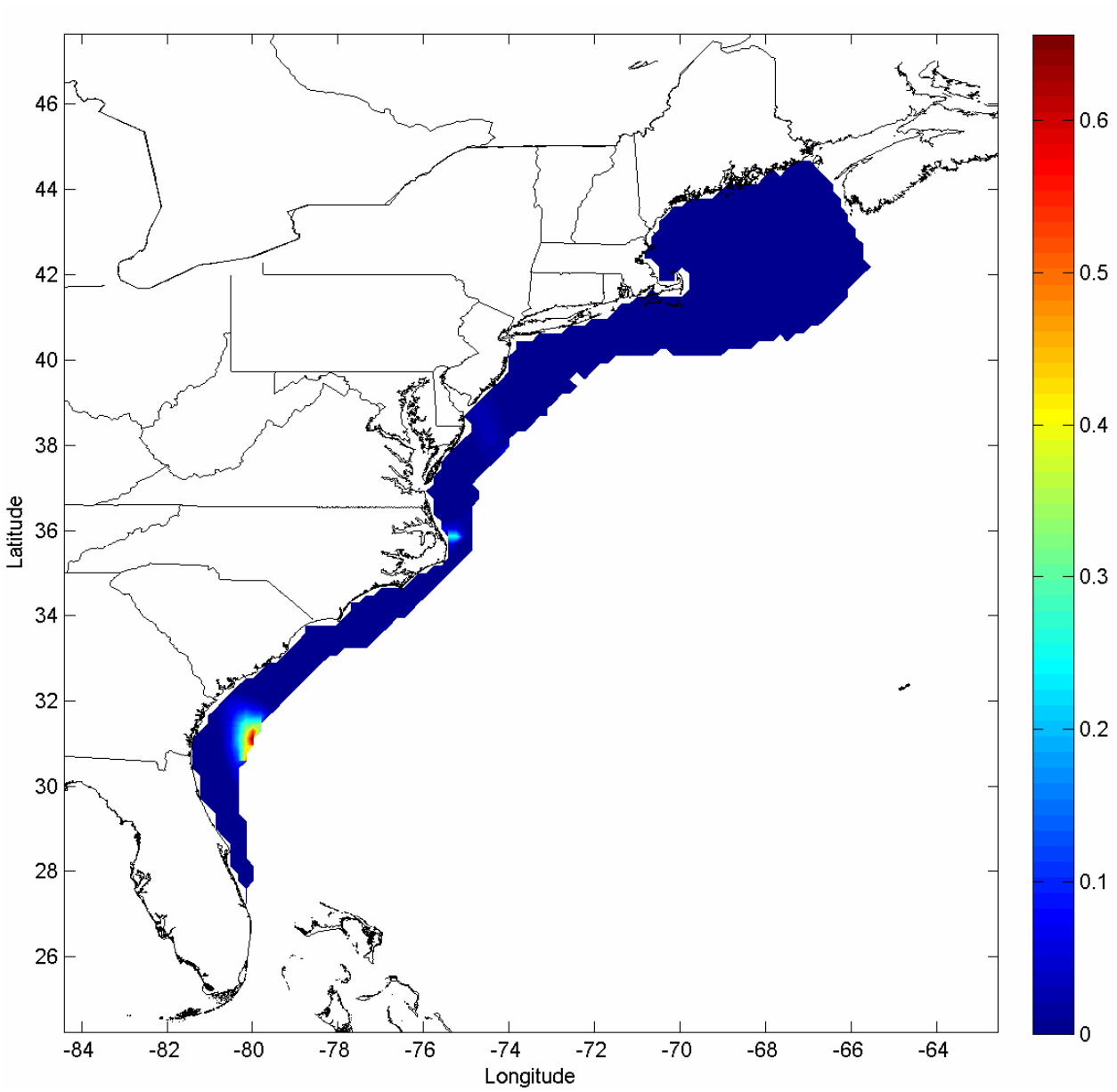

Figure 3-24. Density surface for the leatherback turtle during summer off the United States Atlantic Coast.

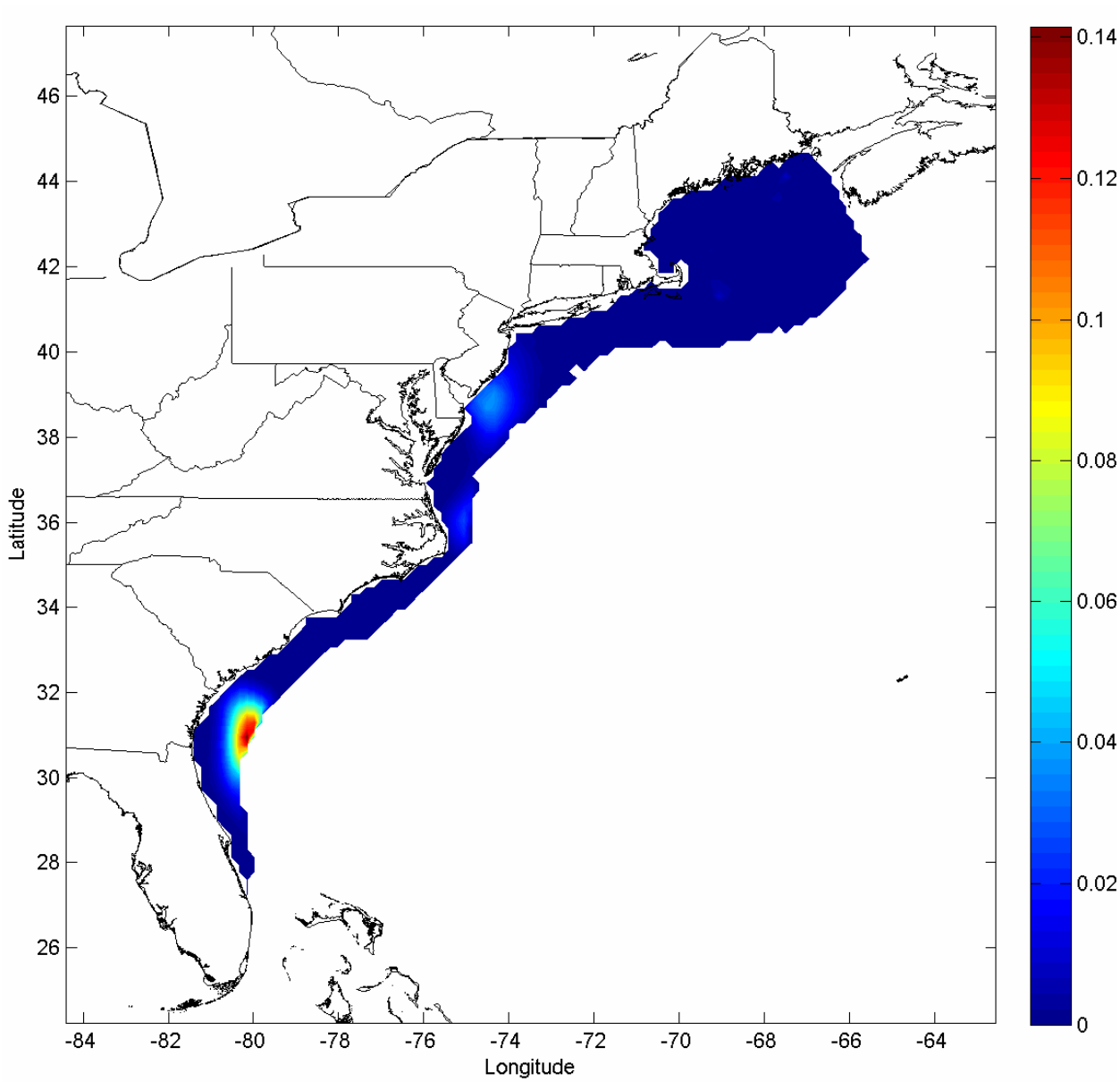

Figure 3-25. Density surface for the leatherback turtle during fall, winter, and spring off the United States Atlantic Coast.

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

Distribution and habitat preferences

- The Kemp's ridley is restricted to the North Atlantic Ocean (Marquez-M. 1994). Individuals occur primarily in the GOMEX and in moderate numbers along the U.S. Atlantic coast as far north as Nova Scotia (Lazell 1980; Morreale et al. 1992).

- Kemp's ridley turtles occur in open-ocean and *Sargassum* habitats as post-hatchlings and early juveniles (e.g., Manzella et al. 1991; Witherington and Hirama 2006). As older individuals, these are coastal migrants that travel along relatively narrow coastal corridors (reviewed by Morreale et al. 2007).

- Habitats frequently utilized 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).

- Along the U.S. Atlantic Coast, known feeding areas include Cape Cod Bay, Long Island Sound, Chesapeake Bay, and bays and sounds from North Carolina south to Florida (Lazell 1980; Lee and Palmer 1981; Lutcavage and Musick 1985; Barnard et al. 1989; Epperly et al. 1995b; Weber 1995). Mature Kemp's ridleys likely forage along the eastern coast of Florida (Henwood and Ogren 1987).

- Offshore water temperatures play a major role in determining the number of Kemp's ridleys present in the North Atlantic Ocean. Kemp's ridleys that forage in nearshore waters of the Mid-Atlantic Bight during warm months often overwinter in waters south of Cape Hatteras (Keinath et al. 1996). Individuals that do not emigrate from these waters become susceptible to hypothermia during late fall and winter. Most Kemp's ridleys overwinter in Florida near Cape Canaveral (Henwood and Ogren 1987).

- Although nesting occurs primarily on a single nesting beach at Rancho Nuevo, Tamaulipas, on the eastern coast of Mexico (USFWS and NMFS 1992), there are a few additional nests in Texas, Florida, South Carolina, and North Carolina (Meylan et al. 1990; Weber 1995; Godfrey 1996; Foote and Mueller 2002).

Table 3-16. Density surface model results for the Kemp's ridley turtle by season. These are abundance estimates for the Kemp's ridley turtle in the Southeast study area.

Season	Abundance
Spring	3,073
Summer	3,073
Fall	3,073
Winter	3,073

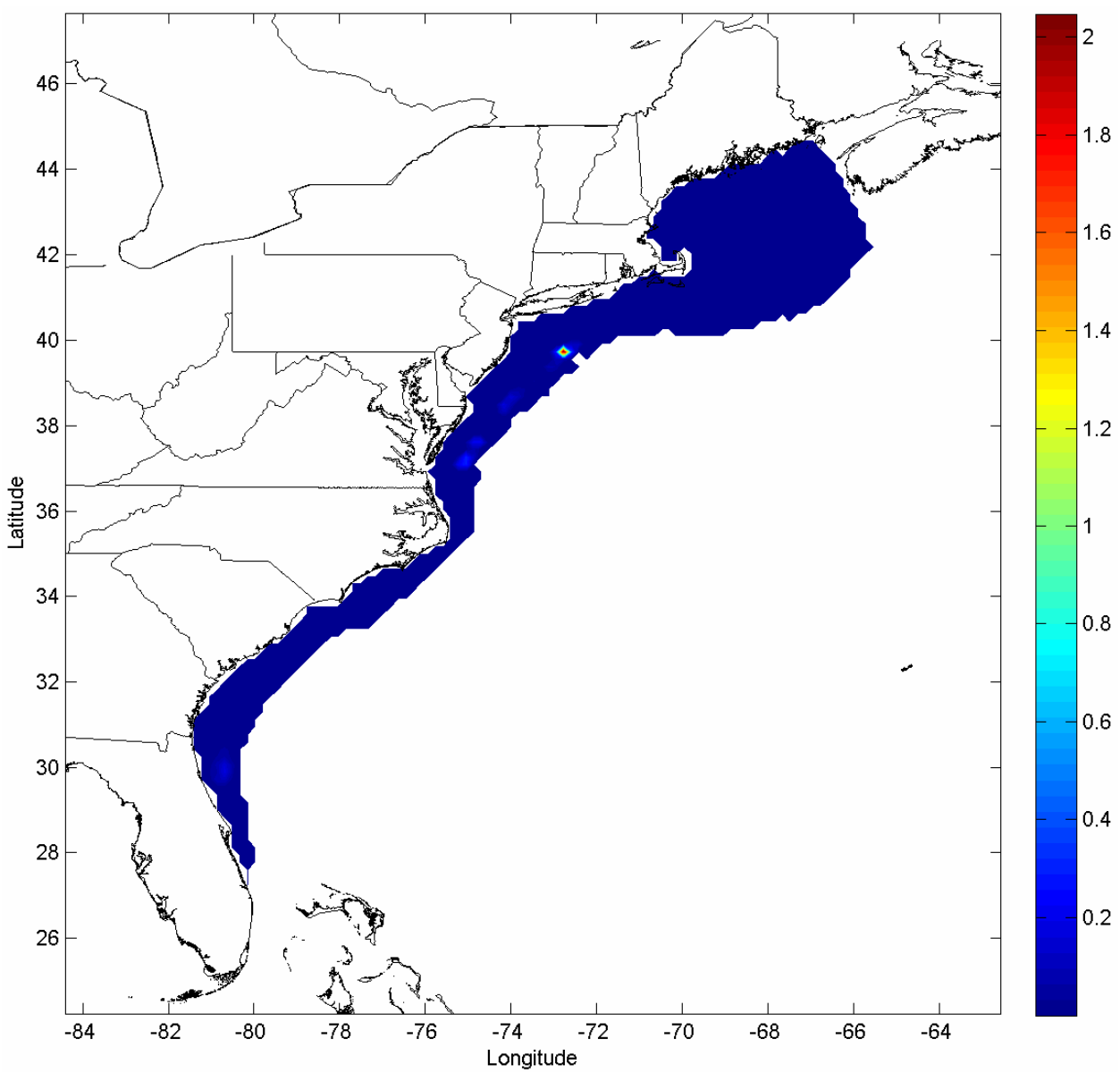

Figure 3-26. Density surface for the Kemp's ridley turtle during all seasons off the United States Atlantic Coast.

- Loggerhead Turtle (*Caretta caretta*)

Distribution and habitat preferences

- Loggerhead turtles are widely distributed in subtropical and temperate waters (Dodd 1988). Loggerhead turtles can be found along the U.S. Atlantic coast from Cape Cod to the Florida Keys during any season. Loggerheads seem generally restricted to waters of the North Atlantic Ocean south of 38°N, with mean SSTs around 22.2°C.

- The loggerhead turtle occurs in habitats ranging from coastal estuaries to waters far beyond the continental shelf (Dodd 1988). The species may be found hundreds of miles out to sea, as well as in inshore areas such as bays, lagoons, salt marshes, creeks, ship channels, and the mouths of large rivers.

- In the Mid-Atlantic Bight, loggerheads concentrate in continental shelf waters but are also commonly sighted in deeper, offshore waters (Shoop and Kenney 1992).

- North of Cape Hatteras, North Carolina, loggerhead occurrence is highly seasonal (CETAP 1982; Lutcavage and Musick 1985; Shoop and Kenney 1992). South of Cape Hatteras, loggerheads are resident year-round. Loggerheads distributions in North Carolina waters vary throughout the year (Epperly et al. 1995b); such variations are based upon seasonal water temperatures that influence migrations. During winter, the species' range is presumed to contract to waters south of where the Gulf Stream Current deflects off Cape Hatteras, so that turtles avoid hypothermia (Shoop and Kenney 1992). In early spring, juvenile loggerheads over-wintering in southeastern U.S. waters begin to migrate north to developmental feeding habitats (Morreale and Standora 2005). Migrating juvenile loggerheads appear in North Carolina waters in April; many individuals move into Core and Pamlico Sound developmental habitats and are present in these areas through December (Epperly et al. 1995b). Individuals will disperse throughout the sounds during the summer, and leave as water temperatures cool in the late fall and early winter (Epperly et al. 1995a; Epperly et al. 1995b).

- 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).

- Results from tagging data of juvenile loggerheads in both the eastern and western North Atlantic suggest that the location of currents and associated frontal eddies is important to the foraging ecology of the pelagic stage of this species (McClellan 2007).

- The neritic juvenile stage and adult foraging stage both occur in the neritic (nearshore) zone. Coral reefs, rocky places, and ship wrecks are often used as feeding areas. The turtles here are active and feed primarily on the bottom (epibenthic/demersal), though prey is also captured throughout the water column (Bjorndal 2003; Bolten 2003). The neritic zone not also provides crucial foraging habitat, but can also provide inter-nesting and overwintering habitat. Tagging data has revealed that migratory routes may be coastal or may involve crossing deep oceanic waters; an oceanic route may be taken even when a coastal route is an option (Schroeder et al. 2003).

- Loggerhead nesting grounds are located in warm, temperate, and subtropical regions (between 40°N and 40°S), with some scattered nesting in the tropics (The SWOT Team 2007b). The world's largest nesting colonies in 2005 were in SE Florida (about 40,000 nests per year [nests/yr]) and Masirah Island, Oman (bordering the Arabian Sea; about 30,000 nests/yr) (Hutchinson, B., International Union for Conservation of Nature and Natural Resources–Species Survival Commission [IUCN-SSC] Marine Turtle Specialist Group, pers comm., 7 March 2007). The majority of nesting in the U.S. occurs in southeastern Florida, scattered nesting reports have been documented further north of North Carolina (NMFS and USFWS 1991a). Genetic research involving analysis of mitochondrial deoxyribonucleic acid (DNA) has identified four different loggerhead nesting subpopulations in the southeastern United States: (1) the Northern Subpopulation occurring from North Carolina through NE Florida; (2) South Florida Subpopulation occurring from just north of Cape Canaveral on Florida's east coast and extending up to around Sarasota on Florida's west coast; (3) Dry Tortugas, Florida, Subpopulation, and (4) Northwest Florida Subpopulation occurring on Florida's Panhandle beaches (Bowen et al. 1994; Encalada et al. 1998). During non-nesting years, adult females from U.S. beaches are distributed in waters off the U.S. Atlantic coast and throughout the GOMEX, Bahamas, Greater Antilles, and Yucatán.

Table 3-17. Density surface model results for the loggerhead turtle by season. These are abundance estimates for the loggerhead turtle in the Southeast study area.

Season	Abundance
Spring	1,355
Summer	14,426
Fall	1,355
Winter	1,355

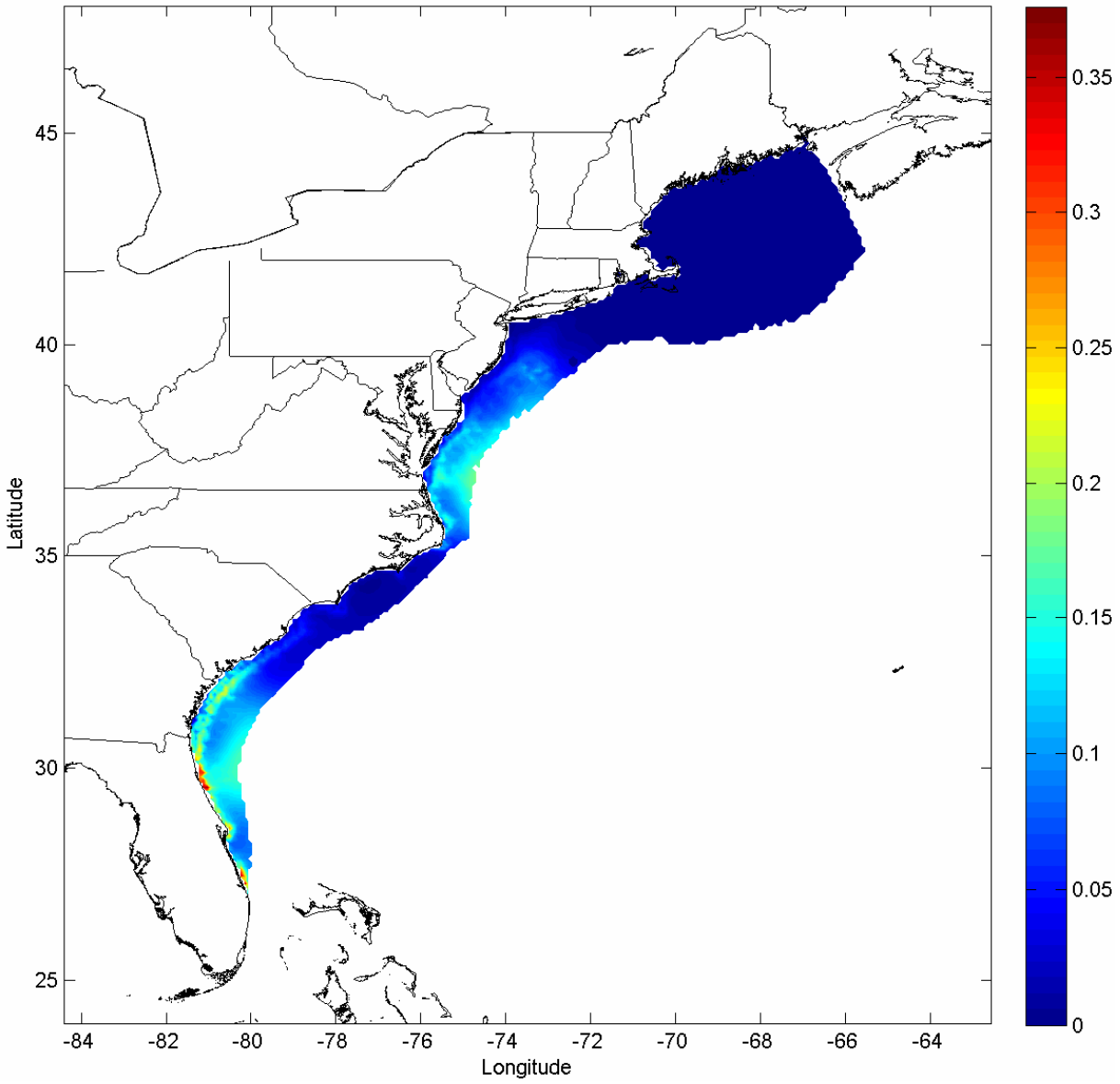

Figure 3-27. Density surface for the loggerhead turtle during summer off the United States Atlantic Coast.

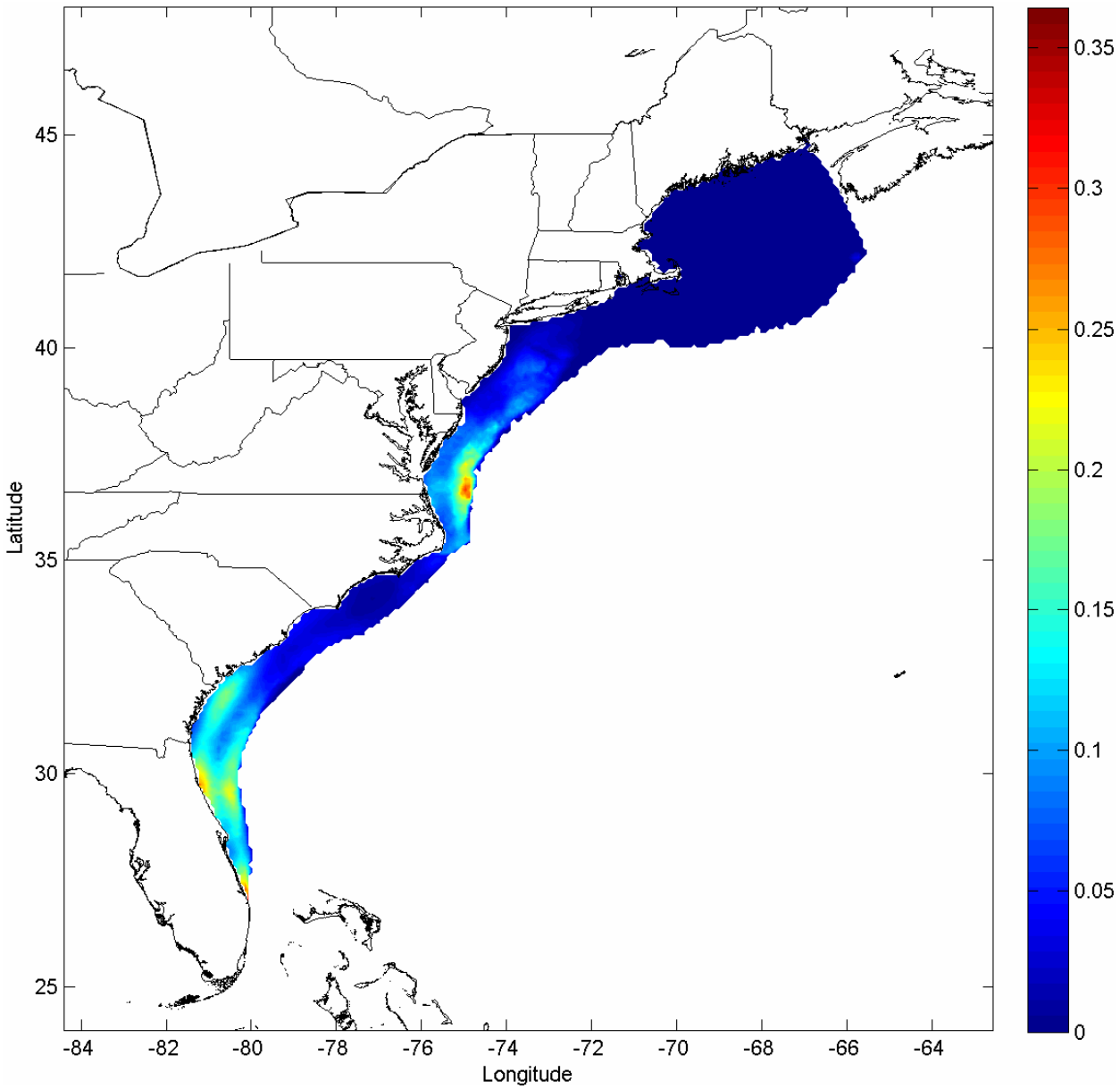

Figure 3-28. Density surface for the loggerhead turtle during fall, winter, and spring off the United States Atlantic Coast.

3.2.2 Species Groups

Hardshell Turtles

This group includes the green, hawksbill, and unidentified hardshell turtles (which might include extralimital occurrences of the olive ridley turtle [*Lepidochelys oliveacea*]) (**Table 3-1**). The distribution and habitat preference information for the species in the Hardshell Turtles group is listed below and is followed by the density results for the group.

- Green Turtle (*Chelonia mydas*)

Distribution and habitat preferences

- Green turtles are distributed worldwide in tropical and subtropical waters (NMFS and USFWS 1991b; Hirth 1997). Green turtles nest of both island and continental beaches between 30°N and 30°S latitudes (Witherington et al. 2006). Florida is near the northern extent of this turtle's Atlantic nesting range, however, other than Costa Rica, Florida is likely second or third in the annual number of nests made on beaches bordering the western Atlantic (Witherington et al. 2006). Approximately 99% of green turtle nesting in Florida occurs on the Atlantic coast, with the greatest nesting activity in Brevard through Broward counties (Witherington et al. 2006). There are scattered records in Georgia, and the Carolinas (Peterson et al. 1985; Schwartz 1989; NMFS and USFWS 1991b). Green turtles are known from much of Florida's coastal waters where there is sufficient seagrass or algae to support foraging by the species (Witherington et al. 2006).

- Nearshore water temperatures play a major role in determining green turtle distribution along the Atlantic and Gulf coasts of the U.S (e.g., Musick and Limpus 1997; Witherington et al. 2006).

- Post-hatchling and early-juvenile green turtles reside in convergence zones in the open ocean, where they spend an undetermined amount of time in the pelagic environment (Carr 1987; Witherington and Hirama 2006).

- Juvenile green turtles utilize estuarine waters along the U.S. Atlantic coast as summer developmental habitat, as far north as Long Island Sound, Chesapeake Bay, and North Carolina sounds (Epperly et al. 1995a; Epperly et al. 1995b; Musick and Limpus 1997).

- 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 and Provancha 2005; Witherington et al. 2006).

- 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). The hawksbill is rare north of Florida (Lee and Palmer 1981; Keinath et al. 1991; Parker 1995; Plotkin 1995; USFWS 2001).

- 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. They 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).

- 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).

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

Table 3-18. Density surface model results for Hardshell Turtles by season. These are abundance estimates for Hardshell Turtles in the Southeast study area.

Season	Abundance
Spring	10,917
Summer	10,917
Fall	10,917
Winter	10,917

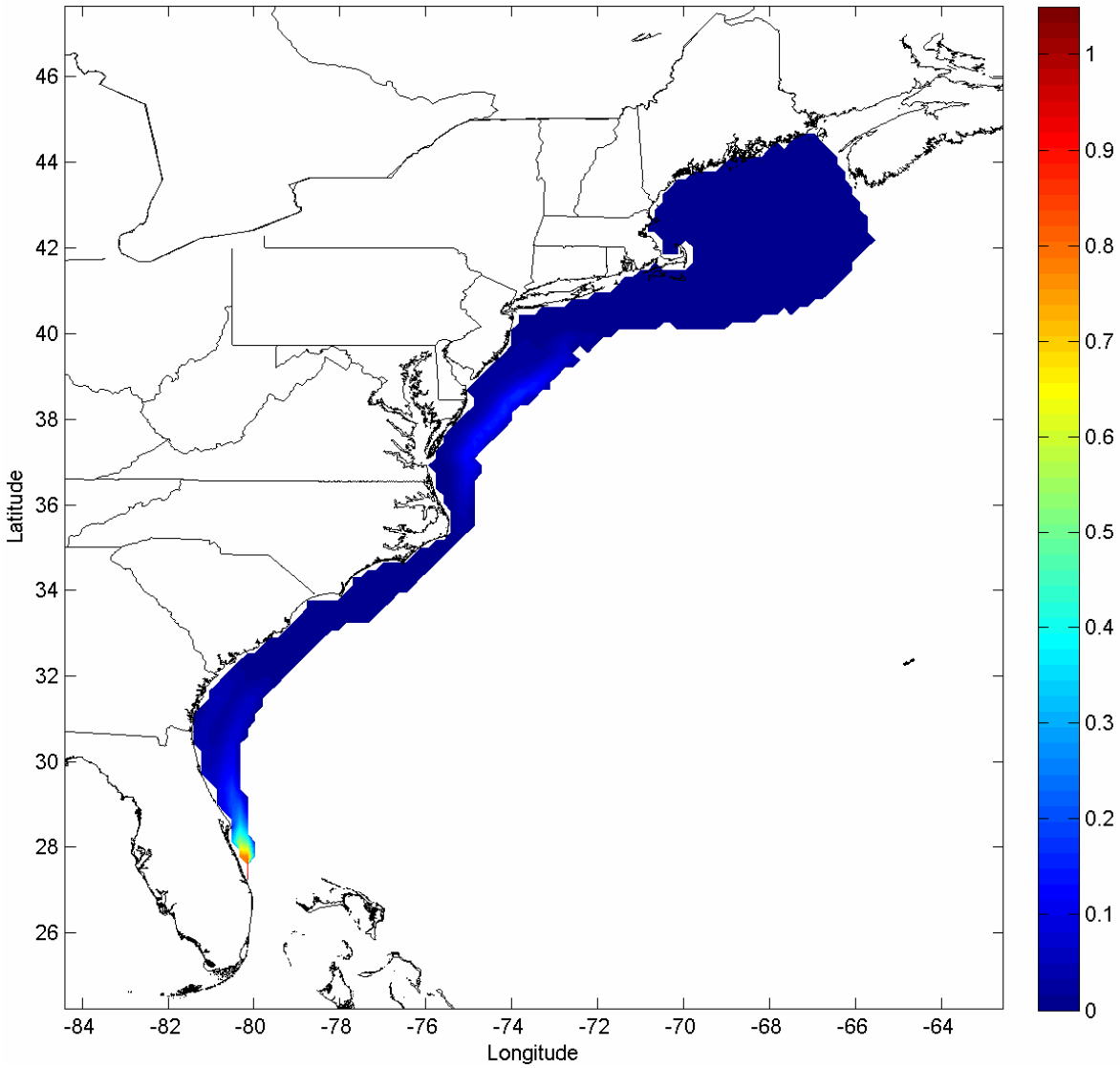

Figure 3-29. Density surface for Hardshell Turtles during summer off the United States Atlantic Coast.

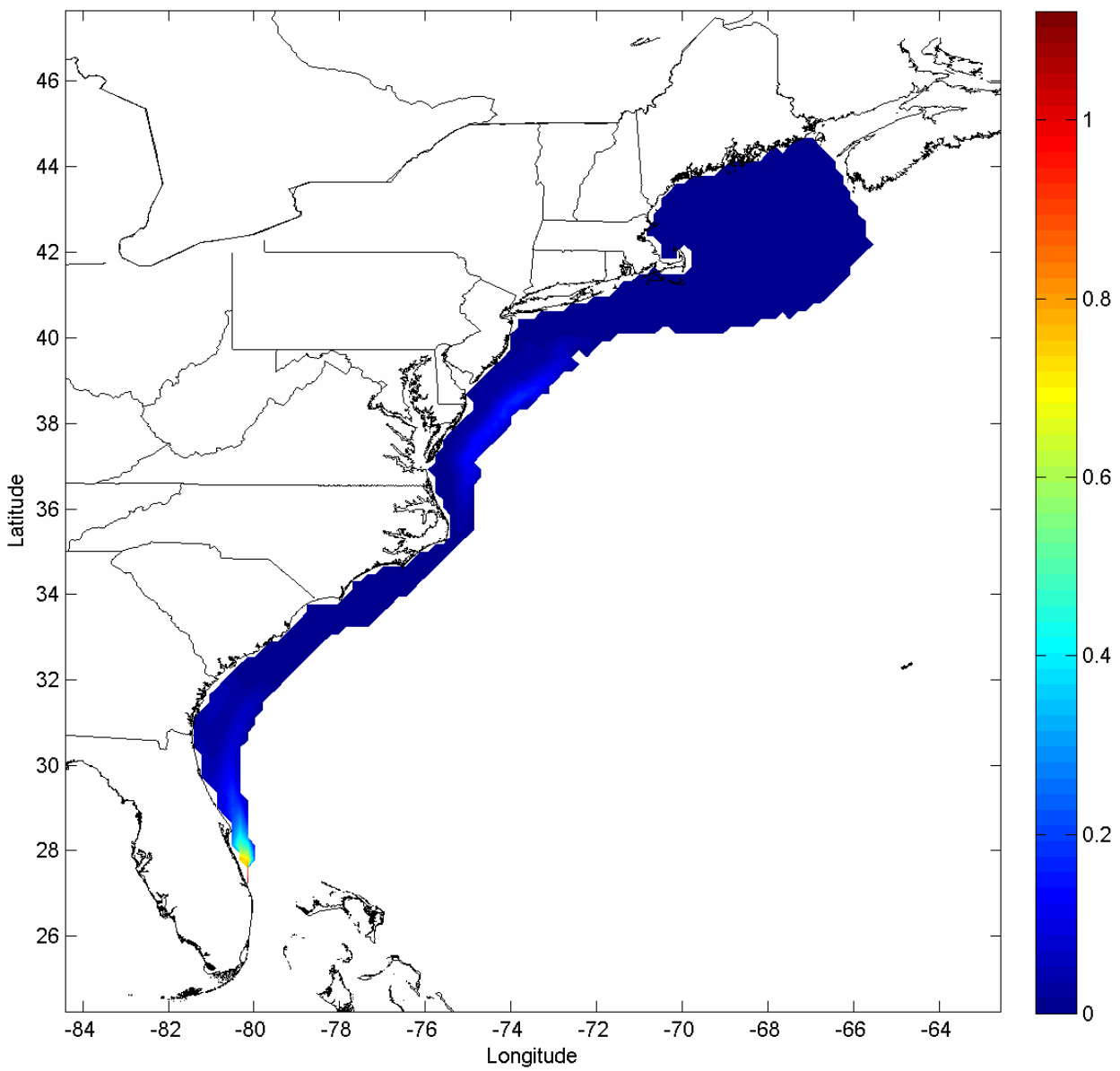

Figure 3-30. Density surface for Hardshell Turtles during fall, winter, and spring off the United States Atlantic Coast.

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APPENDIX: SPATIAL MODELING OUTPUT

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This appendix contains the spatial modeling output for all species in the Southeast 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**.

- Fin Whale *(Balaenoptera physalus)*

Table A-3. Detection function results for the fin whale during all seasons in the Southeast study area.

Detection Function	
No. of observations	31
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.6394
SE	1.1191
Hazard shape parameter (Exponent)	
Estimate	1.0334
SE	0.5476
Average p	
Estimate	0.3572
SE	0.1752
CV (Coefficient of Variation)	0.4906
N in covered region	
Estimate	86.7891
SE	44.3711
CV	0.5113

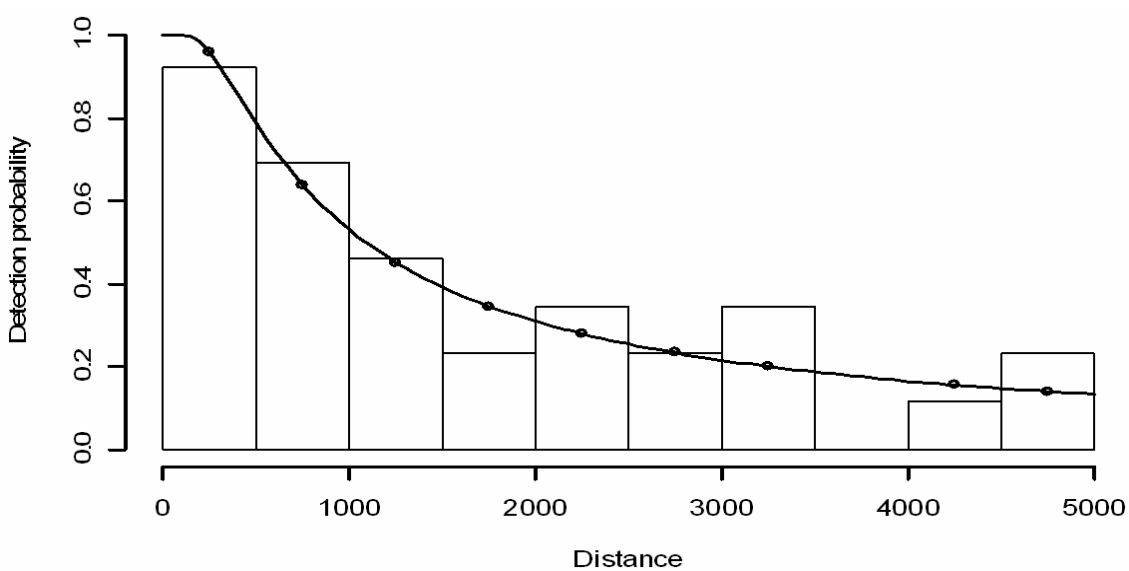

Figure A-4. Plot of the detection function for pooled sightings of the fin whale during all seasons in the Southeast study area. Distance is measured in meters.

Table A-4. Response surface model (Generalized Additive Model) results for the fin whale during all seasons in the Southeast study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon,lat) + s(slope) + offset(off.set)
Approximate significance of smooth terms	
s(lon,lat)	
Edf	23.432
Est. rank	16.000
F	8.579
p-value	<2e-16
s(slope)	
Edf	7.777
Est. rank	5.000
F	4.178
p-value	9.89e-04
R-sq. (adj)	0.278
n segments	22
Deviance explained	60.6%

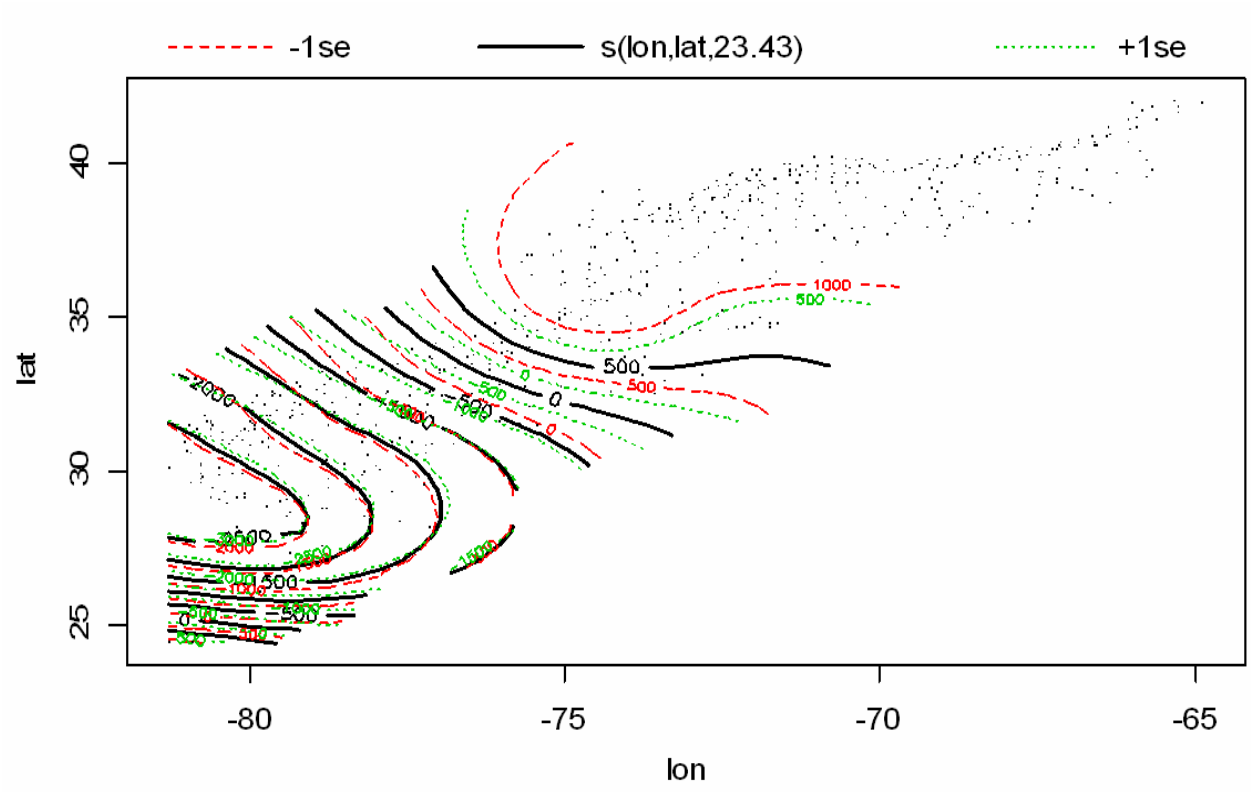

Figure A-5. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the fin whale during all seasons in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

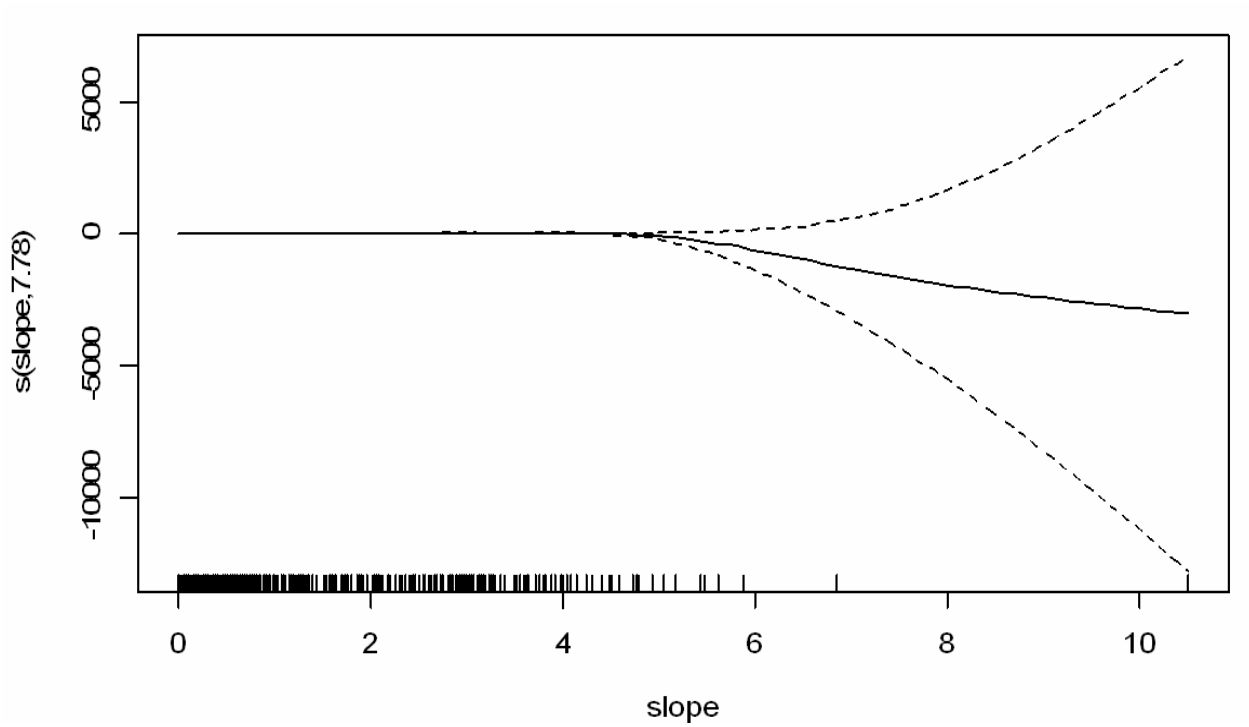

Figure A-6. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the fin whale during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the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

Table A-5. Variance estimate model results for the fin whale during all seasons in the Southeast study area.

