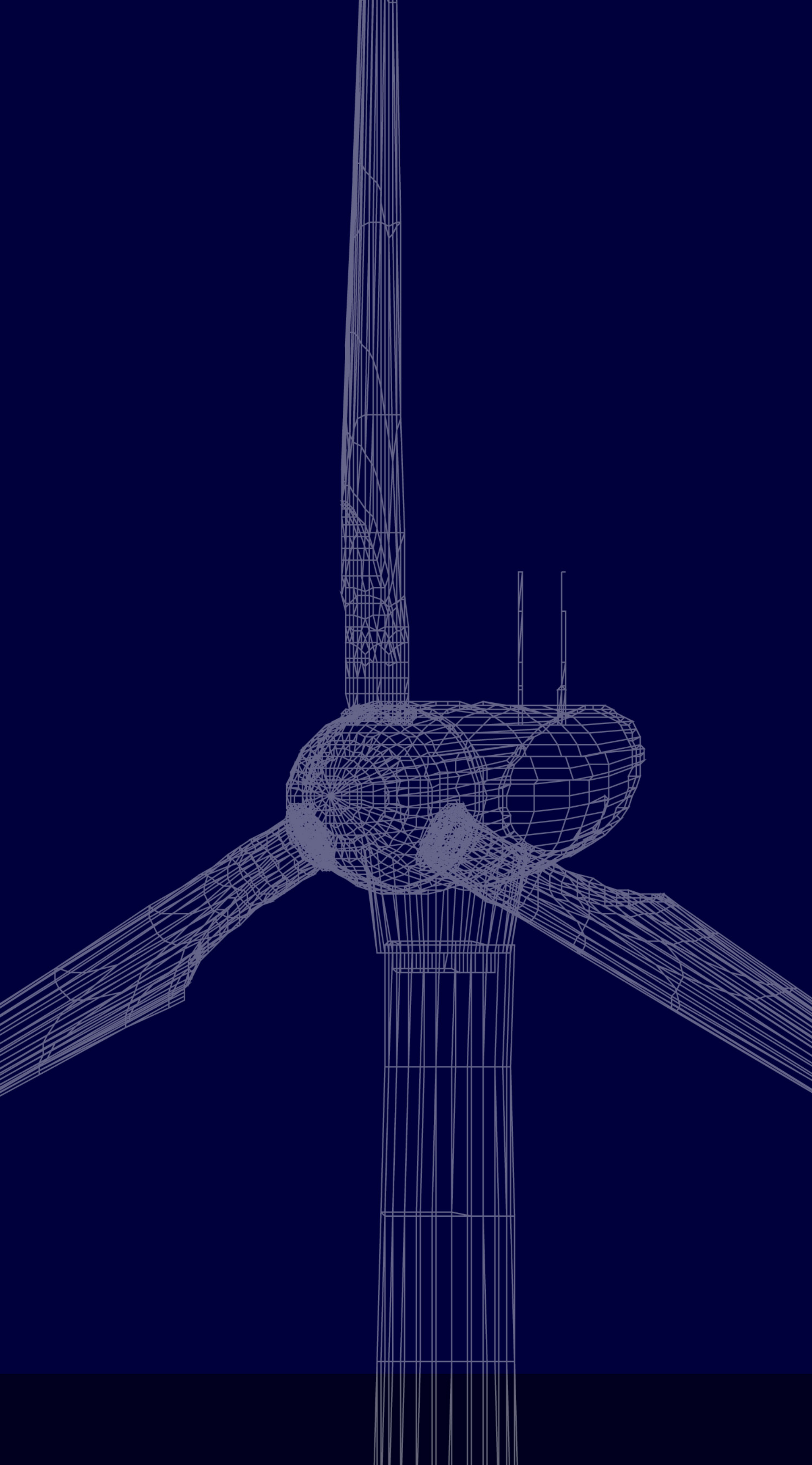
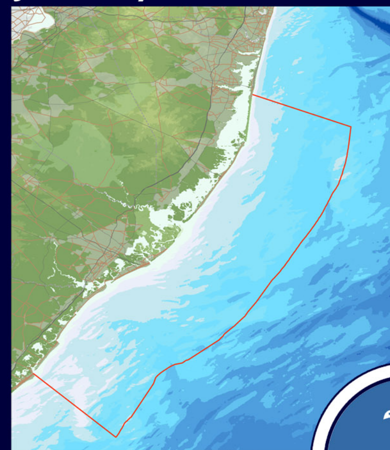
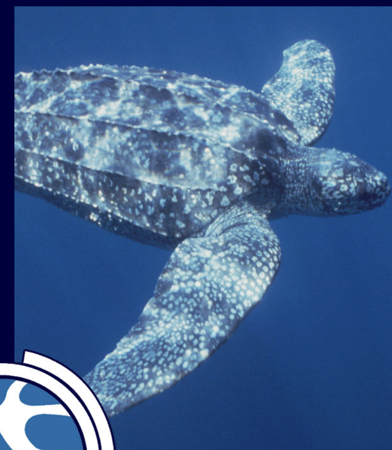


Ocean/Wind Power Ecological Baseline Studies

January – December 2008

REVISED INTERIM REPORT

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
DIVISION OF SCIENCE, RESEARCH, & TECHNOLOGY

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February 2009

GMI
GEO-MARINE INCORPORATED

GEO-MARINE INCORPORATED

March 9, 2009

ERRATA

The following issues observed by Gary Buchanan of the NJDEP on March 9, 2009 were addressed and corrected. The revised pages are provided for replacement in the NJDEP EBS Revised Interim Report.

Page & Section	Comment	Resolution
Page 7-10; Section 7.3.1	Paragraph 2 & Figure 7-2: Text does not match the figure, i.e., appears there are three locations (not two) with higher densities during Jan-Apr, and grids 17 and 55 in addition to 42, (and not locations 7 and 29)	Text in paragraph 2 in Section 7.3.1 was revised to match Figure 7-2.
Page 7-11; Figure 7-1	Grid 29 is blank (i.e. white), should this be red or ?	The map in Figure 7-1 was corrected to accurately reflect data

New Jersey Department of Environmental Protection
Baseline Studies

January – December 2008 Revised Interim Report

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February 27, 2009

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LIST OF ACRONYMS AND ABBREVIATIONS

%	Percent
°	Degree(s)
°C	Degree(s) Celsius
°F	Degree(s) Fahrenheit
‘	Minute(s)
“	Second(s)
µg/L	Microgram(s) per Liter
µ in	Microinch(es)
µm	Micron(s)
µs	Microsecond
AEAU	Alternative Energy and Alternate Use
AIC	Akaike’s Information Criterion
AKPSE	Average Kriging Prediction (Estimation) Standard Error
Alt	Altitude
AMSL	Above Mean Sea Level
ANOVA	Analysis of Variance
AREC	Atlantic Renewable Energy Corporation
ARGT	Avian Radar Ground Truthing
ARO	Avian Radar Operator
ASMFC	Atlantic States Marine Fisheries Commission
AWS	AWS Scientific, Inc.
BLUE	Best Linear Unbiased Estimate
BRP	Bioacoustics Research Program (Cornell Laboratory of Ornithology)
BSS	Beaufort Sea State
CCL	Curved Carapace Length
CETAP	Cetacean and Turtle Assessment Program
CFD	Cumulative Frequency Distribution
CI	Confidence Interval
CL	Confidence Level
cm	Centimeter(s)
cm/s	Centimeter(s) per Second
CTD	Conductivity-Temperature-Depth
CV	Coefficient of Variation
DF	Degree(s) of Freedom
DSM	Density Surface Model
DVD	Digital Versatile Disc
E	East
EA	Environmental Assessment
EBS	Ecological Baseline Studies
EDT	Eastern Daylight Time
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
ELMR	Estuarine Living Marine Resources
EMF	Electromagnetic Field
ENE	East-Northeast
EO	Executive Order
EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESE	East-Southeast
FAD	Fish Aggregating Device
FL	Fork Length
FMC	Fishery Management Council
FMP	Fishery Management Plan

LIST OF ACRONYMS AND ABBREVIATIONS (*continued*)

FPV	Focal Plan Array
ft	Foot(Feet)
ft/s	Foot(Feet) per Second
ft^3/s	Cubic Foot(Feet) per Second
g	Gram(s)
GAM	Generalized Additive Model
GIS	Geographic Information System
GMFMC	Gulf of Mexico Fishery Management Council
GMI	Geo-Marine, Inc.
GOES	Geostationary Operational Environmental Satellites
GOF	Goodness-of-fit
GPS	Global Positioning System
GTO	Ground Truth Observer
HAPC	Habitat Area of Particular Concern
HMS	Highly Migratory Species
hr	Hour
Hz	Hertz
IDW	Inverse Distance Weighting
IFMP	Interstate Fisheries Management Program
in	Inch(es)
in/s	Inch(es) per Second
IR	Infrared
IUCN	International Union for Conservation of Nature and Natural Resources
kg	Kilogram(s)
kg/m^3	Kilogram(s) per Cubic Meter
kHz	Kilohertz
km	Kilometer(s)
km^2	Square Kilometer(s)
kph	Kilometer(s) per Hour
kt	Knot
kW	Kilowatt(s)
lat	Latitude
lb	Pound
LJFL	Lower Jaw Fork Length
lon	Longitude
m	Meter(s)
m/s	Meter(s) Per Second
m^3/s	Cubic Meter(s) per Second
MAB	Mid-Atlantic Bight
MAFMC	Mid-Atlantic Fisheries Management Council
MARMAP	Marine Resources Monitoring, Assessment, and Prediction
MARS®	Mobile Avian Radar System
MATS	Mid-Atlantic *Tursiops* Surveys
MHz	Megahertz
mi	Mile(s)
mi^2	Square Mile(s)
min	Minute(s)
mm	Millimeter(s)
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MPE	Mean Prediction Error
mph	Mile(s) per Hour
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act

LIST OF ACRONYMS AND ABBREVIATIONS (*continued*)

MSPE	Mean Standardization Prediction Error
MTR	Migration Traffic Rate
MU	Management Unit
N	North
NAO	North Atlantic Oscillation
NE	Northeast
NEFMC	New England Fisheries Management Council
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NJDEP	New Jersey Department of Environmental Protection
NM	Nautical Mile(s)
NM^2	Square Nautical Mile(s)
NMFS	National Marine Fisheries Service
NNE	North-Northeast
NNW	North-Northwest
NOAA	National Oceanic and Atmospheric Administration
ns	Nanosecond(s)
NW	Northwest
OBIS-SEAMAP	Ocean Biogeographic Information System - Spatial Ecological Analysis of Megavertebrate Populations
OCS	Outer Continental Shelf
PAO	Primary Avian Observer
PC	Personal Computer
PCA	Principal Components Analysis
PDF	Probability Density Function
PRF	Pulse Repetition Frequency
psu	Practical Salinity Unit(s)
QA/QC	Quality Assurance/Quality Control
Radar	Radio Detection and Ranging
RMSPE	Root Mean Square Prediction Error
RMSSPE	Root Mean Square Standardized Standard Error
rpm	Revolution(s) per Minute
RSZ	Rotor Swept Zone
s	Second(s)
S	South
SAB	South Atlantic Bight
SAFMC	South Atlantic Fishery Management Council
SAR	Stock Assessment Report
SAS	Sighting Advisory System
SD	Standard Deviation
SE	Southeast
SEFSC	Southeast Fisheries Science Center
SFA	Sustainable Fisheries Act
SPUE	Sightings per Unit Effort
SSB	Senior Seabird Biologist
SSE	South-Southeast
SST	Sea Surface Temperature
SSW	South-Southwest
Sv	Sverdrup(s)
SW	Southwest
SWFSC	Southwest Fisheries Science Center
TIN	Triangular Irregular Network
TI-VPR	Thermal Imaging Camera-Vertically Point Radar

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

TL	Total Length
TV	Television
U.K.	United Kingdom
U.S.	United States
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
UTC	Coordinated Universal Time
Var	Variance
VGA	Video Graphics Array
VM	von Mises
VOR	Voice Operated Recording
VPS	Video Peak Store
W	West
WNW	West-Northwest
WSW	West-Southwest
X^2	Chi-Square
YBP	Year(s) Before Present
yr	Year

LIST OF METRIC TO U.S. MEASUREMENT CONVERSIONS

To convert from	To	Multiply by
LENGTH		
Kilometer (km)	Mile, statute (mi)	0.6214
	Nautical mile (NM)	0.5400
Nautical Mile (NM)	Mile, statute (mi)	1.150
Meter (m)	Foot (ft)	3.281
Centimeter (cm)	Inch (in)	0.3937
Millimeter (mm)	Inch (in)	0.03937
Micrometer or Micron (µm)	Microinch (µ in)	39.37
DISTANCE PER UNIT TIME		
Meter per second (m/s)	Mile per second (mi/s)	0.0006
	Foot per second (ft/s)	3.281
Centimeter per second (cm/s)	Inches per second (in/s)	0.394
AREA		
Square kilometer (km^2)	Square mile (mi^2)	0.3861
	Square nautical mile (NM^2)	0.2916
Square meter (m^2)	Square foot (ft^2)	10.76
VOLUME		
Cubic meter (m^3)	Cubic foot (ft^3)	35.31
	Gallon (gal)	264.2
VOLUME PER UNIT TIME		
Cubic meter per second (m^3/s)	Cubic foot per second (ft^3/s)	35.31
	Gallon per minute (gal/min)	15,850
Sverdrup (Sv) = 10^6 m^3/s	Gallon per second (gal/s)	264.2
WEIGHT		
Metric Ton (MT)	Ton, short (T)	1.102
Kilogram (kg)	Pound (lb)	2.205
DENSITY		
Kilograms per cubic meter (kg/m^3)	Pounds per cubic foot (lb/ft^3)	0.0624
CONCENTRATION		
Microgram per liter (µg/L)	Ounces per gallon (oz/gal)	1.34×10^{-7}
TEMPERATURE		
Degree Celsius (°C)	Degree Fahrenheit (°F)	(9/5)*(°C + 32)

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1.0 INTRODUCTION

On December 23, 2004, New Jersey Governor Richard Codey signed Executive Order (EO) #12. This order established a Blue Ribbon Panel on Development of Wind Turbine Facilities in Coastal Waters, which was tasked with three distinct charges:

- Identify and weigh the costs and benefits of developing offshore wind turbine facilities, considering both environmental costs and benefits
- Consider the need for offshore wind turbines and a comparison to other electric power sources, including fossil, nuclear and renewable fuels as part of the state's long-term energy needs
- Submit to the governor a report providing policy recommendations regarding the appropriateness of developing offshore wind turbine facilities

The Blue Ribbon Panel submitted a Final Report to Governor Jon Corzine in April 2006, providing policy recommendations regarding the appropriateness of developing offshore wind turbine facilities. The Panel determined that offshore wind turbines could be a part of New Jersey's long-term energy solution; however, they noted a lack of sufficient information on potential impacts of these types of facilities. The Panel recommended that the State initiate a limited test project "…to obtain practical knowledge of benefits and impacts resulting from offshore wind turbine facilities." The Panel also advised that the test project needed "…to be preceded by scientific baseline studies that collect basic data about the existence, location and nature of New Jersey's offshore natural resources…" (State of New Jersey 2006).

1.1 PROJECT GOALS

The Panel noticed that there was little information concerning potential impacts of wind farms upon marine and avian species, and there were few basic scientific data available regarding the distribution, abundance, and migratory patterns of birds and mammals beyond New Jersey's outer continental shelf (OCS). Recommendation 4 of the Blue Ribbon Panel's Final Report stated: "The state should conduct baseline studies of New Jersey's coastal waters to inform federal rules regulating use of such areas, to develop spatial and temporal information regarding ocean uses and living natural resources, and to assess tourism and related economic sectors" (State of New Jersey 2006).

Recommendation 6 stated: "Planning for a test project must proceed with caution; its development must be preceded, accompanied, and followed by collection and analysis of scientifically valid data and monitoring of environmental and economic impacts of the project." These recommendations were further explained in terms of ecological resources as:

"Baseline data should be collected regarding the distribution, abundance, and migratory patterns of avian species, fish, marine mammals, and turtles in the offshore area where development may be feasible. These data may be gathered variously by physical counts by boat and airplane, remote sensing by radar and sonar applications, and historic record reviews. Data collection should be designed to answer fundamental questions regarding which species use what areas and to what degree, and collected data should be made available to inform risk assessment and cumulative impact modeling" (State of New Jersey 2006; NJDEP 2007).

In order to comply with the Panel's recommendations, the New Jersey Department of Environmental Protection (NJDEP) released a Solicitation for Research Proposals for Ocean/Wind Power Ecological Baseline Studies (EBS). Geo-Marine, Inc. (GMI) was ultimately contracted to provide those studies. To meet the project goal, baseline data were to be collected on birds, sea turtles, and marine mammals over an 18-month period to fill major data gaps identified for each group. The major data gaps identified in the Solicitation were:

➢ Avian Species: Data are lacking on the abundance, distribution, and flight behavior (i.e., height and regular pathways) for bird species in the offshore waters of New Jersey. Data are also needed on the distribution, abundance, and behavior of birds during various environmental conditions (e.g., fog, night, poor visibility) where wind turbines may have greater impacts.

- Marine Mammals: Population estimates are available but have been deemed unreliable due to spatial and temporal variability. There is a limited data set for the Study Area (which extends out to 20 nautical miles [NM] offshore), but standardized abundance data and information on movement pathways are lacking.

- Sea Turtles: Available data indicates that most turtle sightings in waters off New Jersey's coast are made during the summer months of June through August, however, turtles can be found in New Jersey waters from May to November. Data sources include tracking devices (e.g., satellite tracking), strandings, and accidental encounters. There is a very limited data set for the Study Area. Essentially no standardized abundance data is available.

- Fish and Shellfish: Data in the literature on commercial and recreational landings, as well as reports on the distributions of species (e.g., NJDEP and National Marine Fisheries Service [NMFS] reports) are available. Both NJDEP and federal agencies conduct surveys of offshore waters for fish and shellfish, therefore, existing data are available to assess the spatial and temporal distribution of most major commercial and recreational species in offshore waters. The major data gap is the lack of a recent and comprehensive compilation of spatial and temporal data on these species in a digital and Geographic Information System (GIS)-compatible format.

1.2 PROJECT OBJECTIVES

The overall goal of the study is to provide spatial and temporal data on species utilizing New Jersey offshore waters to assist in determining potential areas for wind power development. The answers to the following objectives are needed to provide the data necessary to meet the study goal (NJDEP 2007):

1. What are the abundance, distribution, flight behavior (i.e., height and regular pathways), and utilization (e.g., feeding, breeding) of bird species in the Study Area?
2. What are the abundance, utilization, and distribution (e.g., feeding, breeding) of marine mammals in the Study Area?
3. What are the abundance, utilization, and distribution (e.g., feeding, breeding) of sea turtles in the Study Area?
4. What are the abundance, utilization, and distribution of other marine biota (e.g., fish, shellfish) in the Study Area?
5. What is the distribution of other existing natural resources, including, but not limited to, shoals and sand?
6. Using predictive modeling, mapping, and environmental assessment methodologies, what portions of the Study Area are more or less suitable for energy power facilities based on potential ecological impacts?

Three primary field surveys (Avian, Marine Mammal, Sea Turtle) along with supporting oceanographic studies are required to provide the data necessary to answer the project objectives. Other study components necessary to answer the project objectives include literature review, data compilation (digital and historical), model development, impact assessment, GIS (development of new and existing data coverages for the Study Area), and reporting (Buchanan 2008). Some of the requirements in the Solicitation include:

1.2.1 Avian Baseline Study

Most wind power impact data in the United States (U.S.) have been collected in terrestrial systems; however, impact studies in marine systems have been conducted in Europe. As recommended by the Blue Ribbon Panel, this baseline study will be based on those methods used successfully in European studies of offshore wind power (e.g., Horns Rev and Nysted Wind Farms). The scope of work requires the collection of spatial and temporal avian population data and development of a model that will predict avian usage based on seasonal survey data. This data will be used to complete an impact analysis on effects of wind power development activities on avian species in the Study Area.

The contractor, in conjunction with NJDEP, will define the spatial and temporal variables of interest. These will include but not be limited to water depth, shoals, location (e.g., distance from shore), and season. The contractor shall perform work such that the critical spring or fall migration periods are sampled twice. Data collected in Year 1 of the study are used to populate and calibrate the model, while subsequent data (i.e., months 13 to 18) will be used to populate and validate the model. The second year of sampling will utilize both Year 1 surveying techniques (e.g., to estimate year-to-year variability), as well as non-random sampling to examine variables that affect bird distribution. These variables include time of day, season, weather, and others that could aid in determining the distribution of avian species during breeding, wintering, and migration. The predictive model and data collection/design will include assessment of the model's power and accuracy and will be detailed in subsequent project reports.

Data collection methods for the avian baseline study include aerial transect surveys (now discontinued), boat transect surveys, and marine radar sensing to determine the abundance, distribution, utilization, and flight behavior of birds in the Study Area. All birds are identified to as fine a scale as possible (e.g., to species or guild) given the survey methodology utilized.

Avian aerial transect surveys were scheduled to be conducted once monthly during the 18-month study period. A fixed high-wing, twin-engine or single-engine float-equipped aircraft with good all-around visibility (e.g., bubble windows) was used to fly transects within the Study Area. Two experienced biologists recorded all observations (including species, number, approximate altitude, behavior, sources of food, transect number, and time). A Global Positioning System (GPS) unit was used to record latitude and longitude at 5-second (s) intervals. Surveys were flown only under appropriate conditions (e.g., visibility, sea state) as defined in consultation with Federal and State representatives. Weather conditions were recorded for all surveys (e.g., temperature, wind speed and direction, percent cloud cover, barometric pressure, precipitation, etc.) and any substantial changes in weather just prior to surveys (e.g., 24 hours [hrs]) or during surveys will also be noted. Survey methods generally followed U.S. Fish Wildlife Service (USFWS) methods (e.g., Fisher et al. 2002 and Camphuysen et al. 2004). Aerial surveys have since been discontinued in favor of increased radar surveys.

Boat line-transect surveys are conducted during daylight hours at defined intervals during the 18-month study period. Two (2) experienced avian biologists use the appropriate-sized stabilized binoculars to enumerate, estimate flight altitude, identify bird species within an established range, and record other observations (e.g., behavior, sources of food). Survey methods generally follow Camphuysen et al. (2004) and Ballance (2007).

The third avian survey technique involves the use of radar technology (i.e., bird detection radar systems) for observing avian usage and migration patterns (including night migrations and periods of poor visibility). A radar configuration that has the ability to collect data in a vertical and horizontal direction at multiple stations is used within the Study Area. The radar was secured on a stable temporary platform (e.g., barge) in the Study Area, as this configuration allowed a more comprehensive survey zone. The survey design maximizes data collection in order to describe avian usage of the Study Area.

Scientific literature, databases (e.g., Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations [OBIS-SEAMAP]) and recent/ongoing research will be added to the digital database. Aerial, boat, and avian radar data will be used to determine the spatial and temporal distribution of avian species off the New Jersey coast.

1.2.2 Marine Mammal and Sea Turtle Baseline Study

1.2.2.1 Marine Mammals

Studies of wind turbine impacts on marine mammals have been conducted in Europe (e.g., Elsam Engineering and ENERGI E2 2005) and as recommended by the Blue Ribbon Panel (State of New Jersey 2006), the design of this baseline study is based on methods used in Europe as well as standard methods for marine mammal surveys used in North America. The spatial and temporal distribution of marine mammals and sea turtles in waters off the New Jersey coast will be determined during the 18-

month avian baseline study. The contractor has obtained any permits (e.g., NMFS) needed to conduct surveys in waters offshore of New Jersey.

Three sampling techniques are used to determine the spatial and temporal abundance, distribution, and behavior of marine mammals in the Study Area. These include aerial line transects, boat line transects, and acoustic sampling.

Aerial line-transect surveys for marine mammals are conducted in the Study Area in conjunction with the sea turtle surveys. Surveys are conducted once monthly; the survey days are randomly selected. A fixed high-wing, twin-engine aircraft with good all-around visibility (e.g., bubble windows) is used to fly along transect lines perpendicular to the shoreline within the Study Area (i.e., shoreline to 20 NM offshore) at an altitude of approximately 500 feet (ft) and speed of 100 knots (kts). Transect lines are fixed and 2 miles (mi) apart for a total of 35 transects per survey. Two experienced biologists record all observations of marine mammals (including species, abundance, behavior, transect number, and time). A GPS unit records latitude and longitude at 5-s intervals for correlation to field observations. When feasible, digital photographs of marine mammals are taken. Photographs of right whales will be provided to the New England Aquarium photo-identification database. Weather conditions are recorded for all surveys, including temperature, wind speed and direction, percent cloud cover, barometric pressure, and precipitation. Any substantial changes in weather just prior to surveys (e.g., 24 hrs) or during surveys are also noted. In addition, the observers note the presence food sources for marine mammals, boats, other aircraft, etc. that may affect the abundance, distribution, and behavior of marine mammals along each transect. Surveys are flown only under appropriate conditions (e.g., visibility, sea state) as defined in consultation with federal and NJDEP representatives.

Boat line-transect surveys are conducted concurrently for sea turtles and marine mammals in the Study Area. At least two (2) experienced biologists per boat use the appropriate sized image-stabilized binoculars to enumerate, identify, and determine the behavior of marine mammal species within an established range. In addition, the biologists record observations on the presence of food resources for marine mammals.

Hydrophone technology is used for detecting marine mammals. Acoustics from different species generate different profiles on the hydrophone allowing for species identification and location. Marine hydrophone technologies are available in many forms and can be either mobile (towed behind a boat) or sessile (anchored to a station or buoy). A hydrophone-equipped vessel is used to collect data along the boat transects (e.g., during line-transect surveys) or the hydrophoneis set up on a stationary platform (e.g., spud barge) or anchored (e.g., surface buoy or submerged) and monitored from various locations in the Study Area.

The final survey design, data recording methods, and safety guidelines were prepared in consultation with the NJDEP, the NMFS Northeast Fisheries Science Center (NEFSC) personnel, and other marine mammal experts identified by NJDEP. The contractor follows the recommendations of the NEFSC.