Variance	
Legitimate values	440
Non-legitimate bootstrap replicates	59
Infinites	59
NAs	0
NaNs	0
Percentile method computed 95% CI	99.81678 – 149.91939
Point estimate	114.4206
SE of bootstraps	12.56399
Est. CV for density surface model	0.1098
CV in detection probability	0.4906
CV in overall estimate including density surface model and detection probability	0.5027
Confidence interval incorporating detection function uncertainty	45.13011 , 290.0962

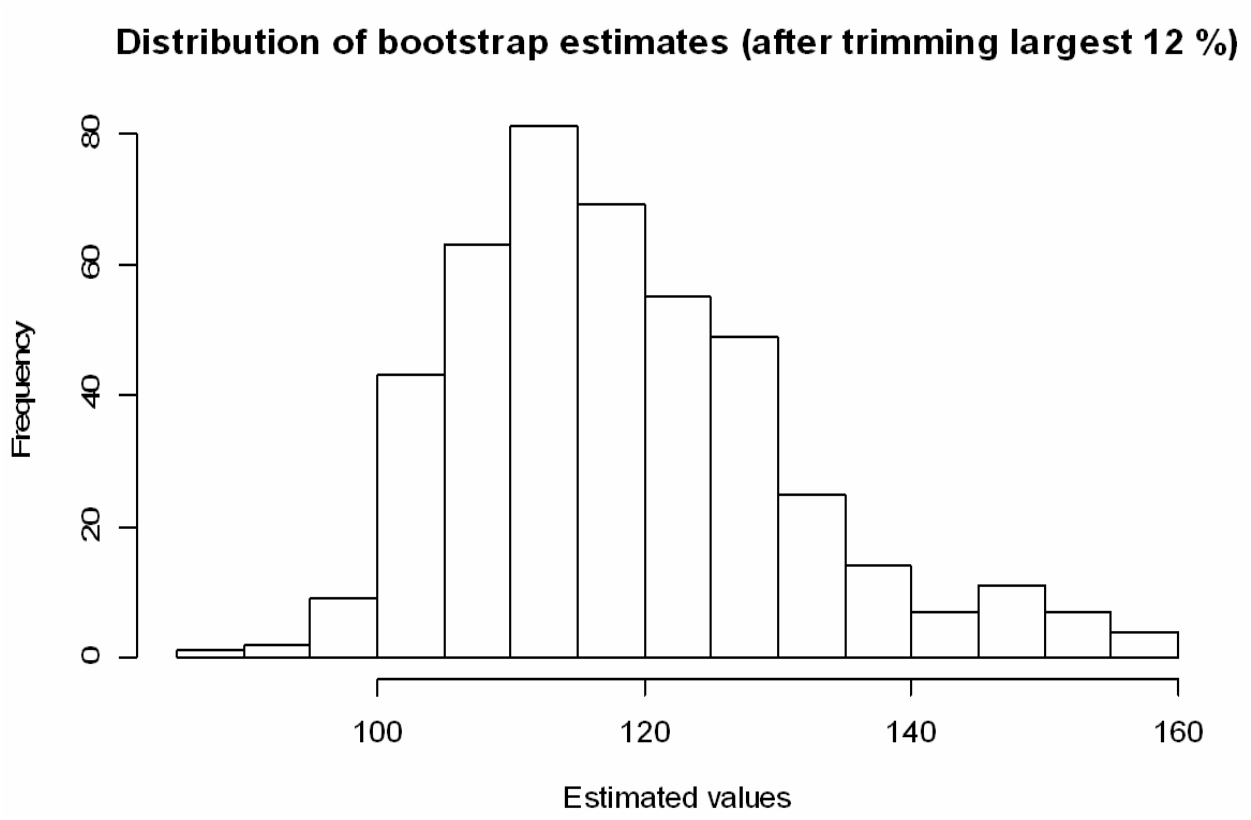

Figure A-7. Distribution of bootstrap estimates (after trimming largest 12%) for pooled sightings of the fin whale during all seasons in the Southeast study area.

- Sperm Whale (*Physeter macrocephalus*)

Table A-6. Detection function results for the sperm whale during summer in the Southeast study area.

Detection Function	
No. of observations	192
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.7622
SE	0.1230
Hazard shape parameter (Exponent)	
Estimate	2.5511
SE	0.4000
Average p	
Estimate	0.3826
SE	0.0303
CV	0.0791
N in covered region	
Estimate	501.7738
SE	48.8515
CV	0.0974

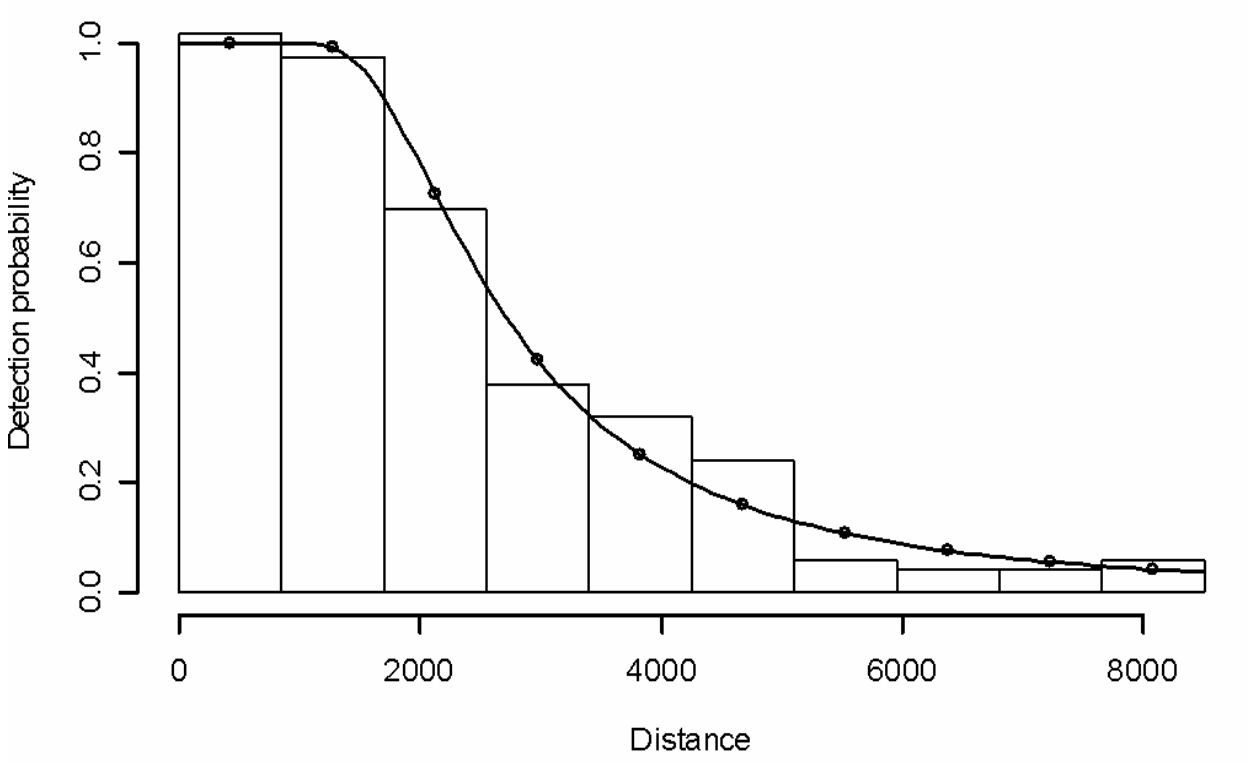

Figure A-8. Plot of the detection function for pooled sightings of the sperm whale during summer in the Southeast study area. Distance is measured in meters.

Table A-7. Response surface model (Generalized Additive Model) results for the sperm whale during summer in the Southeast 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	28.574
	Est. rank	12.000
	F	8.179
	p-value	4.67e-15
s(depth)		
	Edf	8.446
	Est. rank	9.000
	F	22.174
	p-value	<2e-16
s(SST)		
	Edf	6.887
	Est. rank	9.000
	F	5.899
	p-value	4.04e-08
R-sq. (adj)		0.348
n segments		121
Deviance explained		51.7%

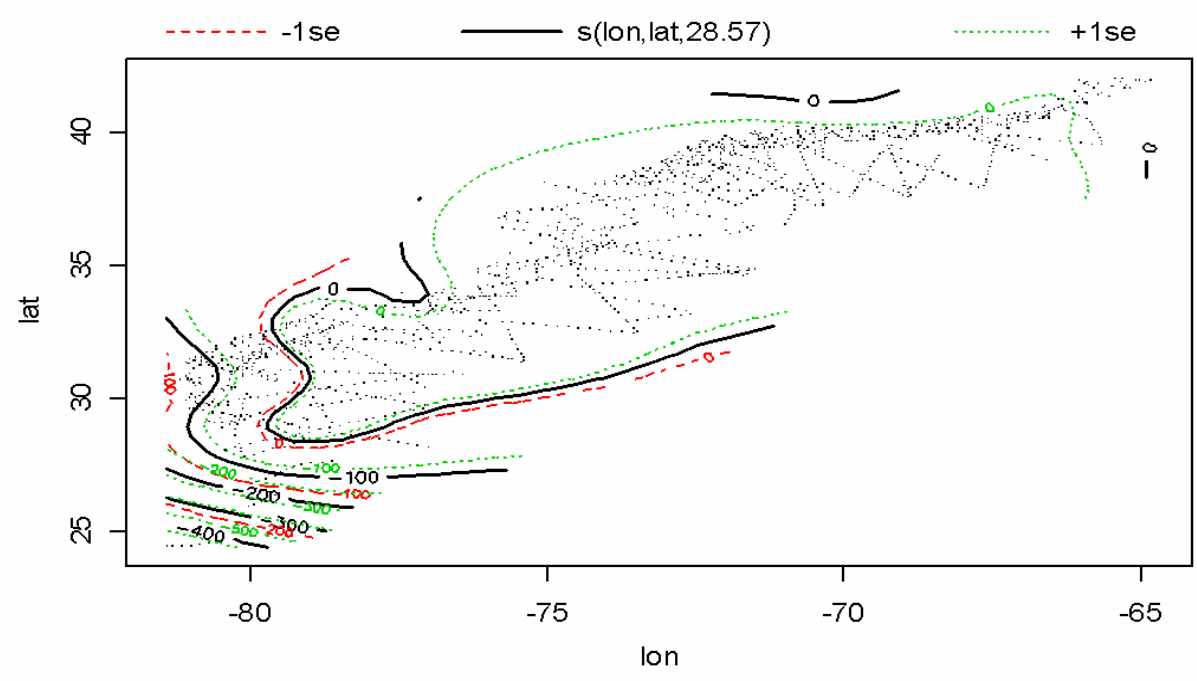

Figure A-9. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the sperm whale during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

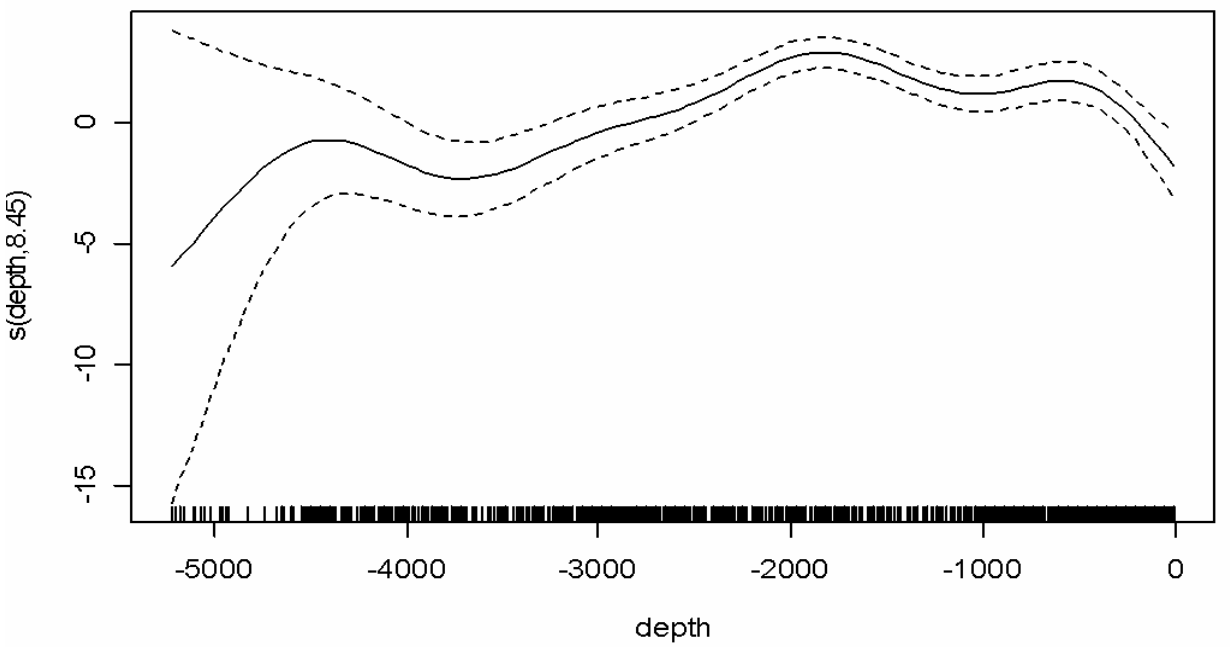

Figure A-10. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the sperm whale during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

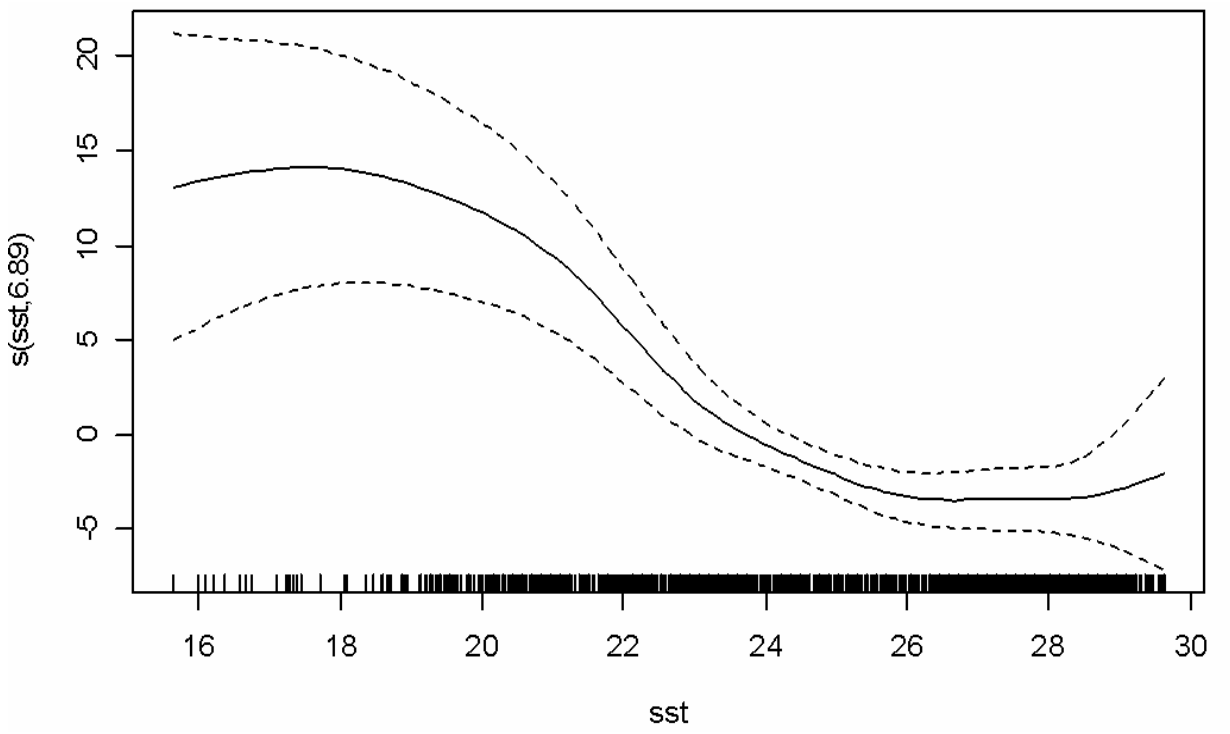

Figure A-11. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for the sperm whale during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-8. Variance estimate model results for the sperm whales during all seasons in the Southeast study area.

Variance	
Legitimate values	488
Non-legitimate bootstrap replicates	11
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	1604.919 - 2045.821
Point estimate	1827.356
SE of bootstraps	112.6780
Est. CV for density surface model	0.0617
CV in detection probability	0.049
CV in overall estimate including density surface model and detection probability	0.0787
Confidence interval incorporating detection function uncertainty	1566.428, 2131.747

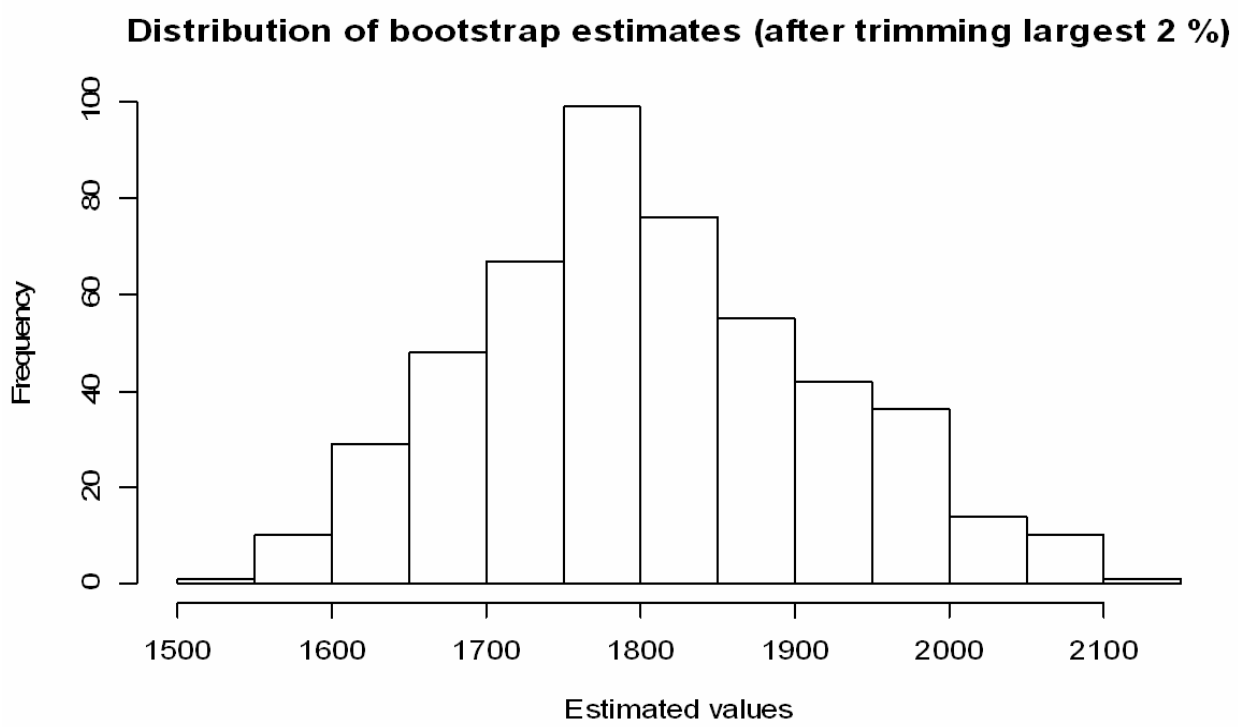

Figure A-12. Distribution of bootstrap estimates (after trimming largest 2%) for pooled sightings of the sperm whale during all seasons in the Southeast study area.

- Beaked Whales (Family Ziphiidae)

Table A-9. Detection function results for the beaked whale during spring, fall, and winter in the Southeast study area.

Detection Function	
No. of observations	74
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.3557
SE	0.0805
Average p	
Estimate	0.4219
SE	0.0330
CV	0.0781
N in covered region	
Estimate	175.3943
SE	20.6931
CV	0.1180

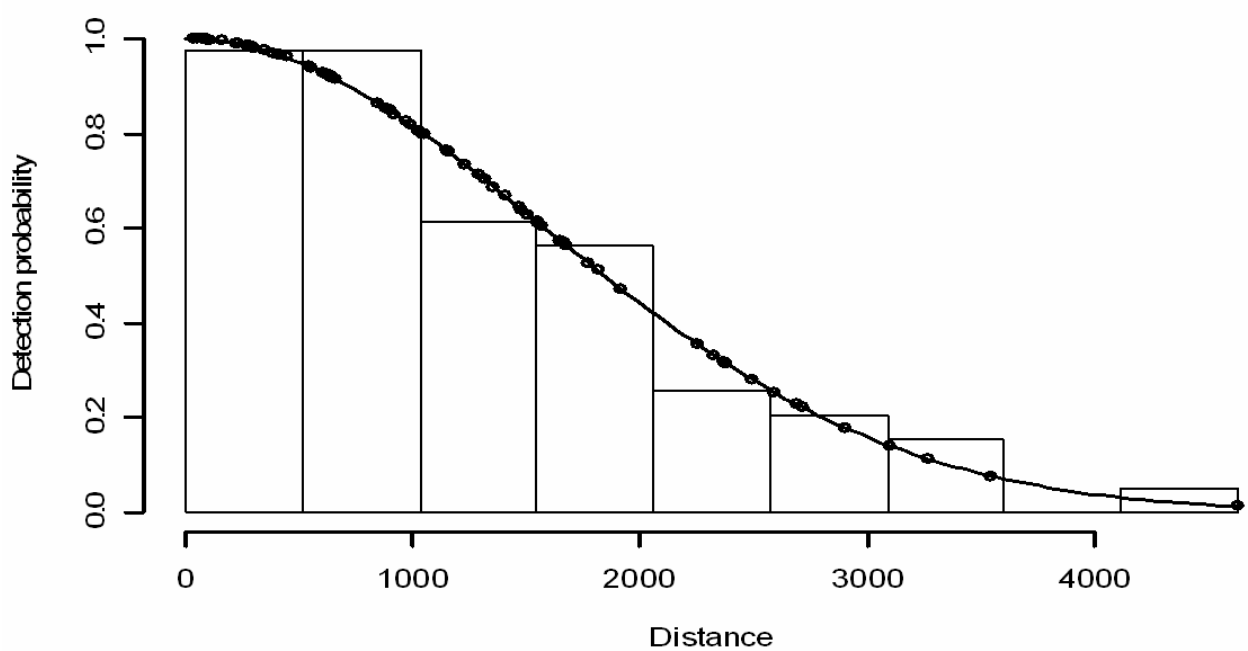

Figure A-13. Plot of the detection function for pooled sightings of the beaked whale during spring, fall, and winter in the Southeast study area. Distance is measured in meters.

Table A-10. Response surface model (Generalized Additive Model) results for the beaked whale during spring, fall, and winter in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + s(slope) + offset(off.set)
Approximate significance of smooth terms		
s(lon,lat)		
	Edf	28.524
	Est. rank	18.000
	F	6.724
	p-value	1.69e-15
s(depth)		
	Edf	7.906
	Est. rank	9.000
	F	7.556
	p-value	1.65e-10
s(shelf)		
	Edf	6.595
	Est. rank	9.000
	F	4.605
	p-value	6.77e-06
s(slope)		
	Edf	6.851
	Est. rank	9.000
	F	7.796
	p-value	6.89e-11
R-sq. (adj)		0.387
n segments		50
Deviance explained		57.9%

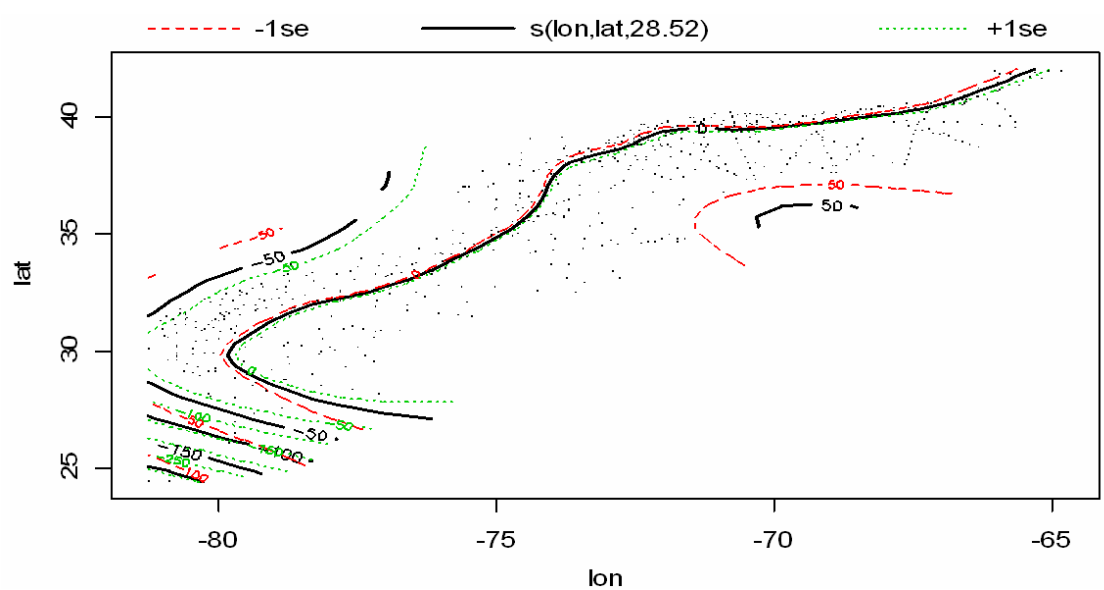

Figure A-14. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the beaked whale during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

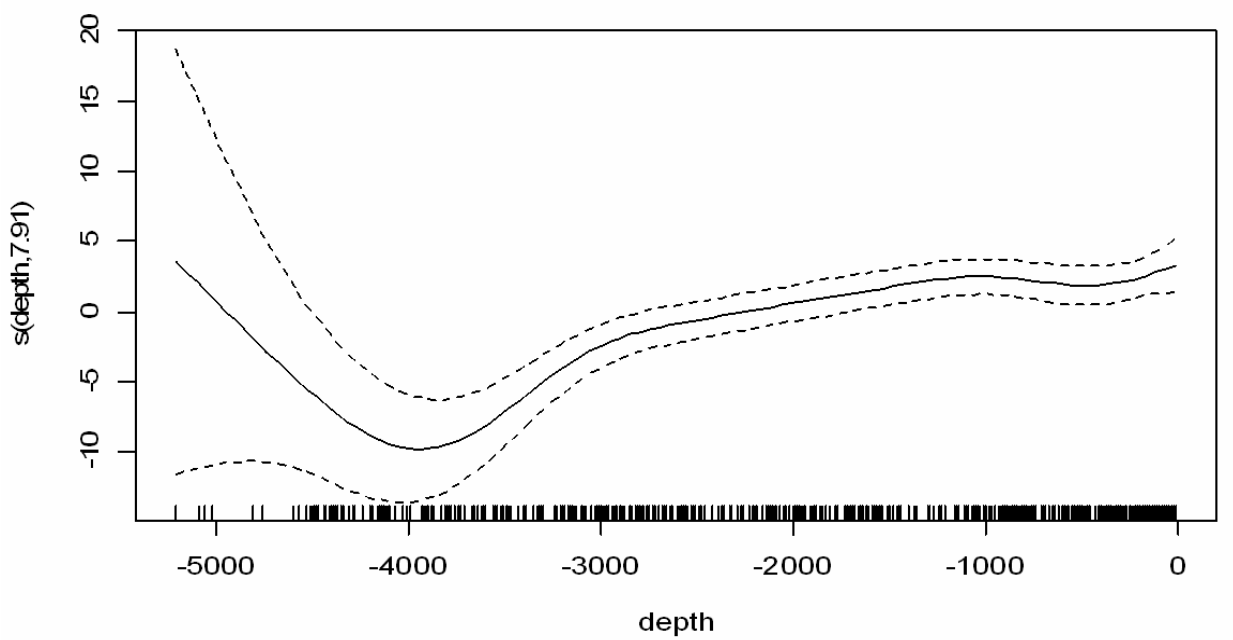

Figure A-15. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the beaked whale during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

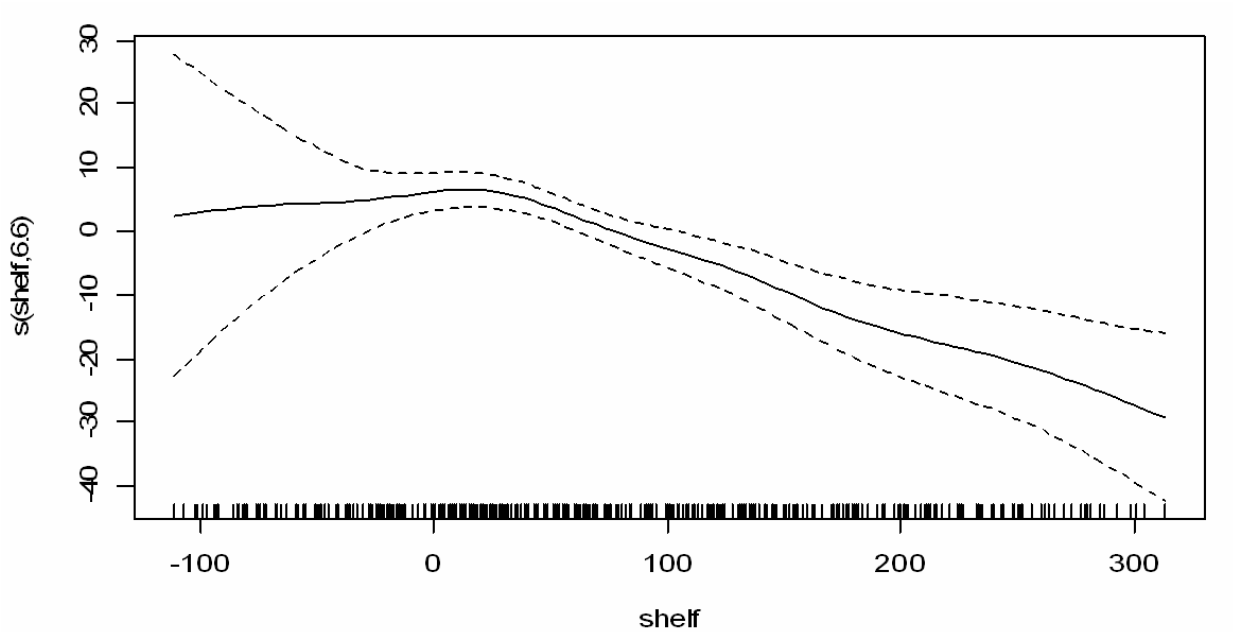

Figure A-16. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the beaked whale during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

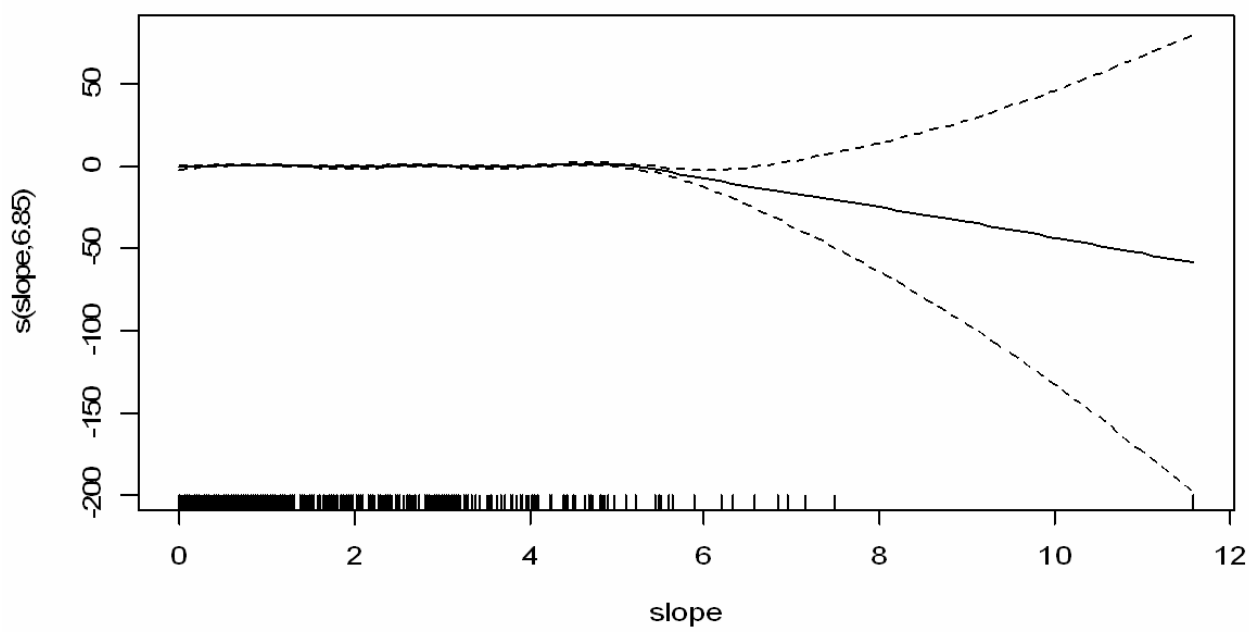

Figure A-17. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the beaked whale during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-11. Variance estimate model results for the beaked whale during all spring, fall, and winter in the Southeast study area.

Variance	
Legitimate values	463
Non-legitimate bootstrap replicates	36
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	903.5458 - 1218.4631
Point estimate	1054.039
SE of bootstraps	80.45141
Est. CV for density surface model	0.0763
CV in detection probability	0.0781
CV in overall estimate including density surface model and detection probability	0.1092
Confidence interval incorporating detection function uncertainty	851.4249, 1304.870

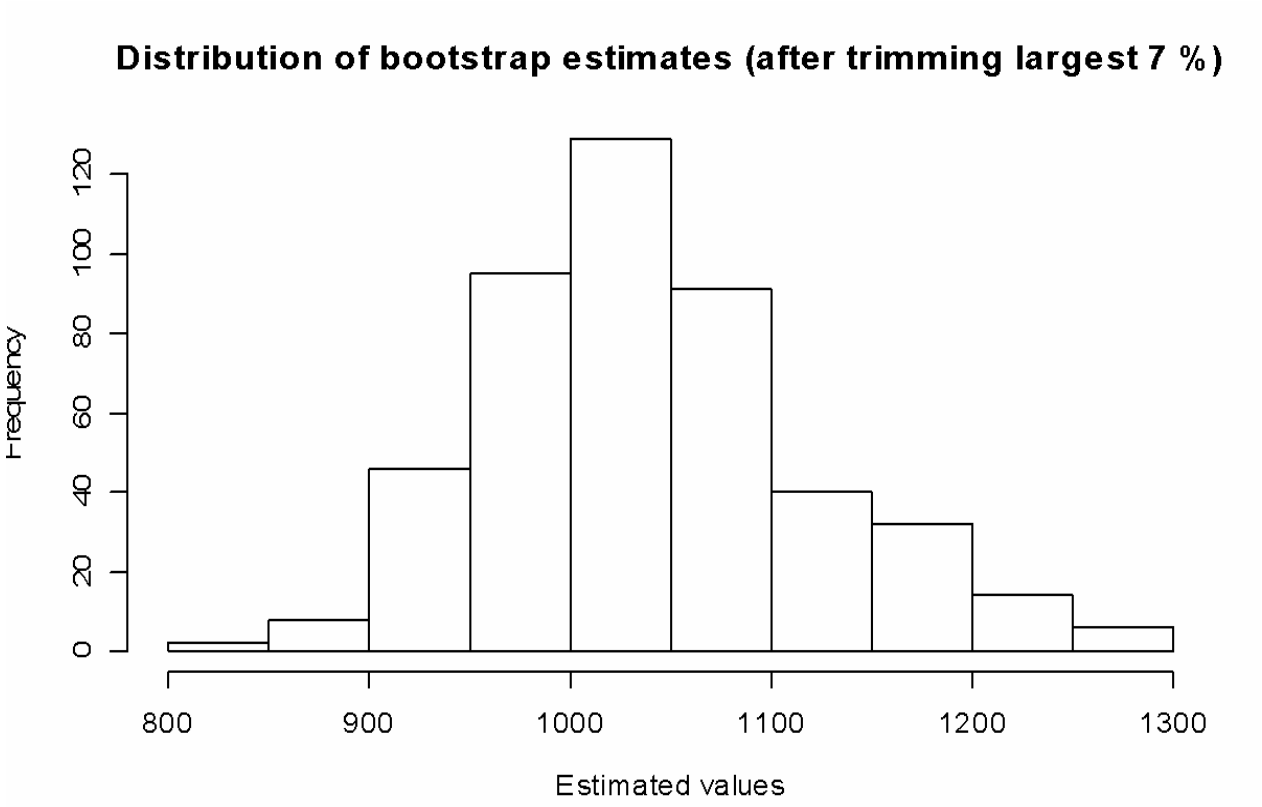

Figure A-18. Distribution of bootstrap estimates (after trimming largest 7%) for pooled sightings of the beaked whale during spring, fall, and winter in the Southeast study area.

Table A-12. Detection function results for the beaked whale during summer in the Southeast study area.

Detection Function	
No. of observations	74
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.3557
SE	0.0805
Average p	
Estimate	0.4219
SE	0.0330
CV	0.0781
N in covered region	
Estimate	175.3943
SE	20.6931
CV	0.1180

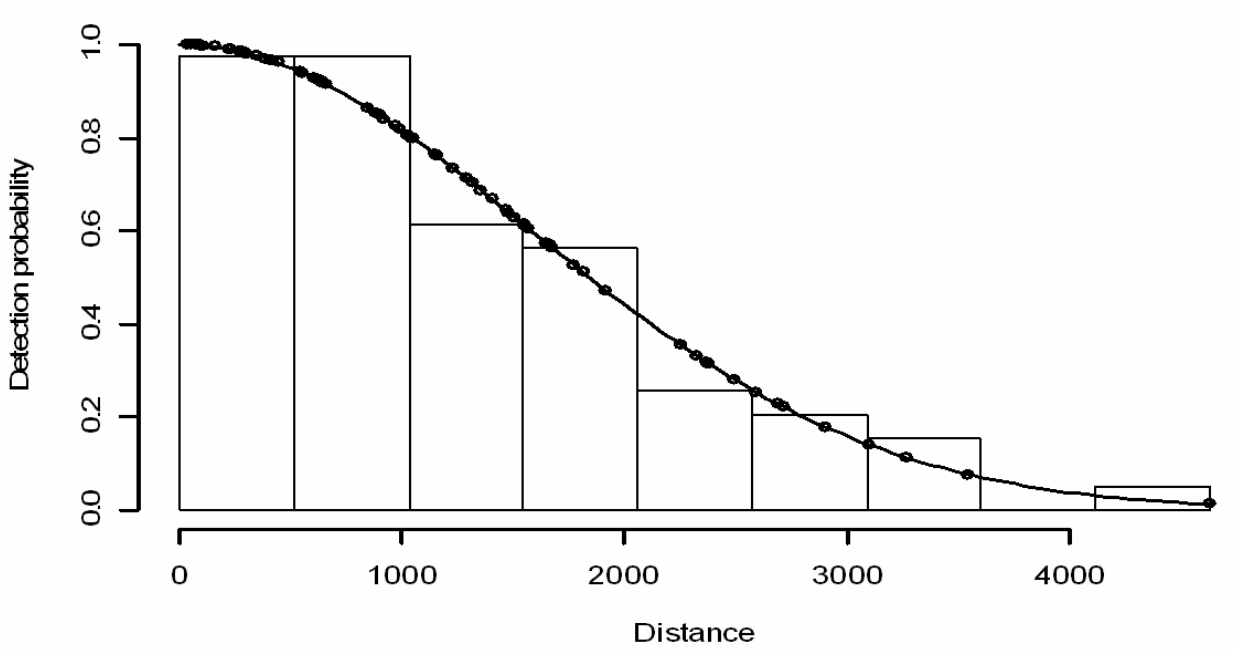

Figure A-19. Plot of the detection function for pooled sightings of the beaked whale during summer in the Southeast study area. Distance is measured in meters.