The GMI team collects and uses data from scientific literature, databases (e.g., OBIS-SEAMAP), reports from the New Jersey Marine Mammal Stranding Center, and recent/ongoing research (e.g., Rutgers University, J. Toth, pers. comm.) and adds this information to the digital database. All data collected are used to determine the spatial and temporal distribution of marine mammals off the New Jersey coast.

1.2.2.2 Sea Turtles

Two (2) techniques are used to determine the spatial and temporal abundance, distribution, and behavior of sea turtles in the Study Area. The final survey design, data recording methods, and safety guidelines was developed in consultation with the NJDEP and sea turtle experts (e.g., NMFS-NEFSC personnel). The recommendations of the NEFSC were followed, and GMI has obtained permits (e.g., NMFS) needed to conduct surveys in waters offshore of New Jersey.

Aerial line-transect and boat line-transect surveys for sea turtles are completed in conjunction with the marine mammal aerial and boat surveys and use the same sampling periods and reporting methods as specified above.

Sea turtle data are collected from databases (e.g., OBIS-SEAMAP), sightings reports, power plant impingement reports, and scientific literature. These data are compiled by the contractor and added to the digital database to assist in determining the spatial and temporal distribution of sea turtles off the coast of New Jersey.

1.2.3 Fish and Shellfish Baseline Studies

Existing Federal and State aquatic baseline data, as well as other data sources, are identified, collected, and placed into the digital database. Sources to consult include the NMFS (e.g., NEFSC), the Atlantic States Marine Fisheries Commission (ASMFC), the Mid-Atlantic Fisheries Management Council (MAFMC), and the New England Fisheries Management Council (NEFMC; e.g., fisheries management plans and Essential Fish Habitat [EFH]), as well as local researchers (e.g., value of sand shoals by Rutgers University). For shellfish the maps to be prepared and submitted consist of GIS maps showing the latest densities and distribution of two important commercial species (i.e., surf clam and quahog). The contractor will use NJDEP (1982) fishing grounds maps along with the most recent data available for the Study Area. These maps are digitized and converted by the contractor into GIS format (e.g., GIS layers) so that the contractor produces a cumulative picture of offshore distribution. These data will be used to map the spatial and temporal distributions of major marine fish and shellfish species in the Study Area. The maps will be submitted as part of the draft and final reports to be submitted for this contract.

1.2.4 Other Natural Resources

Existing data on the distribution of other natural resources including, but not limited to: shoals, sand borrow areas, and artificial reef sites in the Study Area are collected. Federal and State data, as well as other available data sources will be compiled and added to the digital database and used to map the location and distribution of these resources.

1.2.5 Environmental Assessment of Impacts

The Ecological Baseline data collected and analyzed shall be used to conduct an assessment of potential environmental impacts (e.g., noise, cable electromagnetic field [EMF] and thermal impacts, displacement/loss of habitat) related to the construction and operation of offshore wind power facilities in the Study Area. The GMI team will prepare an environment assessment report for the State Contract Manager as part of the deliverables under this contract. The collection, presentation, and evaluation of data provided shall address the following issues:

- Avian utilization, abundance, and distribution
- Marine mammal utilization, abundance, and distribution
- Sea turtle utilization, abundance, and distribution
- Potential impacts to birds (including migratory routes)
- Potential impacts to marine mammals (e.g., whales, dolphins)
- Potential impacts to sea turtles
- Federal and State threatened and endangered species
- Potential impacts to aquatic life and their habitat: fish and benthos (e.g., invertebrates, bivalves, etc.) and submerged aquatic vegetation
- Lighting impacts
- Impacts to air quality
- Impacts to water quality
- Impacts to the seabed, wetlands and uplands (e.g., transmission cables)
- Noise impacts

- Cumulative impacts
- Any other important potential environmental impacts

Two (2) classes of environmental impacts will be assessed: the potential permanent changes connected with the construction and operation phases of a wind power facility, and potential temporary changes during the construction phase. All relevant available information and data, including, but not limited to, the New Jersey Offshore Wind Energy: Feasibility Study (December 2004) report by Atlantic Renewable Energy Corporation (AREC) and AWS Scientific, Inc. (AWS) will be used to prepare the environmental assessment (EA).

GMI will compile data and characterize the existing conditions within the Study Area for all environmental topics in order to estimate the potential impacts of construction and operation of a wind-turbine facility and associated infrastructure. The contractor's assessment will include a literature review of potential and known impacts, including data and information from planned and operating offshore wind facilities (e.g., those in Europe). The contractor shall review and reference the Programmatic Environmental Impact Statement (EIS) for the OCS Alternative Energy and Alternate Use (AEAU) program and associated regulations issued by the Minerals Management Service (MMS 2007) for this task. The contractor shall also review the Cape Wind Energy Project final EIS (MMS 2009), and the MMS (1999) environmental report concerning the use of offshore sand resources. This EA of Impacts shall be prepared and submitted in the Draft Final Report and Final Report.

1.3 Report Organization

Following this introductory section is a description of the Study Area (including weather, oceanography, and habitats) in Section 2.0, followed by study methodologies and results for avian, marine mammal, sea turtle, and fisheries studies in Sections 3.0 through 9.0. Sections 3.0 through 6.0 present the avian survey methodologies and results including offshore ship, coastal boat, aerial, and radar/thermal imager, respectively. Section 7.0 discusses predictive modeling of the avian results. Section 8.0 presents the survey methodologies and survey results for marine mammals and sea turtles, including both aerial and offshore shipboard surveys. Section 9.0 includes a literature review of the fish and fisheries of the Study Area, including commercial and recreational fisheries and essential fish habitat. Section 10.0 will include a discussion of potential impacts to these resources, followed by a list of contributors in Section 11.0

1.4 Literature Cited

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2.0 STUDY AREA

The New Jersey Study Area borders a barrier island chain along part of the New Jersey shoreline. The Study Area encompasses approximately 1,360 square nautical miles (NM^2) and stretches from the area adjacent to Seaside Park in the north (approximate latitude [lat]/longitude [lon] 39 degrees [°] 55 minutes ['] 56 seconds ["] North [N], 74°04'10" West [W]) to Stone Harbor in the south (approximate lat/lon 39°01'58"N, 74°46'11"W) and extends 20 NM perpendicular to the shoreline (i.e., 68 x 20 NM in size; **Figure 2-1**). Major rivers that have outflows into the region include the Toms River (north), Mullica River via Great Bay (central), and Great Egg Harbor River via Great Egg Harbor (south).

2.1 LOCATION

The state of New Jersey is located on the northeast coast of the U.S. between 41°21'N and 38°55'N (Vermeule 1898). The length of the state (267 kilometers [km; 166 mi]) is more than twice the distance at its widest point (105 km [65 mi]). New Jersey is bordered to the east by the northwest Atlantic Ocean (Vermeule 1898; Hammer 2006). The Mid-Atlantic Bight (MAB) makes up the marine region of the continental shelf from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina (Steimle and Zetlin 2000).

The location of New Jersey is such that it lies approximately midpoint within the middle latitudes (60°N and 30°N). This geographical position allows the region to experience atmospheric and climatic variations throughout the year; including all four seasons. The seasonal breakout is based on the Sea Surface Temperature (SST) of the Study Area for data derived from the National Oceanic and Atmospheric Administrations's (NOAA) Geostationary Operational Environmental Satellites (GOES) from 1 January 2001 to 1 January 2009. Winter and summer are defined as the time periods when the change in SST is less than the median change, and winter is distinguished from summer by comparing the SST of each sampled day against the mean SST of all sampled days (i.e., the SST of days in winter will be less than the mean SST, and the SST of days in summer will be greater than the mean SST). Spring and fall are defined as the time periods when the change in SST is greater than the median change, and spring is distinguished from fall by comparing the sign of change between each sampled day on the curve (i.e., in spring the SST is increasing and in fall the SST is decreasing, so the sign of a value in spring is positive and the sign of a value in fall is negative). The resulting seasons that are used throughout this report are defined as winter (December through February), spring (March through May), summer (June through July), and fall (August through November). Although some seasons may be shorter or longer than the standard seasonal definitions, the intuitive meaning for each of the seasons still applies. That is, winter and summer are still the times of year with the lowest and highest temperatures, respectively, while spring and fall represent transitional periods between the two temperature extremes.

2.1.1 Climate

The climate of the New Jersey Study Area is characteristic of a coastal climate. Due to oceanic proximity and the Atlantic's high heat capacity, the coastal region is less prone to rapid temperature changes and extremes than inland regions. During the standard seasonal definitions of fall and early winter, SST is higher than the terrestrial temperature causing mediated coastal temperatures (Hammer 2006). Robinson (2008a) analyzed SST data, from 1895 to 2008 and found that SSTs varied seasonally along the coast (including 16 km [10 mi] offshore). The average annual SST was 11.9 degrees Celsius (°C; 53.4 degrees Fahrenheit [°F]) with the highest temperatures being recorded in July (average 23.4°C [74.2°F]) and the lowest temperatures in January (average <1°C [<33.4°F]; Robinson 2008a). Precipitation records (1895 to 2008) were also examined and an annual average of 1.1 meters (m; 42.03 inches [in]) was cited for coastal New Jersey. The wettest time of year was June to August, with an average precipitation of 29 centimeters (cm; 11.51 in), while September to November was the driest time of year with an average precipitation of 25 cm (9.76 in; Robinson 2008b). Periods of snowfall generally range from mid-November to mid-April in southern New Jersey with an annual average snowfall of 25.4 to 38 cm (10-15 in; Hammer 2006).

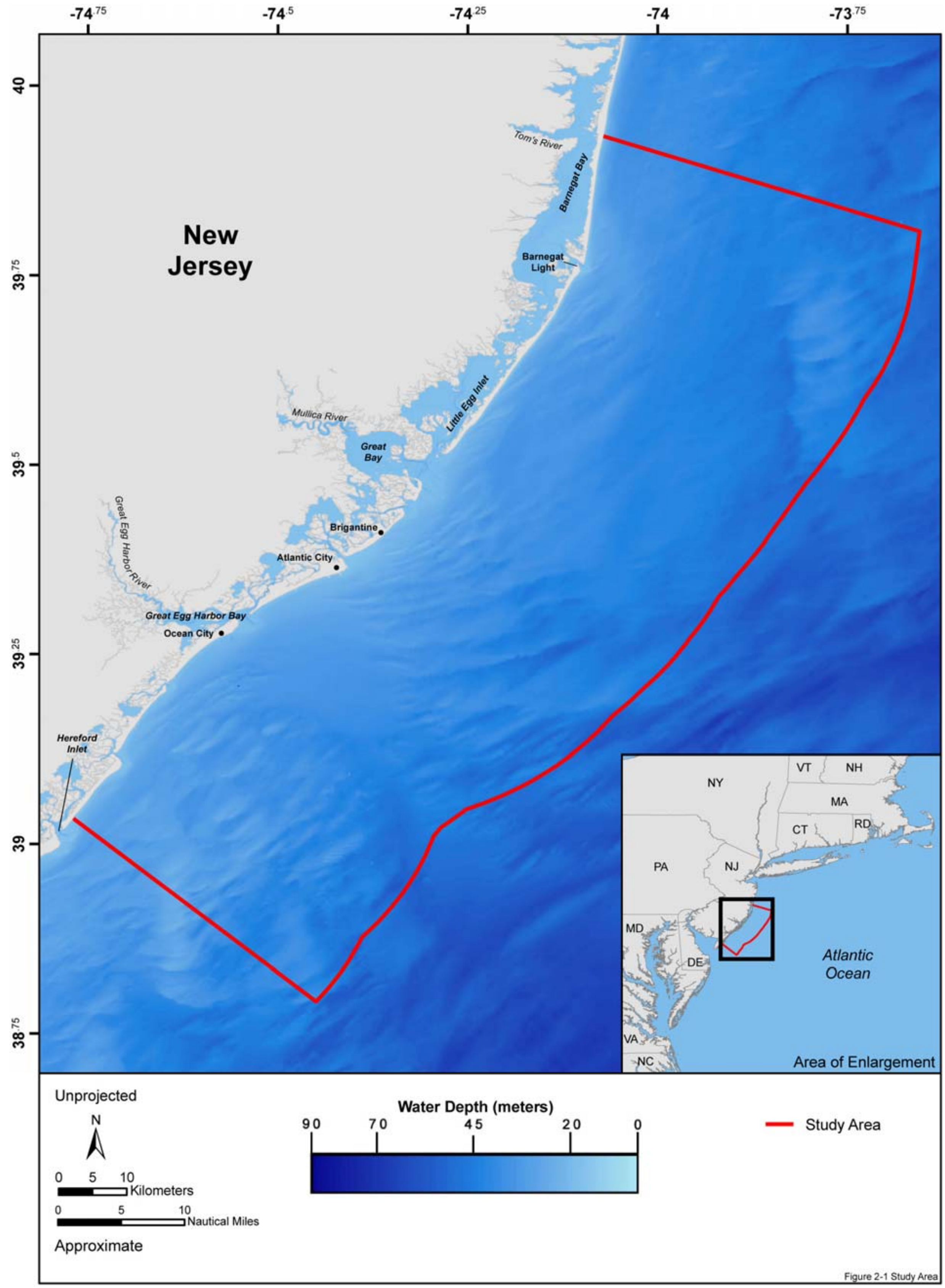

Figure 2-1. Location of the New Jersey Study Area (0-20 NM offshore).

2.1.2 Winds

Atmospheric circulation at middle latitudes over North America is predominately west to east ("westerlies"). Westerlies that effect the Study Area exhibit strength variations, pattern variations, and meridional shifts (a shift of the winds to parallel a line of longitude) throughout the year (Glenn et al. 2004a; Hammer 2006; Castelao et al. 2008a; Schofield et al. 2008). The summer season is influenced by a constant high-pressure system located off Bermuda (Bermuda High). Winds during the summer are typically from the southwest and flow parallel to the shore ("alongshore"); the persistence of wind events resulting from the Bermuda High can last up to a week (Glenn et al. 2004a; Castelao et al. 2008a; Schofield et al. 2008).

Northwesterlies, winds from the northwest, flow perpendicular to the coast and are dominant in winter months. Spring and fall experience varied alongshore wind currents from either the southwest or northeast. Northeasterlies are generally associated with offshore storms (i.e., nor'easters; Glenn et al. 2004a; Schofield et al. 2008).

Onshore breezes (or "sea breezes") are mesoscale wind pattern events that form perpendicular to the coast and directly influence temperatures experienced. **Figure 2-2** illustrates the characteristics of a sea breeze. These onshore wind events can greatly influence the coastal climate and spread far inland (e.g., 64 km [40 mi]) under favorable conditions. **Figure 2-3** shows the inland progression of a sea breeze front. Onshore breezes are caused by warm continental air rising and moving offshore while cooler oceanic air moves onshore (i.e., dense cool air displaces less dense warm air; Hammer 2006). Diurnal onshore breezes, along New Jersey, are typical during warm spring and summer days and result in cool temperatures along the coast (Hammer 2006; Hunter et al. 2007).

2.1.3 Storms and Hurricanes

Coastal storms, northeasters, or "nor'easters" are common in the Study Area from late fall to mid-spring (i.e., October to April). These storms bring high winds and heavy precipitation and have been known to cause significant damage including severe flooding and shoreline erosion (e.g., Ash Wednesday storm of 1962, Presidents' Day storm of 1979, and Halloween storm of 1991; Bosart and Lin 1984; Uccellini et al. 1984; Young et al. 1995; Sallenger Jr. 2000; Wu et al. 2002; Donnelly et al. 2004; Hammer 2006). Thunderstorms also may arise, but are less common near the coast than inland. New Jersey can also potentially experience tornadoes; however, they are generally few in number and weak (Hammer 2006). Hurricanes that travel along the coastline of the eastern U.S. have the potential to impact the New Jersey Study Area with high winds, severe flooding, and substantial damages. At least five hurricanes have impacted the New Jersey Study Area within the last century; Vagabond Hurricane 1903, Great New England Hurricane 1938, Great Atlantic Hurricane 1944, Hurricane Belle 1976, and Hurricane Gloria 1985. An average 1.9-m (6.23-ft) mean sea level rise was recorded during the storms (Donnelly et al. 2004).

2.2 OCEANOGRAPHY OF THE NEW JERSEY STUDY AREA

2.2.2 Bathymetry

The bathymetry of the New Jersey Study Area is relatively shallow, a gradually deepening region consistent with shelves located along a passive continental margin. In general, passive continental margins are characterized by subsidence, erosion, and thick (although variable) sediment accumulations (Kennett 1982). The eastern margin of the U.S. continental shelf deepens at a very gradual rate of less than 1-m (3.3-ft) increase in depth per 1,000 m (0.6 mi) distance offshore (Hollister 1973; Kennett 1982). Bathymetrically, the New Jersey Study Area consists of a nearly uniform, smooth, and shallow seafloor that slopes gently offshore (**Figure 2-4**); however, one of the major bathymetric features of the Study Area include shoreface sand ridges. Shoreface-attached and detached sand ridges are found along the Atlantic inner shelf of the United States oriented at oblique angles in relation to the shoreline (Duane et al. 1972; Figueiredo et al. 1981). Along the New Jersey coast, there are 71 well-developed shoreface-attached and detached sand ridges with an average orientation of 26° and that are normally characterized by a closed bathymetric contour (Duane et al. 1972; Swift et al. 1972). These shoreface-attached and detached sand ridges consist of unconsolidated fine-to-medium grained sand, are generally over 1000 m long, have relief up to 10 m, side slopes that average less than 1°, and are 1 to 3 km wide with wavelengths of 1 to 8 km (Duane et al. 1972; Field 1980; Figueiredo et al. 1981; Figueiredo 1984). The formation of sand ridges is a function of sediment supply and shelf processes with erosional shoreface retreat, shoreface detachment, and storm-generated flows being recognized as essential components of the origin and evolution of shoreface sand ridges (McBride and Moslow 1991).

Other notable bathymetric features in the vicinity of the New Jersey Study Area include the Delaware Shelf Valley located just south of the Study Area and the Hudson Shelf Valley located just north of the Study Area. The mean flow over the shelf adjacent to the Delaware Bay is southward at speeds of about 10 centimeters per second (cm/s; 3.94 inches per second [in/s]; Beardsley et al. 1976). Upwelling circulation can develop as a response to strong wind events lasting for several days or more. In the case of a southerly wind, surface water moves offshore, while bottom water moves onshore in compensation (Beardsley and Boicourt 1981); for the case of northerly winds, the reverse is observed. Given the predominant southward flow and longshore sediment transport of the area, the Delaware Shelf Valley does not significantly influence the Study Area. The Hudson Shelf Valley is discussed in further detail below.

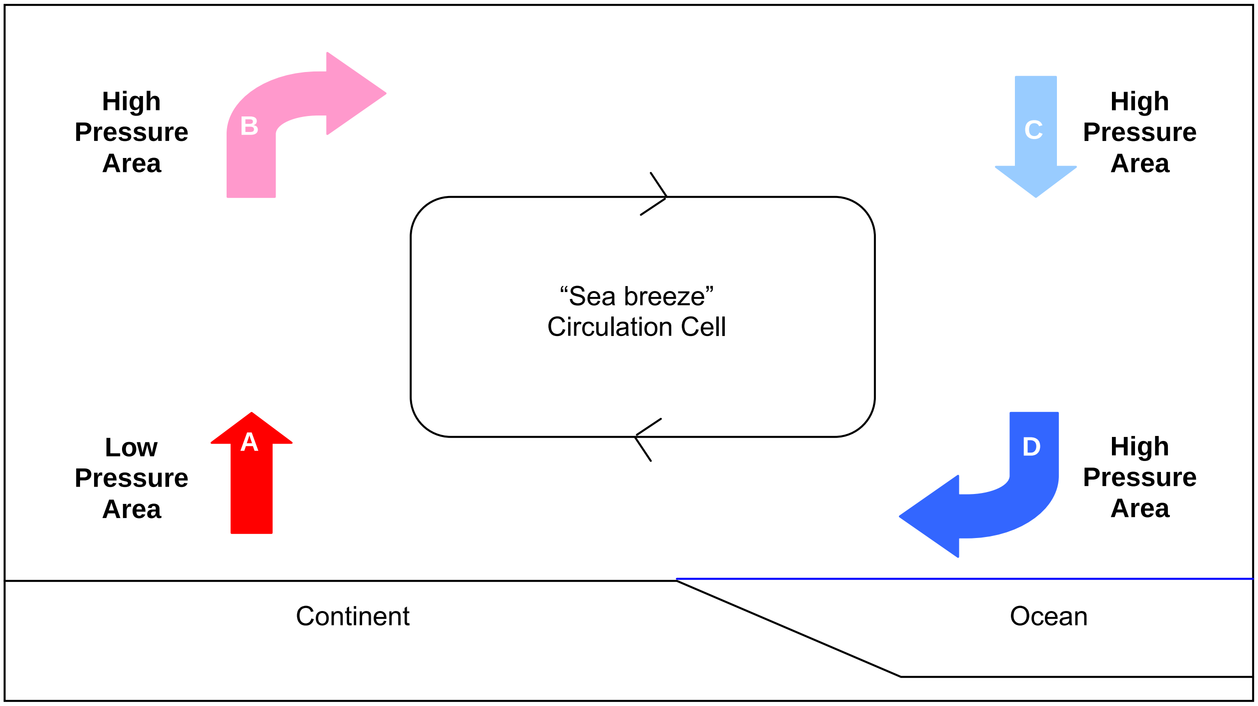

Figure 2-2. Characteristics of a sea breeze. An onshore wind (i.e., a wind blowing from the water onto the land), or sea breeze, results from atmospheric changes induced by the differing heat capacities of land and water. Land heats up and cools down much more quickly than the ocean. When the ambient temperature is relatively high (e.g., during the spring and summer) the land, and thus the air which overlies it, heats up quickly. As the air over the land warms and rises, an area of low pressure is created in the lower portions of the atmosphere (A). This rising air creates an area of high pressure in the upper atmosphere (B). The opposite occurs over the water. The ocean absorbs and discharges heat at a much lower rate than land, so the air over the water remains cooler and denser than the air over land. This results in an area of low pressure in the upper atmosphere (C) and high pressure in the lower atmosphere (D). As the masses of air in the lower atmosphere over land and water balance, the movement of the air from high pressure over the water to low pressure over the land creates a sea breeze. Source information: Abbs and Physick (1992) and Bowers 2004.

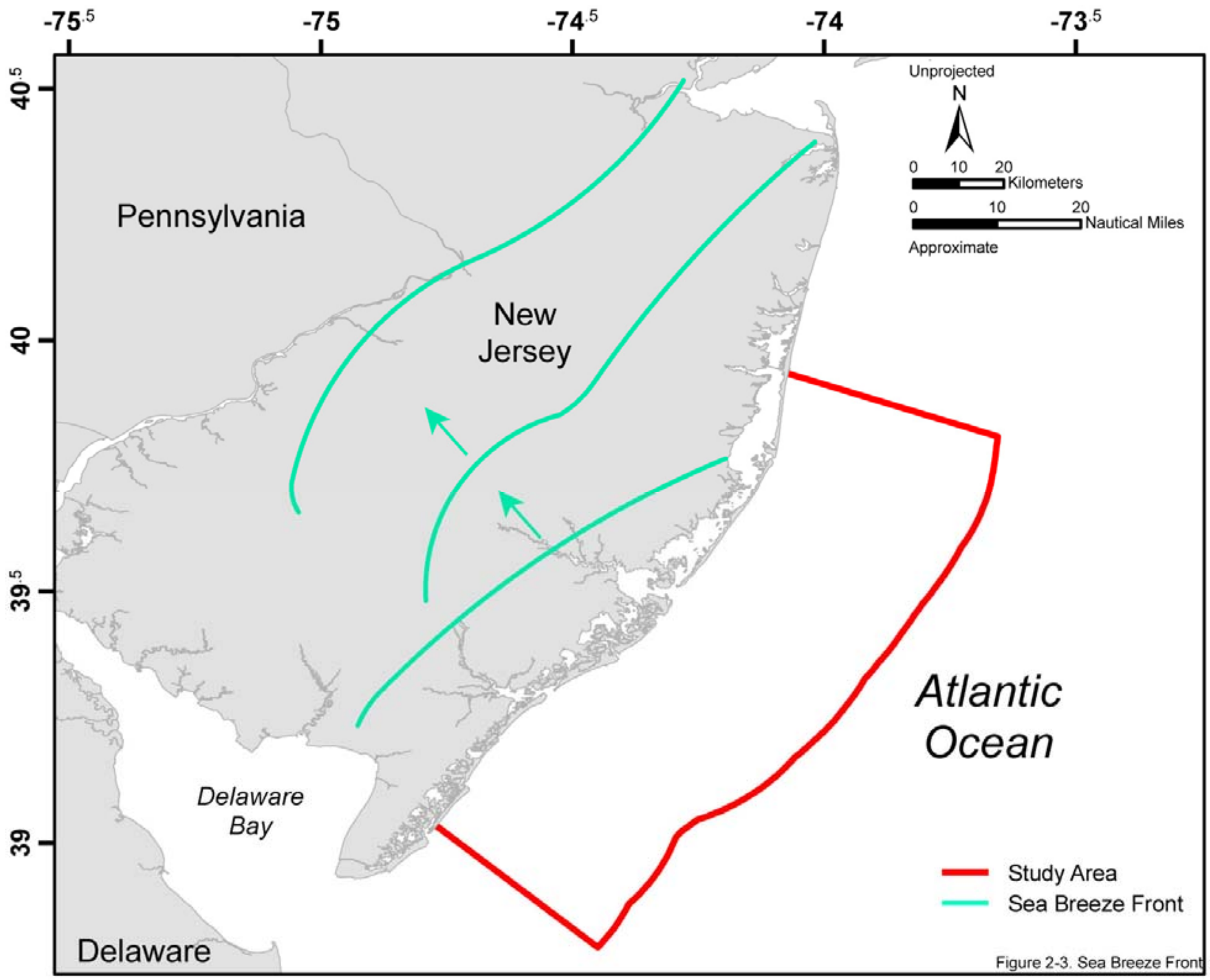

Figure 2-3. The inland progression of a sea breeze. Map adapted from: Bowers (2004).