Table A-13. Response surface model (Generalized Additive Model) results for the beaked whale during summer in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(shelf) + s(SST) + offset(off.set)
Approximate significance of smooth terms		
s(lon,lat)		
	Edf	28.950
	Est. rank	13.000
	F	11.773
	p-value	<2e-16
s(shelf)		
	Edf	7.997
	Est. rank	9.000
	F	10.366
	p-value	8.05e-15
s(SST)		
	Edf	7.669
	Est. rank	9.000
	F	8.381
	p-value	9.65e-12
R-sq. (adj)		0.34
n segments		50
Deviance explained		55.1%

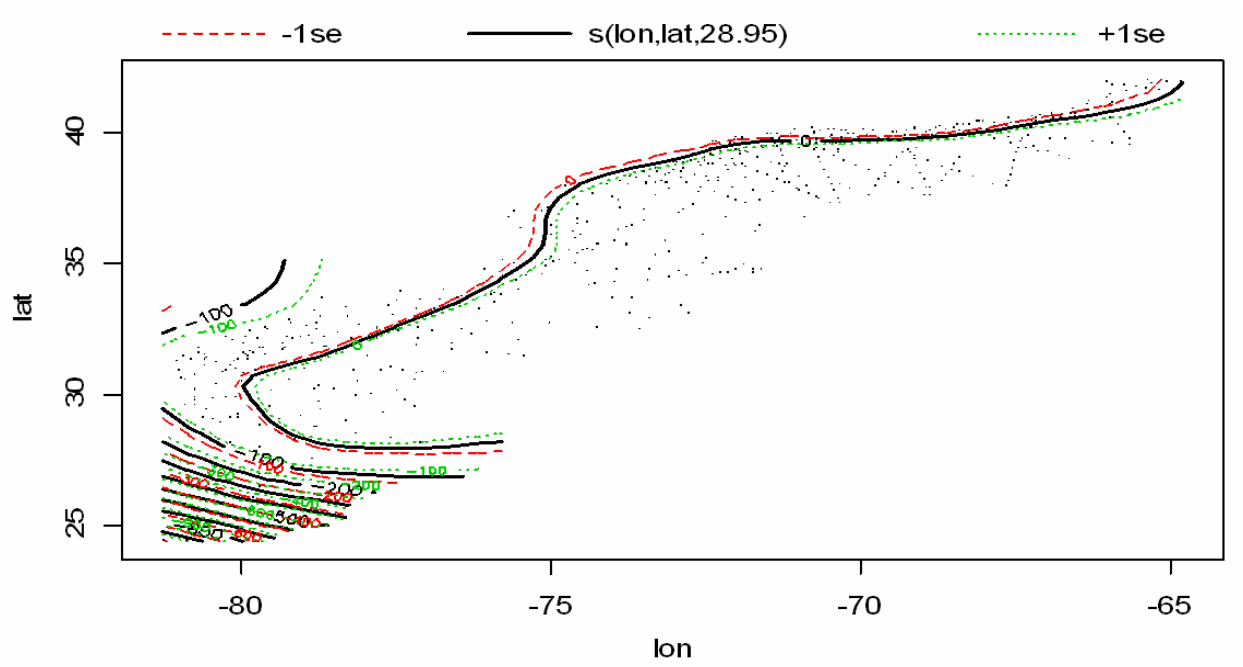

Figure A-20. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the beaked whale during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and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

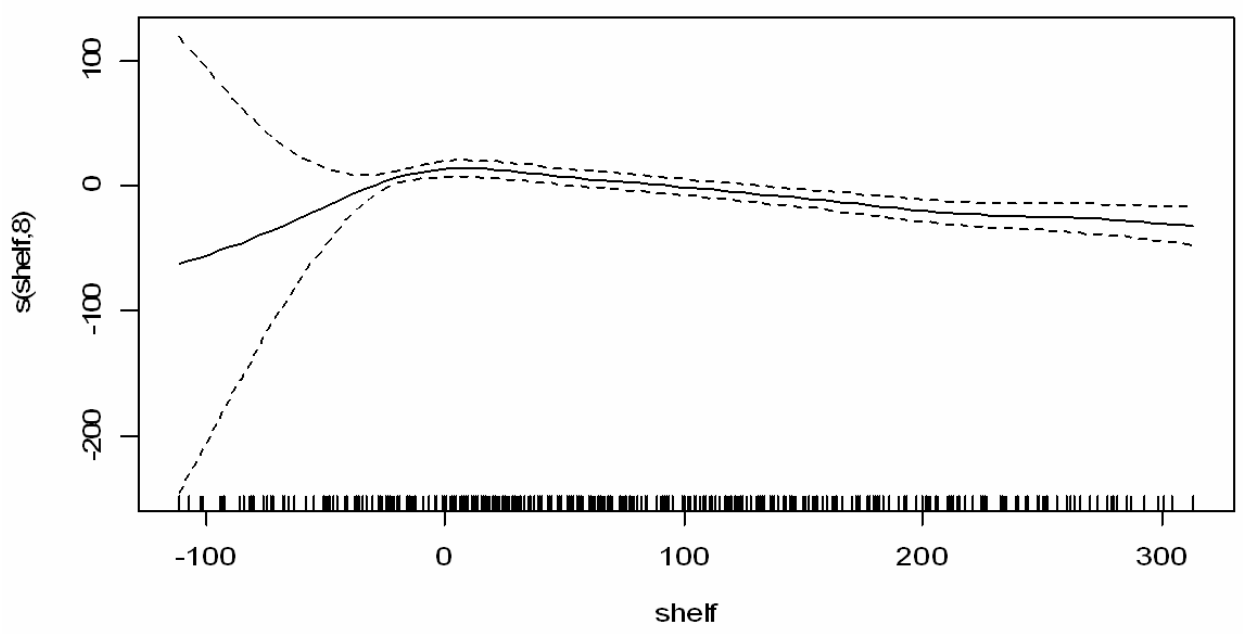

Figure A-21. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the beaked whale during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

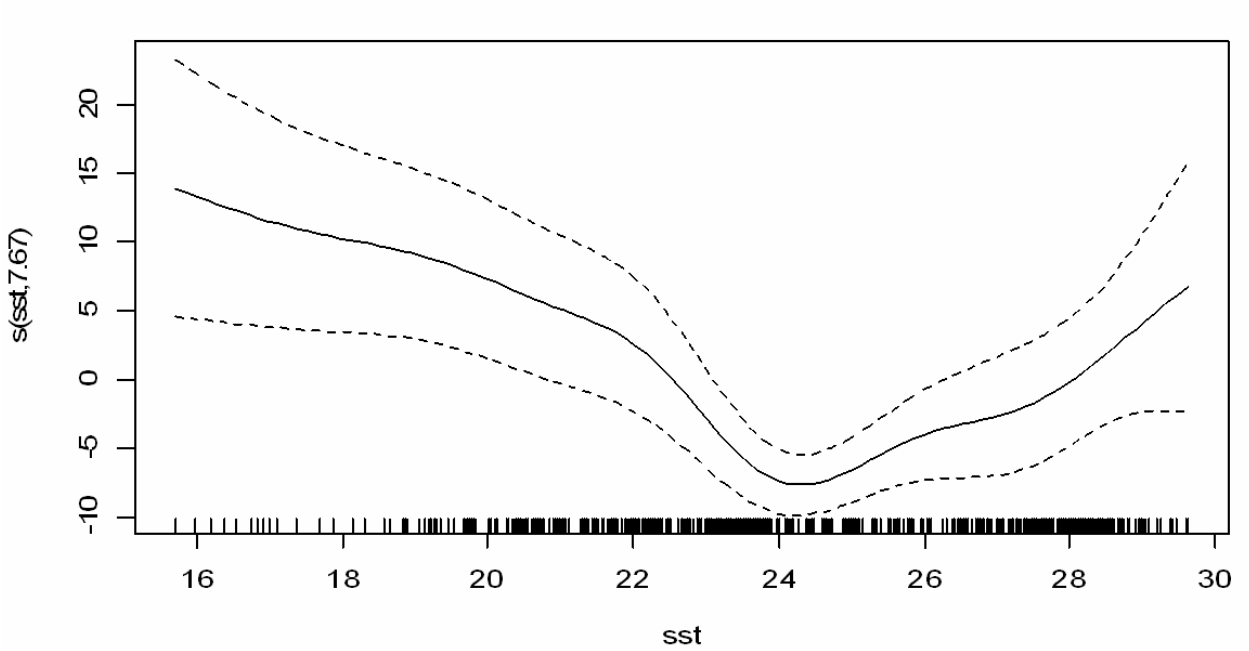

Figure A-22. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for the beaked whale during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-14. Variance estimate model results for the beaked whale during all summer in the Southeast study area.

Variance	
Legitimate values	463
Non-legitimate bootstrap replicates	36
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	903.5458 - 1218.4631
Point estimate	1054.039
SE of bootstraps	80.45141
Est. CV for density surface model	0.0763
CV in detection probability	0.0781
CV in overall estimate including density surface model and detection probability	0.1092
Confidence interval incorporating detection function uncertainty	851.4249, 1304.870

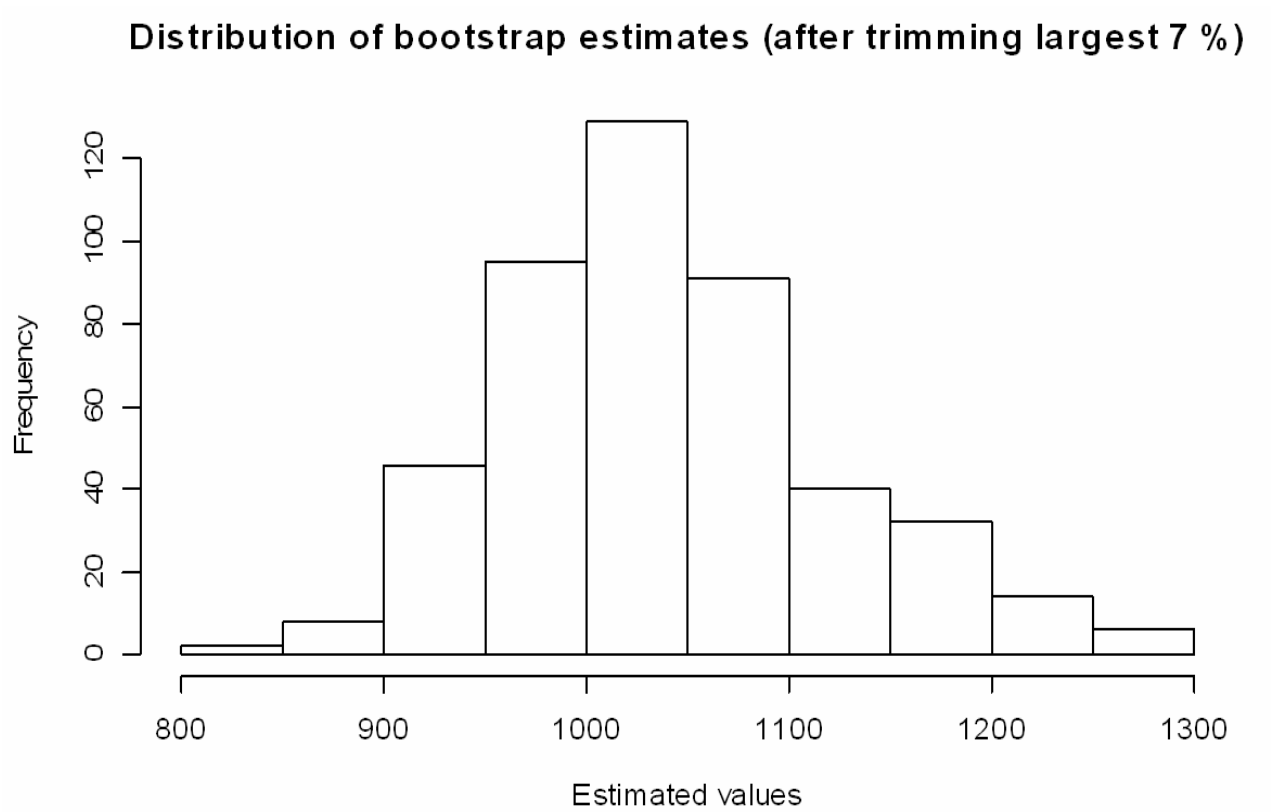

Figure A-23. Distribution of bootstrap estimates (after trimming largest 7%) for pooled sightings of the beaked whale during summer in the Southeast study area.

- Bottlenose Dolphin (*Tursiops truncatus*)

Table A-15. Detection function results for the bottlenose dolphin during spring, fall, and winter in the Southeast study area.

Detection Function	
No. of observations	290
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.0917
SE	0.2277
Hazard shape parameter (Exponent)	
Estimate	1.3794
SE	0.1530
Average p	
Estimate	0.1974
SE	0.0241
CV	0.1220
N in covered region	
Estimate	1469.4257
SE	195.2114
CV	0.1328

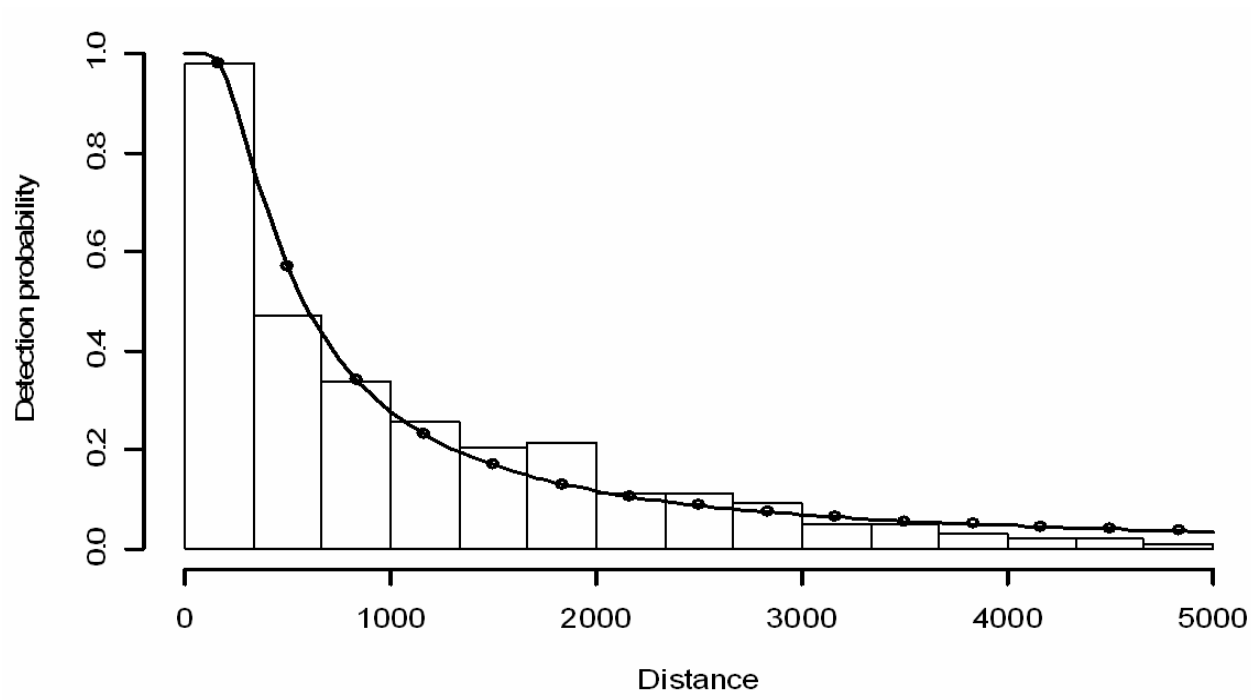

Figure A-24. Plot of the detection function for pooled sightings of the bottlenose dolphin in spring, fall, and winter in the Southeast study area. Distance is measured in meters.

Table A-16. Response surface model (Generalized Additive Model) results for the bottlenose dolphin in spring, fall, and winter in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + s(slope) + offset(off.set)
Approximate significance of smooth terms		
s(lon,lat)		
	Edf	28.997
	Est. rank	29.000
	F	21.407
	p-value	<2e-16
s(depth)		
	Edf	5.731
	Est. rank	9.000
	F	10.258
	p-value	1.25e-15
s(shelf)		
	Edf	5.532
	Est. rank	9.000
	F	6.825
	p-value	9.96e-10
s(slope)		
	Edf	7.366
	Est. rank	9.000
	F	7.553
	p-value	5.76e-11
R-sq. (adj)		0.218
n segments		223
Deviance explained		41.2%

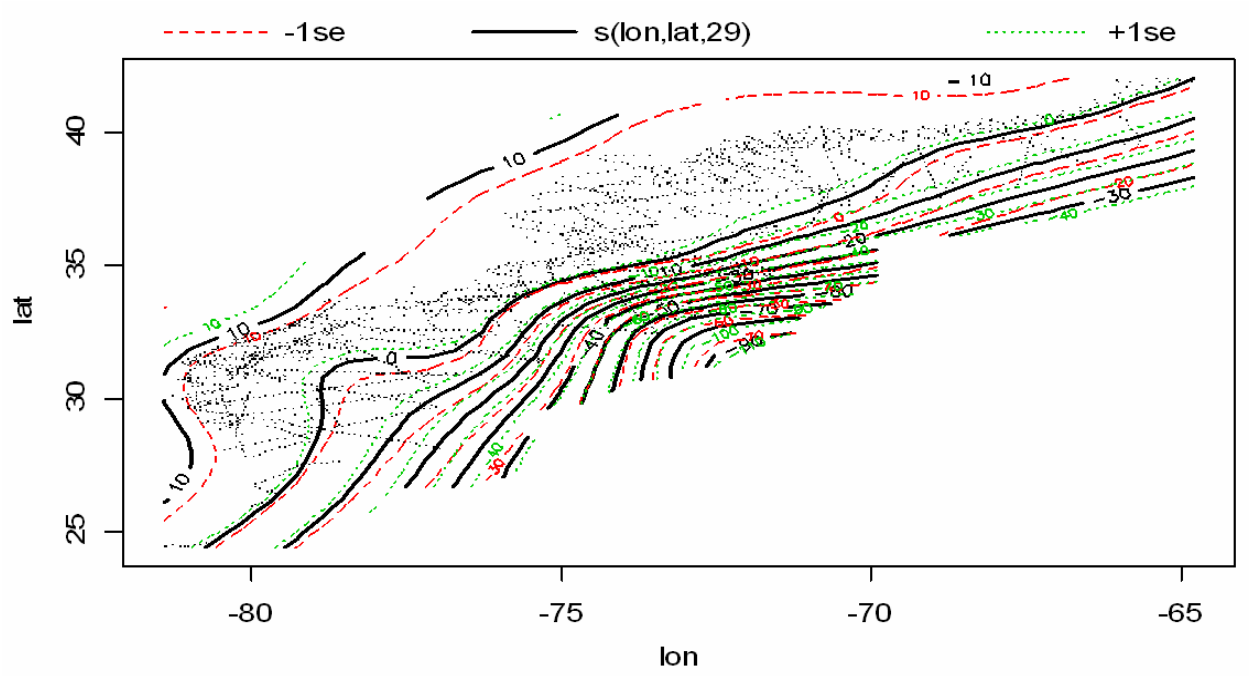

Figure A-25. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the bottlenose dolphin during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

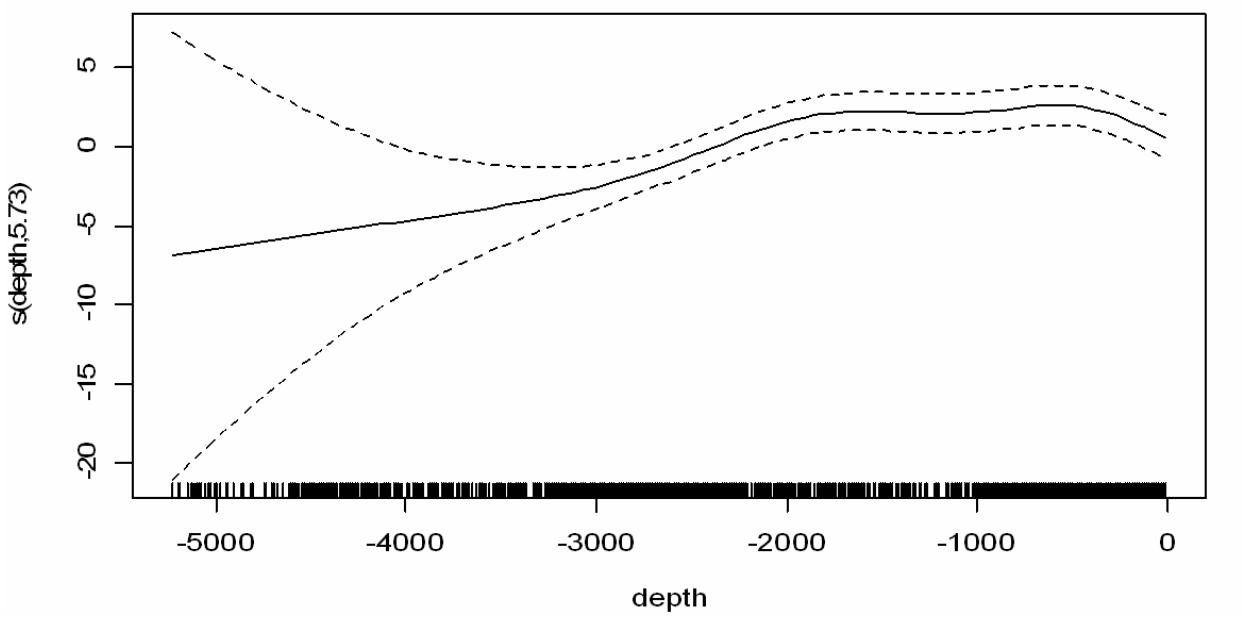

Figure A-26. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the bottlenose dolphin during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

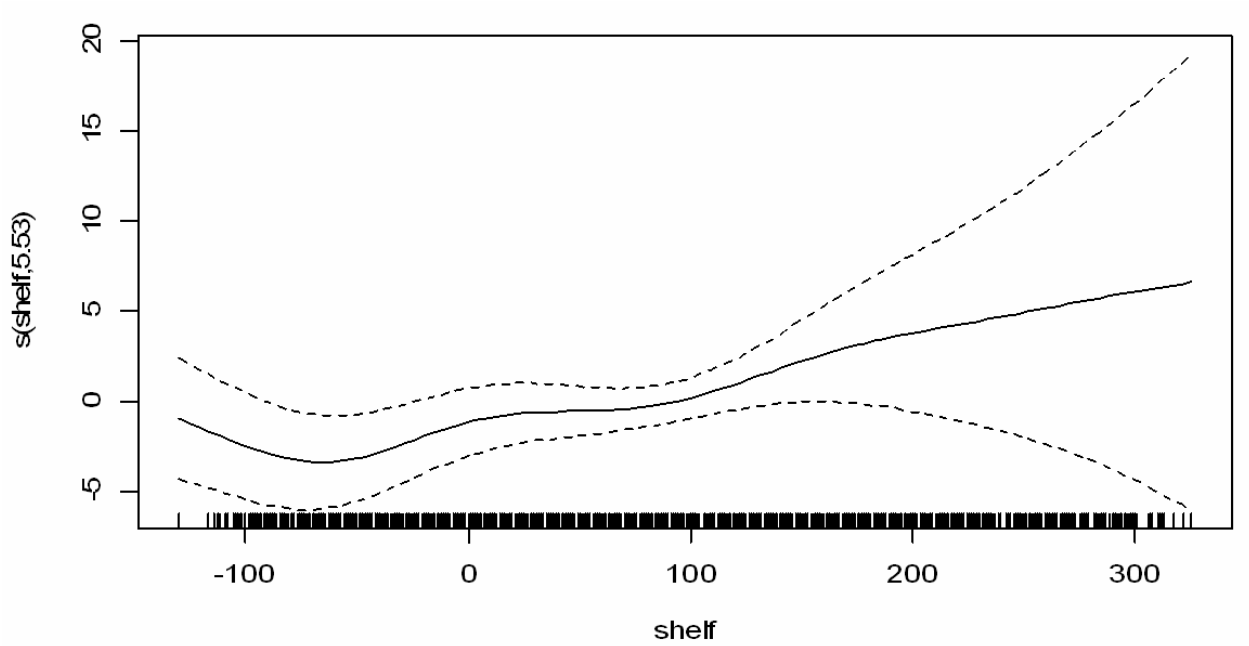

Figure A-27. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the bottlenose dolphin during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

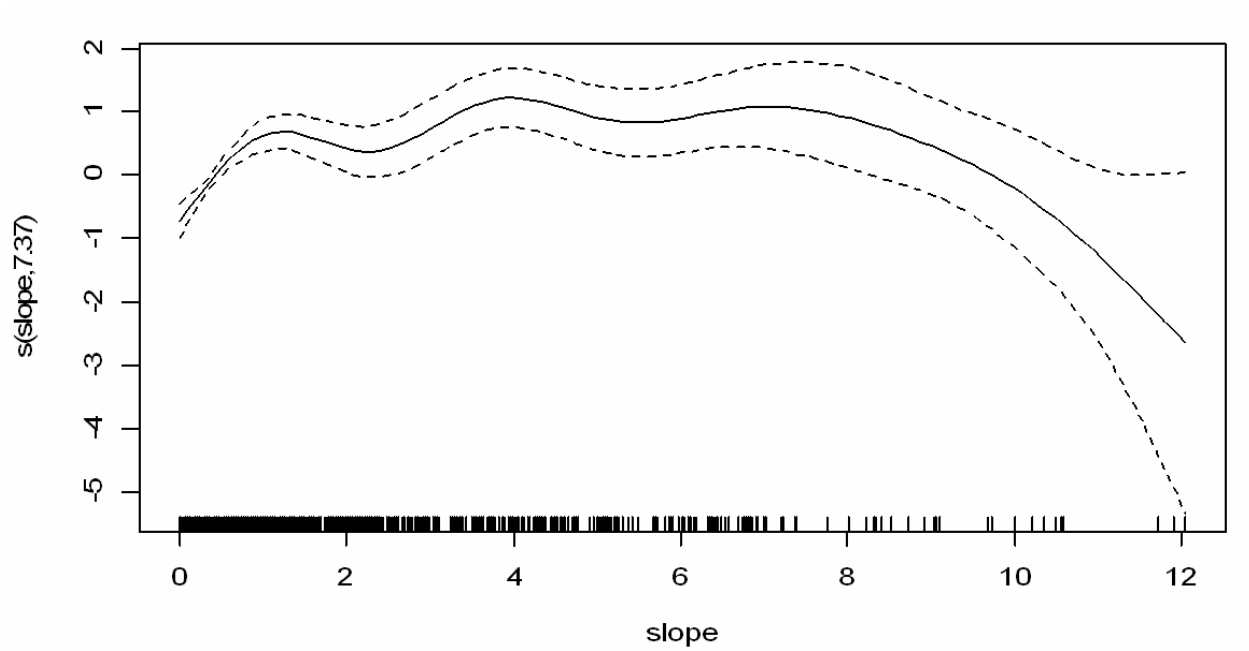

Figure A-28. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the bottlenose dolphin during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-17. Variance estimate model results for the bottlenose dolphin during spring, fall, and winter in the Southeast study area.

Variance	
Legitimate values	453
Non-legitimate bootstrap replicates	46
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	51318.3 - 113265.9
Point estimate	67124.67
SE of bootstraps	15842.29
Est. CV for density surface model	0.236
CV in detection probability	0.122
CV in overall estimate including density surface model and detection probability	0.2657
Confidence interval incorporating detection function uncertainty	40232.78, 111991.3

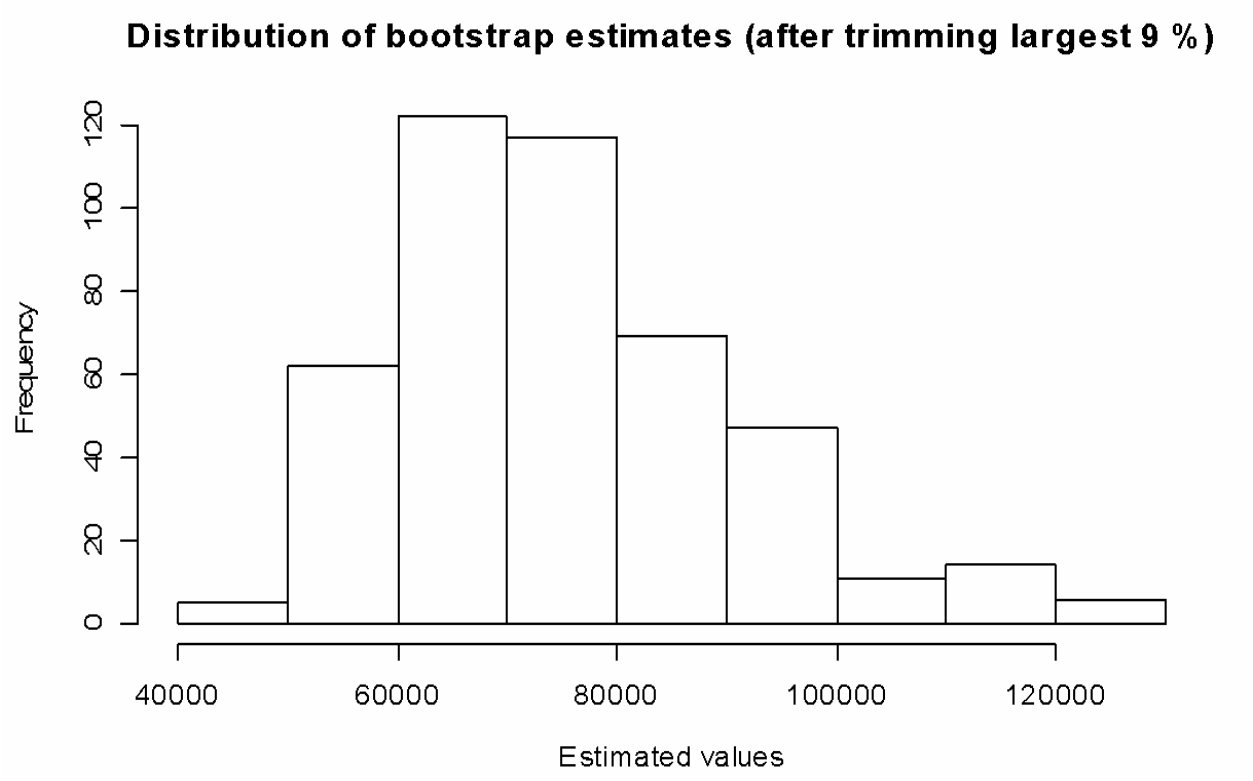

Figure A-29. Distribution of bootstrap estimates (after trimming largest 9%) for pooled sightings of the bottlenose dolphin during spring, fall, and winter in the Southeast study area.

Table A-18. Detection function results for the bottlenose dolphin during summer in the Southeast study area.

Detection Function	
No. of observations	265
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.2739
SE	0.2197
Hazard shape parameter (Exponent)	
Estimate	1.4064
SE	0.1678
Average p	
Estimate	0.2258
SE	0.0266
CV	0.1177
N in covered region	
Estimate	1173.7681
SE	152.0319
CV	0.1295

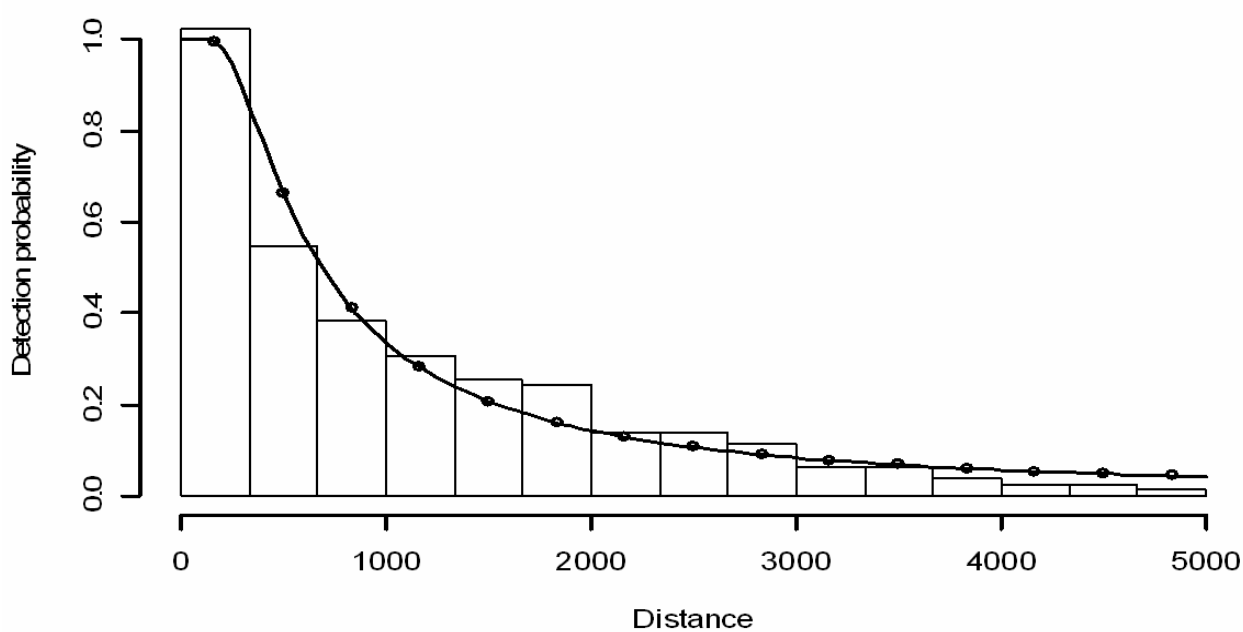

Figure A-30. Plot of the detection function for pooled sightings of the bottlenose dolphin in summer in the Southeast study area. Distance is measured in meters.

Table A-19. Response surface model (Generalized Additive Model) results for the bottlenose dolphin in summer in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + s(slope) + s(SST) + offset(off.set)
Approximate significance of smooth terms		
s(lon,lat)		
	Edf	28.805
	Est. rank	29.000
	F	9.878
	p-value	<2e-16
s(depth)		
	Edf	5.479
	Est. rank	9.000
	F	7.858
	p-value	1.79e-11
s(shelf)		
	Edf	5.903
	Est. rank	9.000
	F	5.721
	p-value	7.18e-08
s(slope)		
	Edf	8.274
	Est. rank	9.000
	F	9.463
	p-value	3.15e-14
s(SST)		
	Edf	6.794
	Est. rank	9.000
	F	11.838
	p-value	<2e-16
R-sq. (adj)		0.341
n segments		203
Deviance explained		46.8%

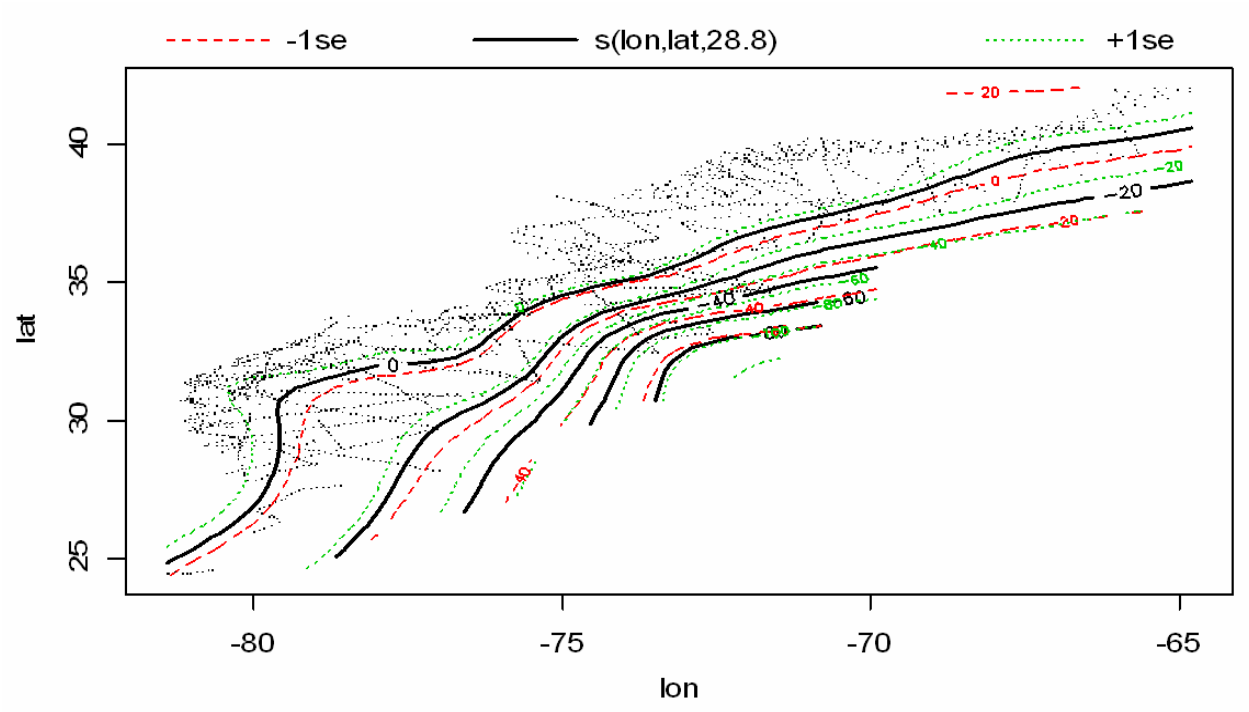

Figure A-31. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the bottlenose dolphin during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

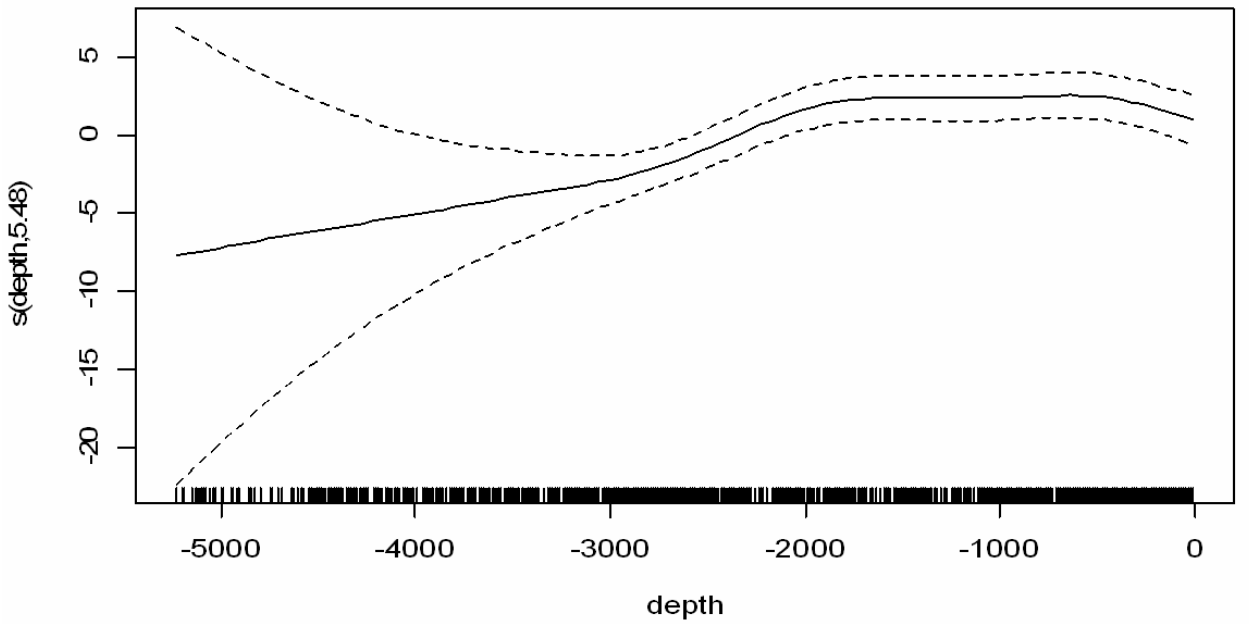

Figure A-32. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the bottlenose dolphin during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

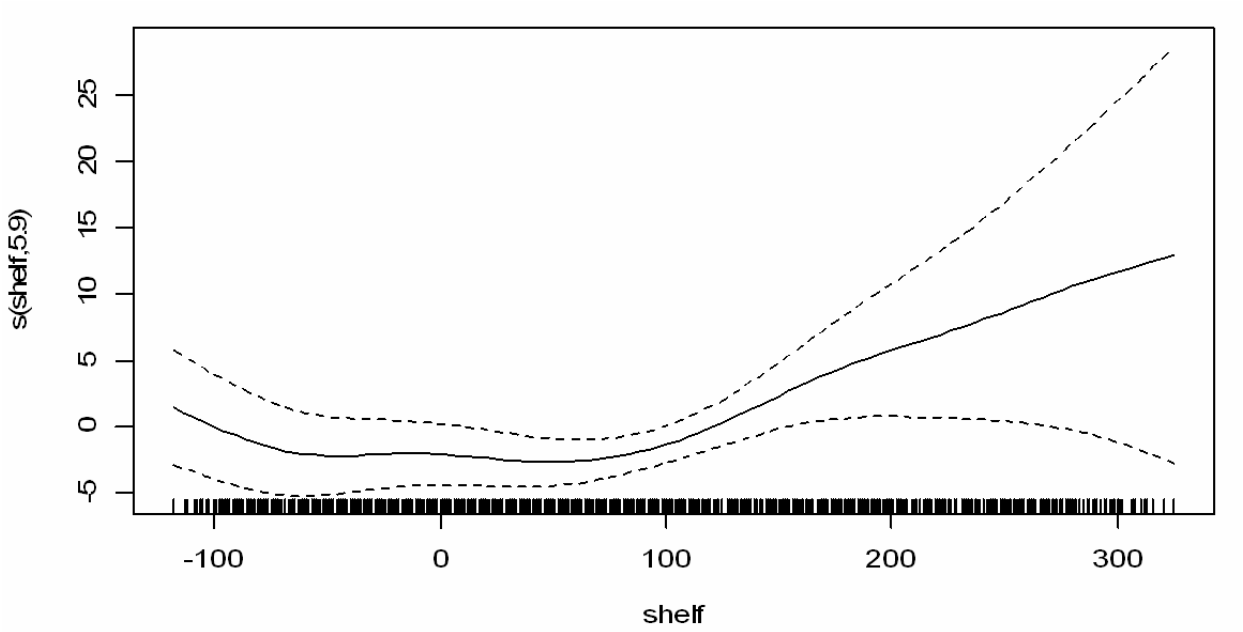

Figure A-33. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the bottlenose dolphin during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

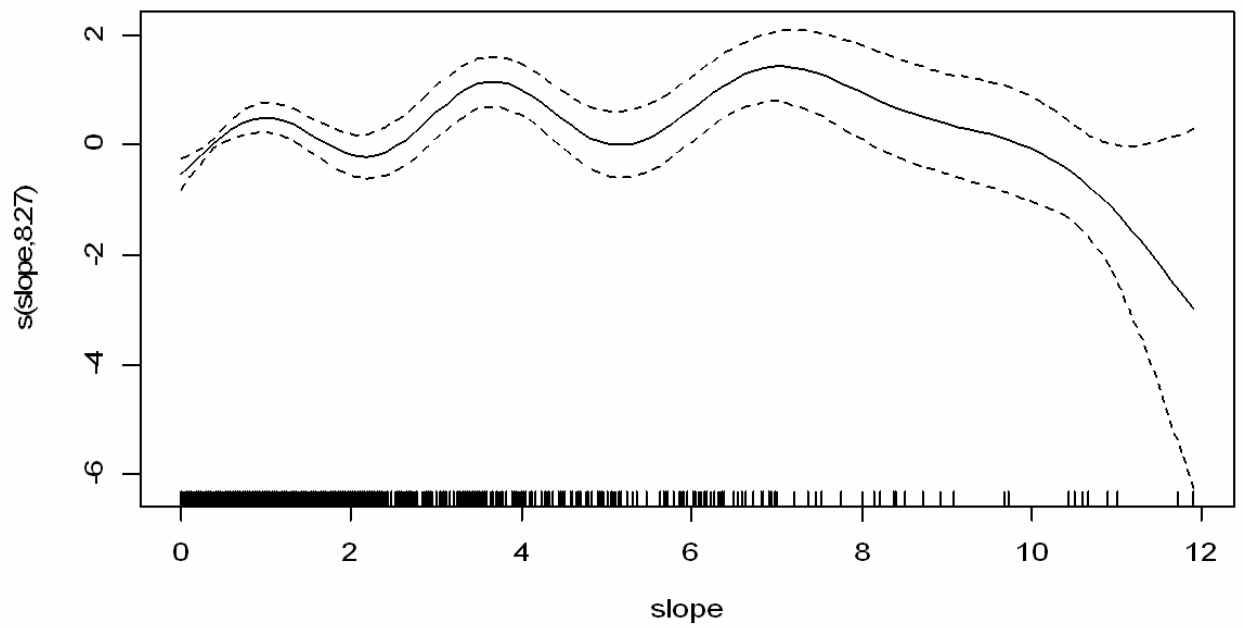

Figure A-34. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the bottlenose dolphin during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

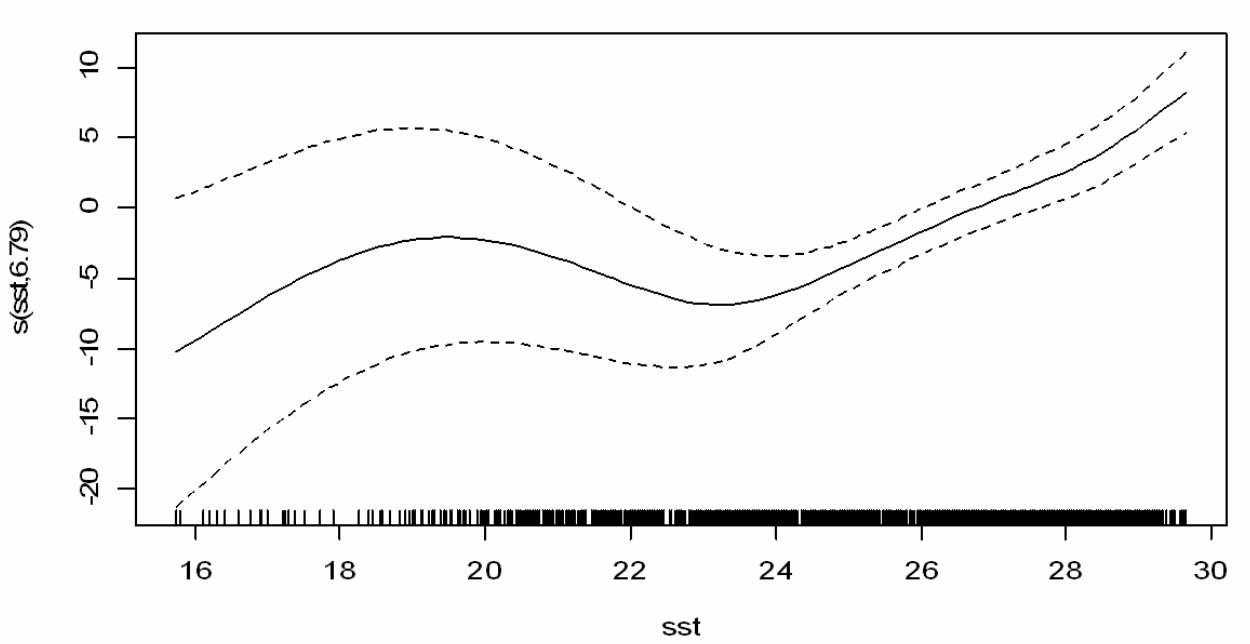

Figure A-35. Plot of the Generalized Additive Model smooth fit of the environmental covariate SST selected for the bottlenose dolphin during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-20. Variance estimate model results for the bottlenose dolphin during summer in the Southeast study area.