Hudson Shelf Valley

A characteristic bathymetric feature just north of the Study Area is the Hudson Shelf Valley. The Hudson Shelf Valley cuts across the 180 km (111.8 mi) wide continental shelf. During the Last Glacial Maximum (approximately 25,000 to 18,000 years before present [YBP]), sea level was much lower and the coastline extended out to the present shelf break and almost to the head of the Hudson submarine canyon (**Figure 2-4**). This shelf valley was formed from the path of the ancestral Hudson River during this period of low sea level. Its formation may have been augmented by catastrophic flooding following the drainage of the late Wisconsin glacial lakes (around 14,000 YBP; Newman et al. 1969; Clayton and Knox 2008).

The Hudson Shelf Valley is characterized by its complicated currents and flows. Offshore directed currents along the Hudson Shelf Valley are usually associated with energetic waves, winds from the east, moderate current velocities (5-10 cm/s [1.97-3.94 in/s]), and sea level setup at Sandy Hook, New Jersey. Shoreward directed currents along the Hudson Shelf Valley are much more common. These currents are associated with winds from the west, low wave energy, high current velocities (20-40 cm/s [7.87-15.75 in/s]), and sea level set-down at the coast (Harris et al. 2003; Schofield et al. 2008).

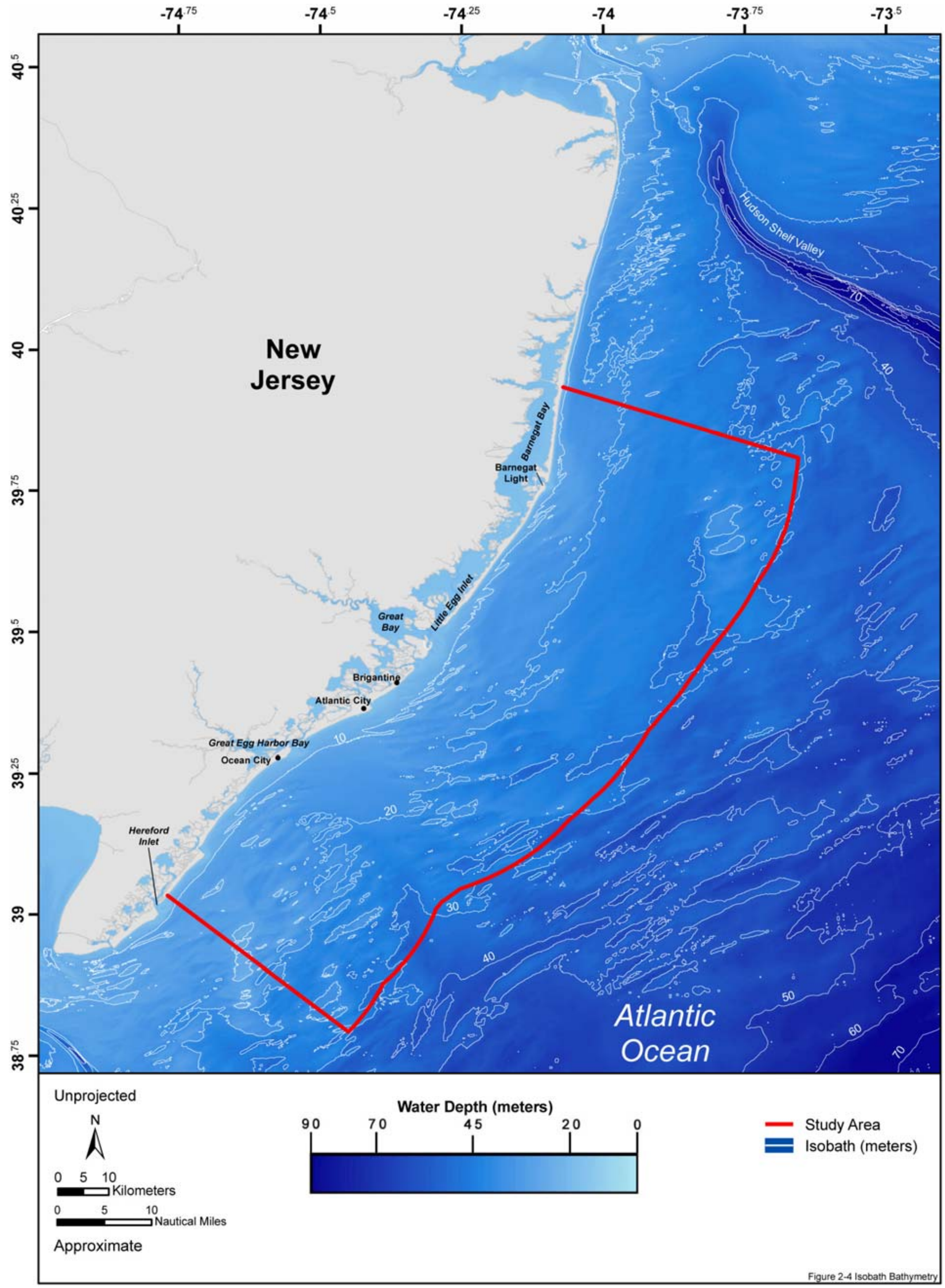

Figure 2-4. Isobath bathymetry of the New Jersey Study Area. Source data: NOAA (1999).

2.2.3 Bottom Substrate

Bottom substrate includes both the biotic surface layer and the abiotic sub-bottom and the sediments which comprise these layers. Although the New Jersey Study Area was located south of the ice edge during the last ice age of the Pleistocene (1.8 million to 10,000 YBP), the bottom sediments are the result of the sand and gravel deposited by glacial meltwater streams. The New Jersey Study Area was largely above sea level and covered with a network of river valleys dominated by the Hudson outflow. With rising sea levels during the Holocene (the last 10,000 years [yrs]), the sand and gravel was reworked by the Atlantic leaving most of the New Jersey Study Area covered with a layer of sandy sediments (Glenn et al. 2008; **Figure 2-5**). The majority of sediments now found on the continental shelf of the Study Area are the result of glacial deposition, erosion, reworking, and re-deposition. According to Amato (1994), 75 percent of the sediment distribution for the shelf of the Study Area is composed of medium (0.025-0.05 cm [0.01-0.02 in]) to coarse (0.05-0.2 cm [0.02-0.079 in]) quartz sand grain size range overlaying larger scale shore-parallel ridges often found mid-shelf (Duane and Stubblefield 1988). Along a narrow (approximately 10 km [6.2 mi] wide) band of the coastline at the southern end of the Study Area, mixtures of medium to fine sand and silt are found overlying small sand ridge features (Twitchell and Able 1993). At the shelf break, there is a narrow band of mixed medium to fine sand and silt, with deepwater sediments further offshore consisting of greater than 75 percent clay (Amato 1994). Parallel elongated bands of gravelly sand are located just south of the Hudson Shelf Valley; these were formed from old meanders of the Hudson River (Schlee 1964). Bottom substrate of the New Jersey Study Area is shown in **Figure 2-5**.

Hydrography

The hydrography in the Study Area undergoes substantial seasonal changes throughout the year. The stratification of the water column is asymmetric in nature; stratification becomes slowly stronger and deeper from mid spring to later summer and is rapidly destratified during early fall as numerous storms pass through the area (Castelao et al. 2008b). During spring, the shelf waters are less saline during the peak of the spring freshet from the Hudson River plume and increased coastal runoff (Loder et al. 1998). As a result, the density structure in this region is largely determined by salinity (Fratantoni and Pickart 2007). During the summer, vertical gradients are strong (Chapman and Gawarkiewicz 1993) with a near-surface thermally warmed layer that intensifies from April/May to late summer; this highly stratified water column is especially evident in the region within 80 km (49.7 mi) from the coast (Castelao et al. 2008b). During the fall, the passage of storms rapidly reduces the stratification causing the salinity and temperature vertical gradients to have a relatively weak signal. During the winter, the water column is nearly vertically homogenous with horizontal gradients dominating the region (Castelao et al. 2008b).

2.2.4 Water Temperature

Water temperature influences physical and biological processes in marine ecosystems. Physically, temperature coupled with salinity drives the vertical and horizontal stratification and geostrophic circulation of large water masses globally (i.e., thermohaline circulation; Broecker 1991) and regionally (e.g., local current patterns; Bergamasco et al. 1999). This circulation affects the movement of nutrients and planktonic organisms within and among water masses (Holliday et al. 2006). Biologically, temperature can determine species composition and distribution within an ecosystem (Murawski 1993; Longhurst 2001; Mountain 2002), seasonal migrations and spawning (Page and Frank 1989; Hagan and Able 2003; Sims et al. 2004), individual metabolic rates affecting consumption and growth (Burel et al. 1996; Hernández-Miranda and Ojeda 2006), and population level processes such as reproduction (Yoneda and Wright 2005) and recruitment (Hare and Able 2007).

During winter, horizontal temperature gradients dominate; with colder water close to the coast and warmer water near the shelfbreak. The vertical temperature profile is nearly homogenous with slightly colder water found near the bottom offshore (Castelao et al. 2008b).

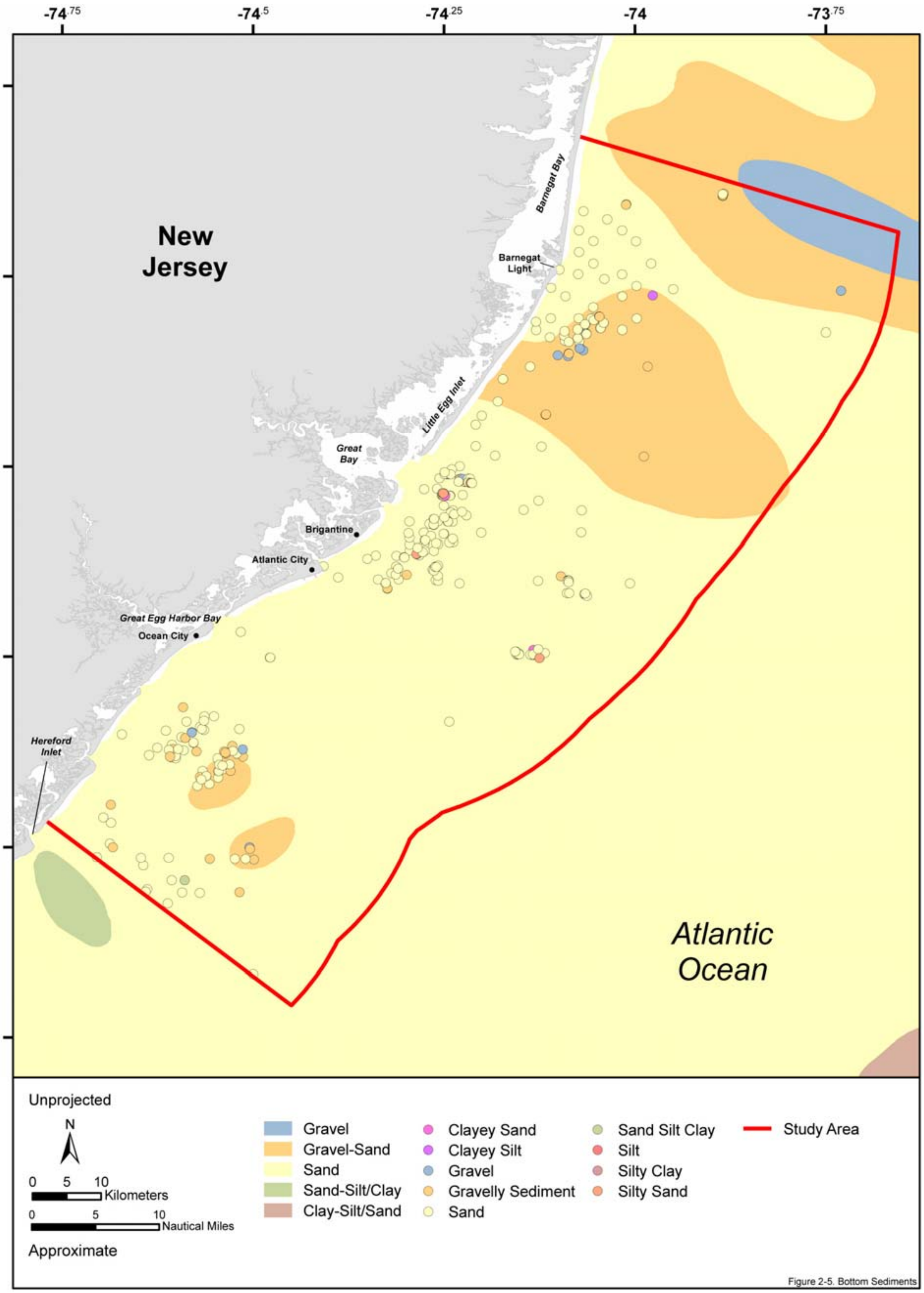

Figure 2-5. Bottom sediments found in the New Jersey Study Area. Source data: USGS (2000).