Variance	
Legitimate values	450
Non-legitimate bootstrap replicates	49
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	50286.02 - 121337.66
Point estimate	67311.2
SE of bootstraps	18251.13
Est. CV for density surface model	0.2711
CV in detection probability	0.1177
CV in overall estimate including density surface model and detection probability	0.2956
Confidence interval incorporating detection function uncertainty	38170.25, 118699.9

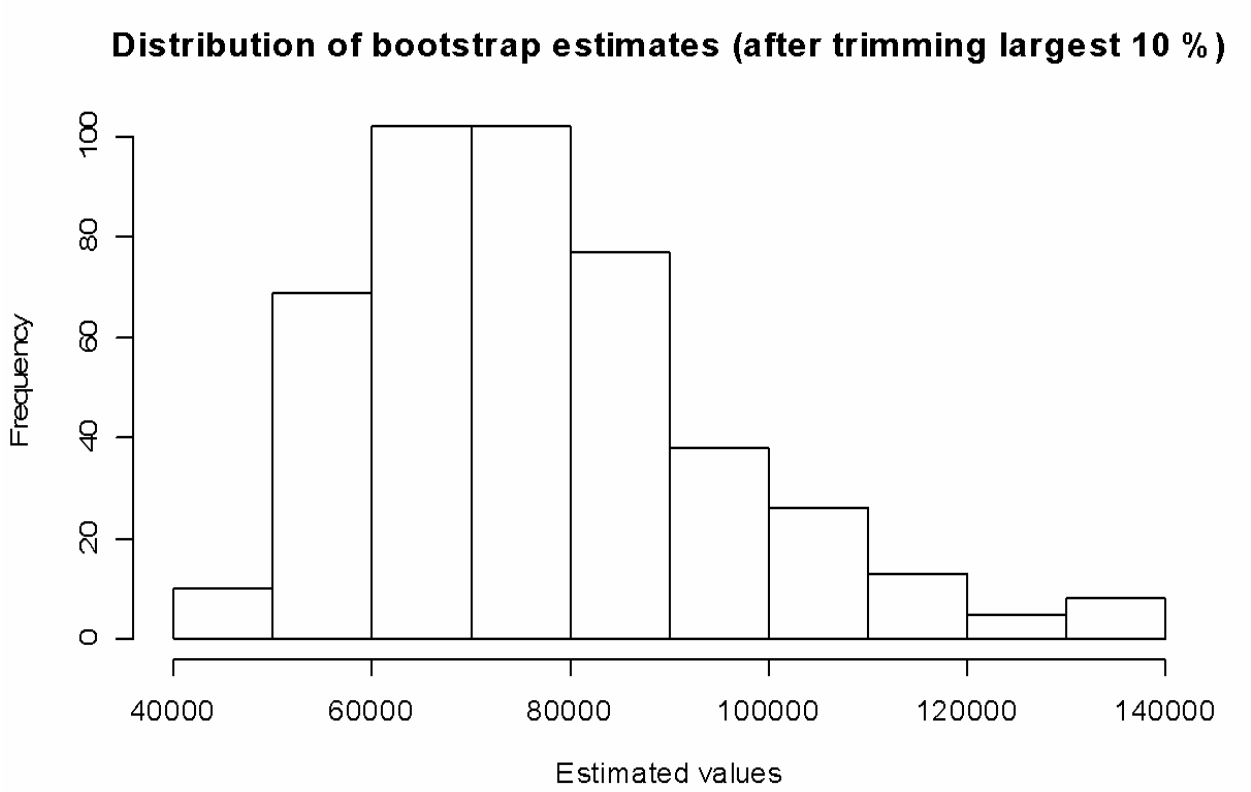

Figure A-36. Distribution of bootstrap estimates (after trimming largest 10%) for pooled sightings of the bottlenose dolphin during summer in the Southeast study area.

- Atlantic Spotted Dolphin (*Stenella frontalis*)

Table A-21. Detection function results for the Atlantic spotted dolphin during all seasons in the Southeast study area.

Detection Function	
No. of observations	189
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.1735
SE	0.2704
Hazard shape parameter (Exponent)	
Estimate	1.5470
SE	0.2161
Average p	
Estimate	0.2002
SE	0.0306
CV	0.1528
N in covered region	
Estimate	944.0764
SE	156.7774
CV	0.1661

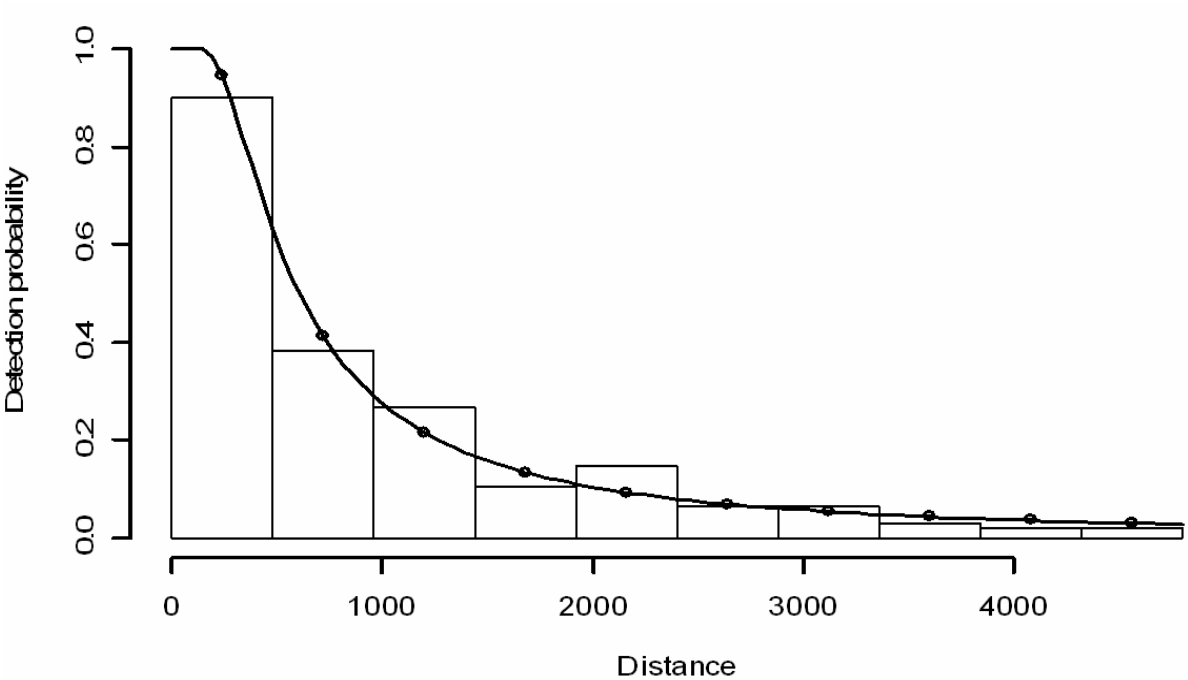

Figure A-37. Plot of the detection function for pooled sightings of the Atlantic spotted dolphin during all seasons in the Southeast study area. Distance is measured in meters.

Table A-22. Response surface model (Generalized Additive Model) results for the Atlantic spotted dolphin during all seasons in the Southeast 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	28.99
Est. rank	22.00
F	10.054
p-value	<2e-16
s(depth)	
Edf	8.99
Est. rank	9.00
F	9.079
p-value	1.57e-13
R-sq. (adj)	0.0941
n segments	141
Deviance explained	44.1%

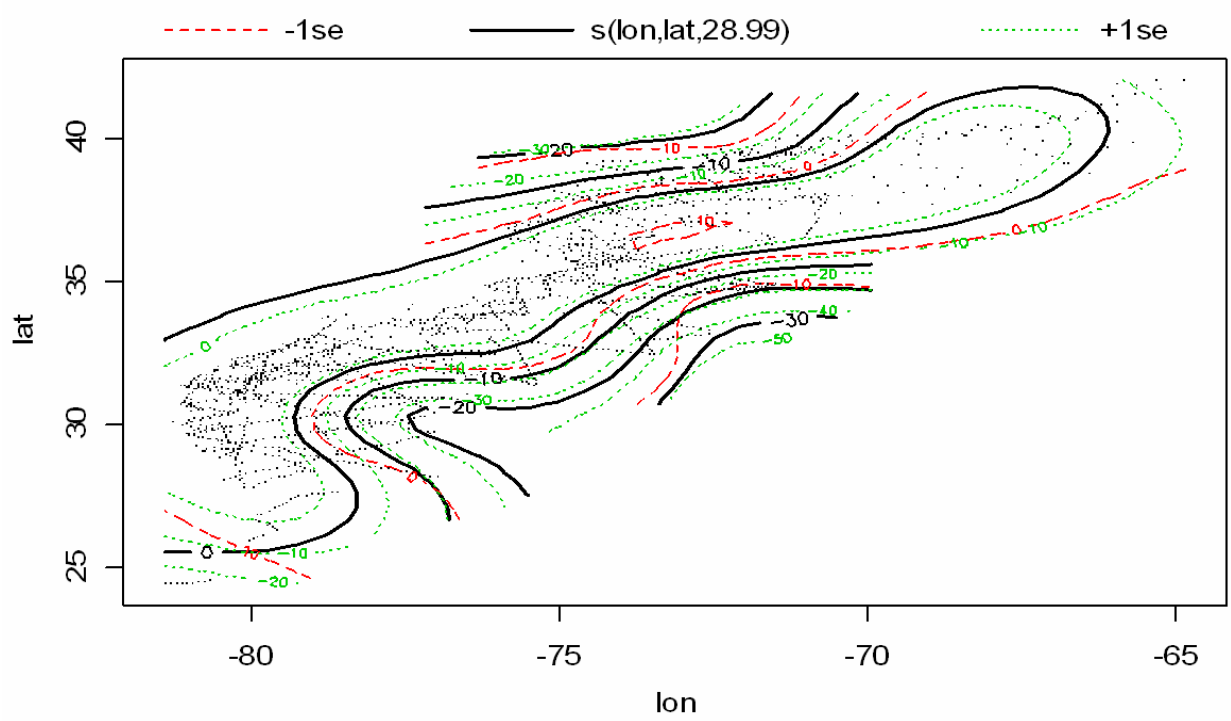

Figure A-38. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the Atlantic spotted dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

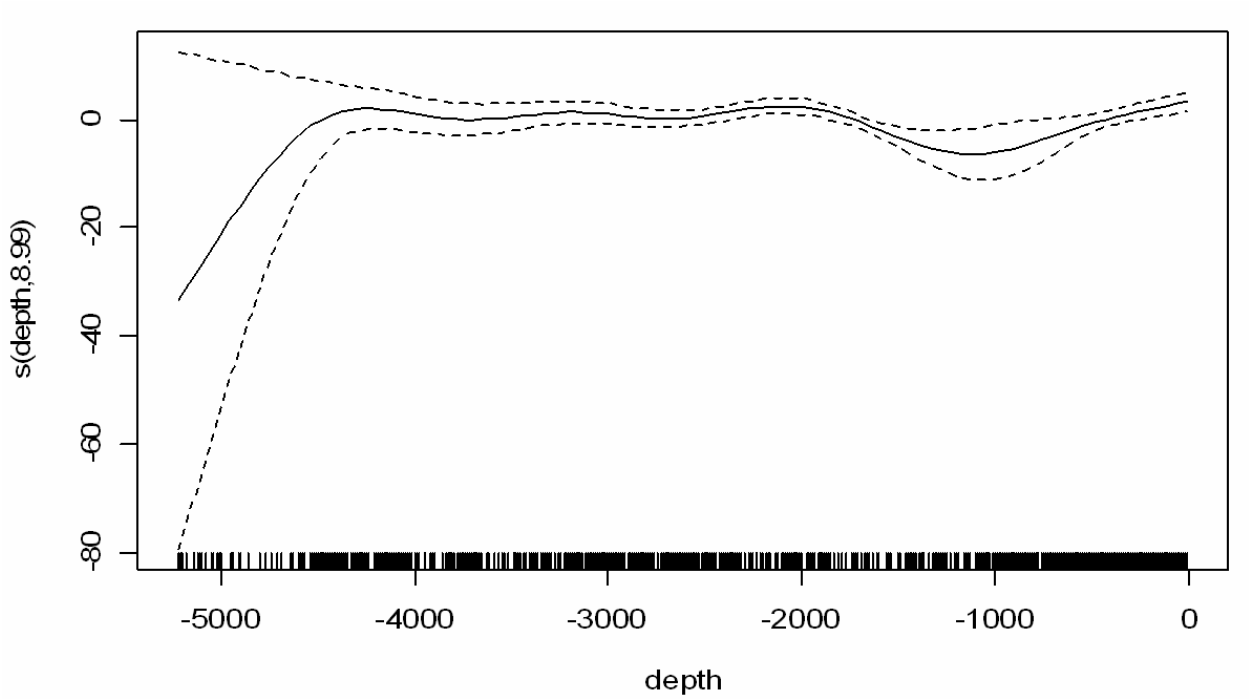

Figure A-39. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the Atlantic spotted dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-23. Variance estimate model results for the Atlantic spotted dolphin during all seasons in the Southeast study area.

Variance	
Legitimate values	472
Non-legitimate bootstrap replicates	21
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	48865.98 - 88561.01
Point estimate	67017.54
SE of bootstraps	10387.95
Est. CV for density surface model	0.155
CV in detection probability	0.1528
CV in overall estimate including density surface model and detection probability	0.2177
Confidence interval incorporating detection function uncertainty	43960.27, 102168.4

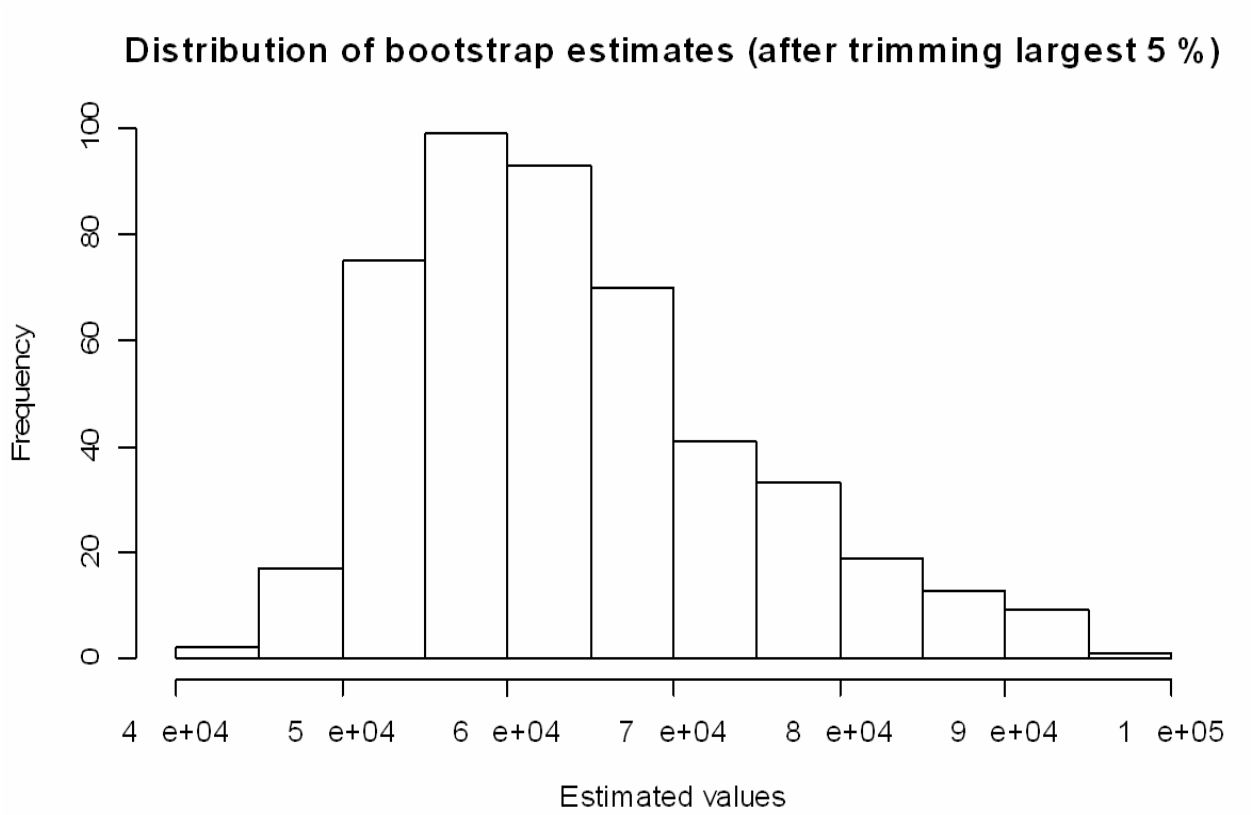

Figure A-40. Distribution of bootstrap estimates (after trimming largest 5%) for pooled sightings of the Atlantic spotted dolphin during all seasons in the Southeast study area.

- Striped Dolphin (*Stenella coeruleoalba*)

Table A-24. Detection function results for the striped dolphin during all seasons in the Southeast study area.

Detection Function	
No. of observations	76
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.6867
SE	0.2690
Hazard shape parameter (Exponent)	
Estimate	1.8318
SE	0.3221
Average p	
Estimate	0.2146
SE	0.0369
CV	0.1718
N in covered region	
Estimate	354.1031
SE	70.6855
CV	0.1996

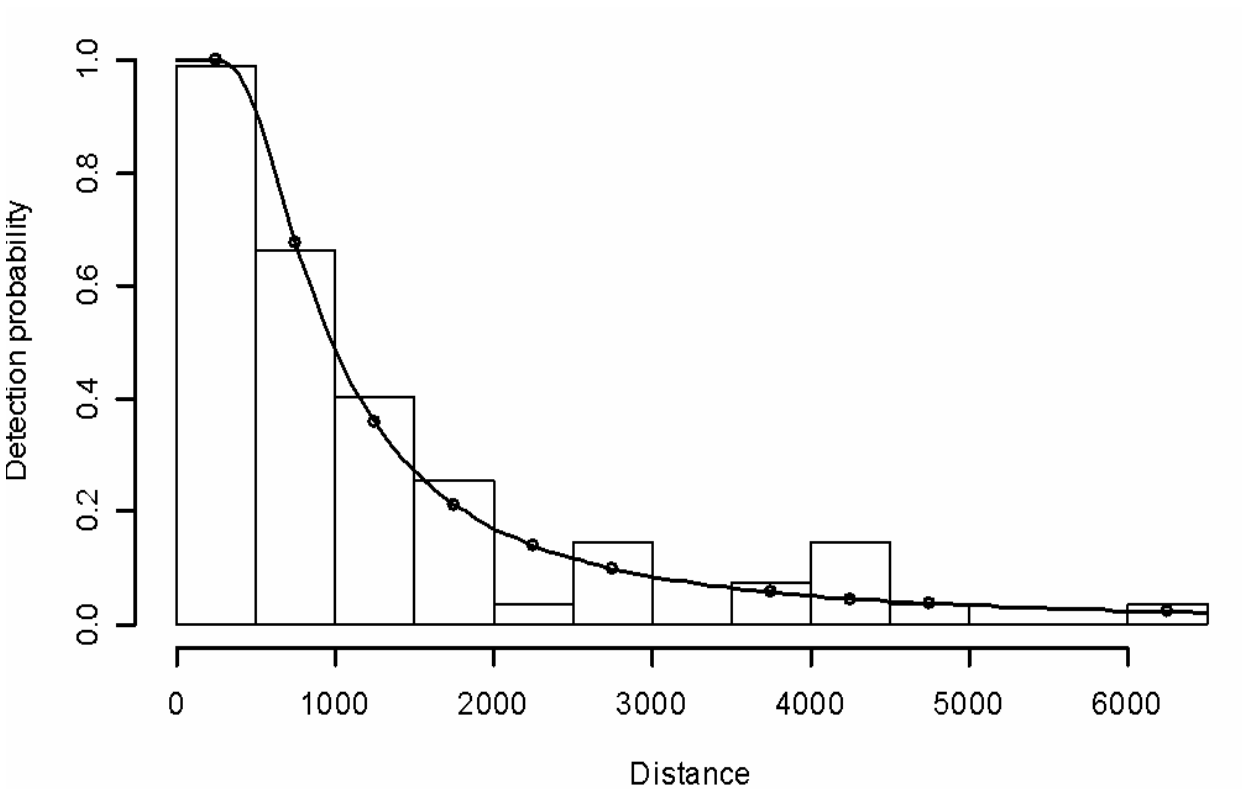

Figure A-41. Plot of the detection function for pooled sightings of the striped dolphin during all seasons in the Southeast study area. Distance is measured in meters.

Table A-25. Response surface model (Generalized Additive Model) results for the striped dolphin during all seasons in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon) + s(lat) + s(depth) + s(shelf) + s(slope) + offset(off.set)
Approximate significance of smooth terms		
s(lon)		
	Edf	5.361
	Est. rank	9.000
	F	7.707
	p-value	7.85e-11
s(lat)		
	Edf	6.133
	Est. rank	9.000
	F	10.977
	p-value	4.78e-16
s(depth)		
	Edf	8.998
	Est. rank	9.000
	F	5.170
	p-value	8.40e-07
s(shelf)		
	Edf	8.999
	Est. rank	9.000
	F	12.097
	p-value	<2e-16
s(slope)		
	Edf	4.886
	Est. rank	9.000
	F	5.494
	p-value	2.60e-07
R-sq. (adj)		0.437
n segments		
Deviance explained		58.8%

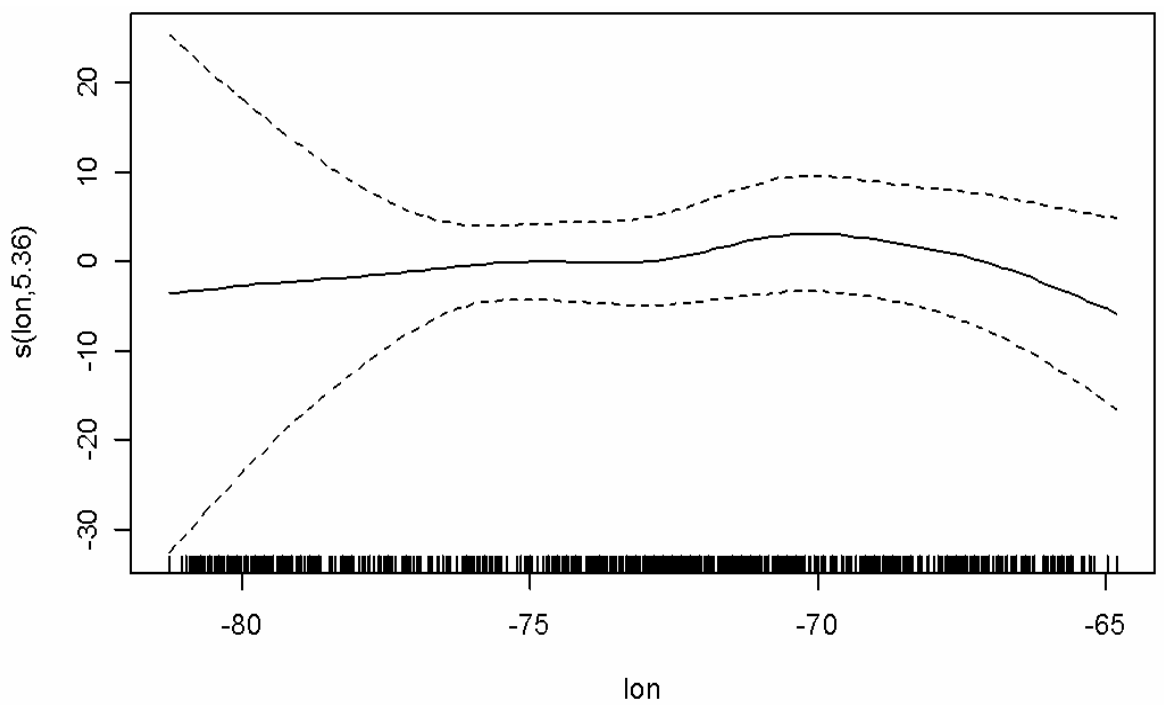

Figure A-42. Plot of the Generalized Additive Model smooth fit of the environmental covariate *longitude* selected for the striped dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

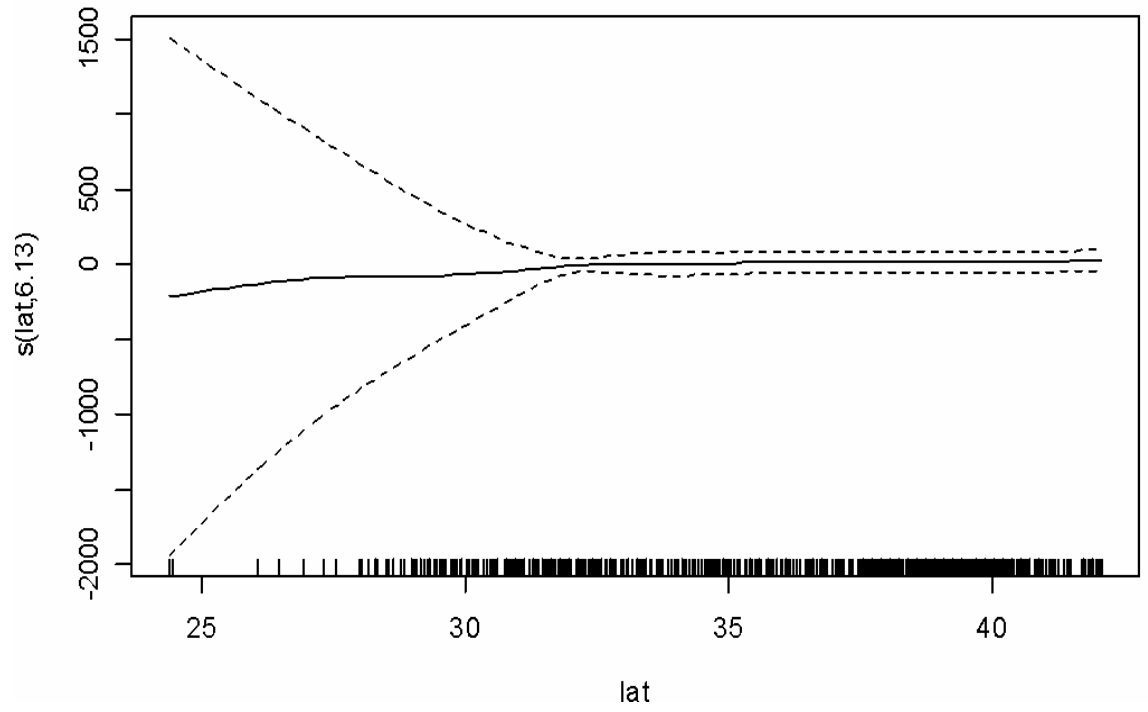

Figure A-43. Plot of the Generalized Additive Model smooth fit of the environmental covariate *latitude* selected for the striped dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

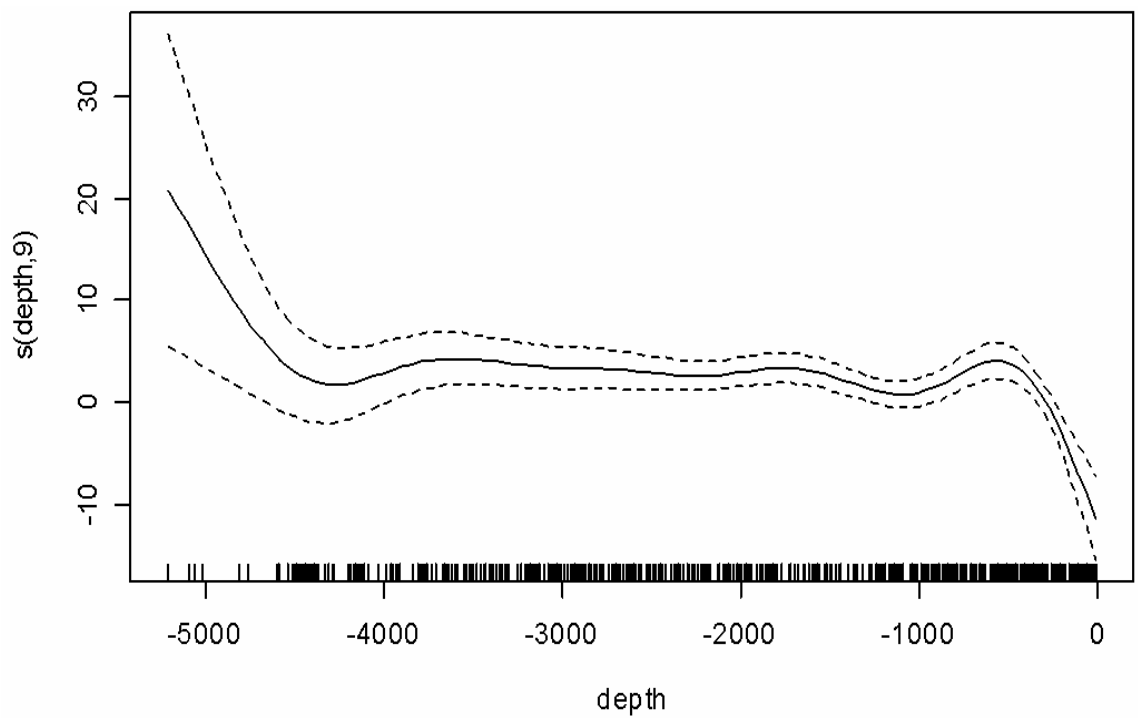

Figure A-44. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the striped dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

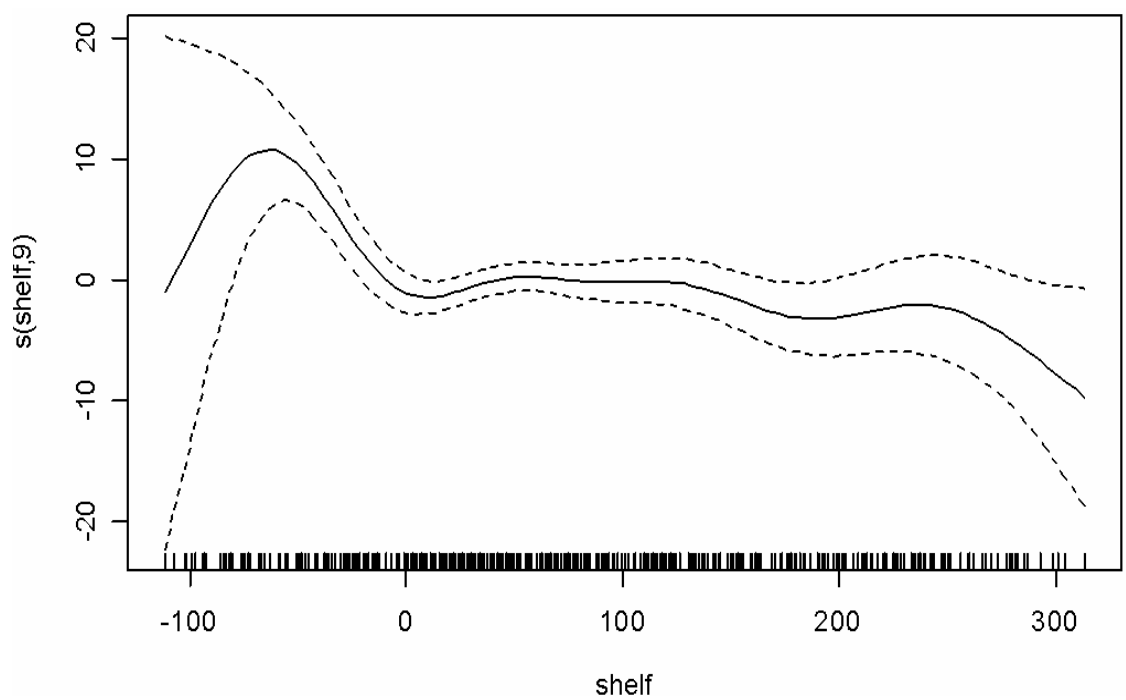

Figure A-45. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the striped dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

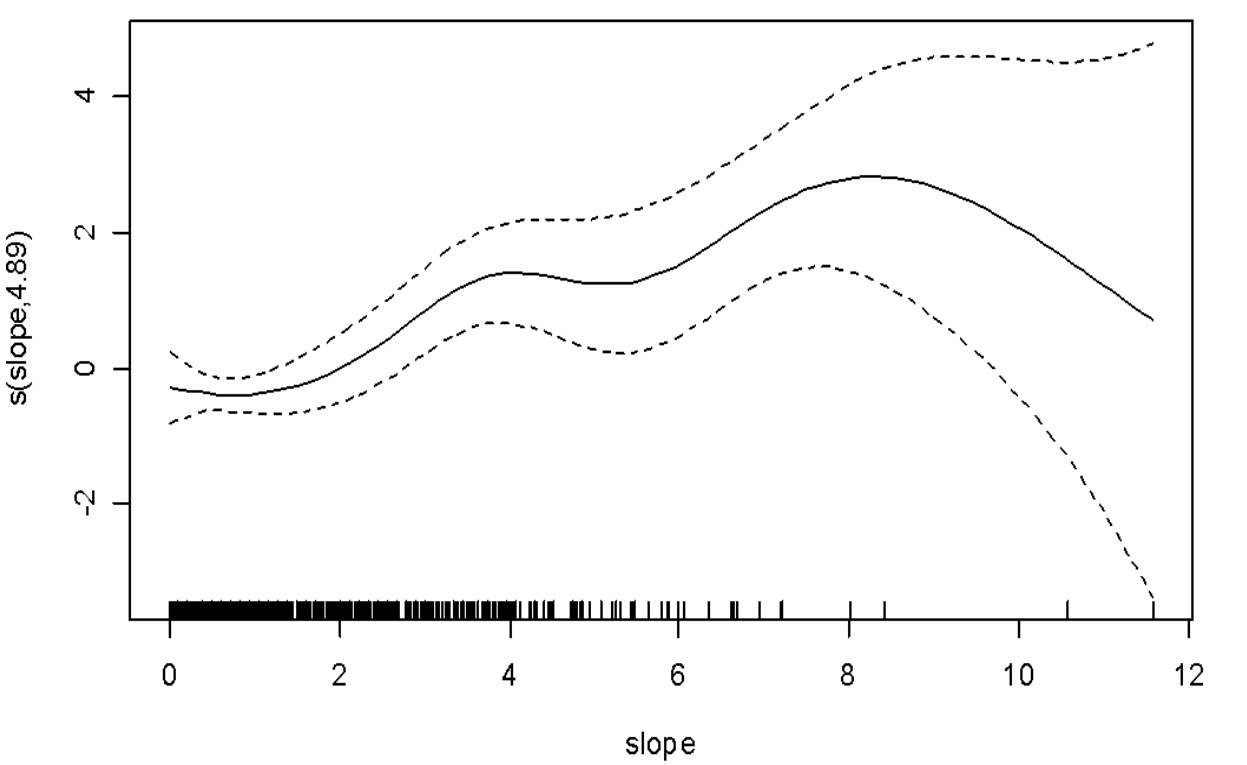

Figure A-46. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the striped dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis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

Table A-26. Variance estimate model results for the striped dolphin during all seasons in the Southeast study area.

Variance	
Legitimate values	419
Non-legitimate bootstrap replicates	80
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	37957.37 - 175466.99
Point estimate	59882.2
SE of bootstraps	33939.53
Est. CV for density surface model	0.5668
CV in detection probability	0.1718
CV in overall estimate including density surface model and detection probability	0.5922
Confidence interval incorporating detection function uncertainty	20443.63, 175403.2

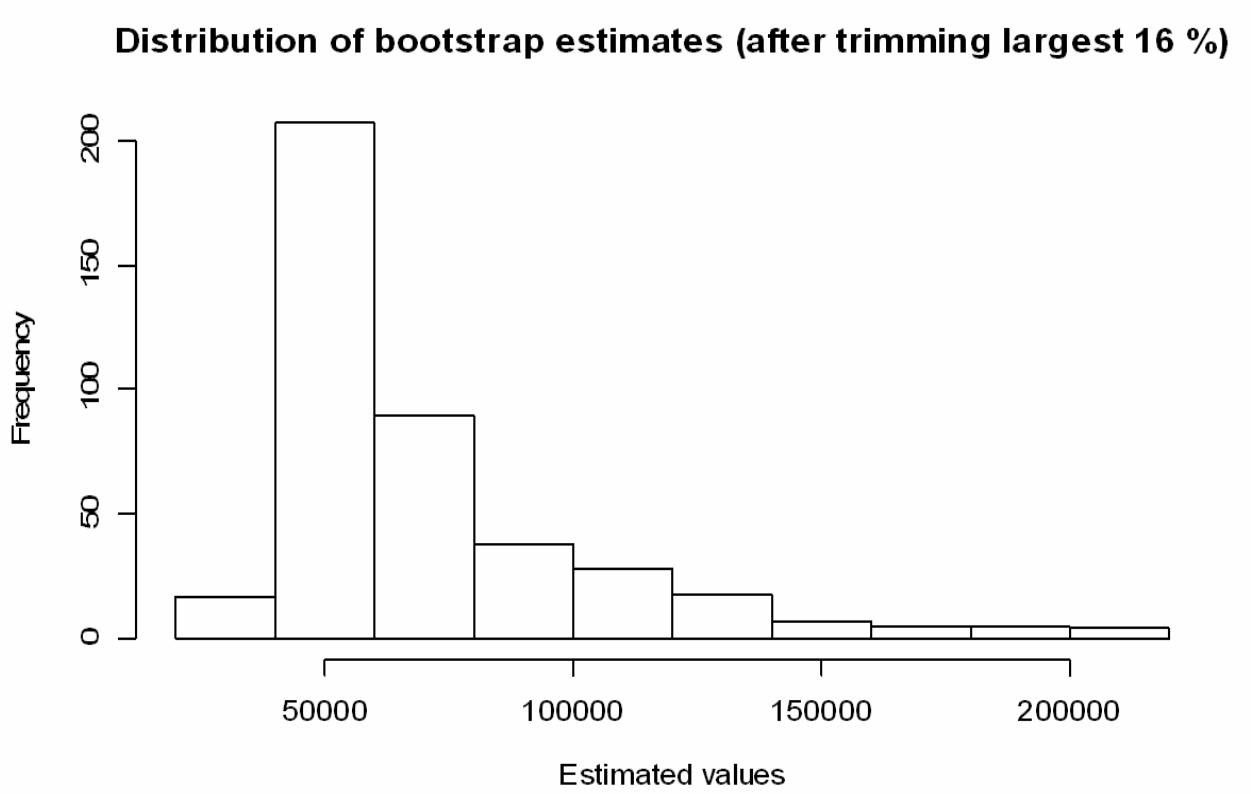

Figure A-47. Distribution of bootstrap estimates (after trimming largest 16%) for pooled sightings of the striped dolphin during all seasons in the Southeast study area.

- Common Dolphin (*Delphinus delphis*)

Table A-29. Detection function results for the common dolphin during all seasons in the Southeast study area.

Detection Function	
No. of observations	46
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.4118
SE	0.0809
Average p	
Estimate	0.3842
SE	0.0307
CV	0.0798
N in covered region	
Estimate	199.7257
SE	16.8303
CV	0.1406

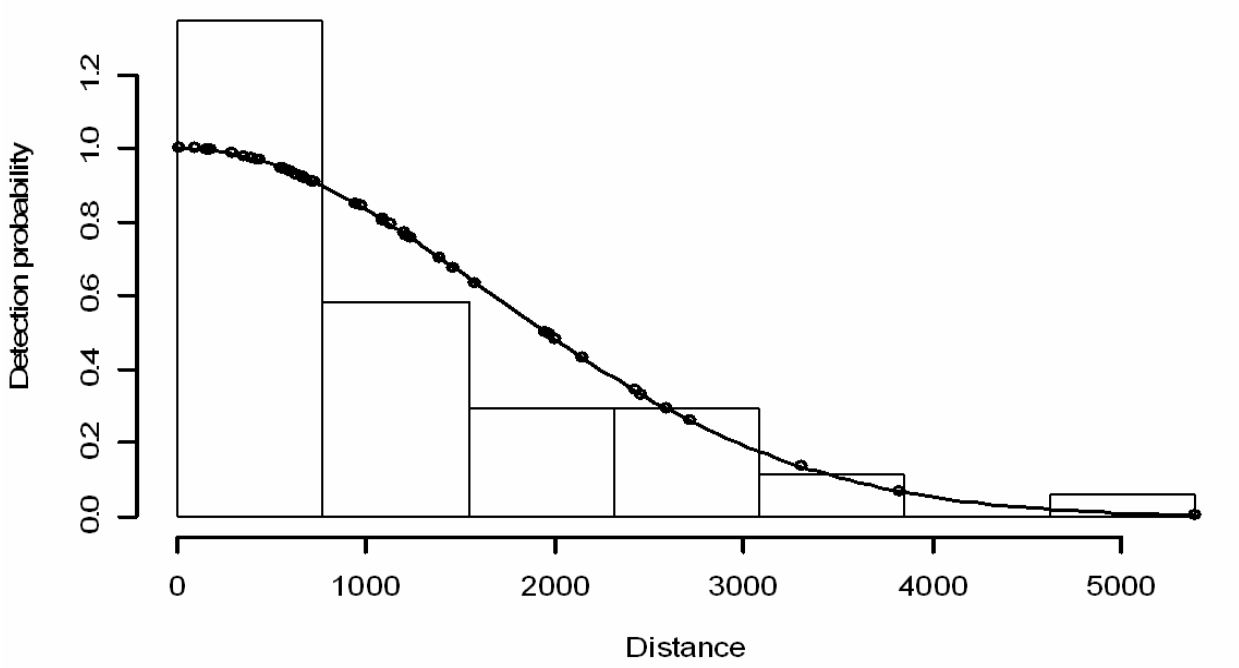

Figure A-51. Plot of the detection function for pooled sightings of the common dolphin during all seasons in the Southeast study area. Distance is measured in meters.

Table A-30. Response surface model (Generalized Additive Model) results for the common dolphin during all seasons in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	28.956
	Est. rank	9.000
	F	3.893
	p-value	7.49e-05
s(depth)		
	Edf	4.664
	Est. rank	8.000
	F	17.787
	p-value	<2e-16
s(shelf)		
	Edf	5.690
	Est. rank	8.000
	F	13.180
	p-value	<2e-16
R-sq. (adj)		0.894
n segments		
Deviance explained		77%

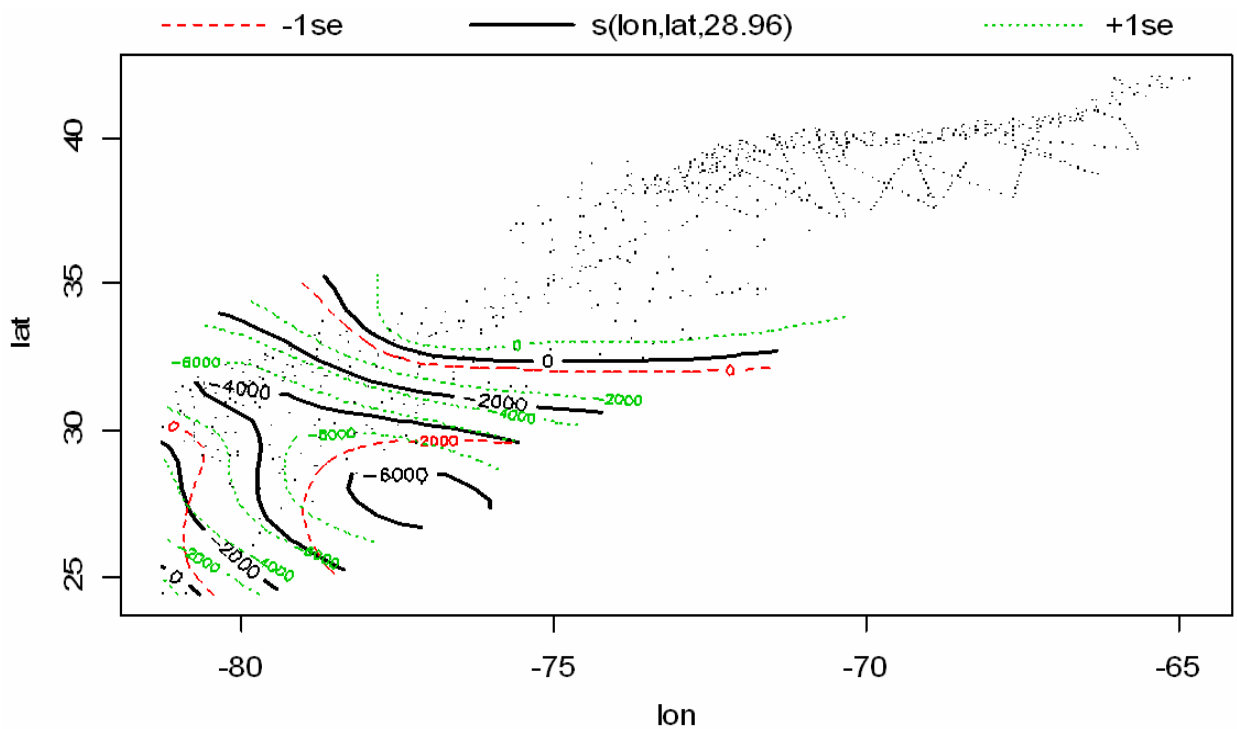

Figure A-52. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the common dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

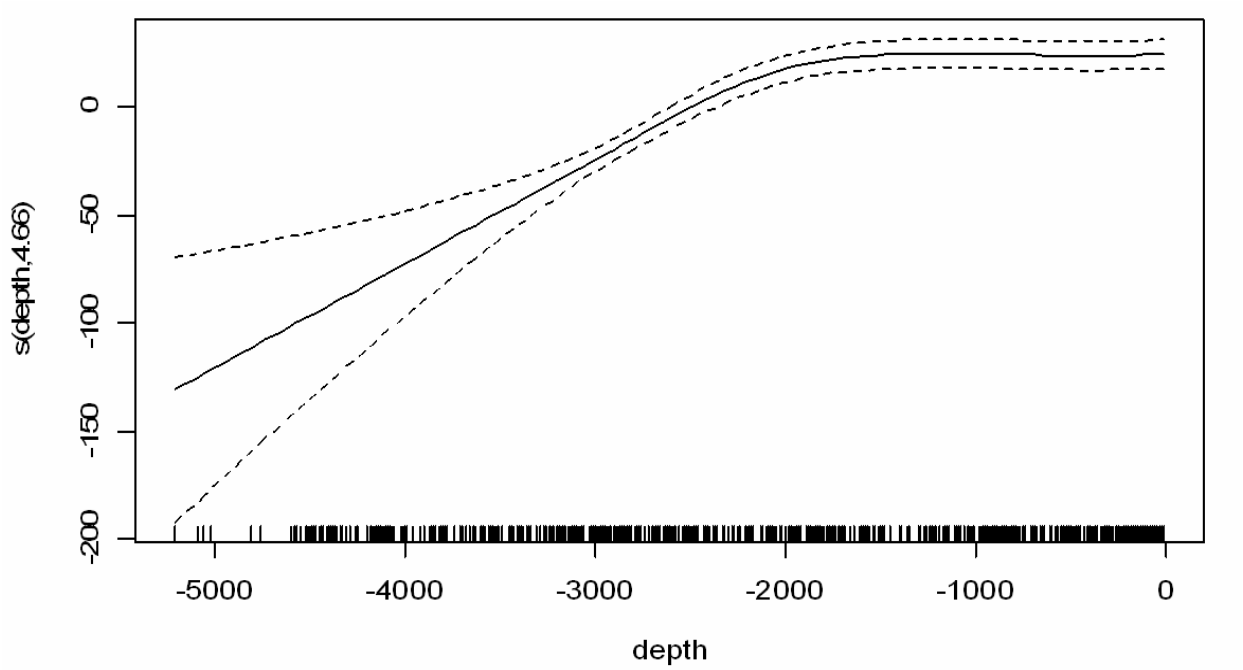

Figure A-53. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the common dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

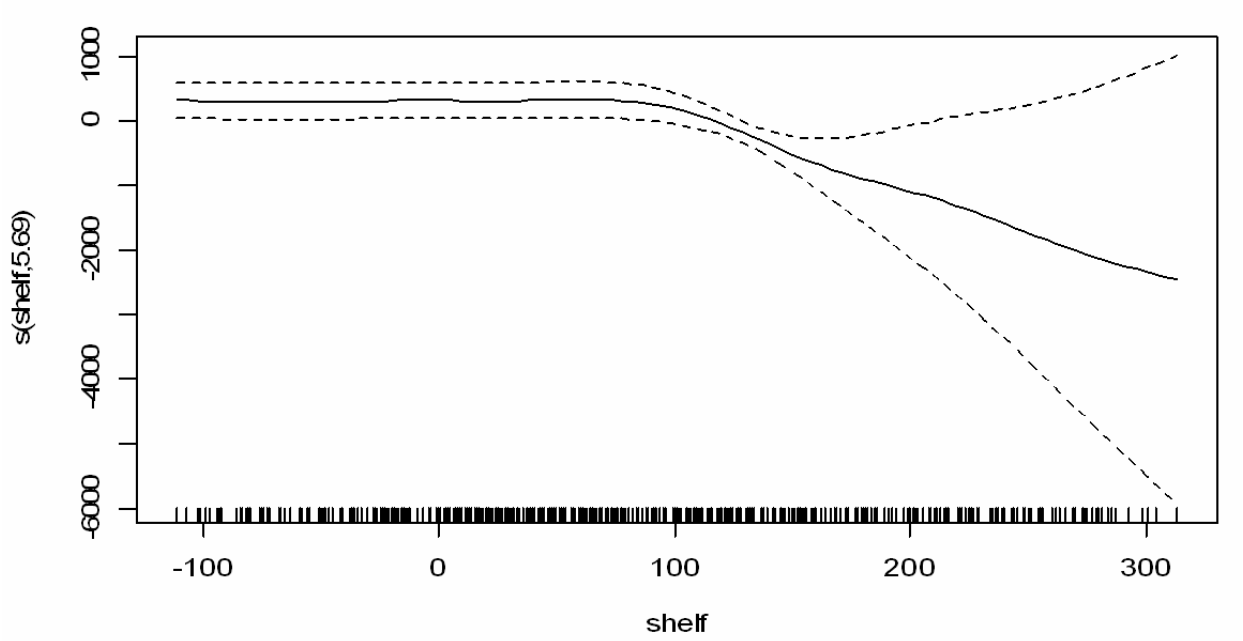

Figure A-54. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the common dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-31. Variance estimate model results for the common dolphin during all seasons in the Southeast study area.

Variance	
Legitimate values	387
Non-legitimate bootstrap replicates	112
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	10506.41 - 292134.77
Point estimate	29415.69
SE of bootstraps	72618.95
Est. CV for density surface model	2.4687
CV in detection probability	0.1051
CV in overall estimate including density surface model and detection probability	2.4709
Confidence interval incorporating detection function uncertainty	1890.631, 457668.6

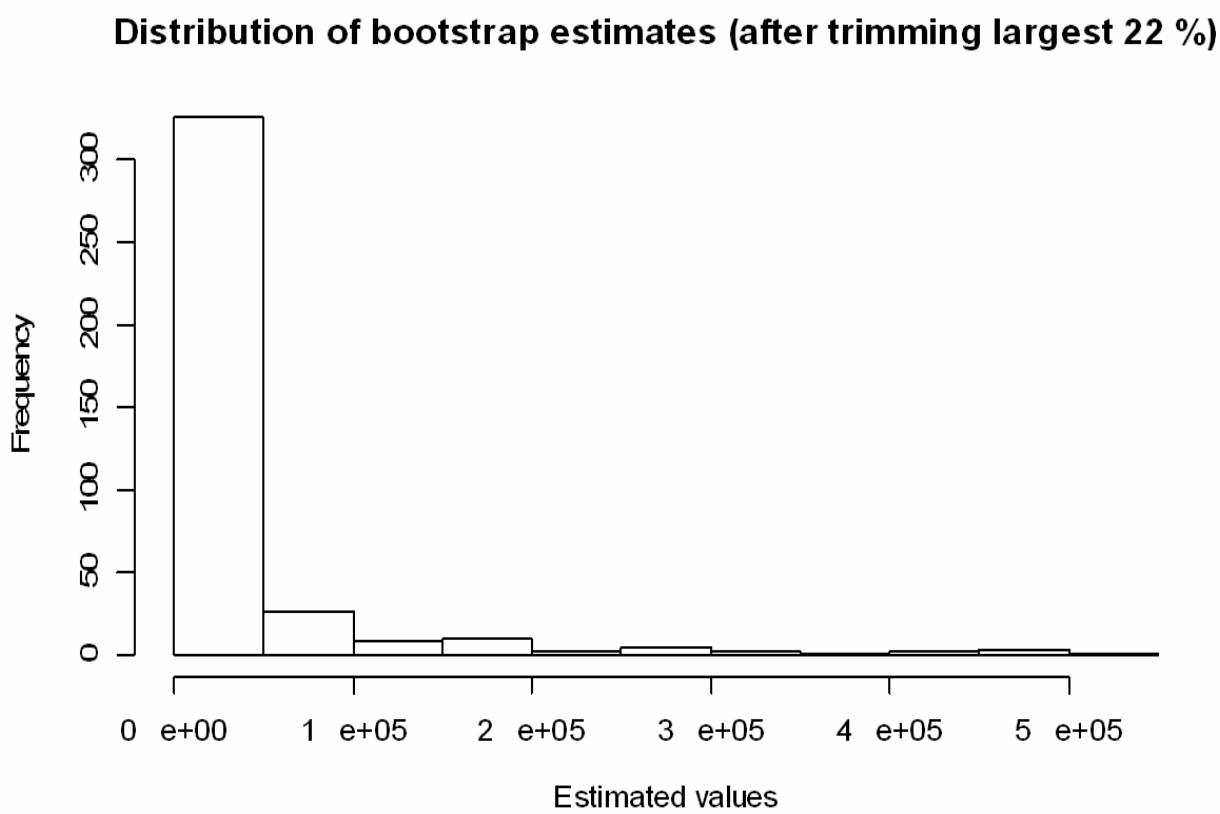

Figure A-55. Distribution of bootstrap estimates (after trimming largest 22%) for pooled sightings of the common dolphin during all seasons in the Southeast study area.

- Risso's Dolphin (*Grampus griseus*)

Table A-32. Detection function results for the Risso's dolphin during all seasons in the Southeast study area.

Detection Function	
No. of observations	168
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	7.0131
SE	0.1223
Hazard shape parameter (Exponent)	
Estimate	2.4368
SE	0.2801
Average p	
Estimate	0.2682
SE	0.0232
CV	0.0865
N in covered region	
Estimate	626.3095
SE	68.1351
CV	0.1088

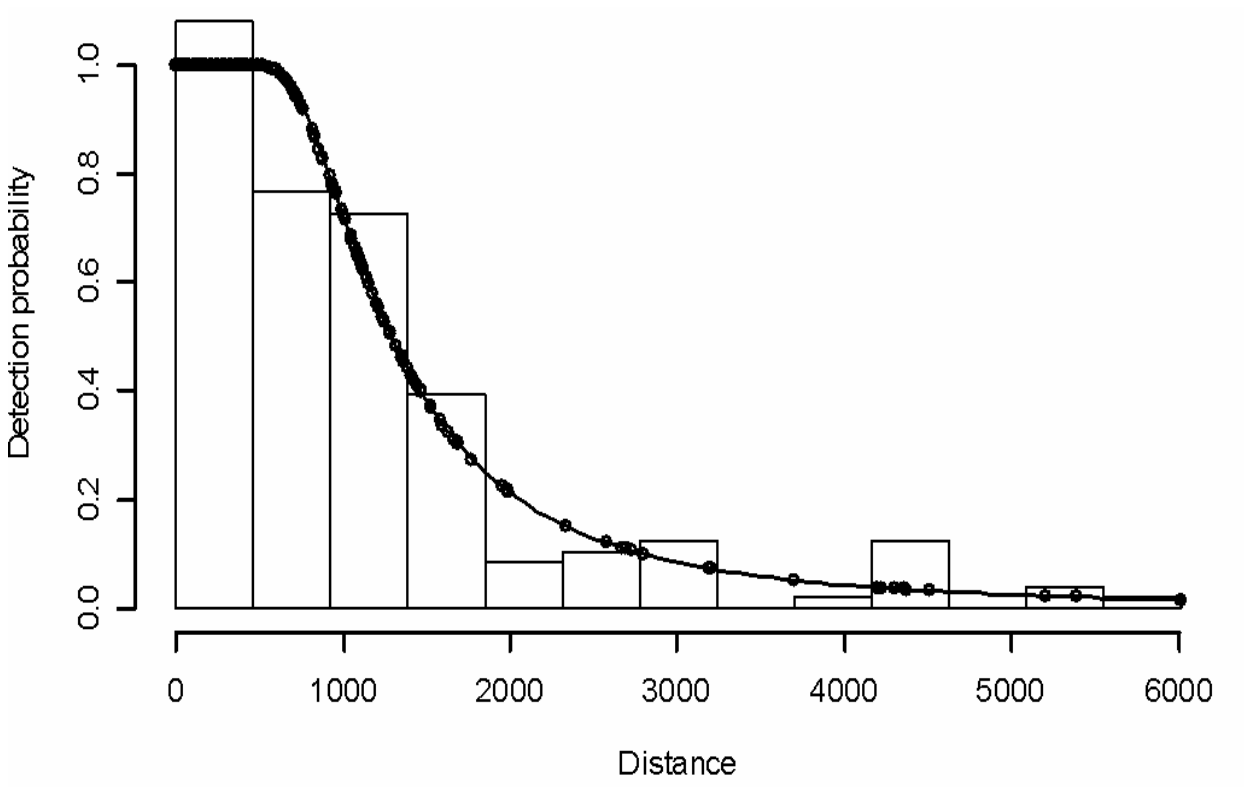

Figure A-56. Plot of the detection function for pooled sightings of the Risso's dolphin during all seasons in the Southeast study area. Distance is measured in meters.

Table A-33. Response surface model (Generalized Additive Model) results for the Risso's dolphin during all seasons in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	29.000
	Est. rank	26.000
	F	9.519
	p-value	<2e-16
s(depth)		
	Edf	1.697
	Est. rank	4.000
	F	13.316
	p-value	1.24e-10
s(shelf)		
	Edf	7.530
	Est. rank	9.000
	F	8.145
	p-value	7.81e-12
R-sq. (adj)		0.185
n segments		
Deviance explained		40%

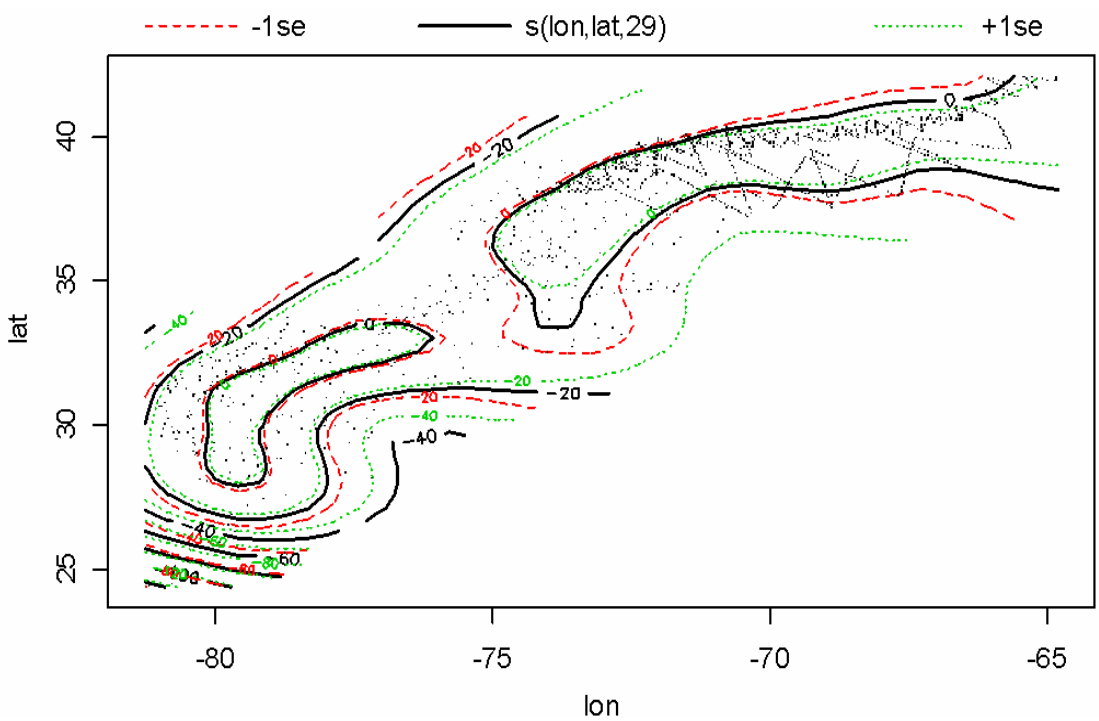

Figure A-57. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the Risso's dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

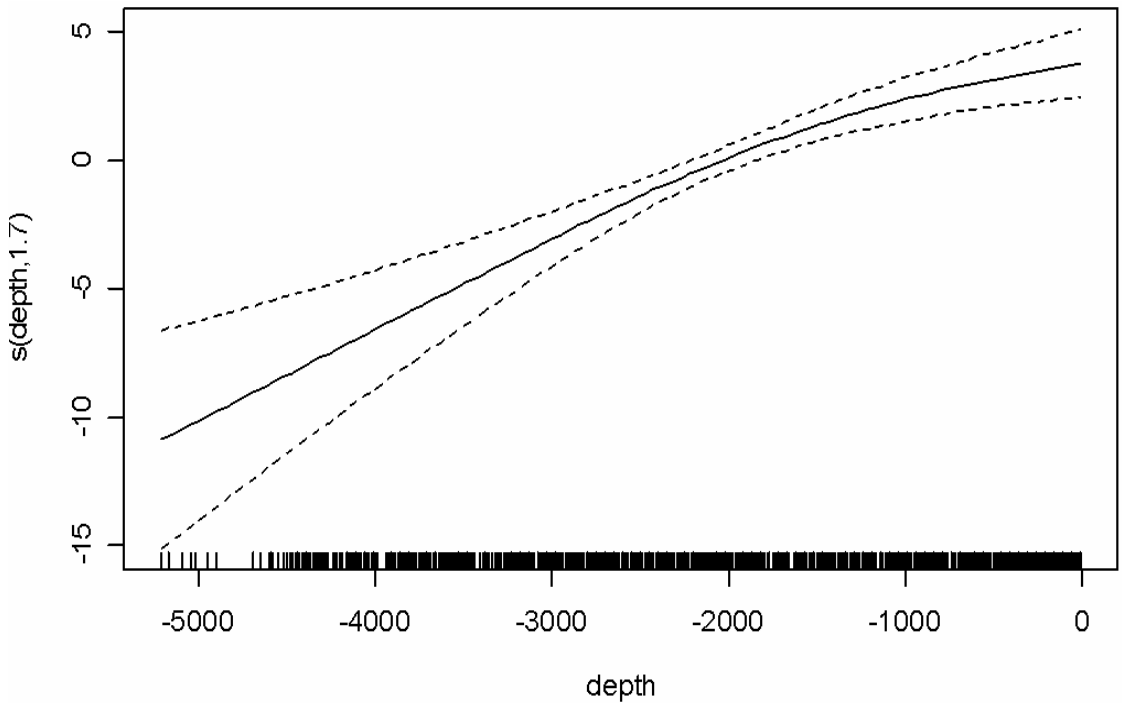

Figure A-58. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the Risso's dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

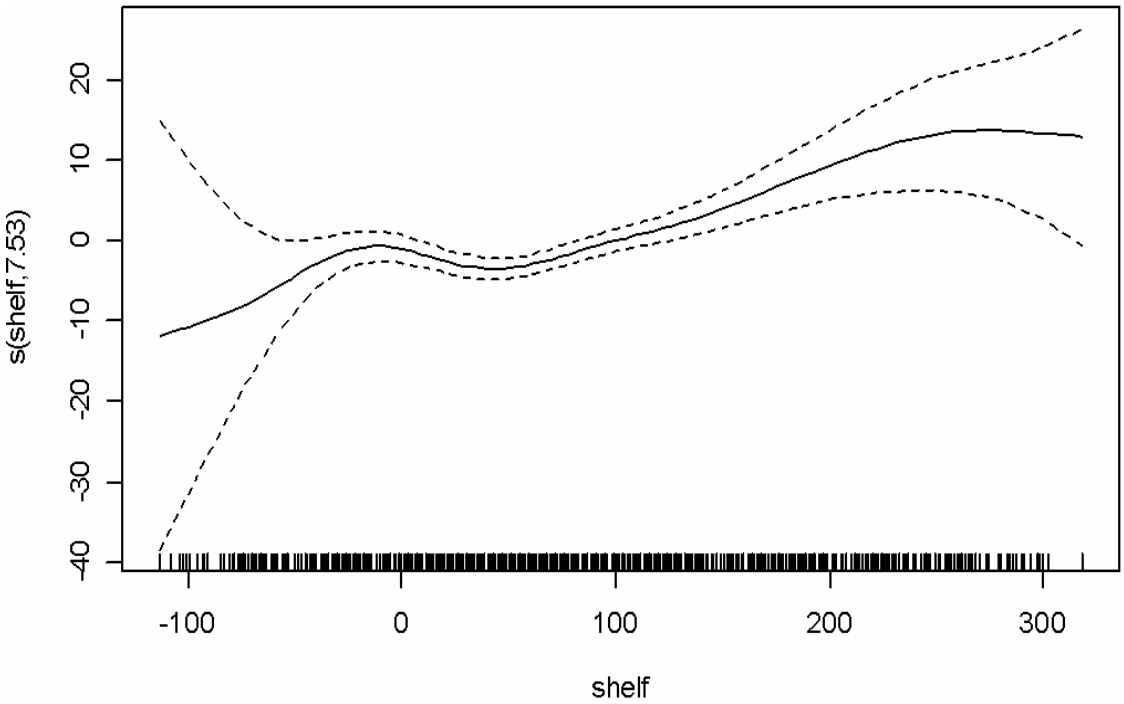

Figure A-59. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the Risso's dolphin during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis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

Table A-34. Variance estimate model results for the Risso's dolphin during all seasons in the Southeast study area.

Variance	
Legitimate values	476
Non-legitimate bootstrap replicates	23
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	9739.843 - 20981.641
Point estimate	13834.79
SE of bootstraps	2952.138
Est. CV for density surface model	0.2134
CV in detection probability	0.0865
CV in overall estimate including density surface model and detection probability	0.2302
Confidence interval incorporating detection function uncertainty	8861.566, 21599.07

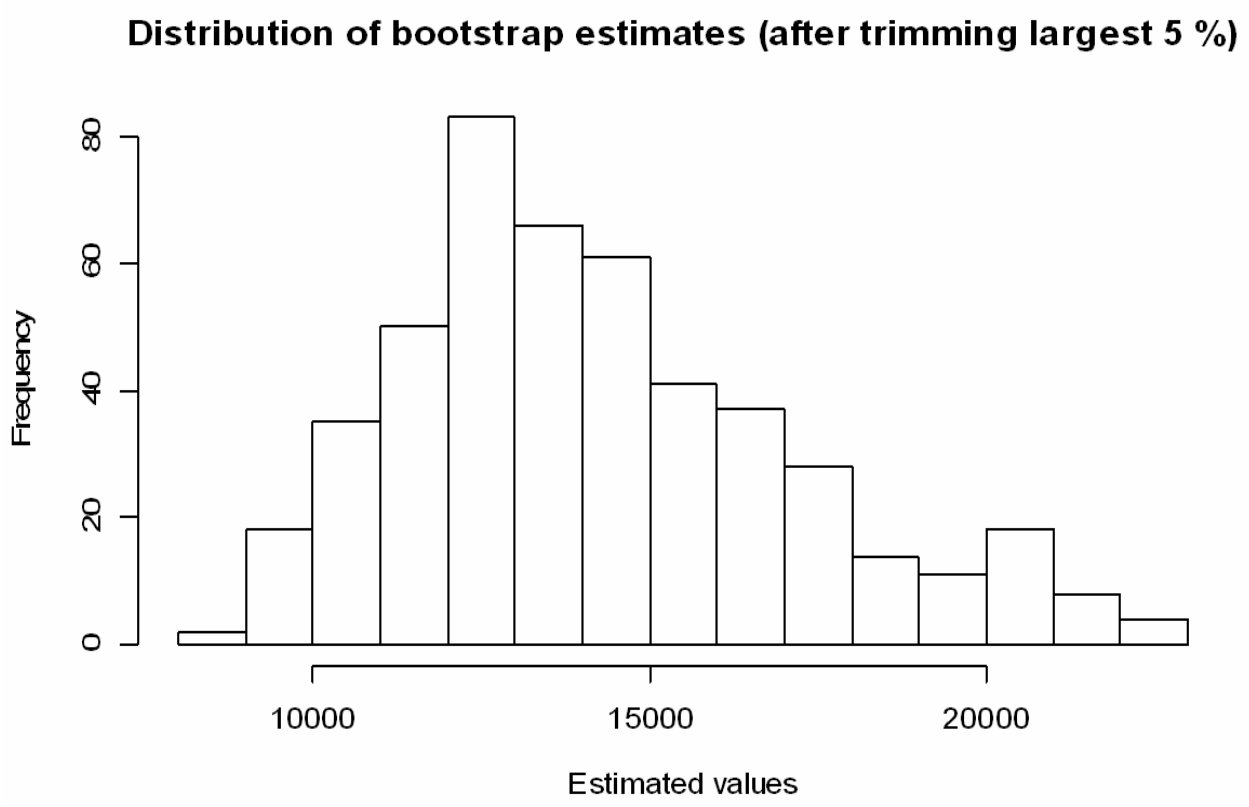

Figure A-60. Distribution of bootstrap estimates (after trimming largest 5%) for pooled sightings of the Risso's dolphin during all seasons in the Southeast study area.

- Pilot Whales (*Globicephala* spp.)

Table A-35. Detection function results for the pilot whale during spring, fall, and winter in the Southeast study area.

Detection Function	
No. of observations	119
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.3655
SE	0.4304
Hazard shape parameter (Exponent)	
Estimate	1.3907
SE	0.2464
Average p	
Estimate	0.1861
SE	0.0447
CV	0.2400
N in covered region	
Estimate	639.4112
SE	162.3344
CV	0.2539

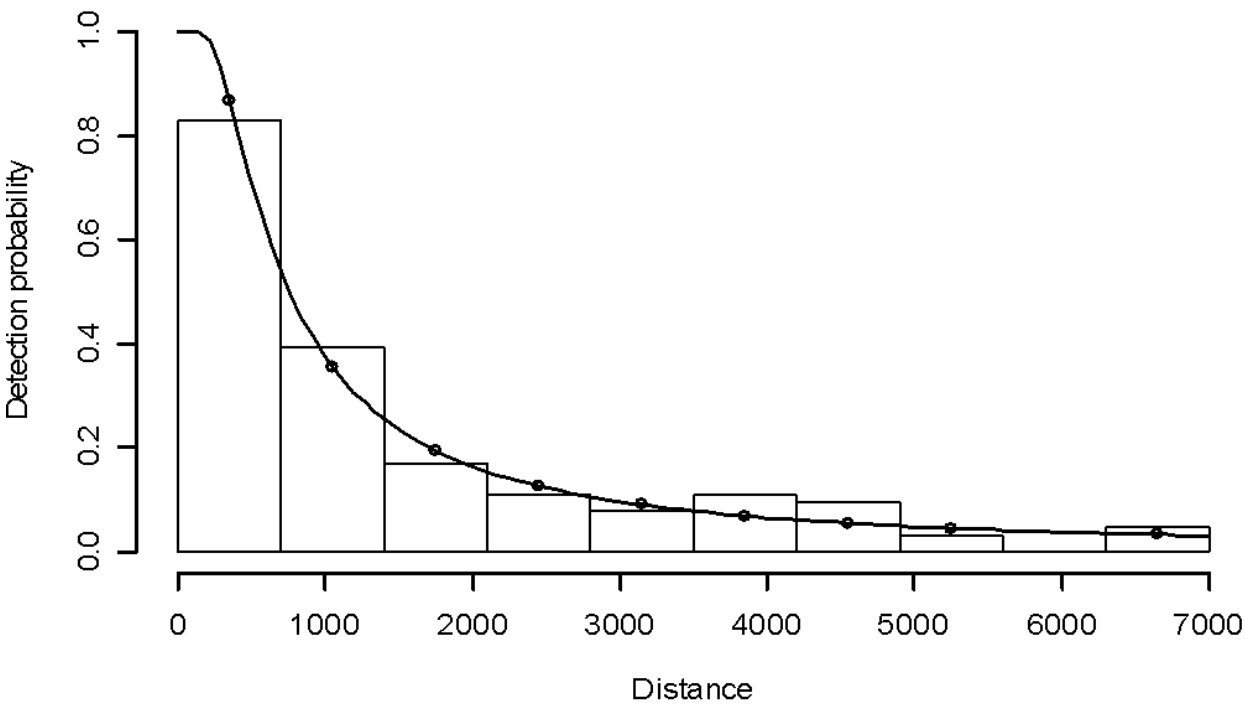

Figure A-61. Plot of the detection function for pooled sightings of pilot whales during spring, fall, and winter in the Southeast study area. Distance is measured in meters.

Table A-36. Response surface model (Generalized Additive Model) results for pilot whales during spring, fall, and winter in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(slope) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	25.076
	Est. rank	29.000
	F	9.406
	p-value	<2e-16
s(depth)		
	Edf	8.829
	Est. rank	9.000
	F	9.985
	p-value	1.07e-14
s(slope)		
	Edf	6.871
	Est. rank	9.000
	F	9.012
	p-value	4.20e-13
R-sq. (adj)		0.284
n segments		74
Deviance explained		47.7%

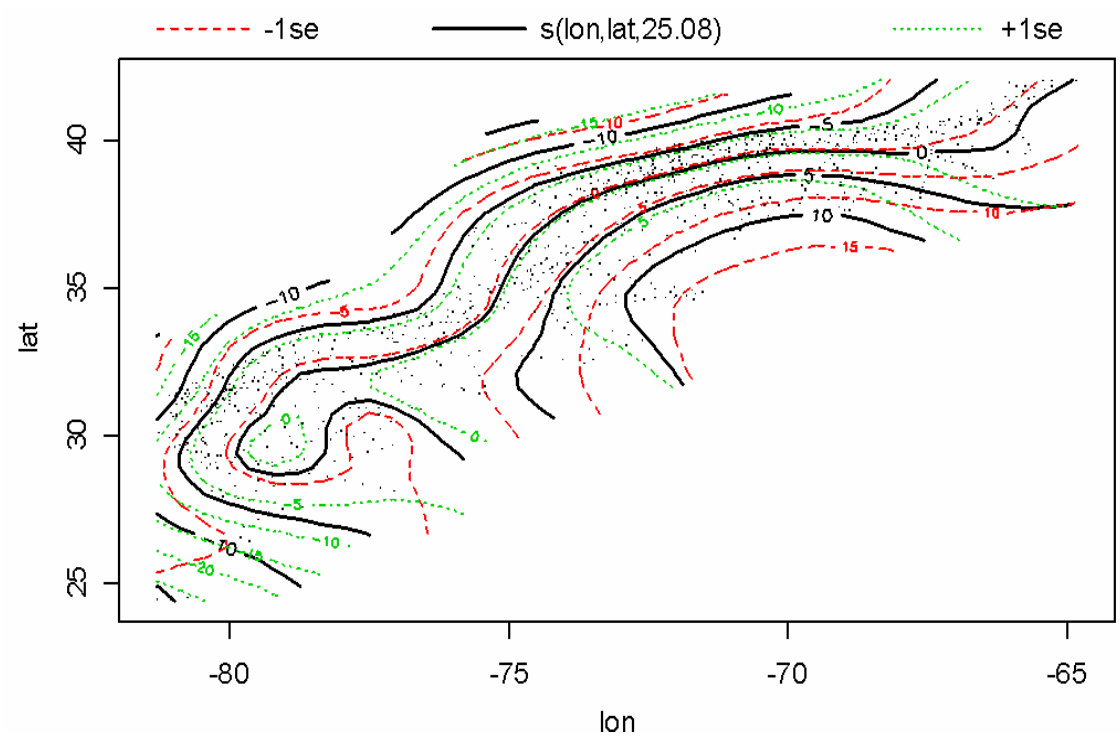

Figure A-62. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for pilot whales during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

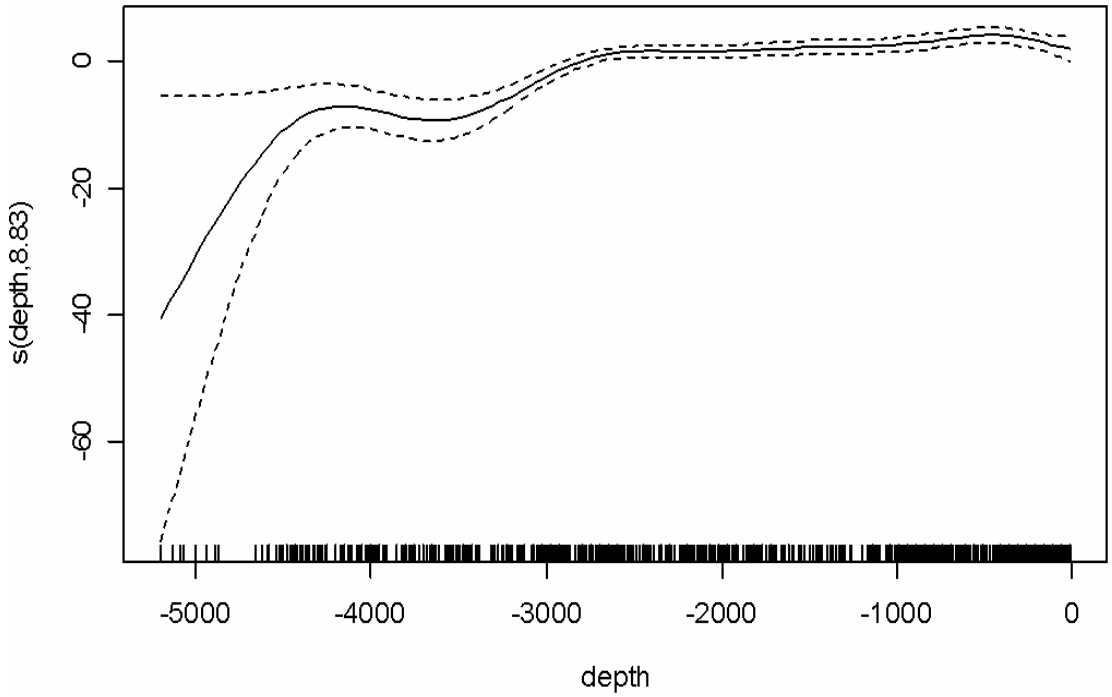

Figure A-63. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for pilot whales during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

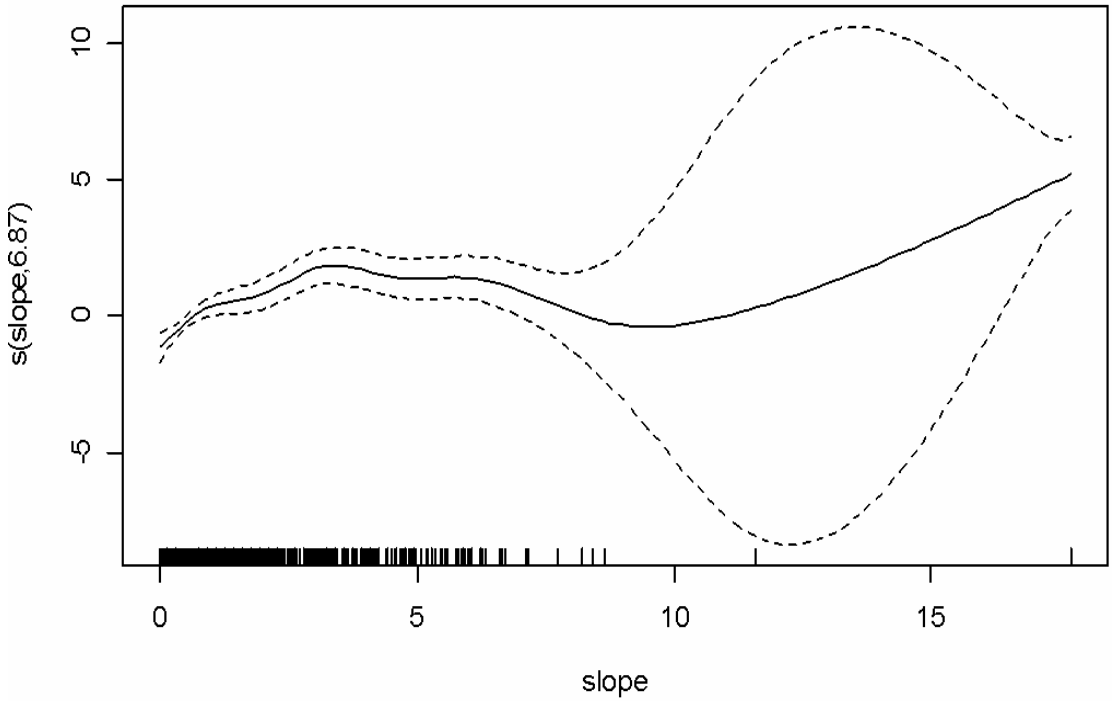

Figure A-64. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for pilot whales during spring, fall, and winter in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-37. Variance estimate model results for pilot whales during spring, fall, and winter in the Southeast study area.