An annual phenomenon particularly important to the Study Area is the formation of the “cold pool”. This mass of cooler water is located on the continental shelf in summer and is a remnant of the winter-cooled water present on the shelf (Beardsley and Flagg 1976). The cold pool becomes identifiable as thermal stratification begins in spring and persists until early fall when normal seasonal mixing occurs and homogenizes the water column (Linder et al. 2004). The cold pool usually exists near the seafloor between the 40-m (131.2-ft) and 100-m (328-ft) isobaths, 70 to 110 km (43.5-68.4 mi) from the coast, and extends 35 m (114.8 ft) up into the water column to the bottom of the seasonal thermocline. The cold pool usually represents about 30 percent of the volume of shelf water. Minimum temperatures for the cold pool occur in early spring and summer and range from 1.1° to 4.7°C (33.98° to 40.46°F).

Average water temperature decreases with depth ubiquitously. Temperature variations in the surface layer (the upper 30 m [98.4 ft]) are related to surface heating, while variations at depth can be correlated to the advection of the “cold pool” from the north during spring/summer and with mixing due to passing storms during fall (Castelao et al. 2008b).

The local SST for the Study Area is shown in **Figure 2-6**.

Thermocline

In the Study Area, the formation of the seasonal thermocline is established in the upper 50 m (164 ft) of the water column through summertime heating (Fratantoni and Pickart 2007). Below the seasonal thermocline, the “cold-pool” is relatively homogenous and is commonly found over the middle and outer shelf (Houghton et al. 1982).

The thermocline thickness increases in the offshore direction. Inshore of approximately 60 km (37.3 mi) from the coast, the thermocline is about 12-15 m (39.4-49.2 ft) thick with its center located above 20 m (65.6 ft). Offshore of approximately 80 km (49.7 mi) from the coast; the thermocline is about 25 m (82 ft) thick and is more diffuse. The difference in thickness of the thermocline inshore versus offshore is attributed to a difference in stratification. Stratification is strong close to the coast due to the presence of freshwater (which is more efficient at trapping solar heat) from the Hudson River plume and coastal runoff whereas the stratification in the offshore region is much weaker as a result of more intense mixing (Castelao et al. 2008b).

2.2.5 Salinity

In general, the average salinity increases in the offshore direction off New Jersey. The offshore region is heavily influenced by the more saline water of the open ocean, while the waters closer to the coast are more heavily influenced by the Hudson River outflow and coastal runoff (Castelao et al. 2008b). The salinity signature of the Study Area is characterized with high seasonal variability due to the seasonal river discharge and wind variations. During the upwelling season (typically May to September), a low salinity plume can span up to 100 km (62.1 mi) across the shelf in a 10-m (32.8-ft) thick surface layer (Castelao et al. 2008b). During this time, saline intrusions near the shelf break can be found at a depth that corresponds with the thermocline.

Although the New Jersey Study Area is located about 100 km (62.1 mi) south of the Hudson River mouth, the Hudson River is the primary local source of freshwater for the region. The Hudson River outflow reaches a maximum during the spring freshet (late March/early April) with a mean April discharge of 1,100 cubic meters per second (m^3/s [38,846 cubic feet per second {ft^3/s}] ; Castelao et al. 2008a; Chant et al. 2008a). This fresh, buoyant water is generally restricted to the coast during the spring, but during the summer the plume, via several mechanisms, can extend across the entire shelf. A coastal jet directed offshore and to the south near the river mouth provides a direct conduit to transport this low salinity water across the shelf of the Study Area. Also, upwelling favorable winds can push this buoyant, low-salinity water to the more offshore reaches of the shelf (Fong et al. 1997; Castelao et al. 2008a). In late summer/early fall (late August/early September), downwelling favorable winds tend to compress the low-salinity waters against the coast and the fresher water is again restricted to a narrow band (approximately 10 km [6.2 mi]; Münchow and Garvine 1993; Castelao et al. 2008a) and the salinity in the offshore region increases rapidly.

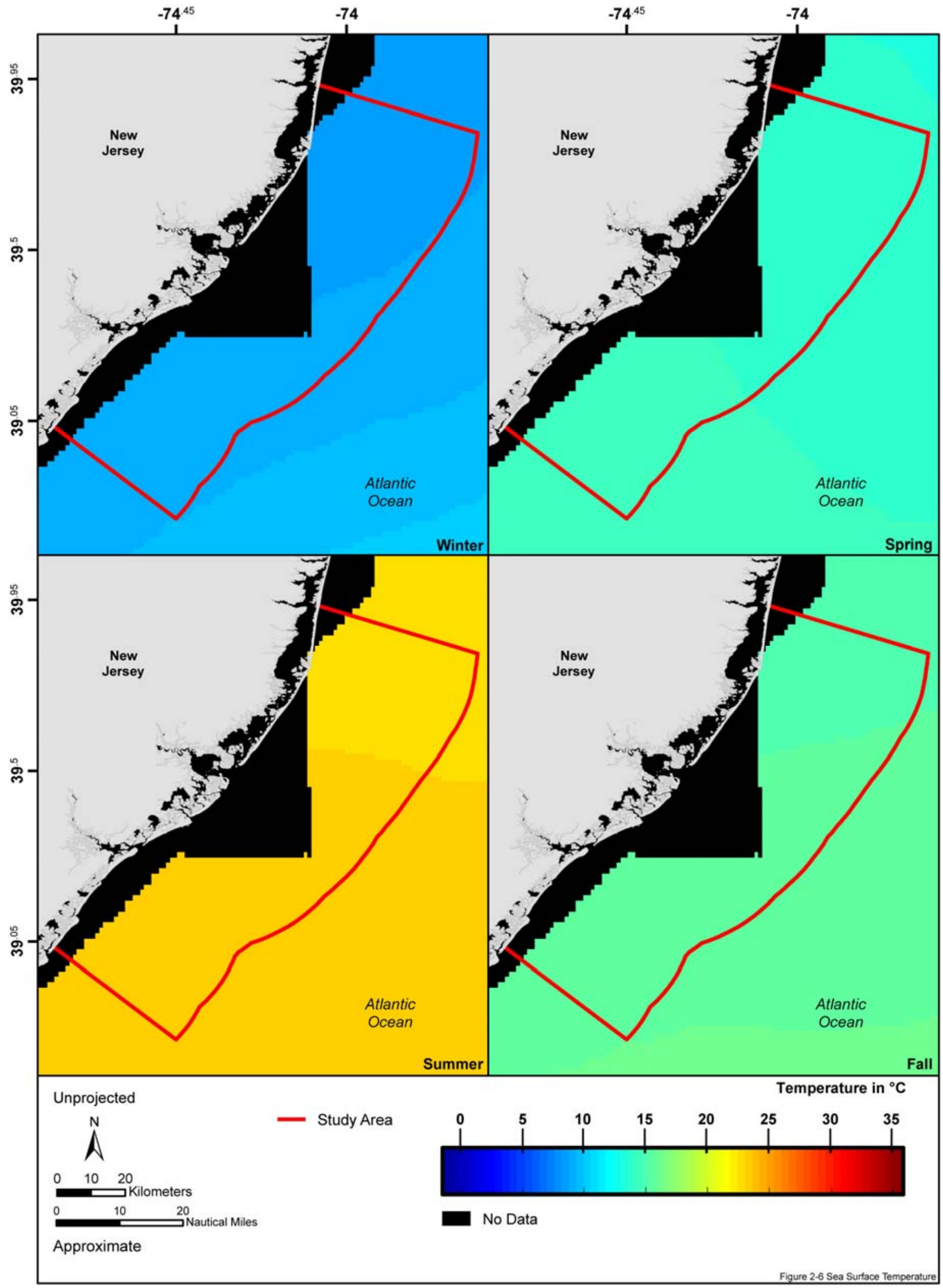

Figure 2-6. Mean seasonal sea surface temperatures in the New Jersey Study Area from 1981 through 2000. The block of missing data shown in the New Jersey Study Area is currently unavailable; this map will be updated for the Final Report. Source data: NASA (2000).

Hudson River Bulge

The anticyclonic turning of large-scale river outflow has been documented at the mouth of the Hudson River (Fong and Geyer 2002). The plume from the Hudson River leaves a significant freshwater signal toward the right, downstream of the river mouth, and can be separated into two distinct regions: a bulge region near the river mouth and a downstream current (Chao and Boicourt 1986). North of the Study Area, high outflow events from the Hudson River form this accumulation of clockwise rotating, recirculating water or "bulge" at the Hudson River mouth (Chant et al. 2008b). The bulge can extend 30 km [18.6 mi] from the coast and 40 km [24.9 mi] along the coast out to the head of the Hudson Shelf Valley where it crosses the 50-m (164-ft) isobath.

The tendency for the Hudson's outflow to form a bulge has important implications on the transport of this low-salinity, buoyant water across the shelf of the Study Area. During upwelling favorable winds, the bulge formation tends to place the Hudson's outflow in the vicinity of the jet that provides a direct pathway to transport the freshwater across the shelf (Castelao et al. 2008a; Chant et al. 2008a). The Hudson River bulge can limit the volume of freshwater that is advected away in a coastal current by 30 to 50 percent (Fong and Geyer 2002; Chant et al. 2008a).

2.2.6 North Atlantic Oscillation

In the Study Area, fluctuations in sea surface and bottom water temperatures have been associated with trends in the North Atlantic Oscillation (NAO; Friedland and Hare 2007). This large-scale phenomenon is an example of the dynamic relationship between the atmosphere and the ocean; the NAO has global significance as it affects SSTs, wind conditions, and ocean circulation of the North Atlantic Ocean (Stenseth et al. 2002). The NAO is an alteration in the intensity of the atmospheric pressure difference between the semi-permanent high-pressure center over the Azores Islands off Portugal and the subpolar low-pressure center over Iceland (Curry and McCartney 2001; Stenseth et al. 2002). The NAO is the dominant mode of decadal-scale variability in weather and climate in the North Atlantic region (Hurrell 1995).

The variability in the NAO is calculated as an index, which is indicative of the mean winter atmospheric pressure difference between the low- and high-pressure centers. Typical conditions expected in the Study Area during the two phases (positive and negative) of the NAO index include warmer than average winter weather during the positive (or warm) NAO phase and colder than average winter weather during the negative (or cold) NAO phase.

The NAO tends to remain relatively stable for extended periods, e.g., the recorded NAO index was mainly positive from 1900 to 1950, mainly negative in the 1960s and 1970s, and has been mainly positive since 1970 (Hurrell et al. 2001).

Since ocean circulation is wind and density driven, it is not surprising to find that the NAO appears to have a direct effect on the position and strength of important North Atlantic Ocean currents (Taylor and Stephens 1998).

A strong association has been established between the variability of the NAO and changes affecting various trophic groups in North Atlantic marine ecosystems on both the eastern and western sides of the basin (Fromentin and Planque 1996; Drinkwater et al. 2003). The temporal and spatial patterns of *Calanus* copepods (zooplankton) were the first to be linked to the phases of the NAO (Fromentin and Planque 1996; Stenseth et al. 2002). When the NAO index was positive, the abundance of *Calanus* copepods in the Gulf of Maine increased, with the inverse true in years when the NAO index was negative (Greene and Pershing 2000; Conversi et al. 2001). Such a shift in copepod patterns has a tremendous significance to upper-trophic-level species, including the North Atlantic right whale, which feeds principally on *Calanus finmarchicus*. Right whale calving rates are linked to the abundance of *Calanus finmarchicus*; when the abundance is high, the calving rate remains stable but fell in the late 1990s when the abundance of its favored copepod also declined (Greene et al. 2003). Direct links to the NAO phase have also been found for recruitment in the North Atlantic of herring, sardines, two tuna species, Atlantic salmon, and swordfish (Drinkwater et al. 2003).

2.2.7 Circulation

The circulation of ocean currents in the vicinity of the Study Area is affected by processes occurring very far away. The coastal current system originates in the Nordic domain as the East Greenland Current, winds around the perimeter of the Labrador Basin in a cyclonic direction, exits the basin as the Labrador Current, and flows adjacent to the Grand Banks of Newfoundland before entering the Study Area as the Western North Atlantic shelfbreak front and current (Chapman and Beardsley 1989). The coastal circulation in the vicinity of the Study Area is dominated by this slow Labrador Current (order of 5 cm/s [1.97 in/s]), which flows equatorward carrying subpolar and Arctic-origin water (Beardsley and Boicourt 1981; Fratantoni and Pickart 2007; **Figure 2-7**). The southern extent of the Labrador Coastal Current flows along the shelf into the New Jersey Study Area from the northeast to the southwest (Chapman and Beardsley 1989; Townsend et al. 2004). The poleward flowing Gulf Stream is deflected from shore south of the Study Area. This deflection forms a distinctive and variable water mass in the vicinity of the Study Area known as Slope Water (or the Slope Water Sea) that is a mixture of several sources. This water mass is formed by the mixing of cooler subpolar and Arctic waters (Labrador Current) with the water found on the continental slope (Gulf Stream) and is strongly influenced by wind, tides, and Gulf Stream instabilities.

The general circulation patterns in the Study Area are depicted in **Figure 2-7**. The actual circulation in the Study Area on any given day is driven by episodic wind events more than by large scale current systems (Glenn et al. 2004a).