Variance	
Legitimate values	462
Non-legitimate bootstrap replicates	37
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	10738.81 - 23778.22
Point estimate	16331.56
SE of bootstraps	3356.233
Est. CV for density surface model	0.2055
CV in detection probability	0.24
CV in overall estimate including density surface model and detection probability	0.316
Confidence interval incorporating detection function uncertainty	8921.262 , 29897.09

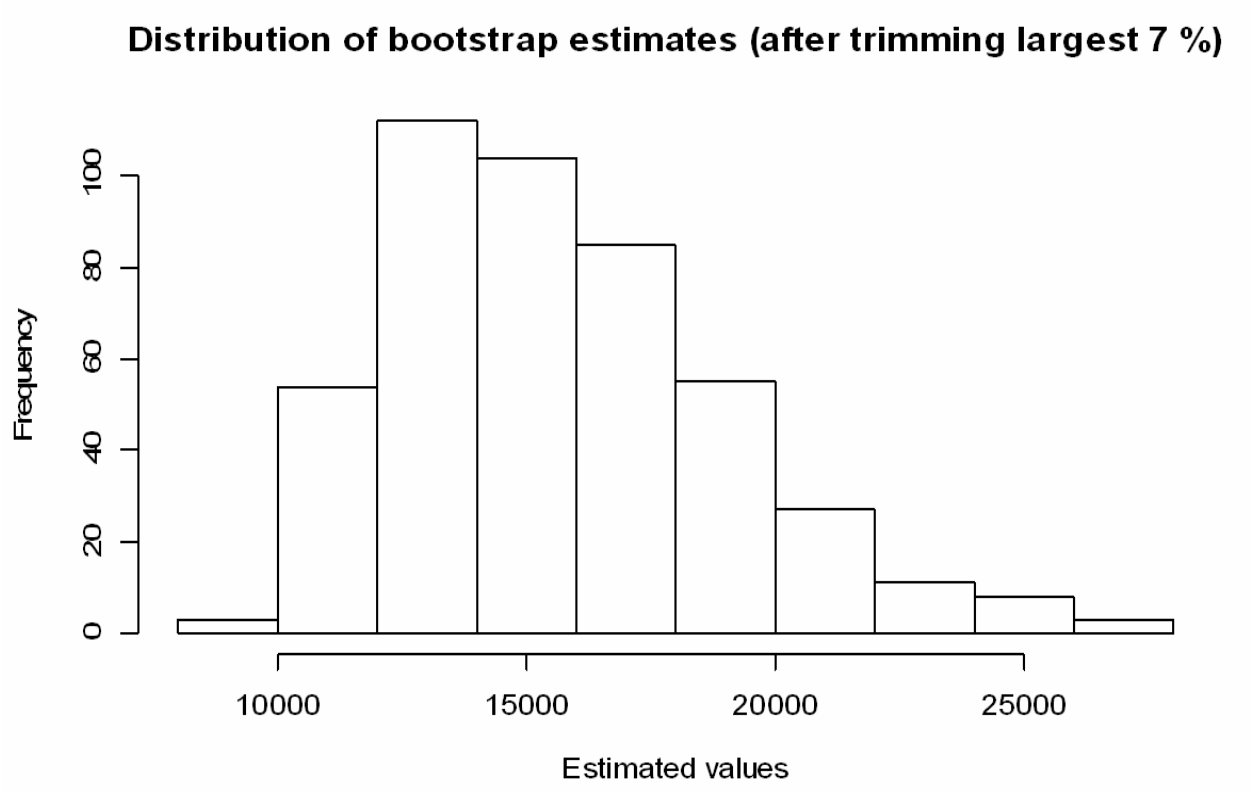

Figure A-65. Distribution of bootstrap estimates (after trimming largest 16%) for pooled sightings of pilot whales during all spring, fall, and winter in the Southeast study area.

Table A-38. Detection function results for pilot whales during summer in the Southeast study area.

Detection Function	
No. of observations	109
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	6.5190
SE	0.4124
Hazard shape parameter (Exponent)	
Estimate	1.3967
SE	0.2592
Average p	
Estimate	0.2106
SE	0.0480
CV	0.2278
N in covered region	
Estimate	517.5482
SE	125.8579
CV	0.2432

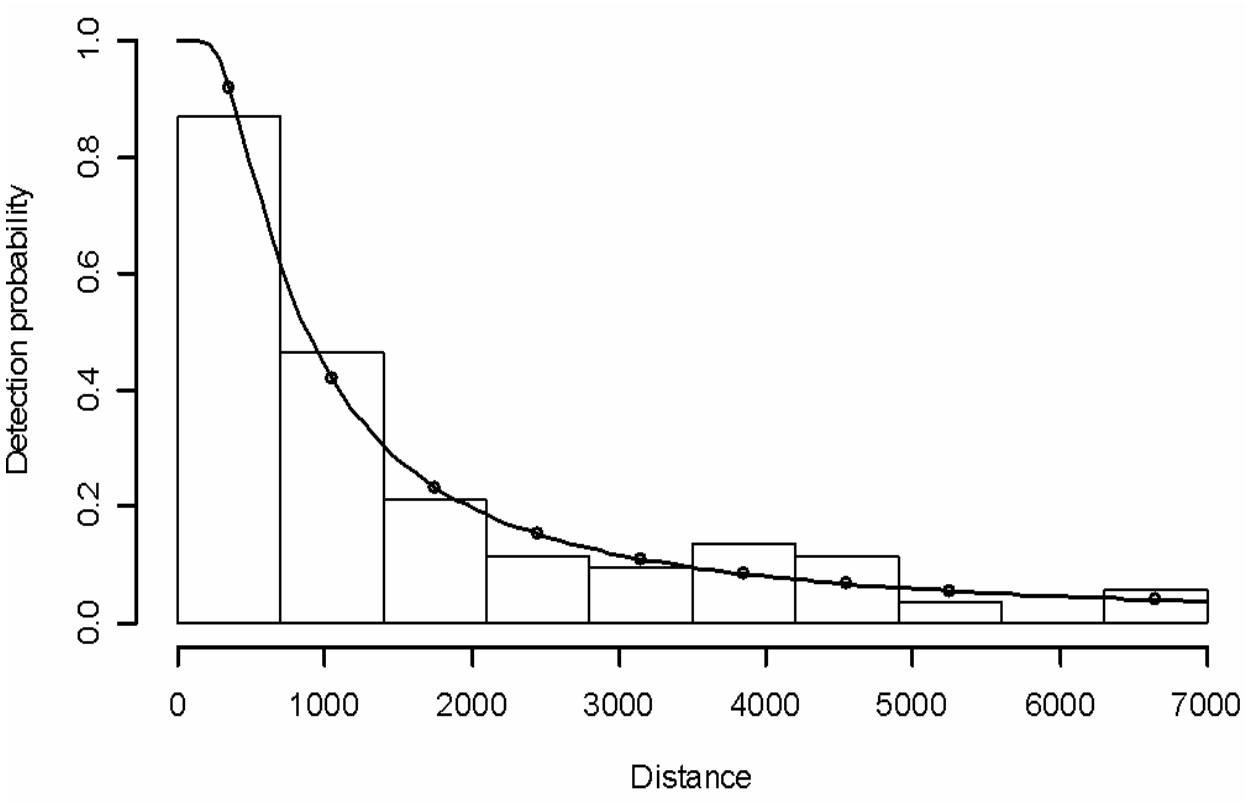

Figure A-66. Plot of the detection function for pooled sightings of pilot whales during summer in the Southeast study area. Distance is measured in meters.

Table A-39. Response surface model (Generalized Additive Model) results for pilot whales during summer in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(slope) + s(SST) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	28.989
	Est. rank	20.000
	F	5.749
	p-value	3.21e-14
s(depth)		
	Edf	8.757
	Est. rank	9.000
	F	5.688
	p-value	1.14e-07
s(slope)		
	Edf	7.129
	Est. rank	9.000
	F	6.101
	p-value	2.46e-08
s(SST)		
	Edf	7.821
	Est. rank	9.000
	F	7.300
	p-value	2.84e-10
R-sq. (adj)		0.273
n segments		69
Deviance explained		49.7%

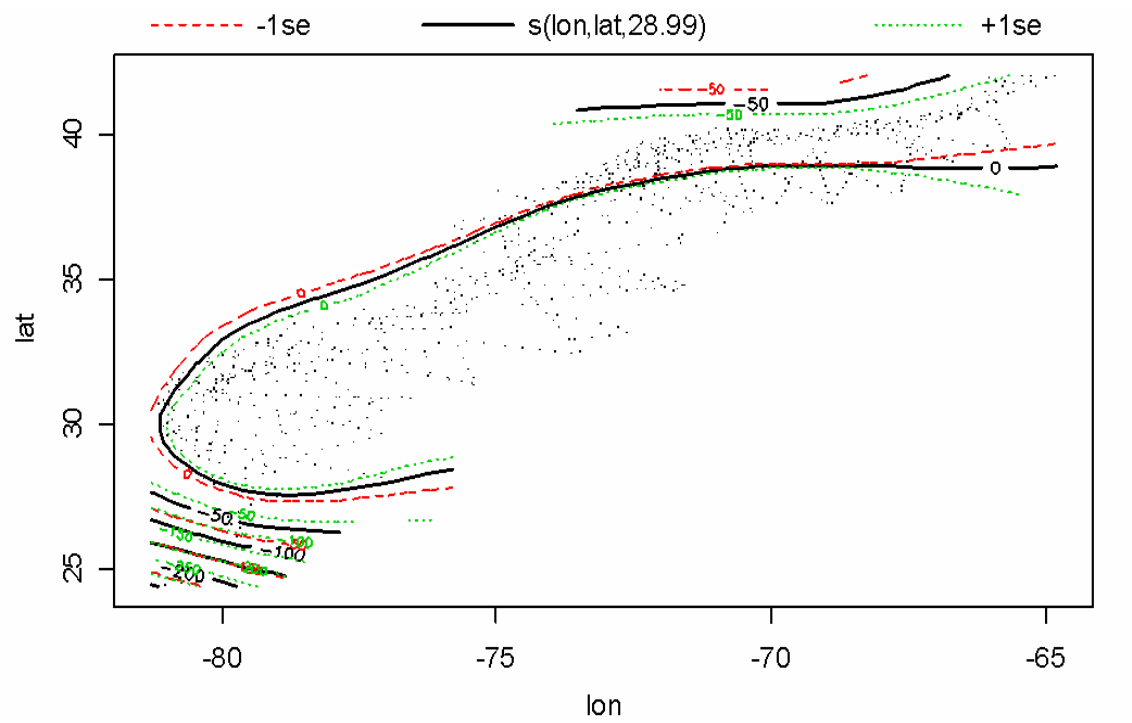

Figure A-67. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for pilot whales during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

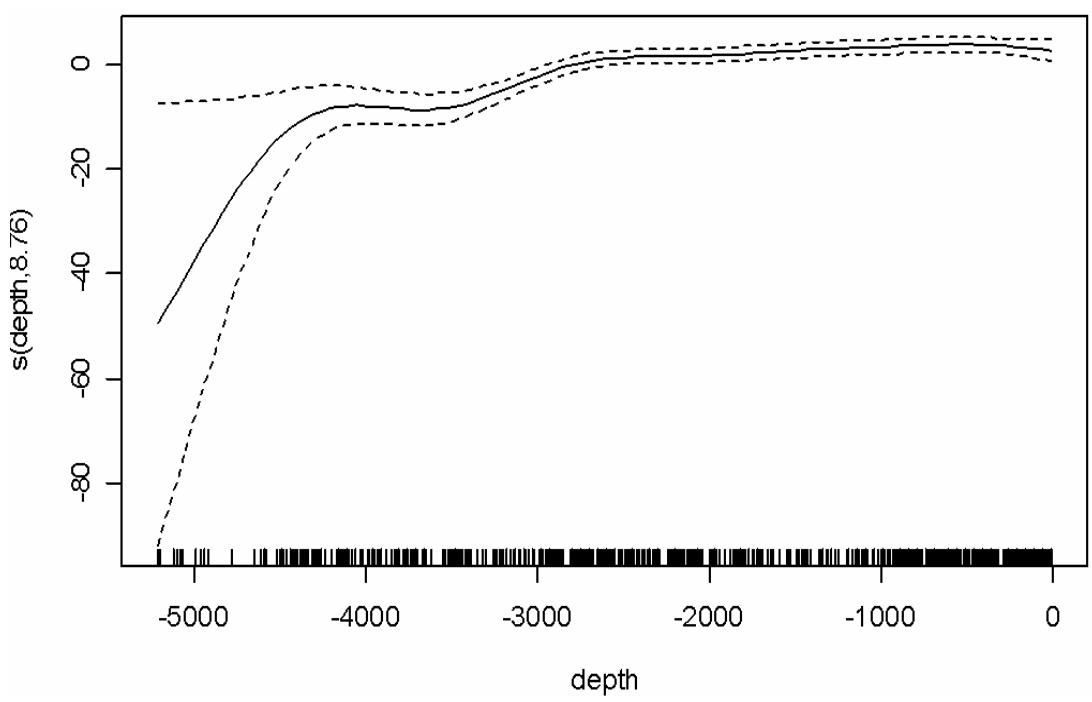

Figure A-68. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for pilot whales during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed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

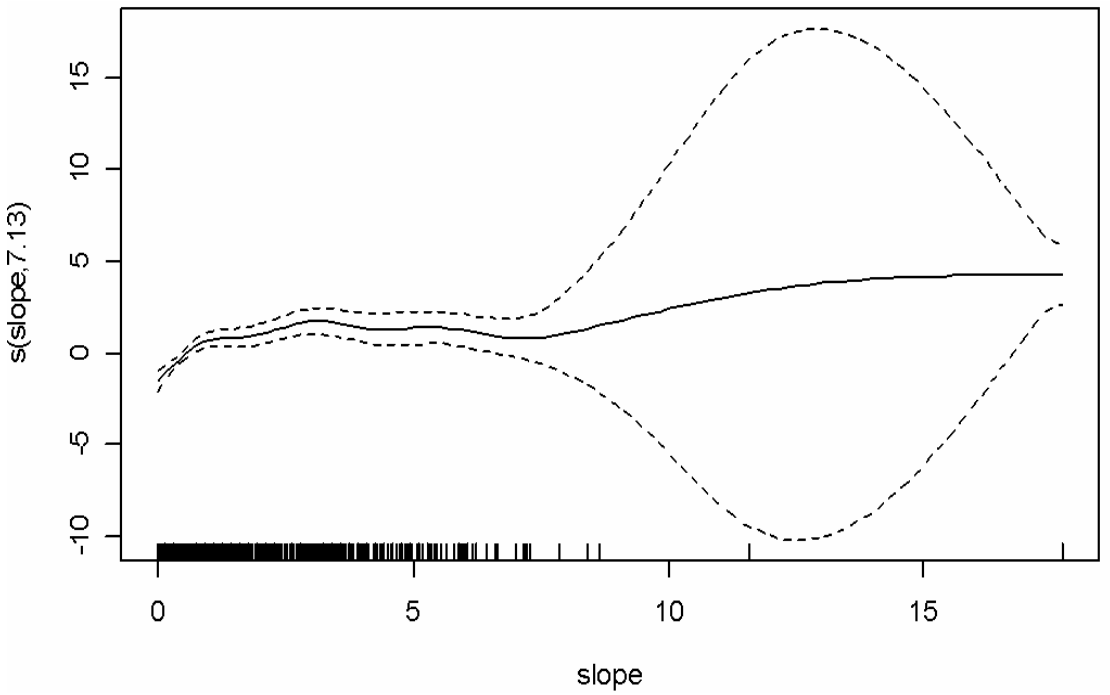

Figure A-69. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for pilot whales during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

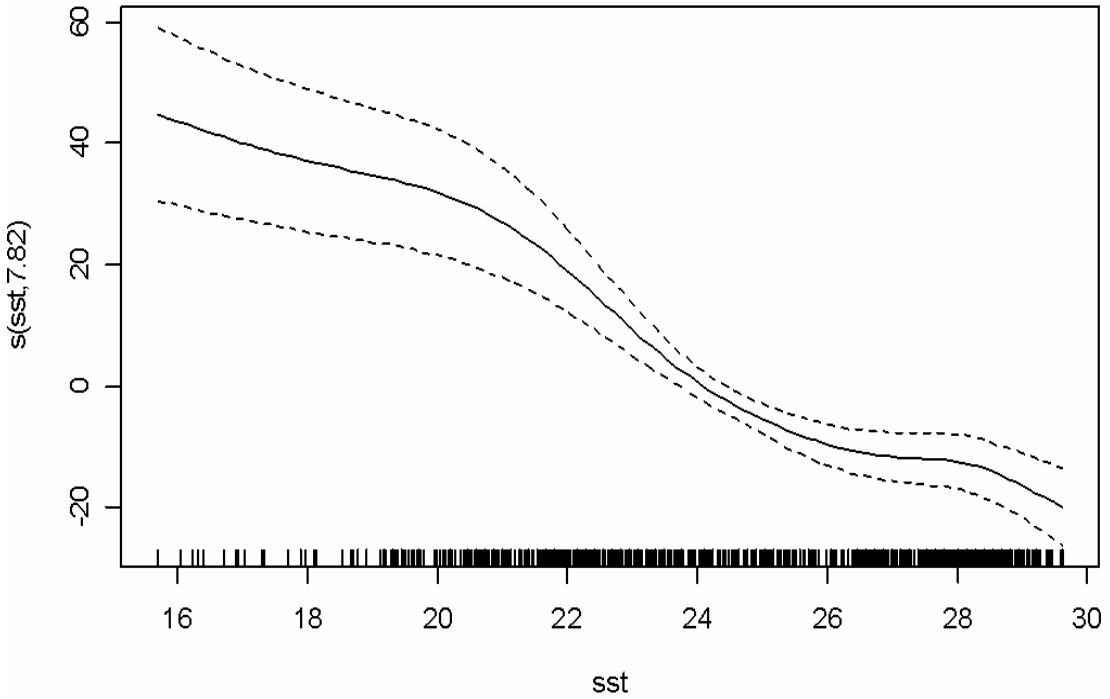

Figure A-70. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for pilot whales during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-40. Variance estimate model results for pilot whales during summer in the Southeast study area.

Variance	
Legitimate values	426
Non-legitimate bootstrap replicates	73
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	10688.74 - 35481.30
Point estimate	17294.62
SE of bootstraps	6443.262
Est. CV for density surface model	0.3726
CV in detection probability	0.2278
CV in overall estimate including density surface model and detection probability	0.4367
Confidence interval incorporating detection function uncertainty	7625.928, 39221.98

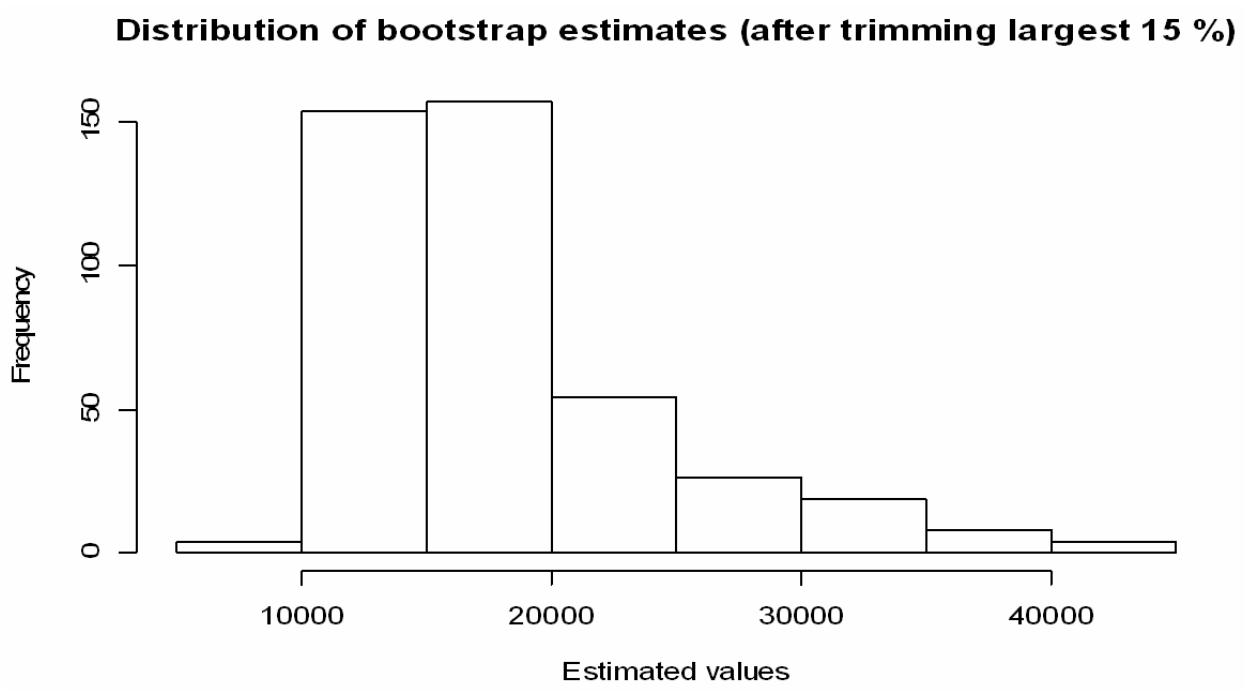

Figure A-71. Distribution of bootstrap estimates (after trimming largest 15%) for pooled sightings of pilot whales during all summer in the Southeast study area.

- Leatherback Turtle (*Dermochelys coriacea*)

Table A-44. Detection function results for the leatherback turtle during fall, winter, and spring in the Southeast study area.

Detection Function	
No. of observations	114
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.2089
SE	0.1441
Hazard Shape Parameter (Exponent)	
Estimate	2.5780
SE	0.4275
Average p	
Estimate	0.3002
SE	0.0294
CV	0.0978
N in covered region	
Estimate	379.6949
SE	47.5842
CV	0.1253

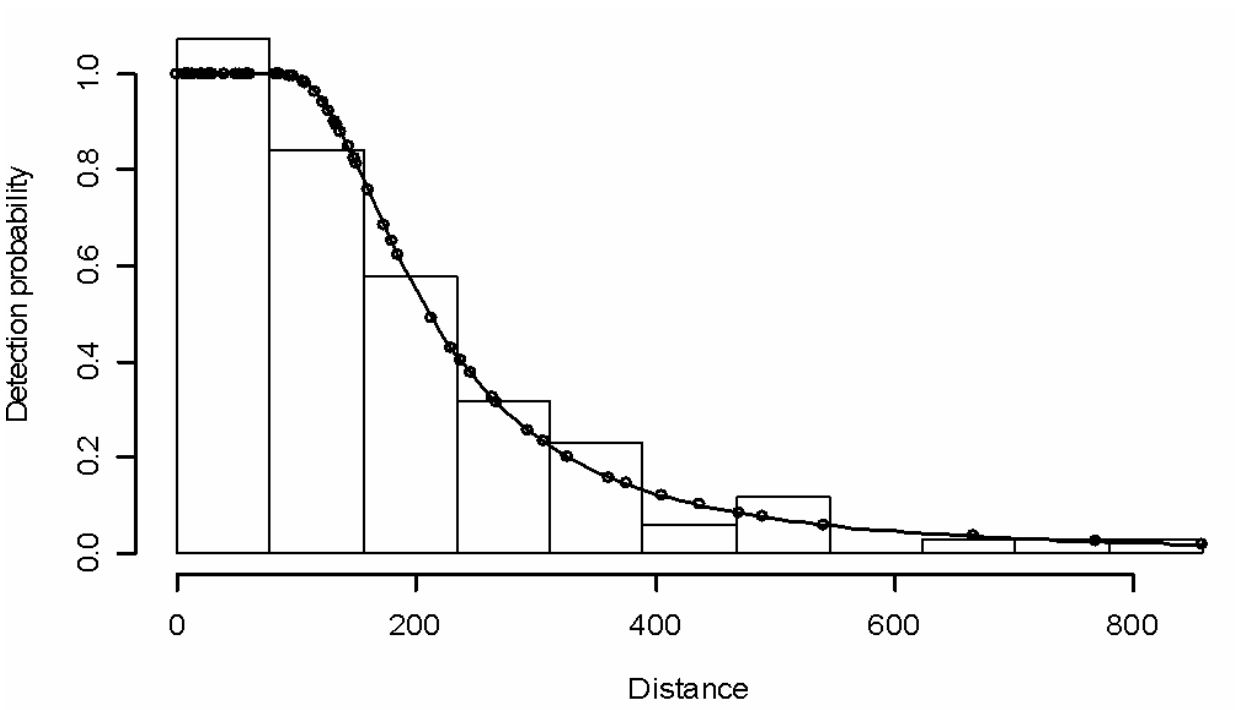

Figure A-78. Plot of the detection function for pooled sightings of the leatherback turtle during fall, winter, and spring in the Southeast study area. Distance is measured in meters.

Table A-45. Response surface model (Generalized Additive Model) results for the leatherback turtle during fall, winter, and spring in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(slope) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	28.352
	Est. rank	29.000
	F	22.272
	p-value	<2e-16
s(depth)		
	Edf	8.936
	Est. rank	3.000
	F	6.707
	p-value	1.68e-04
s(slope)		
	Edf	1.001
	Est. rank	3.000
	F	1.696
	p-value	0.1658
R-sq. (adj)		0.161
n segments		67
Deviance explained		38.7%

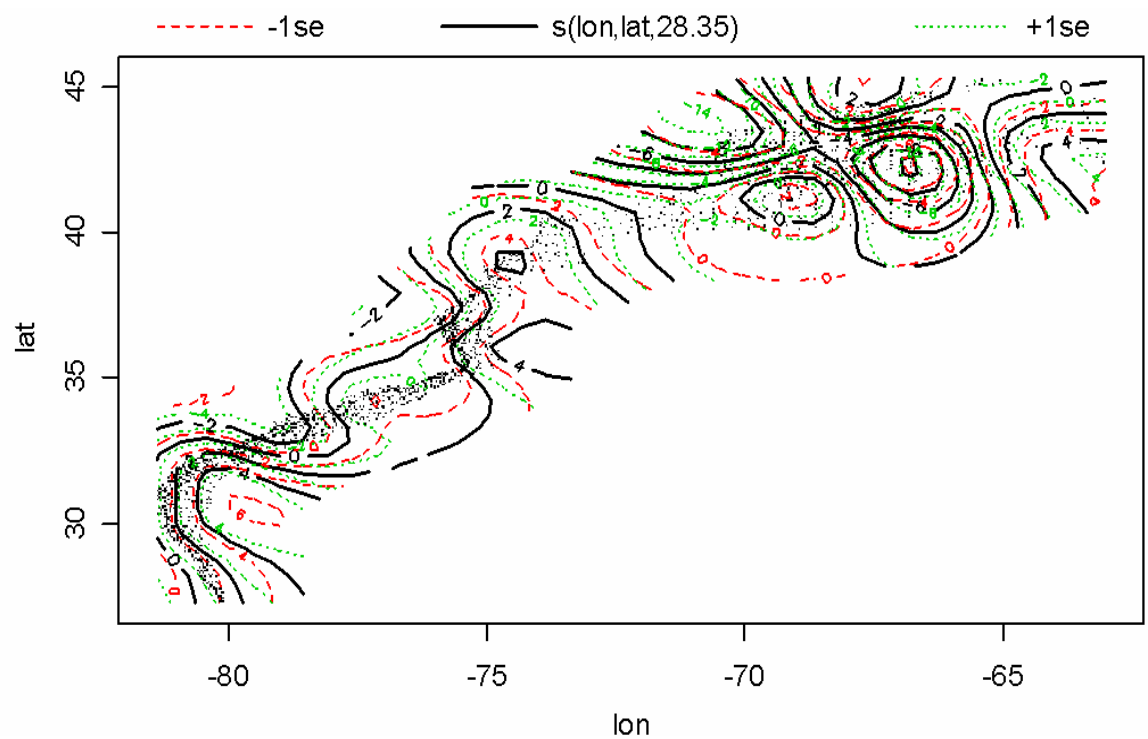

Figure A-79. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the leatherback turtle during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

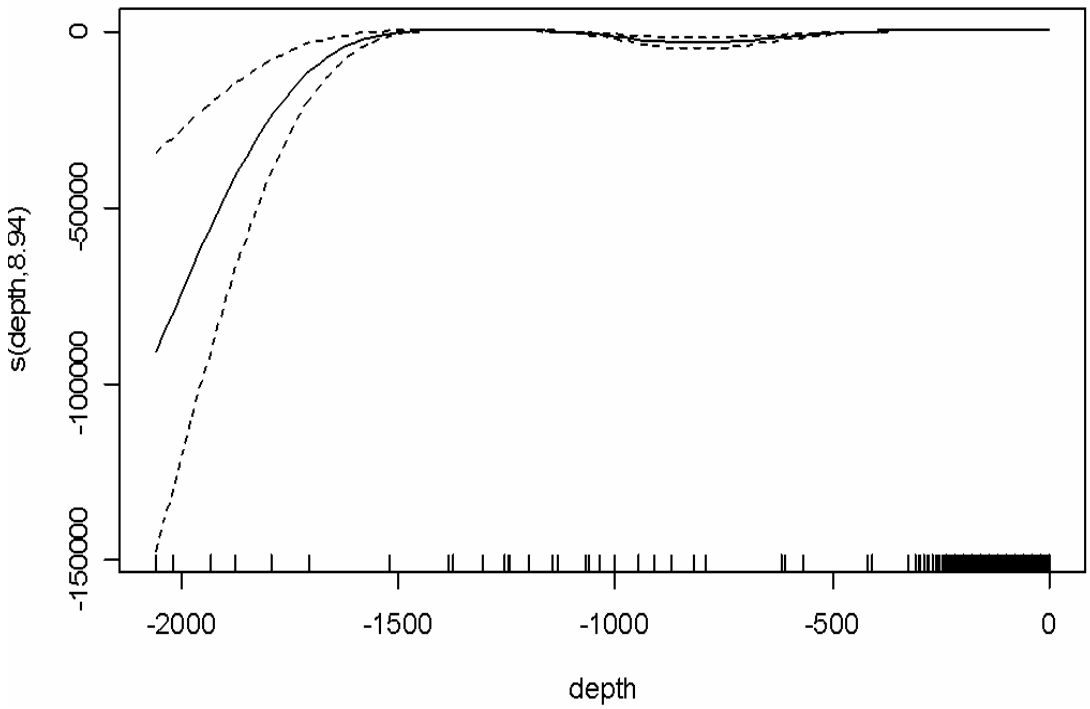

Figure A-80. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the leatherback turtle during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

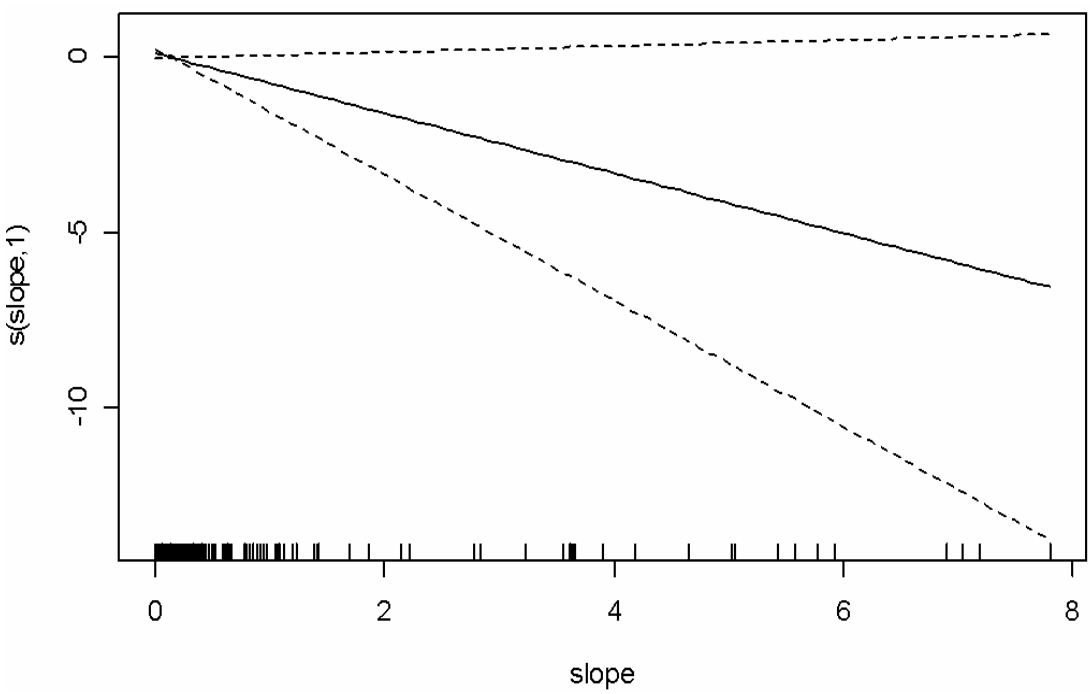

Figure A-81. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the leatherback turtle during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-46. Variance estimate model results for the leatherback turtle during spring, fall, and winter in the Southeast study area.

Variance	
Legitimate values	421
Non-legitimate bootstrap replicates	78
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	1853.876 - 2448.348
Point estimate	2041.509
SE of bootstraps	149.7556
Est. CV for density surface model	0.0734
CV in detection probability	0.0978
CV in overall estimate including density surface model and detection probability	0.1223
Confidence interval incorporating detection function uncertainty	1607.918, 2592.021

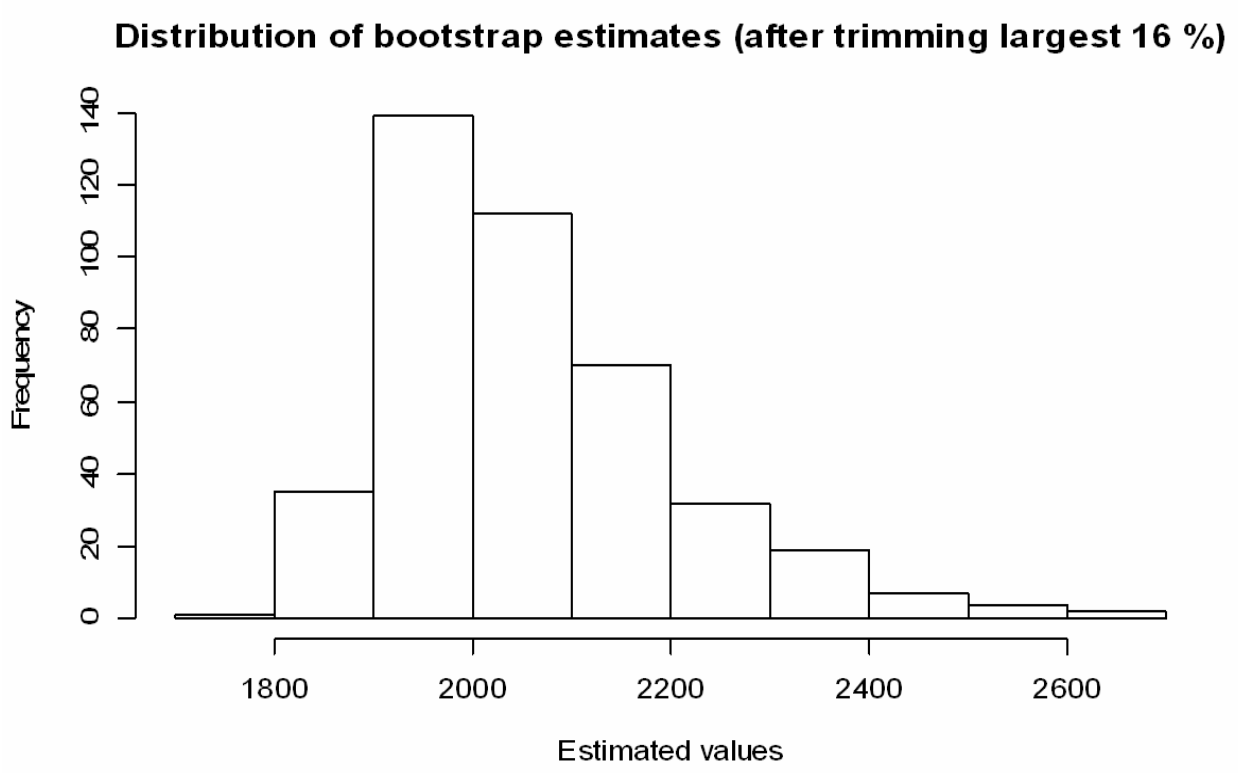

Figure A-82. Distribution of bootstrap estimates (after trimming largest 16%) for pooled sightings of the leatherback turtle during spring, fall, and winter in the Southeast study area.

Table A-47. Detection function results for the leatherback turtle during summer in the Southeast study area.

Detection Function	
No. of observations	102
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.3220
SE	0.0728
Average p	
Estimate	0.4263
SE	0.0300
CV	0.0705
N in covered region	
Estimate	239.2444
SE	24.6174
CV	0.1029

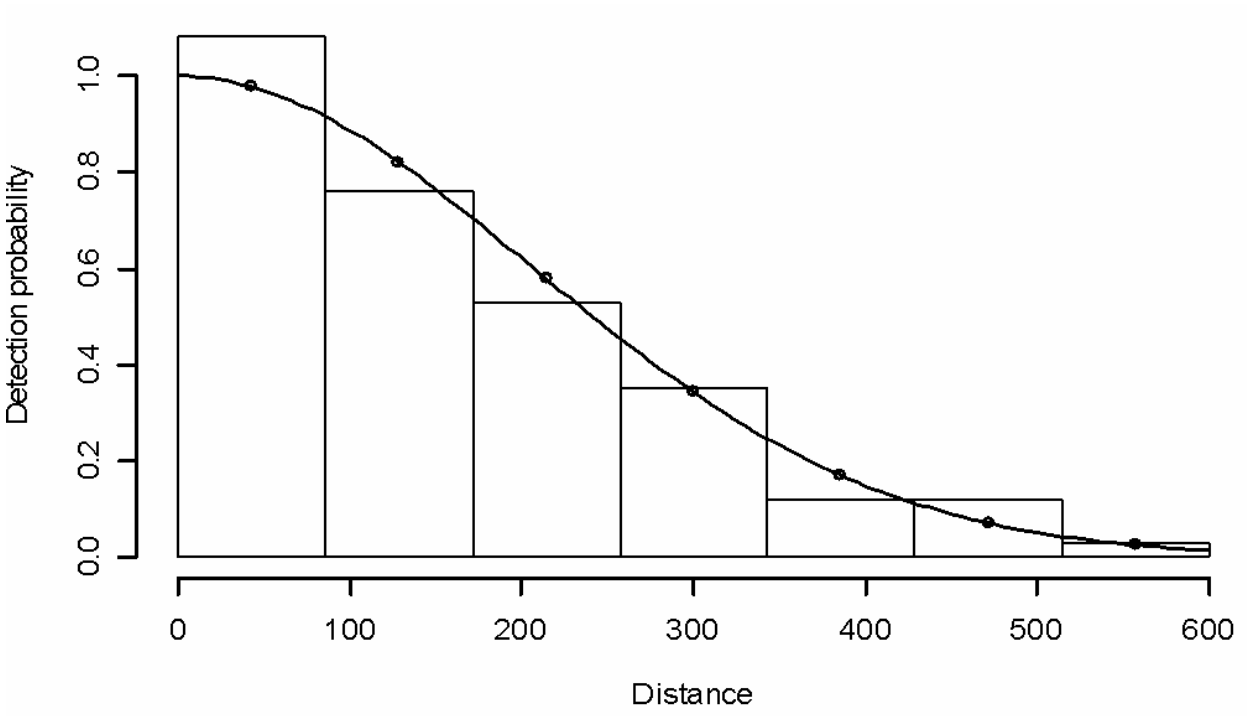

Figure A-83. Plot of the detection function for pooled sightings of the leatherback turtle during summer in the Southeast study area. Distance is measured in meters.

Table A-48. Response surface model (Generalized Additive Model) results for the leatherback turtle during summer in the Southeast 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	29.000
	Est. rank	29.000
	F	15.831
	p-value	<2e-16
s(depth)		
	Edf	8.996
	Est. rank	3.000
	F	5.664
	p-value	7.41e-04
s(SST)		
	Edf	9.000
	Est. rank	9.000
	F	10.512
	p-value	6.95e-16
R-sq. (adj)		0.244
n segments		61
Deviance explained		54.4%

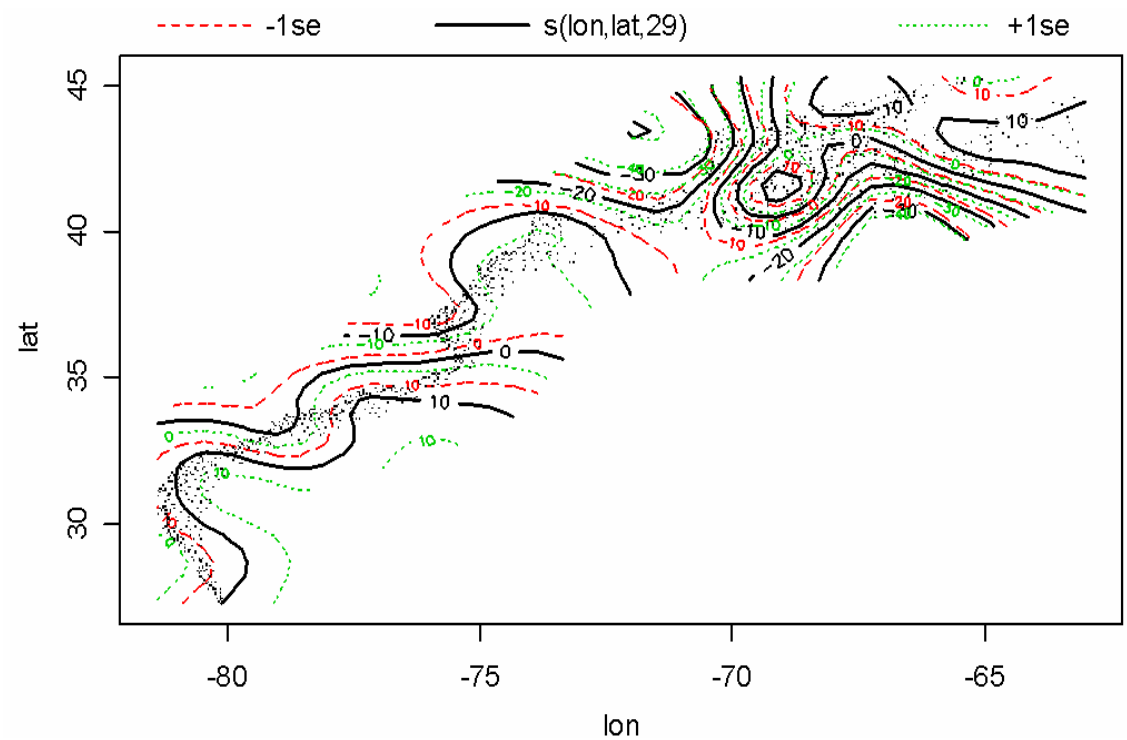

Figure A-84. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the leatherback turtle during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

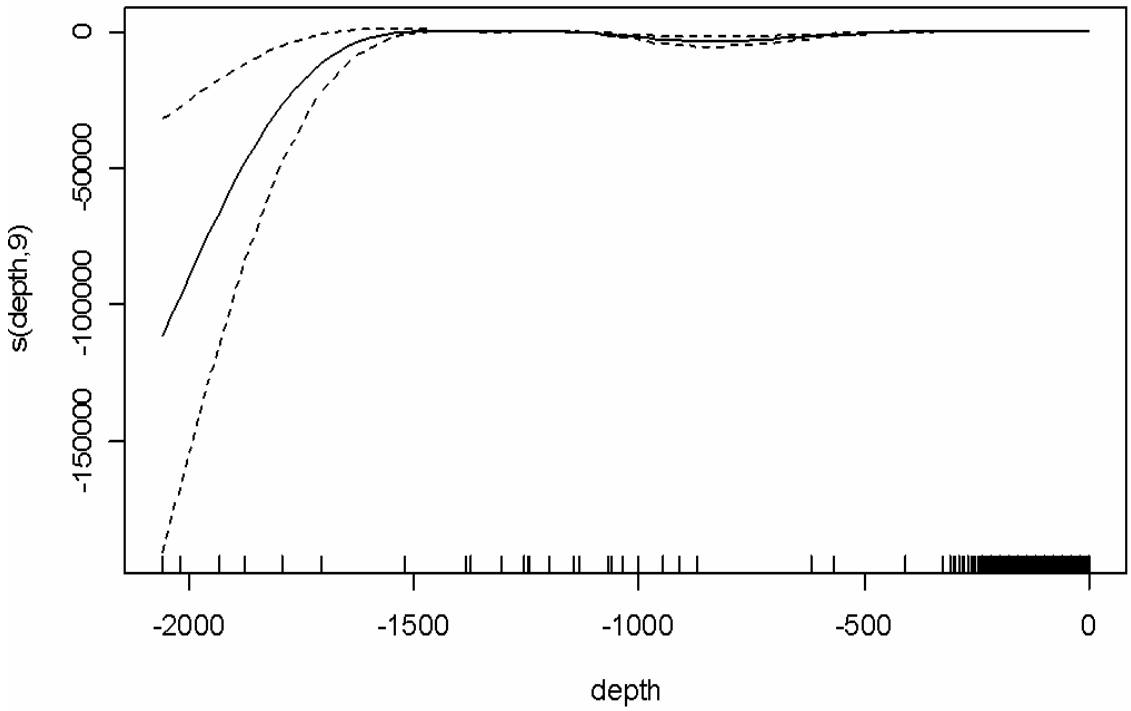

Figure A-85. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the leatherback turtle during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

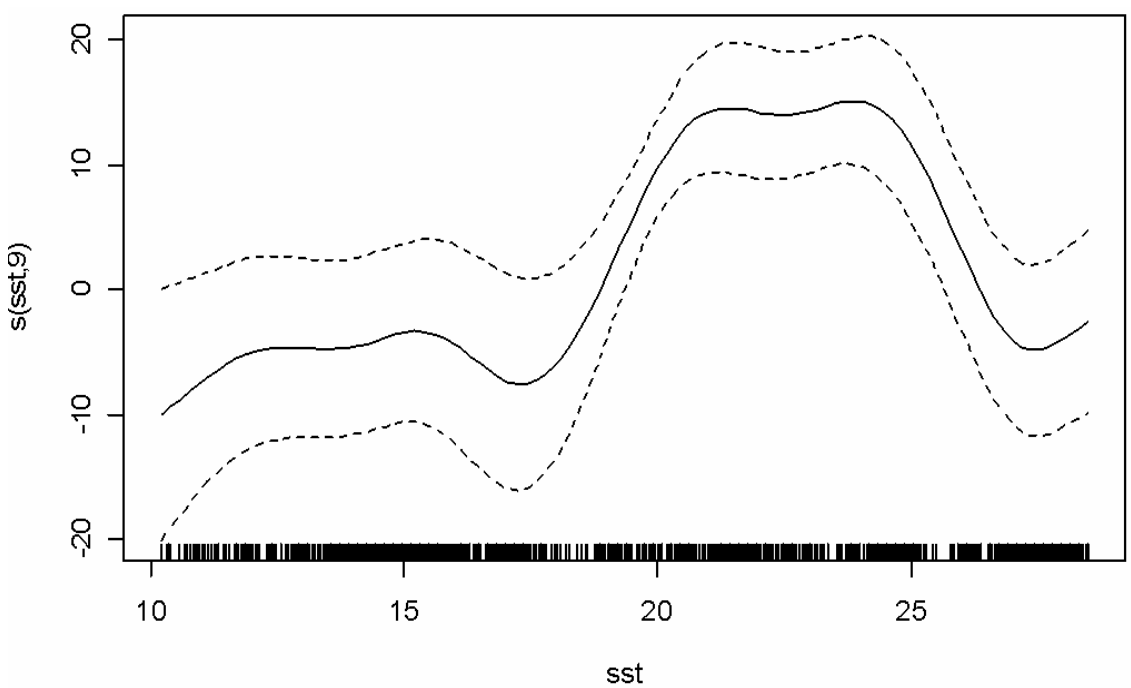

Figure A-86. Plot of the Generalized Additive Model smooth fit of the environmental covariate *SST* selected for the leatherback turtle during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-49. Variance estimate model results for the leatherback turtle during summer in the Southeast study area.

Variance	
Legitimate values	441
Non-legitimate bootstrap replicates	58
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	3259.898 - 4229.054
Point estimate	3773.491
SE of bootstraps	232.4734
Est. CV for density surface model	0.0616
CV in detection probability	0.0705
CV in overall estimate including density surface model and detection probability	0.0936
Confidence interval incorporating detection function uncertainty	3142.331, 4531.423

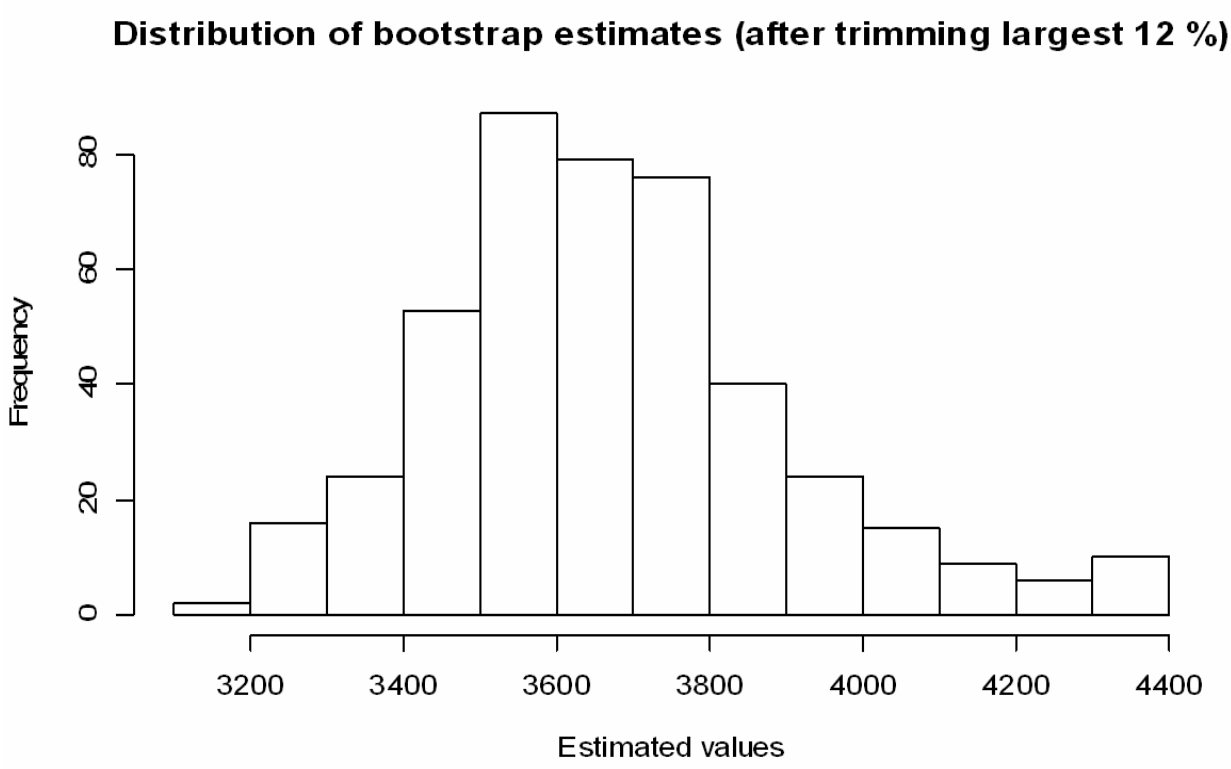

Figure A-87. Distribution of bootstrap estimates (after trimming largest 12%) for pooled sightings of the leatherback turtle during summer in the Southeast study area.

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

Table A-41. Detection function results for the Kemp's ridley turtle during all seasons in the Southeast study area.

Detection Function	
No. of observations	104
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	4.8310
SE	0.3720
Hazard shape parameter (Exponent)	
Estimate	1.2717
SE	0.2485
Average p	
Estimate	0.2758
SE	0.0535
CV	0.1941
N in covered region	
Estimate	377.0406
SE	79.6563
CV	0.2113

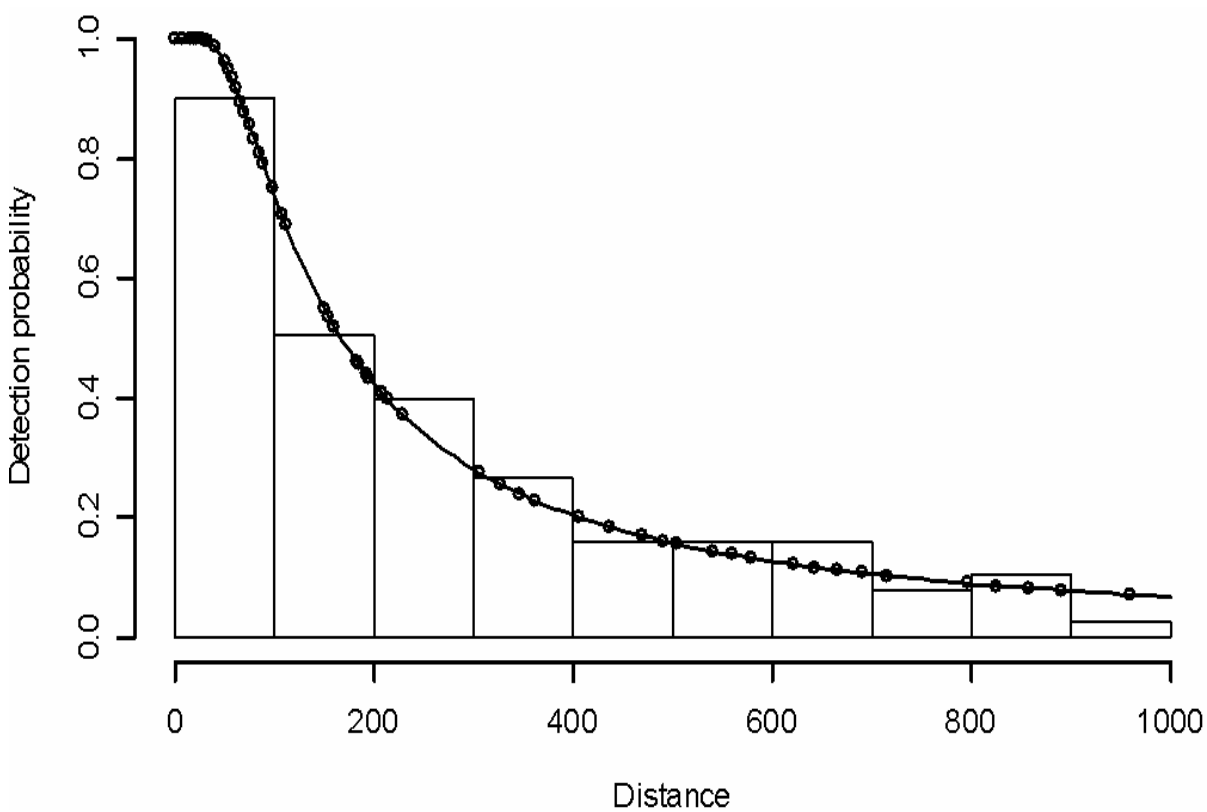

Figure A-72. Plot of the detection function for pooled sightings of the Kemp's ridley turtle during all seasons in the Southeast study area. Distance is measured in meters.

Table A-42. Response surface model (Generalized Additive Model) results for the Kemp's ridley turtle during all seasons in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + s(slope) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	27.992
	Est. rank	10.000
	F	19.71
	p-value	<2e-16
s(depth)		
	Edf	1.000
	Est. rank	1.000
	F	48.84
	p-value	3.75e-12
s(shelf)		
	Edf	5.914
	Est. rank	9.000
	F	29.48
	p-value	<2e-16
s(slope)		
	Edf	1.000
	Est. rank	1.000
	F	27.46
	p-value	1.77e-07
R-sq. (adj)		0.589
n segments		49
Deviance explained		60.9%

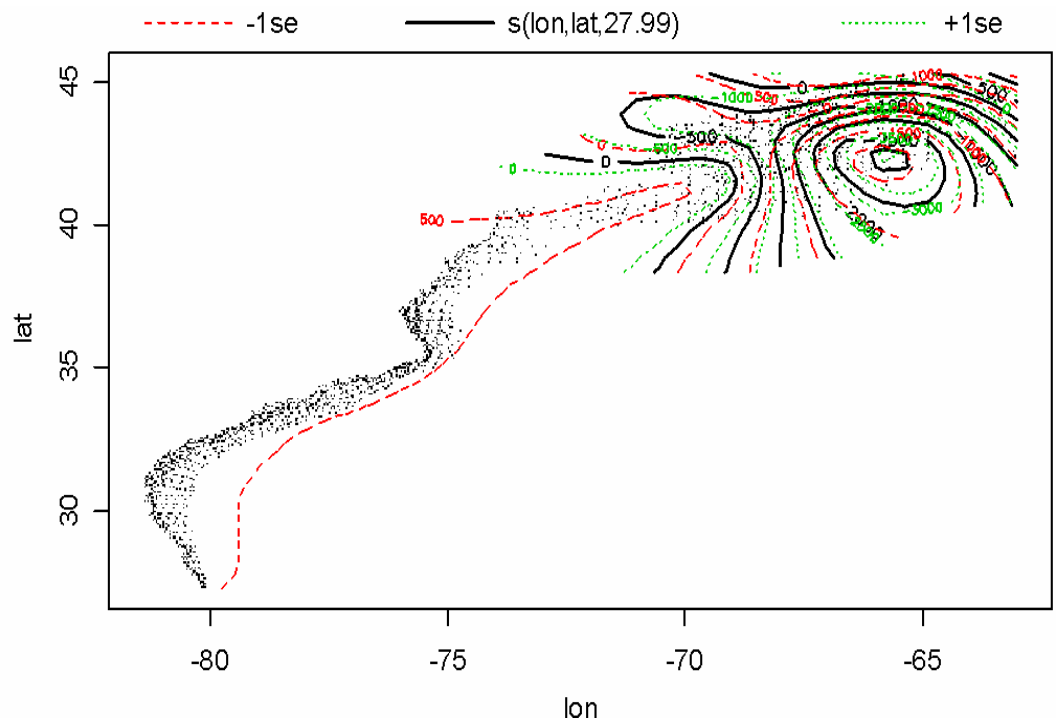

Figure A-73. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the Kemp's ridley turtle during all seasons in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

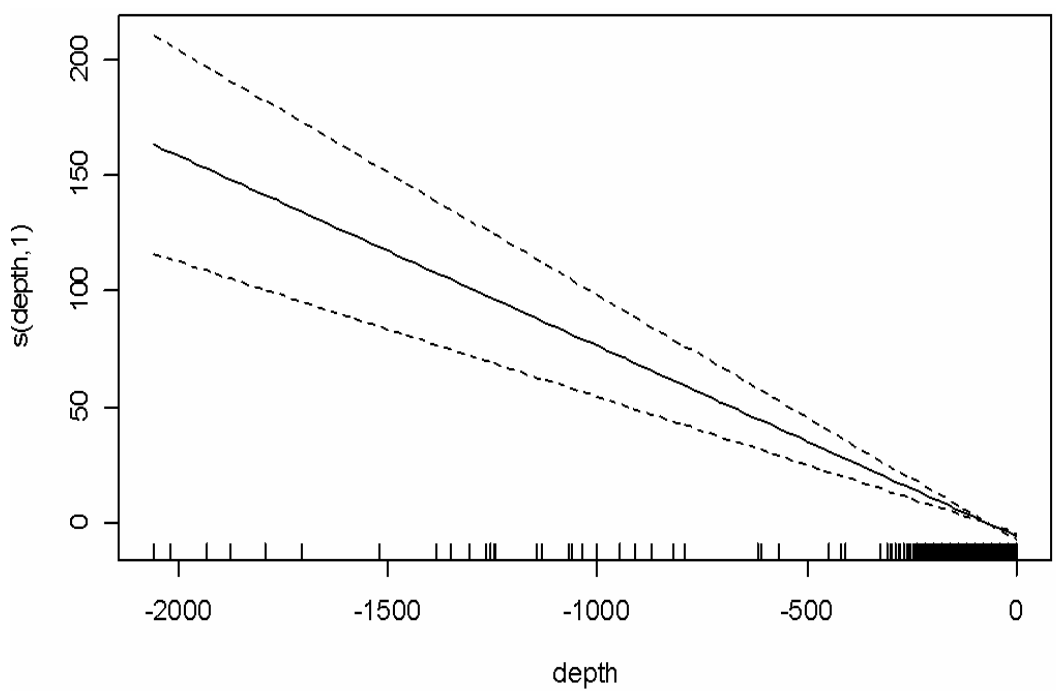

Figure A-74. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the Kemp's ridley turtle during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

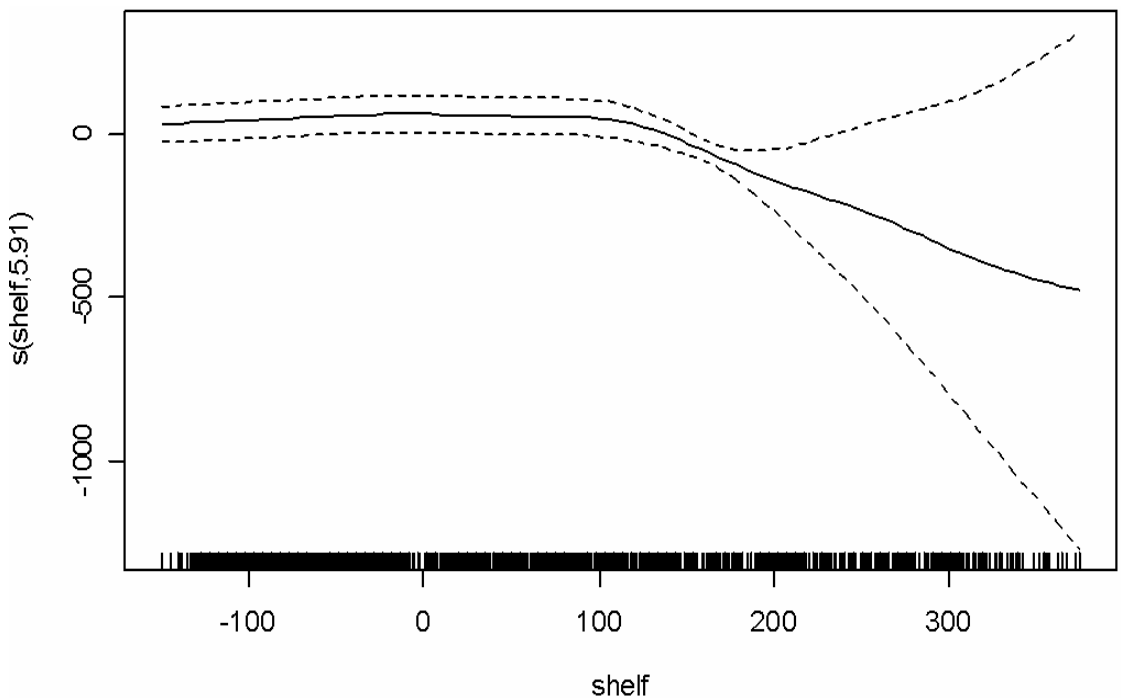

Figure A-75. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the Kemp's ridley turtle during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

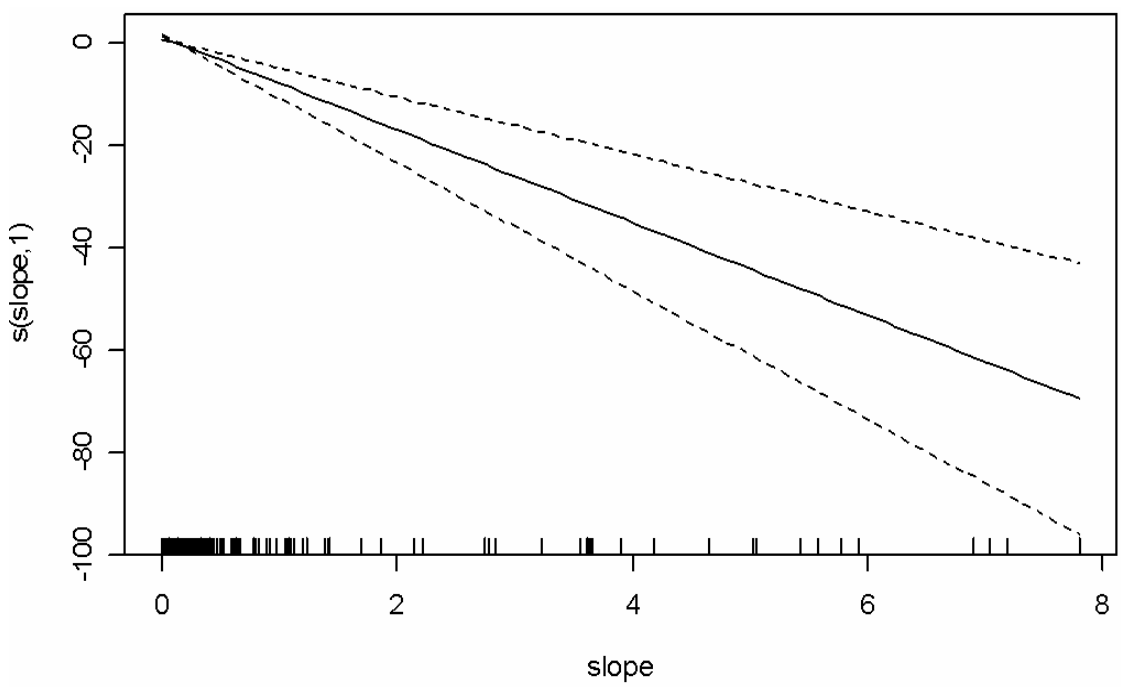

Figure A-76. Plot of the Generalized Additive Model smooth fit of the environmental covariate *slope* selected for the Kemp's ridley turtle during all seasons in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-43. Variance estimate model results for the Kemp's ridley turtle during all seasons in the Southeast study area.

Variance	
Legitimate values	389
Non-legitimate bootstrap replicates	110
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	2229.376 - 5208.289
Point estimate	3073.357
SE of bootstraps	744.9708
Est. CV for density surface model	0.2424
CV in detection probability	0.1941
CV in overall estimate including density surface model and detection probability	0.3105
Confidence interval incorporating detection function uncertainty	1695.692, 5570.308

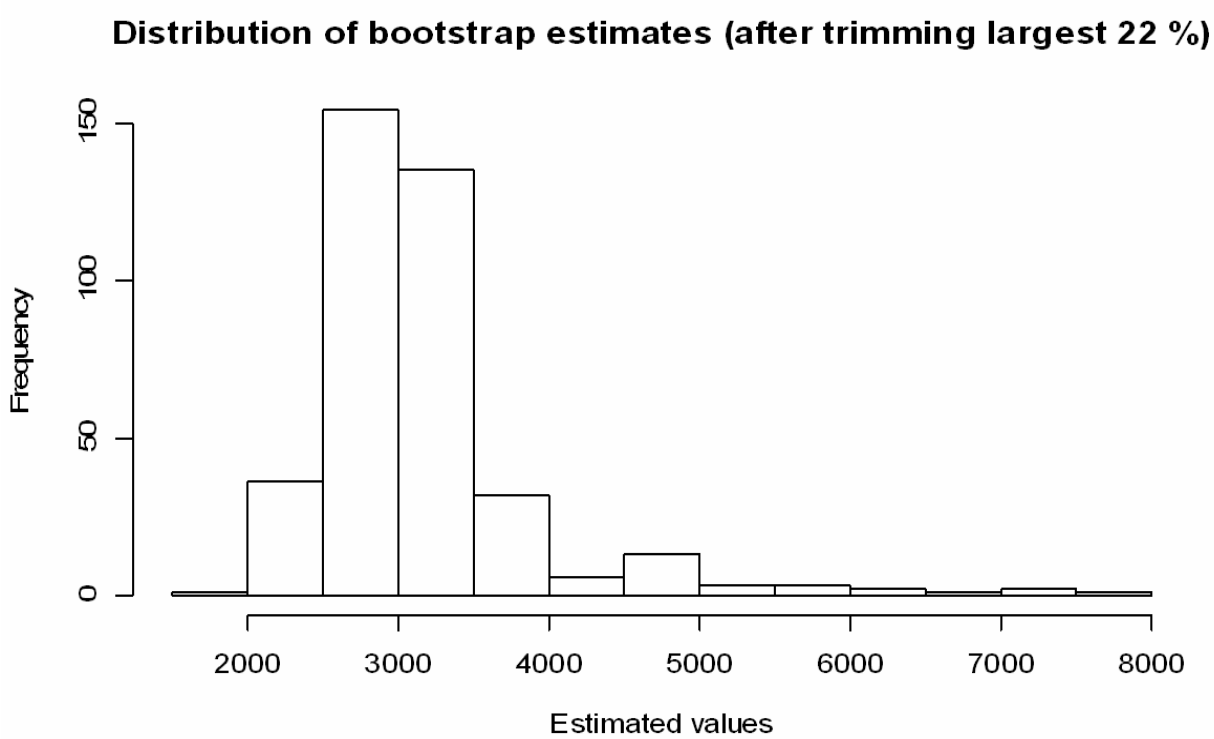

Figure A-77. Distribution of bootstrap estimates (after trimming largest 22%) for pooled sightings of the Kemp's ridley turtle during all seasons in the Southeast study area.

- Loggerhead Turtle (*Caretta caretta*)

Table A-50. Detection function results for the loggerhead turtle during fall, winter, and spring in the Southeast study area.

Detection Function	
No. of observations	823
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.5087
SE	0.0507
Hazard Shape Parameter (Exponent)	
Estimate	2.9670
SE	0.1907
Average p	
Estimate	0.3279
SE	0.0117
CV	0.0358
N in covered region	
Estimate	2509.9806
SE	114.9852
CV	0.0458

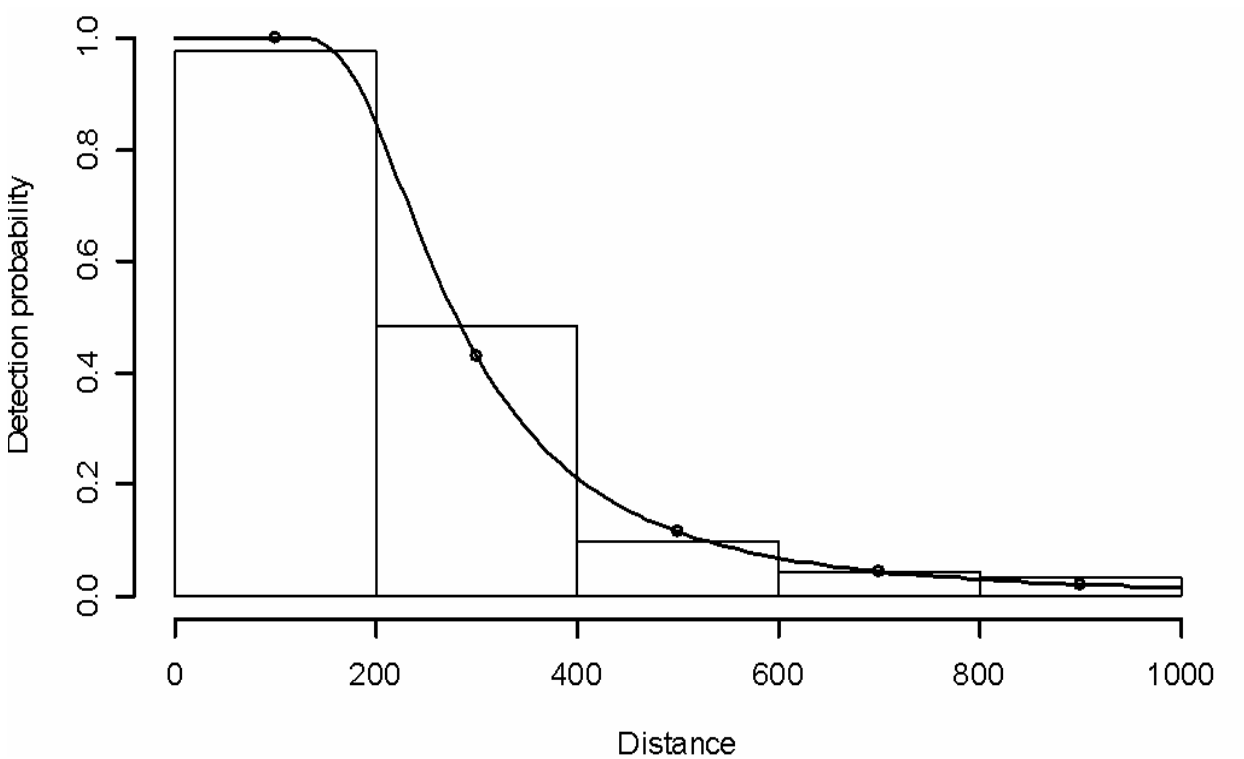

Figure A-88. Plot of the detection function for pooled sightings of the loggerhead turtle during fall, winter, and spring in the Southeast study area. Distance is measured in meters.

Table A-51. Response surface model (Generalized Additive Model) results for the loggerhead turtle during fall, winter, and spring in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(depth) + s(shelf) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	26.859
	Est. rank	28.000
	F	12.825
	p-value	<2e-16
s(depth)		
	Edf	5.733
	Est. rank	7.000
	F	3.610
	p-value	6.99e-04
s(slope)		
	Edf	8.853
	Est. rank	3.000
	F	7.321
	p-value	6.85e-05
R-sq. (adj)		0.376
n segments		575
Deviance explained		41.5%

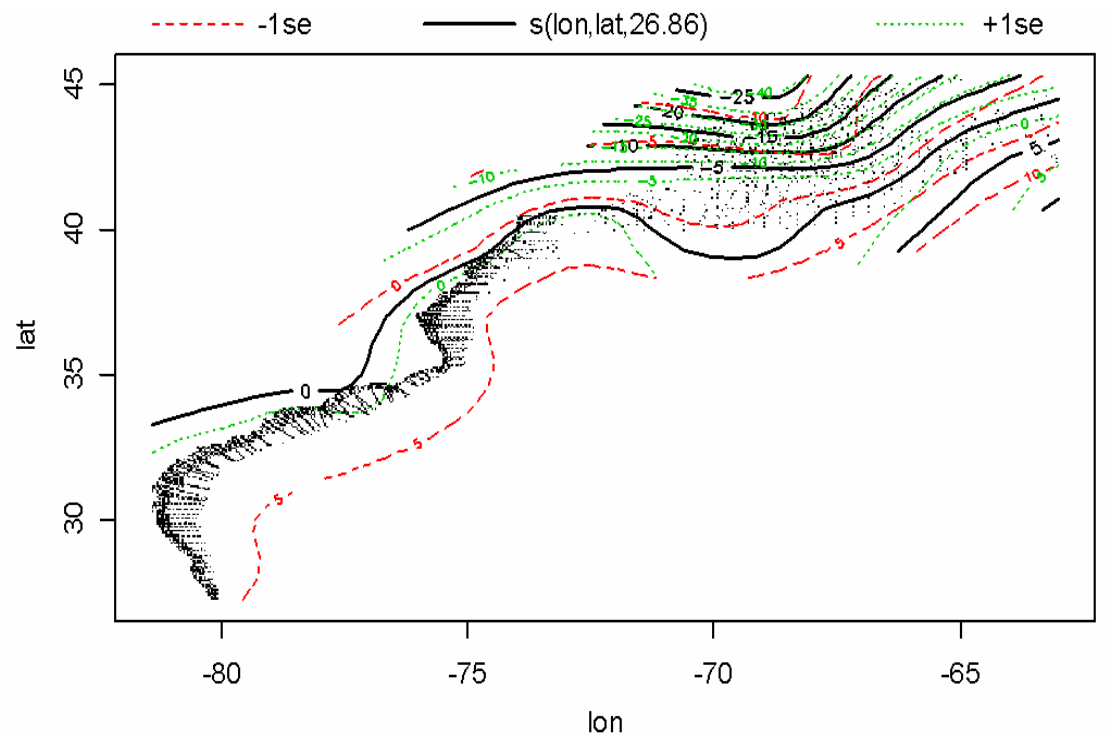

Figure A-89. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the loggerhead turtle during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

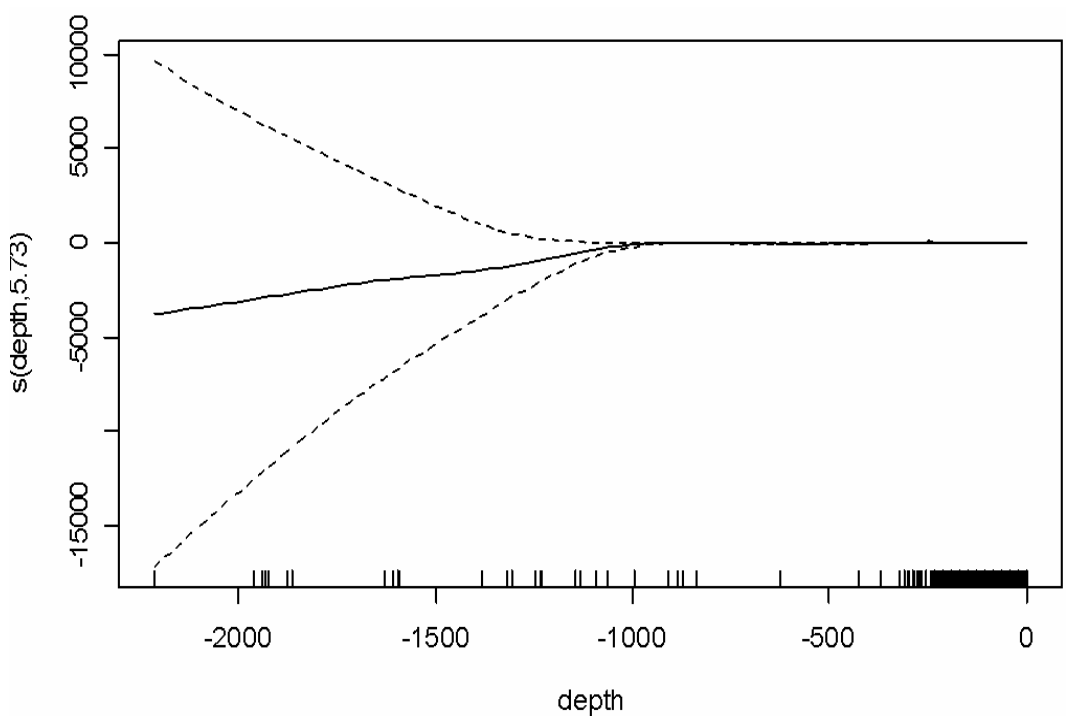

Figure A-90. Plot of the Generalized Additive Model smooth fit of the environmental covariate *depth* selected for the loggerhead turtle during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

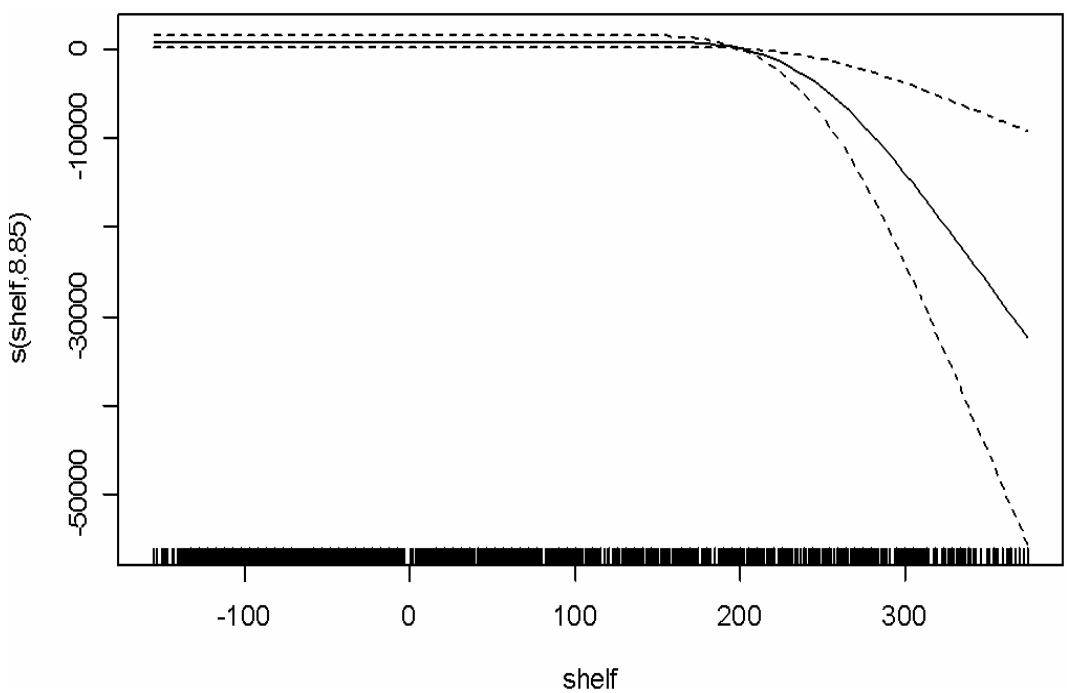

Figure A-91. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for the loggerhead turtle during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-52. Variance estimate model results for the loggerhead turtle during spring, fall, and winter in the Southeast study area.

Variance	
Legitimate values	446
Non-legitimate bootstrap replicates	53
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	12356.40 - 14921.79
Point estimate	13499.96
SE of bootstraps	636.6307
Est. CV for density surface model	0.0472
CV in detection probability	0.0358
CV in overall estimate including density surface model and detection probability	0.0592
Confidence interval incorporating detection function uncertainty	12021.97, 15159.66

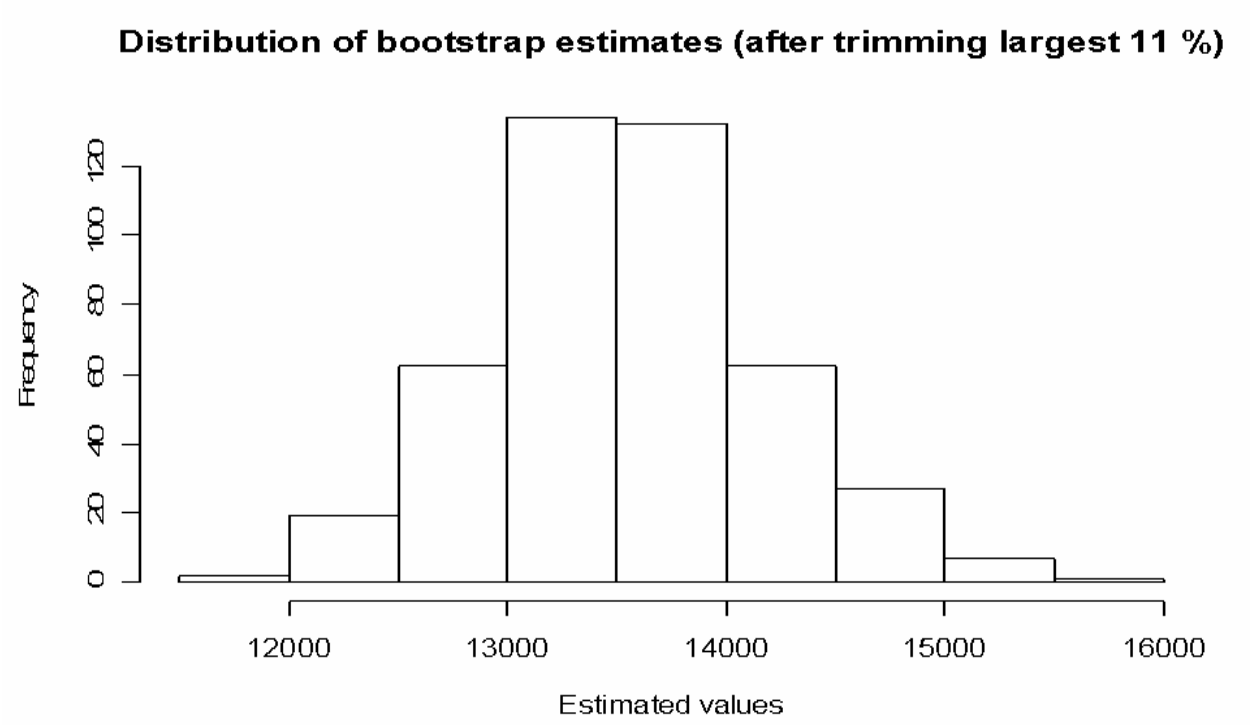

Figure A-92. Distribution of bootstrap estimates (after trimming largest 11%) for pooled sightings of the loggerhead turtle during spring, fall, and winter in the Southeast study area.

Table A-53. Detection function results for the loggerhead turtle during summer in the Southeast study area.

Detection Function	
No. of observations	823
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.5087
SE	0.0507
Hazard Shape Parameter (Exponent)	
Estimate	2.9670
SE	0.1907
Average p	
Estimate	0.3279
SE	0.0117
CV	0.03581
N in covered region	
Estimate	2509.9806
SE	114.9852
CV	0.0458

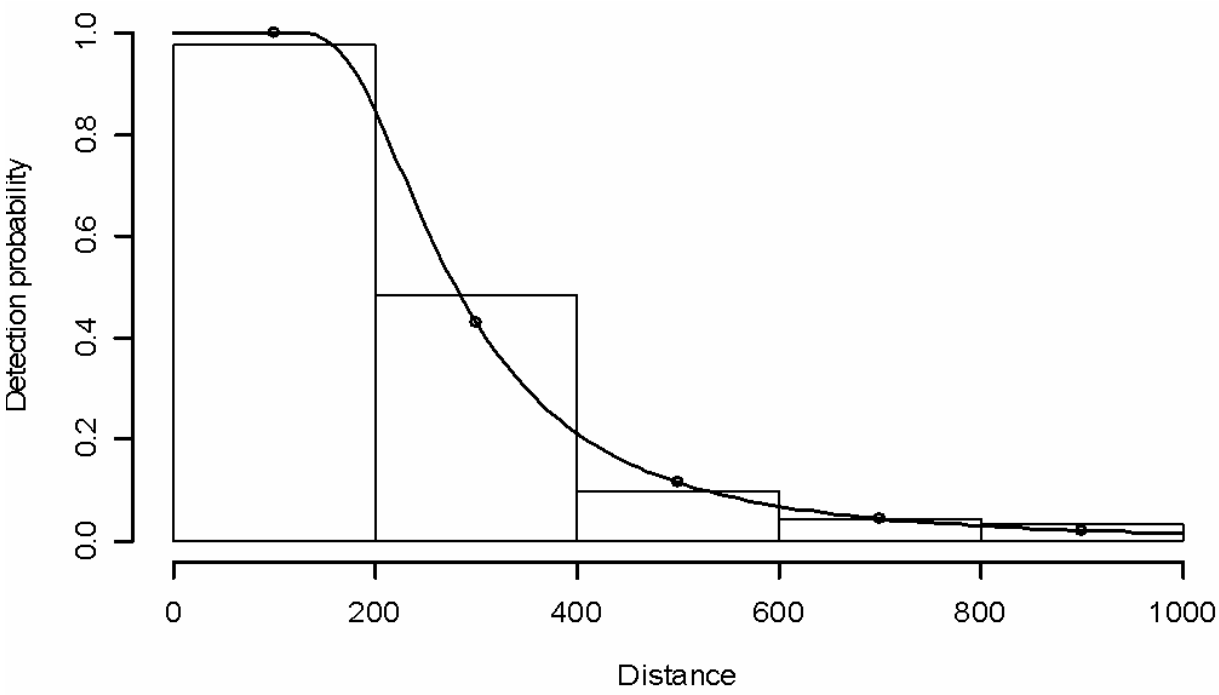

Figure A-93. Plot of the detection function for pooled sightings of the loggerhead turtle during summer in the Southeast study area. Distance is measured in meters.