Shelfbreak Front and Current

The shelf/slope front is generally centered near the shelfbreak and supports a shelfbreak current that is a persistent feature in the vicinity of the Study Area (Fratantoni and Pickart 2007; **Figure 2-7**). The shelfbreak current is formed at the intersection of the continental shelf and slope where the thermohaline shelfbreak front separates relatively cold and saline-depleted shelf waters from warm, saline continental slope waters (Fratantoni et al. 2001). The shelfbreak front extends from the surface downward, where it intersects the seafloor just shoreward of the shelf break (Halliwell and Mooers 1979). The shelfbreak current continues equatorward through the Study Area and terminates inshore of the Gulf Stream off Cape Hatteras, North Carolina, decreasing in volume from north to south (Loder et al. 1998; Fratantoni and Pickart 2007). The shelfbreak front/current system represents a semipermanent barrier that limits the exchange of waters between the shelf and open ocean (Fratantoni et al. 2001). Temperature and salinity of the shelfbreak front increase equatorward; however, the changes in temperature and salinity compensate each other and the density of the front generally remains constant at 1026.5 kilograms per cubic meter (kg/m^3 [64.05 pounds per cubic foot [lb/ft^3]; Linder and Gawarkiewicz 1998). The shelfbreak current transports an estimated 0.2 to 0.3 Sverdrups (Sv; Sv = 10^6 m^3/s [264 million U.S. gallons per second]; Linder and Gawarkiewicz 1998). For comparison, measurements taken in the Gulf Stream between 55° and 60°W lat indicate that the Gulf Stream transports approximately 150 Sv (Hogg 1992). The shelfbreak front/current system is governed by freshwater input, air-sea interactions, wind stress, and ice coverage; all of which vary geographically, seasonally, and interannually (Fratantoni and Pickart 2007). The displacement of the shelfbreak front seaward is largely regulated by the seasonal freshwater input and the advection of this freshwater seaward (Linder and Gawarkiewicz 1998). **Figure 2-7** shows a generalized depiction of the location of the shelfbreak front/current system in relation to the Study Area.

Linder and Gawarkiewicz (1998) provide a comprehensive description of the mean structure of the shelfbreak front and current. Their results illustrate the seasonal progression of the density front from a top to bottom feature in winter to a front isolated from the surface in summer by a seasonal (a rapid change in water density with depth). Offshore of New Jersey from December through May, the front occurs from the surface more or less perpendicular to the bottom. The intersection of the front with the seafloor is located more shoreward during December and January; however, during the summer and early fall months (June through November), the front may not reach the surface of the water and its

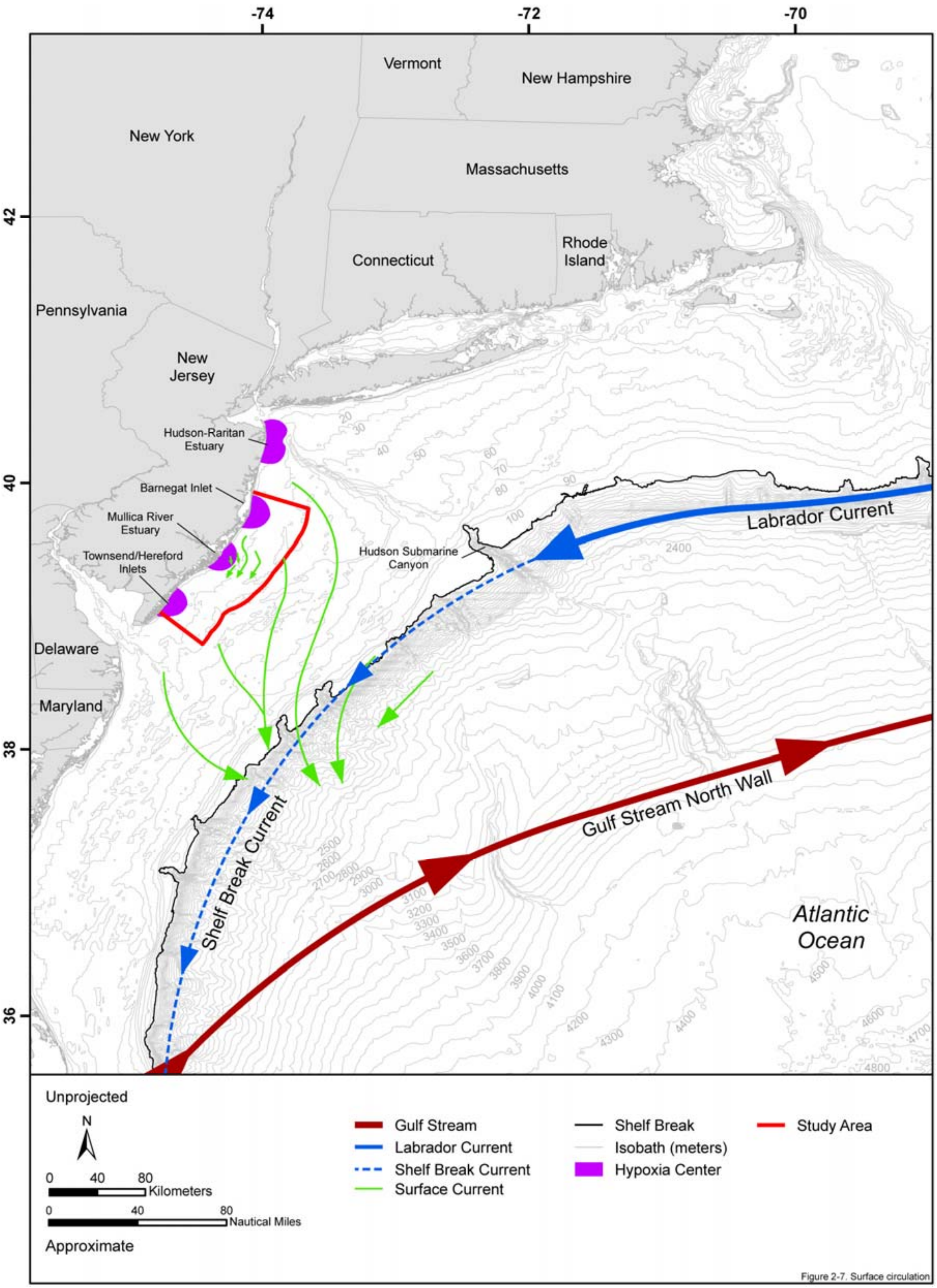

Figure 2-7. Surface circulation, including major currents and hypoxic (upwelling) centers, in the New Jersey Study Area. The block of missing data shown in the New Jersey Study Area is currently unavailable; this map will be updated for the Final Report. Map adapted from: Gilman (1988), Glenn et al. (2004), Kohut et al. (2004), and Fratantoni and Pickart (2007).

leading edge is located as much as 40 km seaward of the 100-m isobath. This is due to the presence of a seasonal thermocline and may be affected by higher volumes of freshwater occurring in the area during this season. Phytoplankton production is enhanced at this frontal boundary, often with twice the phytoplankton concentration as that found in adjacent waters (Ryan et al. 1999).

2.2.8 Upwelling/Downwelling

Upwelling is a dynamic process (through the interaction of currents, density, or bathymetry) where warmer, nutrient-poor surface water is replaced by colder, nutrient-rich, and oxygen-rich water from below the pycnocline (Mann and Lazier 1991). In wind-driven upwelling, surface water is transported offshore and deep, cold water moves vertically to the surface to replace the displaced surface water.

In the Study Area, upwelling often begins as a nearly uniform narrow band (a few kilometers wide) of cold water along the coast; however, following a few days of persistent southwesterly wind, a wave pattern forms along the upwelling front that eventually dissipates the uniform band into a series of isolated cold surface patches (Glenn and Schofield 2003). These upwelling eddies form annually as a result of a series of topographic highs along the New Jersey coast associated with ancient river deltas (Song et al. 2001). They cover a 20-km x 20-km (12.4 x 12.4 mi) swath of ocean (Glenn and Schofield 2003) and typically offshore of four specific estuaries and inlets (the Hudson-Raritan estuary, Barnegat Inlet, the Mullica River estuary, and Townsend/Hereford Inlet; Steimle 1978; Warsh 1987; Glenn et al. 2004a).

These episodic upwelling events occur in the summertime and are driven by southwesterly winds associated with the atmospheric Bermuda High (Glenn et al. 2004a). Winds are predominantly upwelling favorable from mid May to September; however, during September there are a few downwelling favorable wind events with the frequency and intensity increasing through October (Fratantoni and Pickart 2007). The size and duration of the upwelling events are dependent upon the prevailing/prior wind, total precipitation, and overall storm frequency (Glenn et al. 2004a). The upwelling event located offshore of the Mullica River estuary is typically is observed five times each summer, lasts for about a week each time, and covers an average area of about 150 square kilometers (km^2; 57.9 square miles [mi^2]; Glenn et al. 2004a).

These upwelling events are formed as cyclonic eddies; the eddies are formed by a northward flowing surface jet on the offshore side of the eddy and a southward countercurrent located at the coast (Glenn et al. 2004a). These upwelling centers experience recurrent hypoxic conditions reflecting enhanced production and particulate organic carbon concentrations sufficiently high to deplete 75 percent of the oxygen in the bottom water (Chant et al. 2004; Glenn et al. 2004a). With the onset of upwelling conditions, phytoplankton concentrations increase immediately; this indicates that phytoplankton transport to the upwelling center is dominated by advection.

2.2.9 Phytoplankton

Phytoplankton are single-celled organisms that are similar to plants because they use sunlight and chlorophyll to photosynthesize. At the base of the marine food chain, phytoplankton are very important to the overall productivity of the ocean. Their growth and distribution are influenced by several factors, the most important of which are temperature (Eppley 1972), light (Yentsch and Lee 1966), and nutrient concentration (Goldman et al. 1979). Other factors such as pH and salinity affect growth and production (Parsons et al. 1984).

Phytoplankton distribution is patchy, occurring in environments that have optimal light, temperature, and nutrient conditions. In general, the concentration of phytoplankton will be higher in nearshore areas where there is input of nutrients from land sources (**Figure 2-8**). Phytoplankton use dissolved nitrogen (nitrate/nitrite/ammonia), phosphorous (phosphate), and silica (silicate) in their growth and photosynthetic processes. Phosphorous limitation is typical of freshwater systems while marine systems are more likely to be nitrogen limited. Phytoplankton biomass can be estimated from the concentration of chlorophyll measured in the water column or at the sea surface. Thus the chlorophyll concentration is often used as a proxy for phytoplankton abundance (**Figure 2-8**). In general, in continental shelf and slope waters,

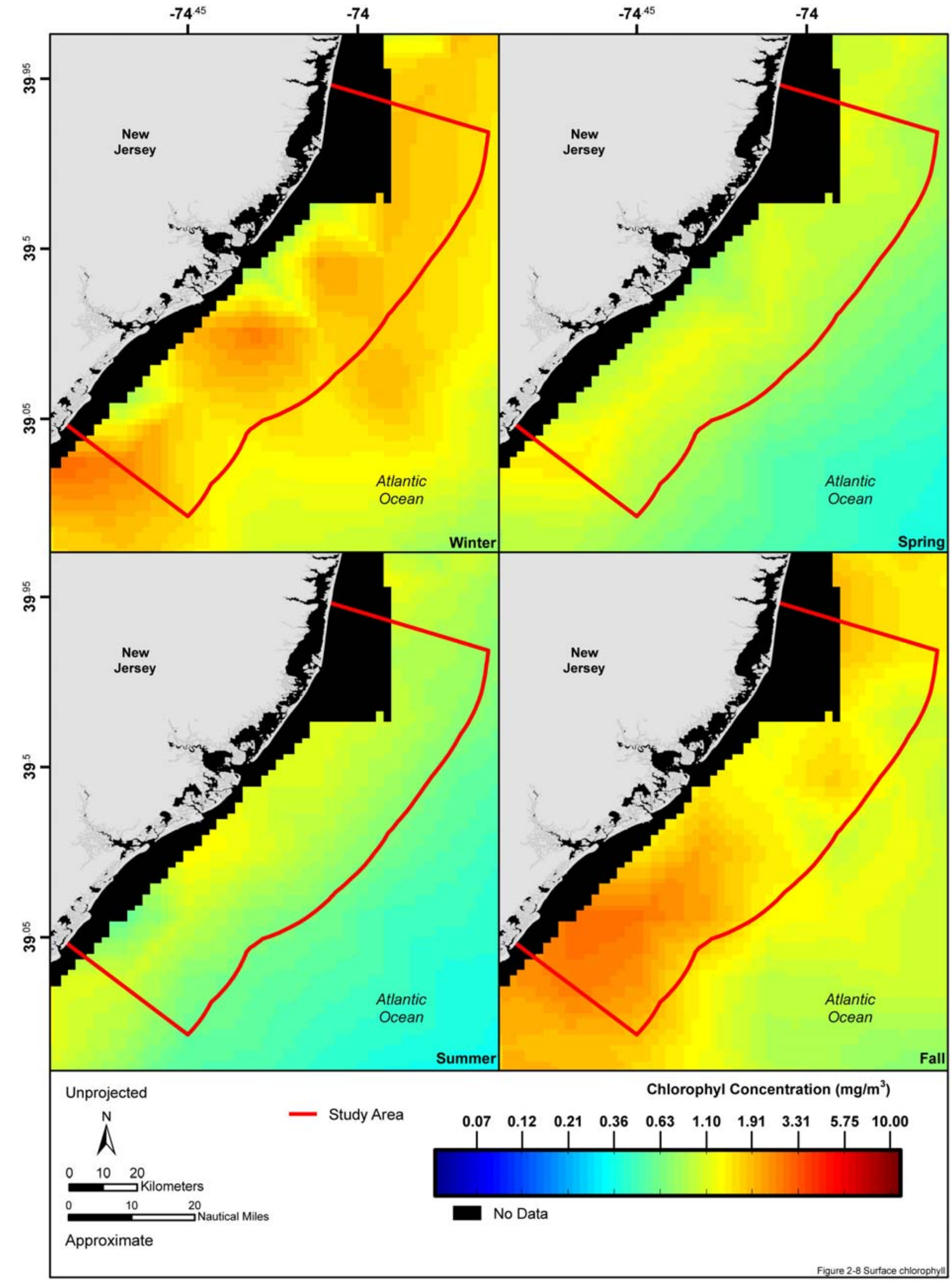

Figure 2-8. Mean seasonal surface chlorophyll *a* concentrations found in the New Jersey Study Area from 1978 through 1986. Source data: NASA (1998).

the concentration of chlorophyll *a* decreases with distance from shore and with increasing water depth. The peak chlorophyll concentration is sometimes found at the sea surface but can also be found below the photic zone (depth to which light penetrates). When there is a sufficient supply of light, the amount of phytoplankton and chlorophyll will be regulated by available nutrient concentrations.