Table A-54. Response surface model (Generalized Additive Model) results for the loggerhead turtle during summer in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(chl *a*) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	20.304
	Est. rank	29.000
	F	24.35
	p-value	<2e-16
s(chl *a*)		
	Edf	8.744
	Est. rank	8.000
	F	13.45
	p-value	<2e-16
R-sq. (adj)		0.302
n segments		575
Deviance explained		41.1%

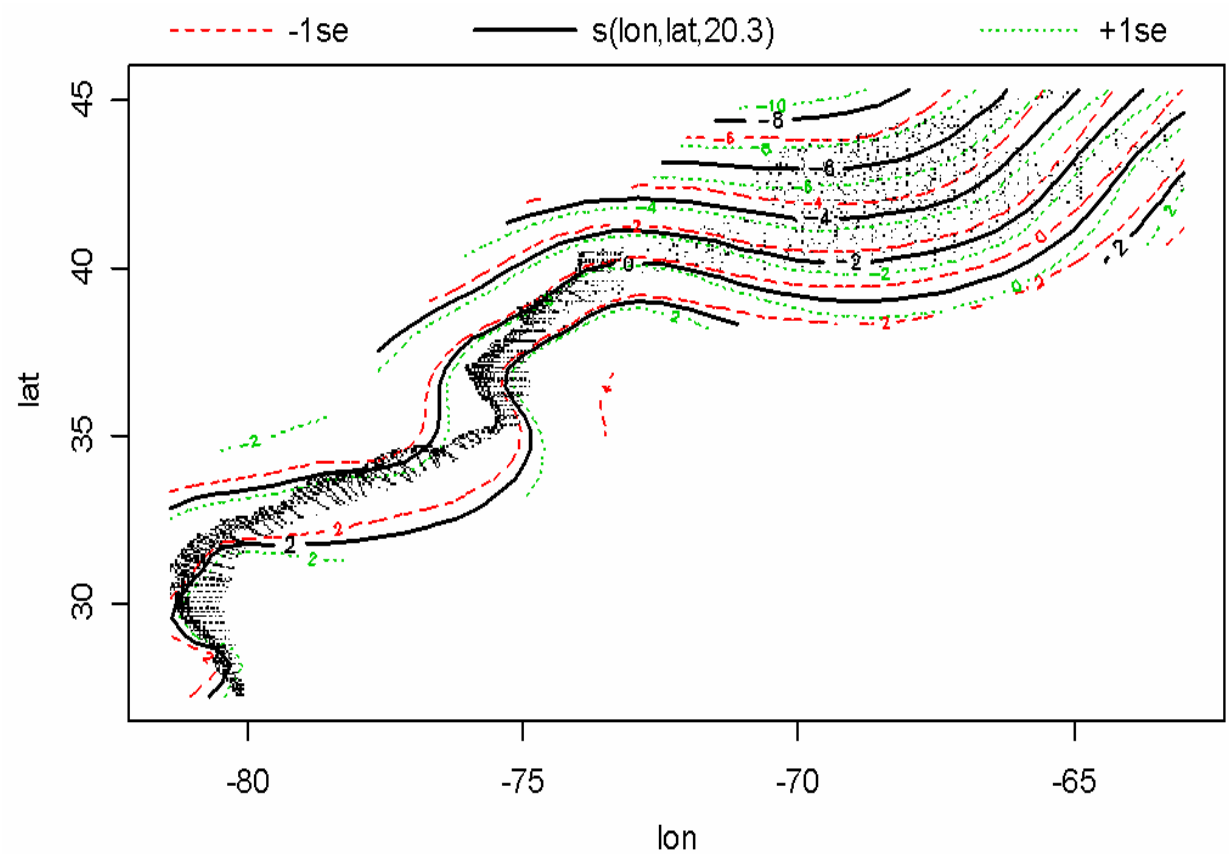

Figure A-94. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for the loggerhead turtle during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

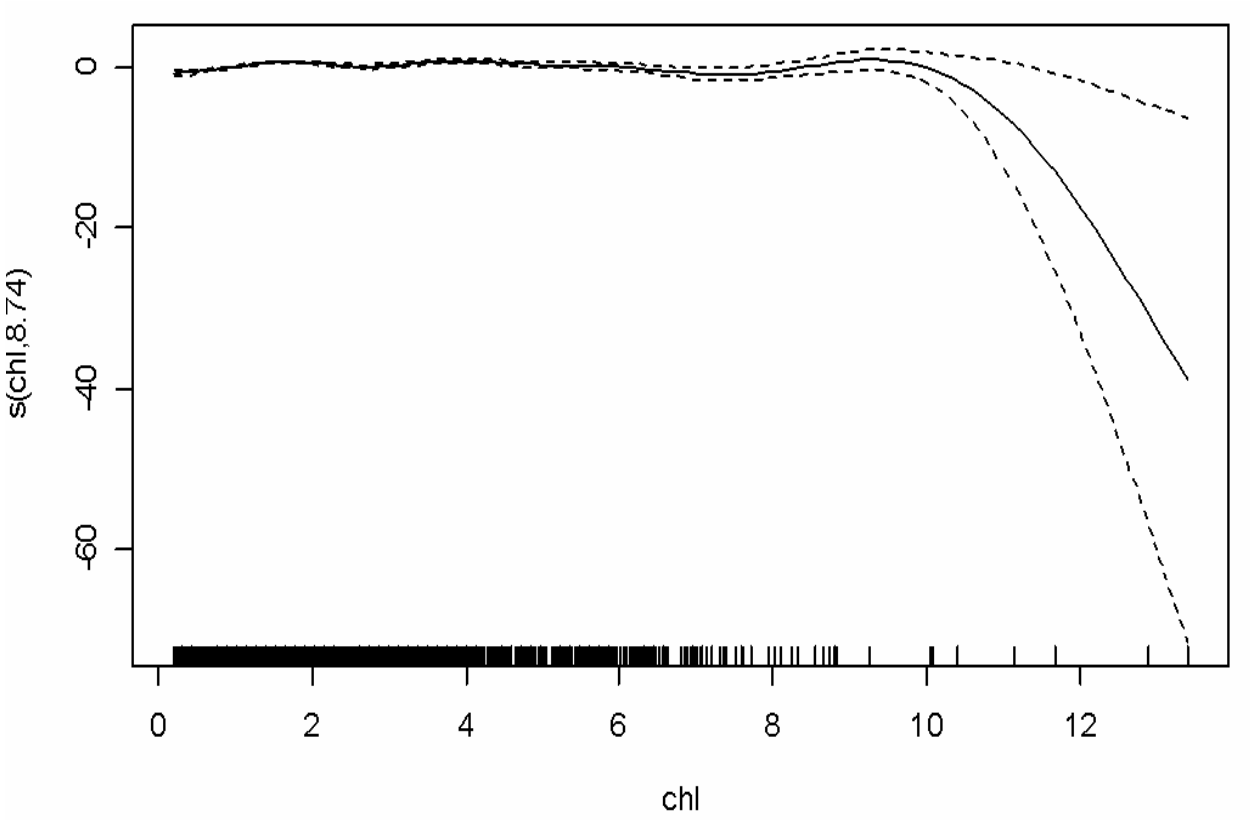

Figure A-95. Plot of the Generalized Additive Model smooth fit of the environmental covariate *chl a* selected for the loggerhead turtle during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-55. Variance estimate model results for the loggerhead turtle during summer in the Southeast study area.

Variance	
Legitimate values	492
Non-legitimate bootstrap replicates	7
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	13107.68 -15679.09
Point estimate	14425.87
SE of bootstraps	659.8748
Est. CV for density surface model	0.0457
CV in detection probability	0.0358
CV in overall estimate including density surface model and detection probability	0.0581
Confidence interval incorporating detection function uncertainty	12874.70, 16163.94

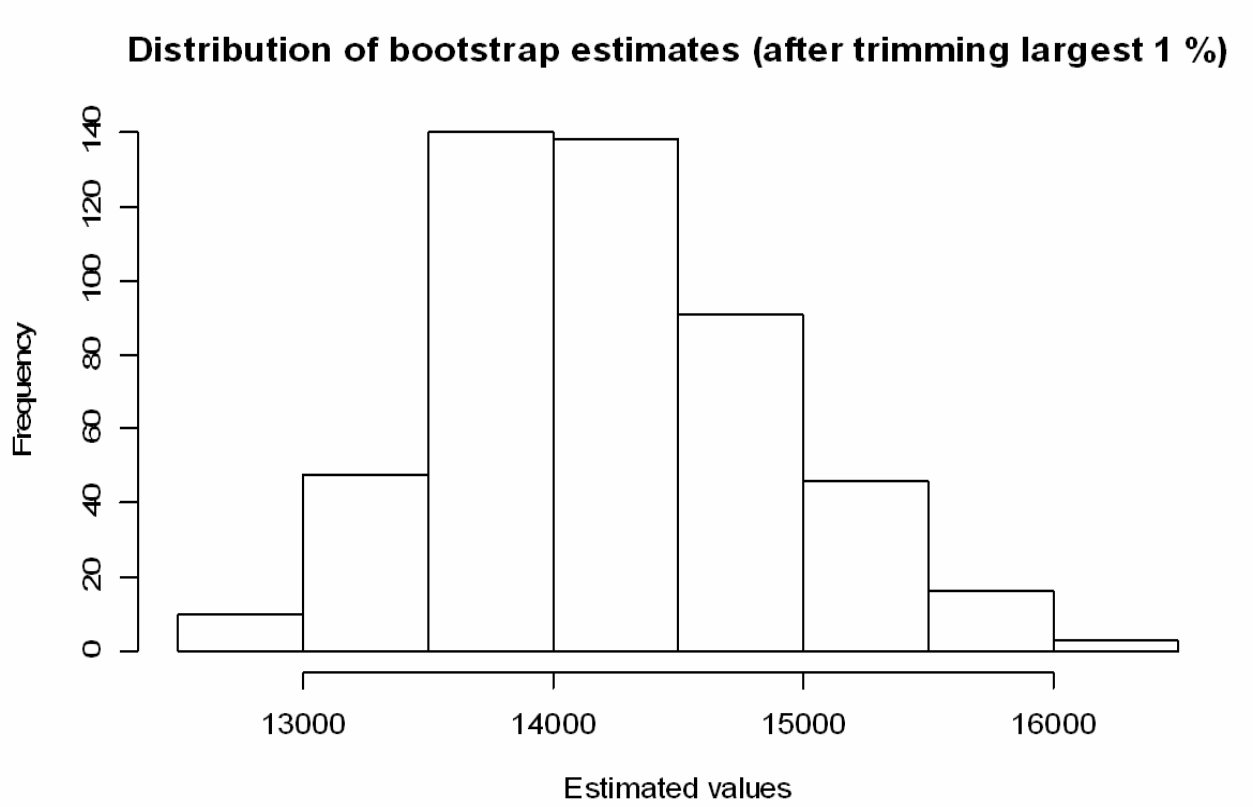

Figure A-96. Distribution of bootstrap estimates (after trimming largest 1%) for pooled sightings of the loggerhead turtle during summer in the Southeast study area.

- Hardshell Turtle

Table A-56. Detection function results for Hardshell Turtles during fall, winter, and spring in the Southeast study area.

Detection Function	
No. of observations	823
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.5087
SE	0.0507
Hazard Shape Parameter (Exponent)	
Estimate	2.9670
SE	0.1907
Average p	
Estimate	0.3279
SE	0.0117
CV	0.0358
N in covered region	
Estimate	2509.9806
SE	114.9852
CV	0.0458

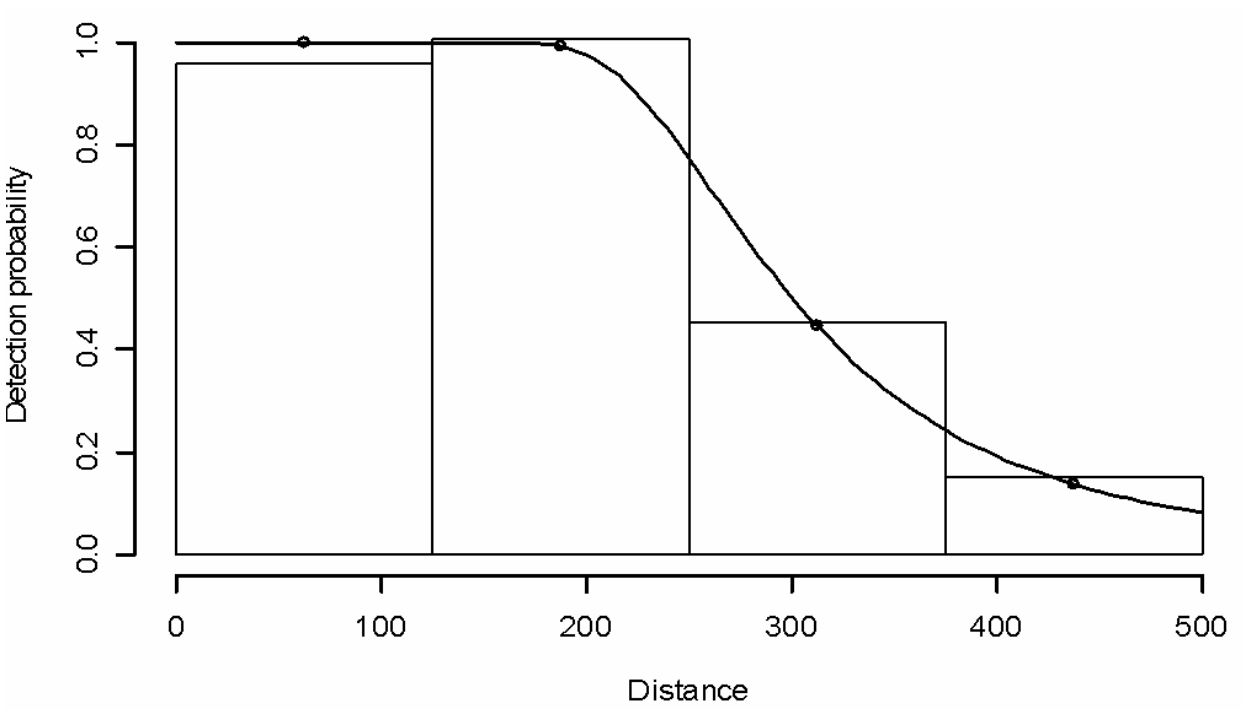

Figure A-97. Plot of the detection function for pooled sightings of Hardshell Turtles during fall, winter, and spring in the Southeast study area. Distance is measured in meters.

Table A-57. Response surface model (Generalized Additive Model) results for Hardshell Turtles during fall, winter, and spring in the Southeast study area.

Response Surface Model (GAM)	
Formula	N ~ s(lon,lat) + s(shelf) + offset(off.set)
Approximate significance of smooth terms	
s(lon, lat)	
Edf	14.738
Est. rank	29.000
F	25.254
p-value	<2e-16
s(shelf)	
Edf	8.756
Est. rank	4.000
F	5.989
p-value	8.6e-05
R-sq. (adj)	0.291
n segments	244
Deviance explained	61.4%

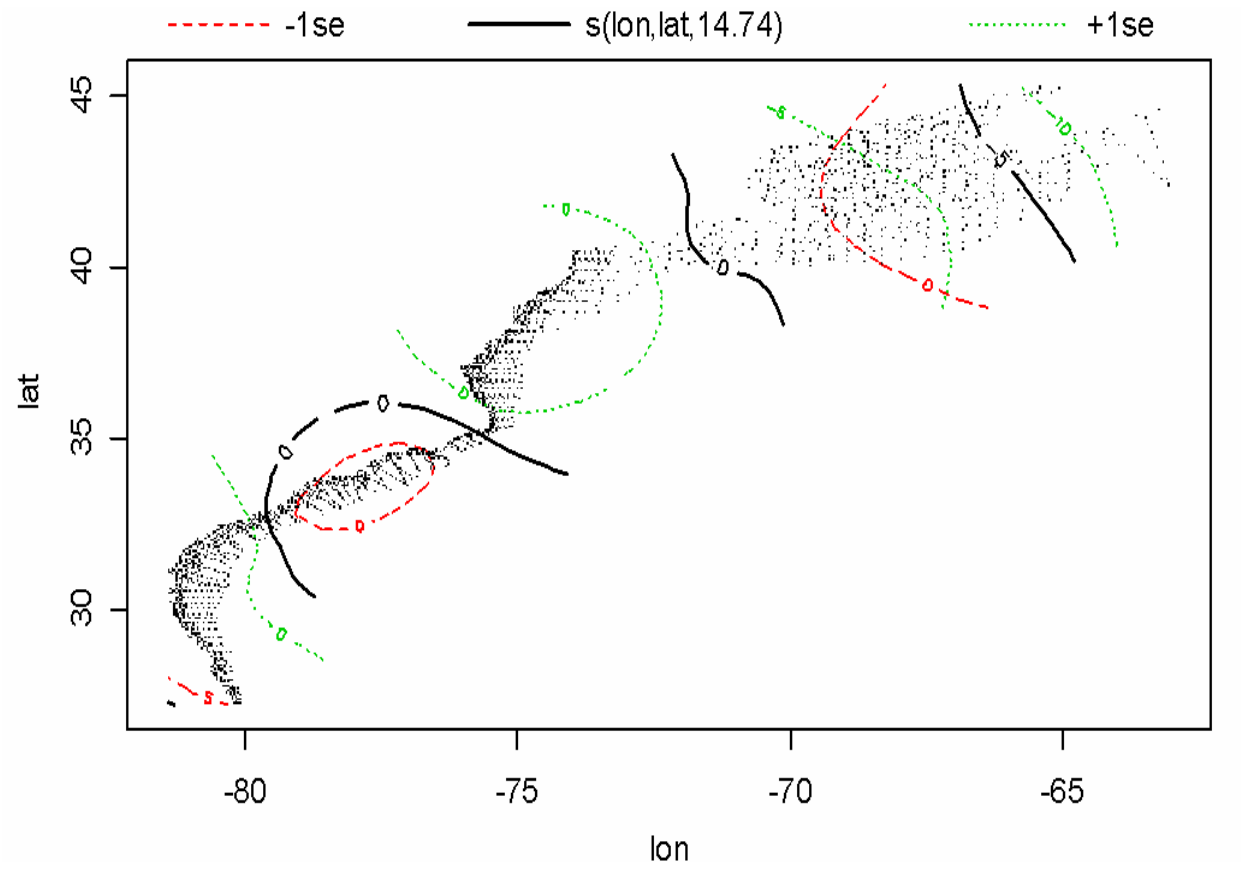

Figure A-98. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for Hardshell Turtles during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

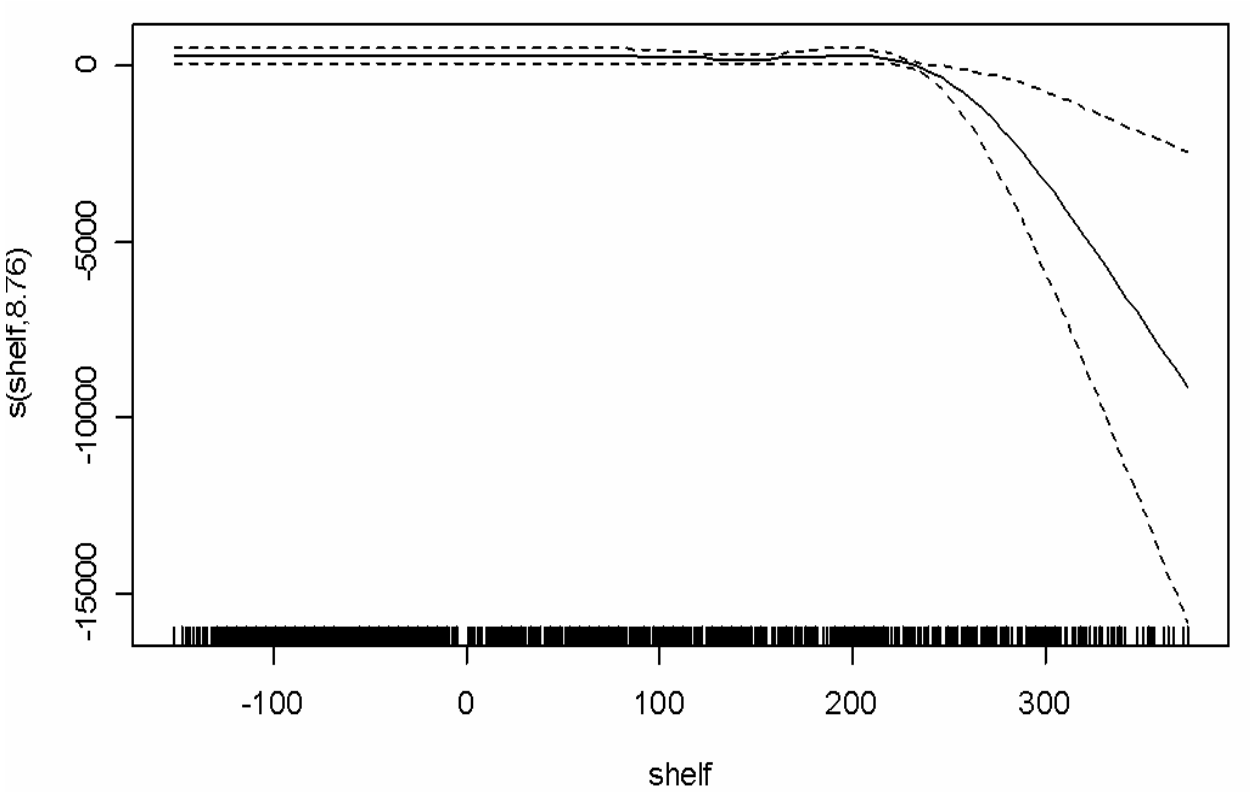

Figure A-99. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for Hardshell Turtles during fall, winter, and spring in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-58. Variance estimate model results for Hardshell Turtles during spring, fall, and winter in the Southeast study area.

Variance	
Legitimate values	486
Non-legitimate bootstrap replicates	13
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	7665.695 - 9661.275
Point estimate	8492.917
SE of bootstraps	525.3194
Est. CV for density surface model	0.0619
CV in detection probability	0.0375
CV in overall estimate including density surface model and detection probability	0.0723
Confidence interval incorporating detection function uncertainty	7371.495, 9784.941

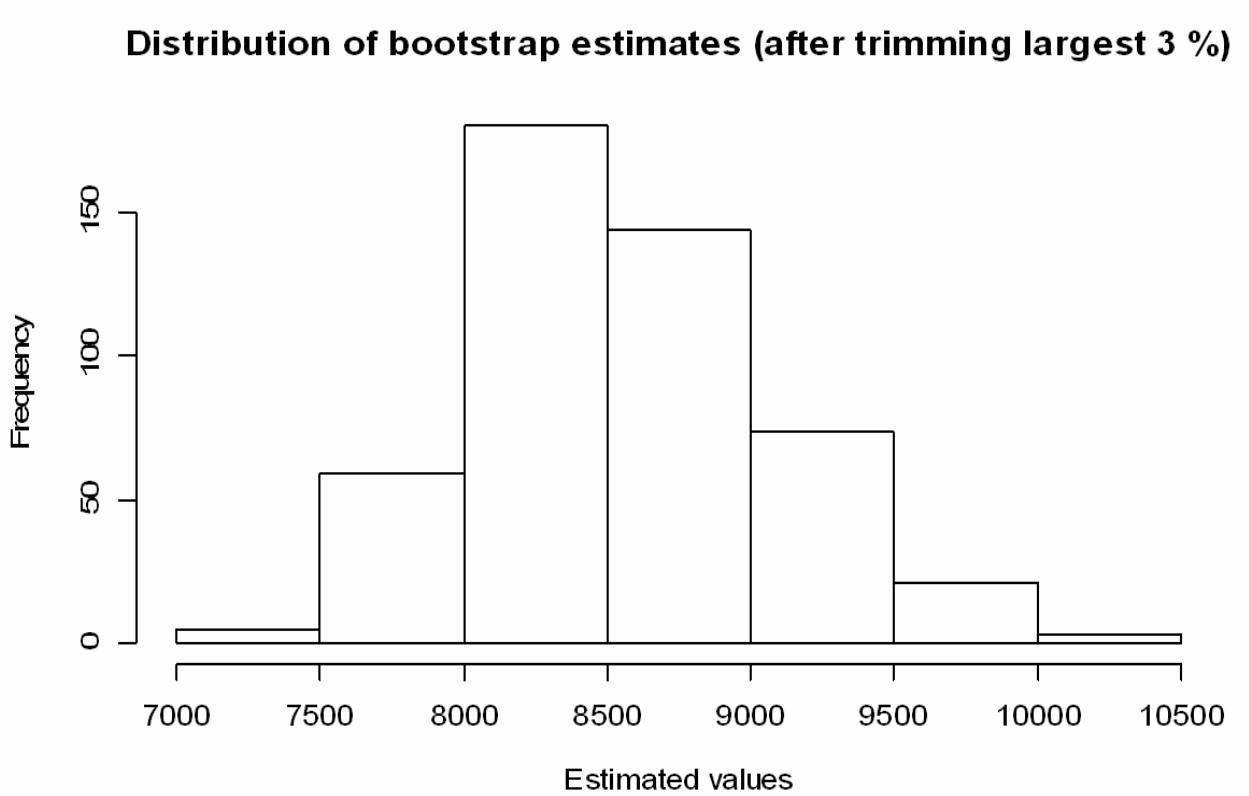

Figure A-100. Distribution of bootstrap estimates (after trimming largest 3%) for pooled sightings of Hardshell Turtles during spring, fall, and winter in the Southeast study area.

Table A-59. Detection function results for Hardshell Turtles during summer in the Southeast study area.

Detection Function	
No. of observations	375
Detection Function Parameters	
Scale Coefficients (Intercept)	
Estimate	5.6161
SE	0.0702
Hazard Shape Parameter (Exponent)	
Estimate	4.1208
SE	0.8655
Average p	
Estimate	0.6415
SE	0.02870
CV	0.0447
N in covered region	
Estimate	584.5676
SE	31.7907
CV	0.0544

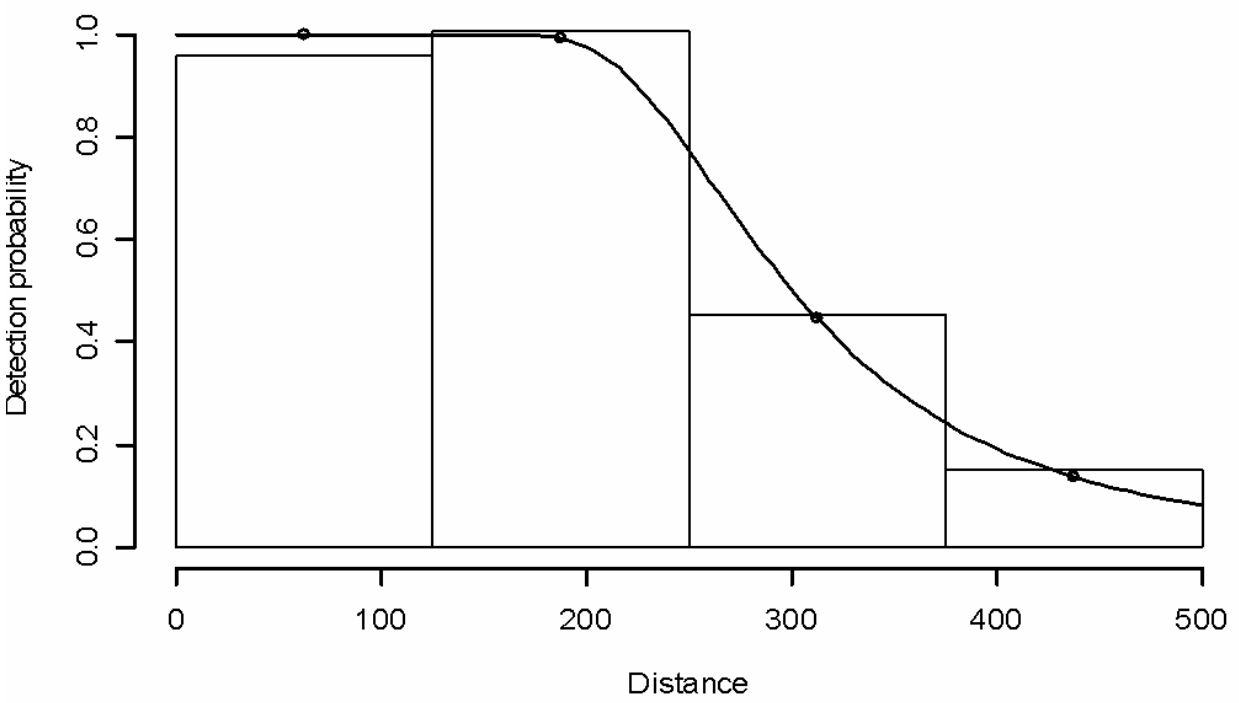

Figure A-101. Plot of the detection function for pooled sightings of Hardshell Turtles during summer in the Southeast study area. Distance is measured in meters.

Table A-60. Response surface model (Generalized Additive Model) results for Hardshell Turtles during summer in the Southeast study area.

Response Surface Model (GAM)		
Formula		N ~ s(lon,lat) + s(shelf) + s(chl *a*) + offset(off.set)
Approximate significance of smooth terms		
s(lon, lat)		
	Edf	14.109
	Est. rank	29.000
	F	25.277
	p-value	<2e-16
s(shelf)		
	Edf	8.709
	Est. rank	4.000
	F	5.049
	p-value	4.74e-04
s(chl *a*)		
	Edf	1.013
	Est. rank	3.000
	F	3.256
	p-value	0.0208
R-sq. (adj)		0.296
n segments		244
Deviance explained		61.5%

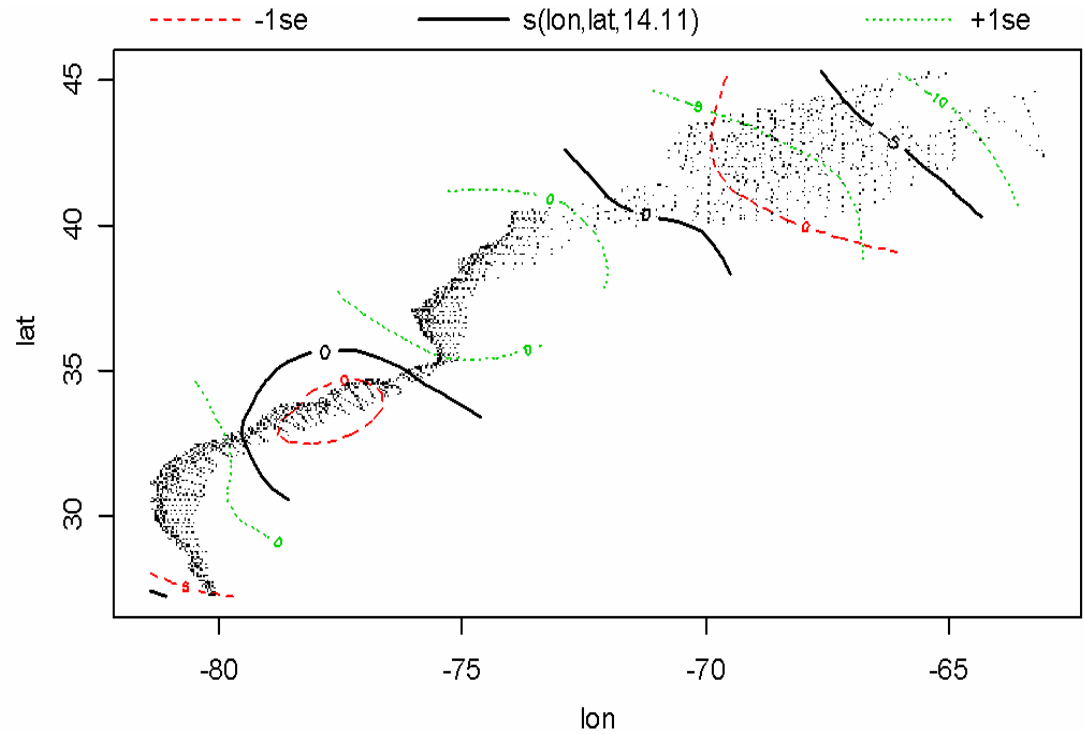

Figure A-102. Plot of the Generalized Additive Model smooth fit depicting the interaction of the covariates *longitude* and *latitude* selected for Hardshell Turtles during summer in the Southeast study area. Solid lines represent the best fit, dashed green lines represent the -1 SE confidence limit, and dashed red lines represent the +1 SE confidence limit.

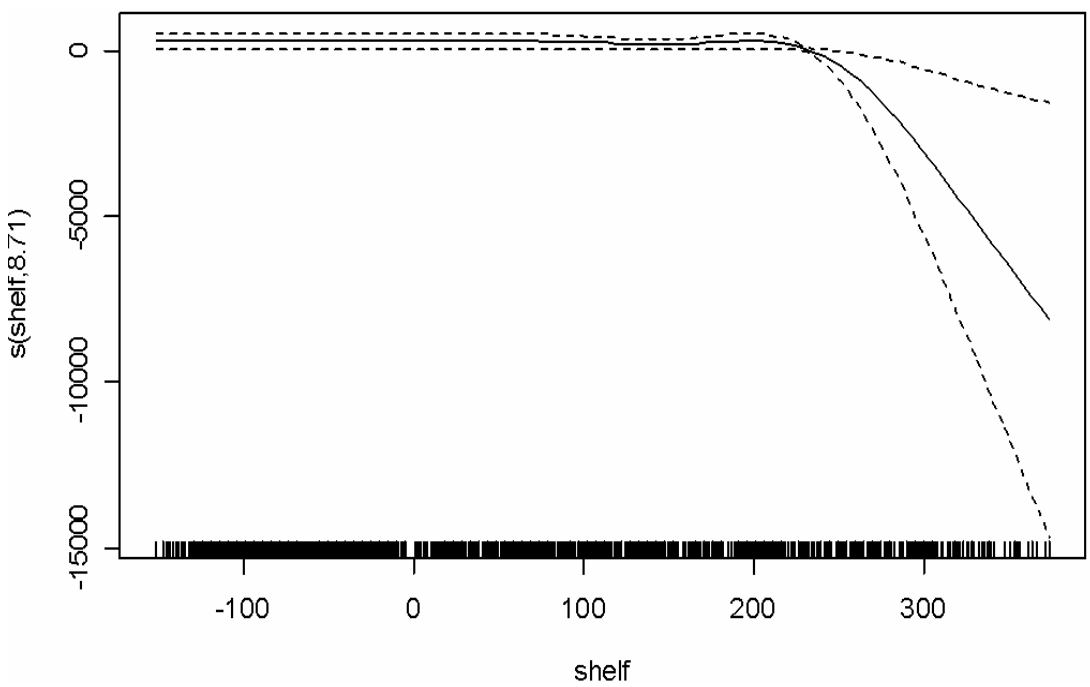

Figure A-103. Plot of the Generalized Additive Model smooth fit of the environmental covariate *shelf* selected for Hardshell Turtles during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

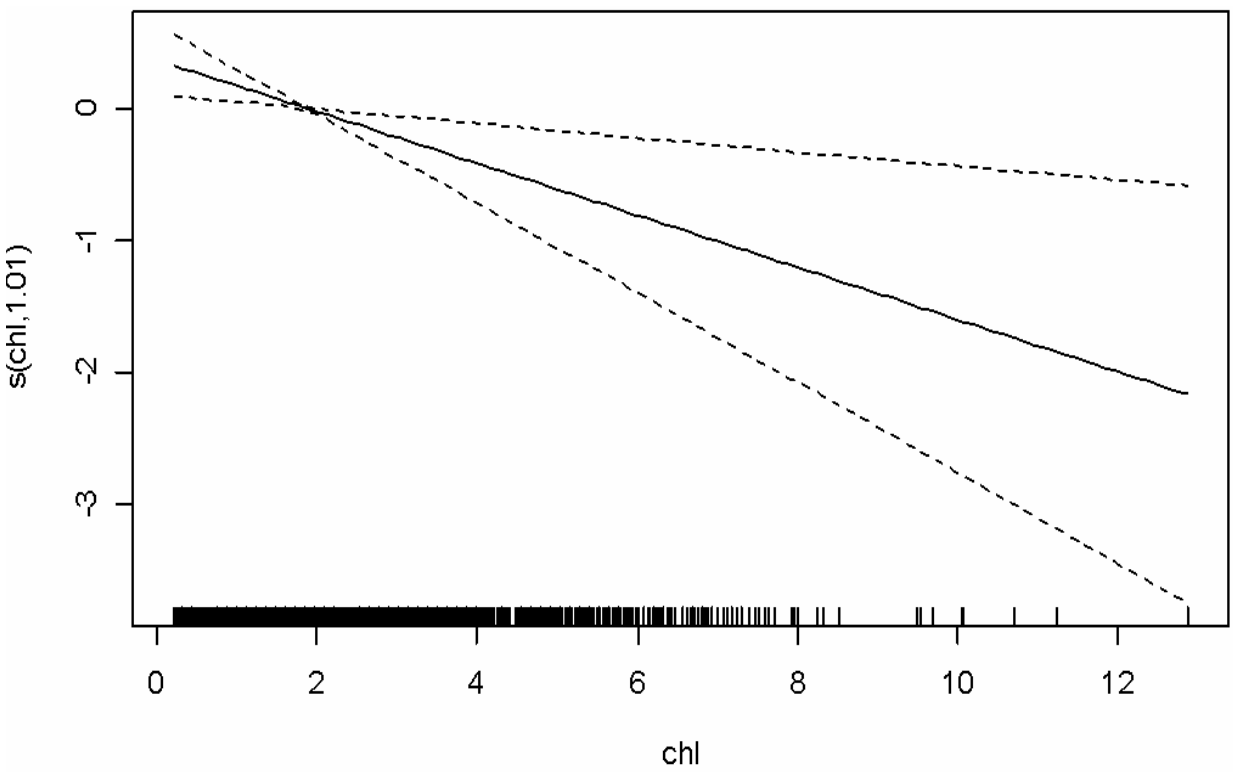

Figure A-104. Plot of the Generalized Additive Model smooth fit of the environmental covariate *chl a* selected for Hardshell Turtles during summer in the Southeast study area. Solid lines represent the best fit, dashed lines represent the 2 SE confidence limits, and vertical lines on the x-axis are the observed data values.

Table A-61. Variance estimate model results for Hardshell Turtles during all summer in the Southeast study area.

Variance	
Legitimate values	419
Non-legitimate bootstrap replicates	80
Infinites	0
NAs	0
NaNs	0
Percentile method computed 95% CI	10111.86 - 12680.08
Point estimate	10918.15
SE of bootstraps	624.283
Est. CV for density surface model	0.0572
CV in detection probability	0.0447
CV in overall estimate including density surface model and detection probability	0.0726
Confidence interval incorporating detection function uncertainty	9471.762, 12585.4

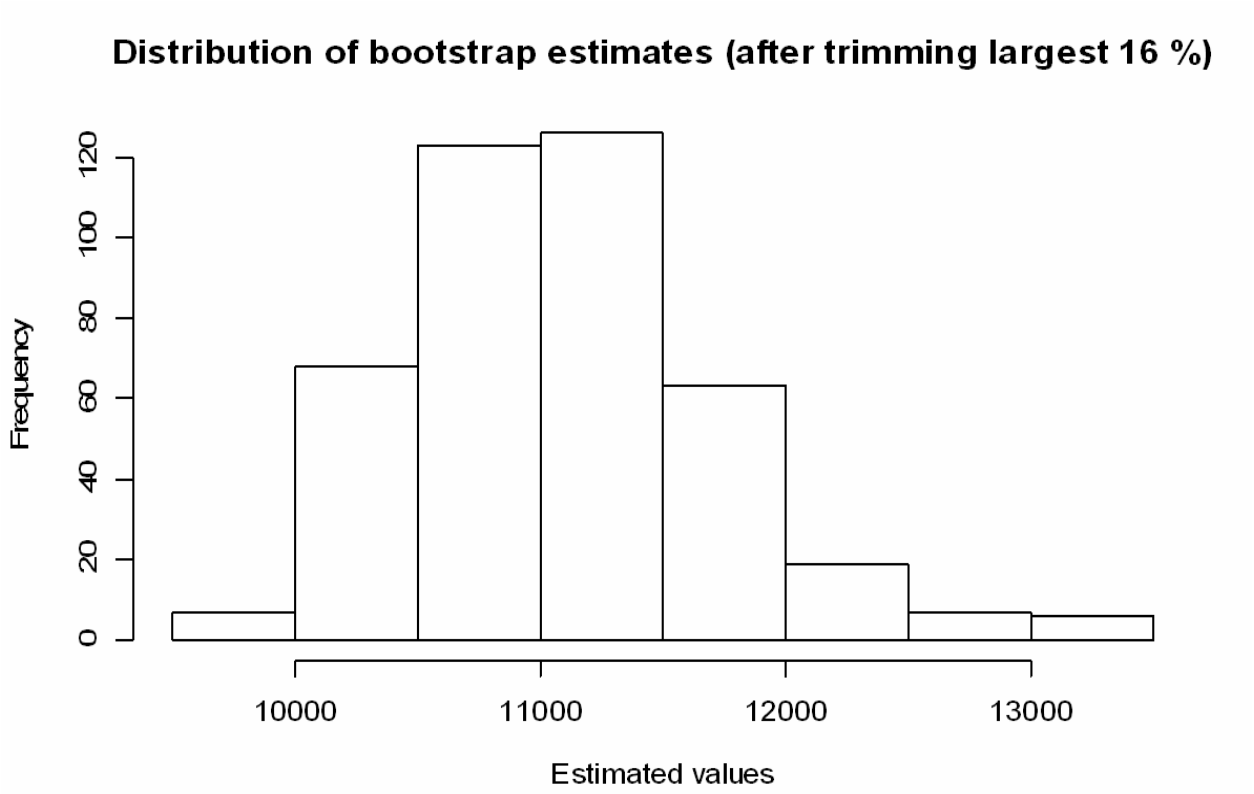

Figure A-105. Distribution of bootstrap estimates (after trimming largest 16%) for pooled sightings of Hardshell Turtles during summer in the Southeast study area.

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