In the MAB, primary productivity is governed by the seasonal stratification of the shelf (Schofield et al. 2008). During summer, stratification is so intense that primary production is low with the exception of the coastal areas, such as in the Study Area, where upwelling allows for high primary production (Glenn et al. 2004a). In the coastal areas of the Study Area, chlorophyll *a* values are significantly higher than those more offshore with the highest concentrations (>10 micrograms per liter [µg/L]) being associated with the upwelling centers located offshore of the Hudson-Raritan estuary, Barnegat Inlet, the Mullica River estuary, and Townsend/Hereford Inlet (Glenn et al. 2004a). Phytoplankton within the upwelled waters are typically dominated by chromophytic algae with diatoms being the major phytoplankton taxa present (Glenn et al. 2004a). Outside of the Study Area, on the mid and outer shelf, primary production is low as the shelf waters remain stratified, nutrients are depleted in the euphotic zone, and the phytoplankton population relies on the diffusive nutrient flux across the pycnocline. Here, stratification is significantly intense that the pycnocline remains intact during tropical storms and hurricanes (Glenn et al. 2008). Therefore, the most recurrent phytoplankton blooms occur during the fall and winter seasons when stratification diminishes (due to seasonal convective overturn and frequent storms) and nutrients are replenished in the euphotic zone (surface layer of the water column [usually 80-200 m {262.5-656.2 ft}], where light penetration is sufficient to support photosynthesis; Ryan et al. 1999; Yoder et al. 2002; Schofield et al. 2008). In the vicinity of the Study Area, the winter bloom generally extends from the shoreline to a mean depth of 41 m (134.5 ft). This corresponds to approximately 24 NM offshore.

2.3 HABITAT

2.3.1 Continental Shelf

The New Jersey Study Area encompasses approximately 1,360 NM^2 of the New Jersey offshore environment (**Figure 2-1**). The northwest Atlantic Ocean creates a natural border to the east of New Jersey. The Study Area is part of the MAB is comprised of the continental shelf from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina (Steimle and Zetlin 2000). The shelf environment of the New Jersey Study Area is characterized as being relatively flat and dominated by sandy to muddy-sandy sediments (Borondy 1997; NJDEP 2000; Steimle and Zetlin 2000). No studies were found to describe the occurrence of marine flora outside the back barrier lagoons of New Jersey; however, various benthic fauna (e.g., arthropoda, bryozoa, cnidaria, echinodermata, and mollusca) are found in the continental shelf habitat ranging in size from microscopic to larger macrofauna (Wigley and Theroux 1981; Serafy and Fell 1985; Vecchione et al. 1989; Ryland and Hayward 1991; Sebens; Steves et al. 1999; Ma et al. 2006).

Worldwide there are at least 955 living species of echinoderms (e.g., sea stars, sea urchins, and sand dollars); of these, about 156 species inhabit the North Atlantic. Echinoderms inhabit the benthic substrate from the intertidal zone to the abyssal plain. Common species found in the New Jersey Study Area are *Cidaris abyssicola*, purple-spined sea urchin (*Arbacia punctulata*), Northern sea urchin (*Strongylocentrotus droebachiensis*), common sand dollar (*Echinarachnius parma*), five-slotted sand dollar (*Mellita quinquiesperforata*), *Schizaster orbignyanus*, and sea potato (*Echinocardium cordatum*; Serafy and Fell 1985).

Various cnidarians (sea anemones and corals) can be found on sandy, muddy, and rocky sediments in the Study Area. Sea anemones that inhabit sandy and muddy substrates often burrow slightly into the sediments while other anemones attach to hard surfaces such as rocks, reefs, artificial structures, and even other organisms (e.g., mollusk shells and crustaceans). Soft corals and sea anemones of the New Jersey Study Area include the deeplet sea anemone (*Bolocera tuediae*), North American tube anemone (*Ceriantheopsis americanus*), northern cerianthid (*Cerianthus borealis*), lined sea anemone (*Edwardsiella lineate*), and plumose anemone (*Metridium senile*; Sebens 1998). Other cnidarians that likely inhabit the Study Area include hydrozoans and gorgonians (i.e., sea whips, sea fans, and sea pens; Wigley and

Theroux 1981). Cnidarians, specifically jellyfish species, are highly important in the diet of leatherback sea turtles (Bjorndal 1997).

Several species of mollusk also occur within the New Jersey Study Area. Mollusks include bivalves (e.g., clams and mussels), cephalopods (e.g., octopus, squid, and cuttlefish), and gastropods (e.g., snails and slugs). Cephalopods of the New Jersey Study Area include the long-finned squid (*Loligo pealei*), short-finned squid (*Illex illecebrosus*), and common octopus (*Octopus vulgaris*; Vecchione et al. 1989). Larval and adult stage mollusks are eaten by many organisms including sea turtles (young green, loggerhead, hawksbill, Kemp's ridley, olive ridley, and flatback; [Bjorndal 1997] fishes, filter feeders, and sea stars [Polis et al. 1989]). Various species of mussels, clams, snails, and slugs are likely to be found along the inner and middle shelf regions of New Jersey (Wigley and Theroux 1981).

Bryozoans are microscopic sessile invertebrates that occur in small to large colonial forms (Ryland and Hayward 1991). They are found in all oceans from the rocky intertidal zone to the abyssal plains; often comprising the abundant majority of mid and outer shelf benthos (Clarke and Lidgard 2000). Some species of this sessile epifauna are capable of producing calcium carbonate exoskeletons while others are not. There are two types of bryozoa; encrusting and erect. Encrusting species form "sheets". Erect species form uncalcified (soft) dense bushes, calcified (hard) coral forms, and branched forms. Erect bryozoans of the New Jersey Study Area can be found on shell and stone substrates as well as attached to hydroids, algae, and other bryozoans. Both encrusting and erect species can be found in the Study Area. The erect species that are found in the Study Area include *Bowerbankia imbricata*, *Bugula fulva*, and *Nolella stipata* (Ryland and Hayward 1991).

Other common macrofauna of the Study Area include sponges, amphipods, and crustacea. The mid-shelf is dominated by sand dollars and surf clams from about 40 to 70 m (131 to 229.7 ft), while various other organisms (e.g., rock crabs, hermit crabs, cancer crabs, horseshoe crabs, spider crabs, and lobsters) are found throughout the shelf (Steves et al. 1999; Ma et al. 2006).

In the southern end of the Study Area is the Dr. Carl N. Shuster, Jr. Horseshoe Crab Reserve. It is located 3 NM south of Little Egg Harbor and extends south of the Delaware Bay. The Reserve was established in 2001 and it encompasses a 3,885 km^2 (1,500 mi^2) area of inner continental shelf habitat. This reserve protects the largest population of the horseshoe crab (*Limulus polyphemus*) in the western Atlantic (NMFS 2001; Walls et al. 2002).

The horseshoe crab has existed for more than 200 million years. Four species of horseshoe crab exist in two regions of the world. Three species, *Tachypleus tridentatus*, *T. gigas*, and *Carcinoscorpius rotundicauda* are found in Asian waters from India to Japan. A single species, 'American' horseshoe crab (*Limulus polyphemus*) is found in the western Atlantic from Maine to the Yucatan; this species is also repeatedly introduced to European waters by fisherman, but is not reproductively viable. The largest population of American horseshoe crab resides in the Delaware Bay (Walls et al. 2002; Smith 2005) and it is found on the continental shelf from 6-18 m (20-60 ft) during the winter season. Horseshoe crabs are an important resource. Commercial fisheries utilize them for eel and conch bait (Walls et al. 2002), biomedical researchers harvest the horseshoe crabs' blood for endotoxin studies (Walls et al. 2002; Smith 2005), and an estimated one million migratory shorebirds (11 species) stop in the Delaware/New Jersey area to feed on eggs and stranded adults. Other predators that feed on horseshoe crabs include: mollusks, crustaceans, fishes, leopard sharks, eels, and loggerhead sea turtles (Walls et al. 2002).

2.3.2 Seagrasses

Seagrasses are an important feature of the MAB ecosystem. Seagrass meadows provide nurseries and shelter for a variety of commercially important marine organisms (e.g., flounder, smelt, striped bass, cod, lobsters, and blue mussels) as well as feeding and resting sites for birds (e.g., ducks, Canada geese, and Atlantic Brant).

Eelgrass (*Zostera marina*) is the primary seagrass species found on the east coast of North America. Previously, eelgrass occurred throughout the western North Atlantic from Quebec, Canada down along

New Jersey; however, in the early 1930s, a protist slime mold (*Labyrinthula zosterae*) caused a wasting disease (Green and Short 2003) that resulted in the mortality of 90 percent of the eelgrass biomass off the eastern seaboard from North Carolina to Nova Scotia (Bochenek 1997). Off of New Jersey alone, 20 km^2 (7.7 mi^2) of eelgrass beds were wiped out (Green and Short 2003). The population gradually recovered in the 40 yrs following the disease; however, previous distribution has not yet been reestablished (Green and Short 2003).

Differences exist between ecosystems that have seagrasses and those that do not. A loss or lack of seagrass meadows can cause sediments to be less stable, often resulting in poor water clarity, loss of organic matter, and increased sediment movement and resuspension. The loss of a seagrass ecosystem can triggar biological changes that can include: suspension feeders taking over where infaunal communities, in the presence of seagrasses, were largely-deposit feeders; a decline in epibenthic species abundance; and a drop in abundance of marine birds dependant on seagrasses (Green and Short 2003).

At least two species of seagrass occur in the back barrier lagoons of New Jersey (i.e., eelgrass and widgeon grass); however, there are no current documented seagrasses within the New Jersey Study Area (Macomber and Allen 1979; Green and Short 2003).

2.3.3 Artificial Reefs

There are several artificial reef sites in the New Jersey Study Area (**Figure 2-9**); no natural reefs are present (Figley 2005). An artificial reef is defined as one or more submerged structures made of natural or man-made materials purposefully or accidentally (e.g., shipwrecks) deposited on the seafloor. Artificial reefs can include piers, docks, bulkheads, ship and plane wrecks, jetties, groins, and breakwaters.

Just like natural reefs, artificial reef habitats offer nursery and foraging sites and protection to marine organisms. Since the beginning of the reef program, large numbers of marine life, both pelagic and benthic, have recruited to New Jersey nearshore waters. In 2006, an estimated 40 percent of recreational landings occurred on artificial reefs; up from 33 percent in 2000 (Spoto 2006).

Artificial reefs have been placed in the waters off New Jersey since the early 1900s (Steimle and Zetlin 2000). Historically, materials used included Christmas trees with concrete bases, concrete filled wooden crates, rubber tires, military vehicles, and decommissioned ships. Recently, the NJDEP requested 600 stainless steel subway cars from the New York City Transit Authority with plans to add them to existing reef sites (Shark River, Garden State North, Atlantic City, Deepwater, and Cape May reefs; NJDEP 2008). Furthermore, specially designed and manufactured artificial reefs have also been added to sites off New Jersy (Steimle and Zetlin 2000). Regardless of the materials used, all reef types are utilized by various marine species (Steimle and Zetlin 2000).

The New Jersey Division of Fish and Wildlife started the New Jersey Reef Program in 1984 (Spoto 2006; NJDEP 2008). Fifteen artificial reef sites have been developed since the inception of the program and at least eight can be found in the Study Area (Spoto 2006; NJDEP 2008). These fifteen sites support over 3,700 patch-reef communities. A patch-reef can be defined as an area of reef that has been created by various materials and can extend up to many square acres in size (NJDEP 2008). New Jersey boasts the largest artificial reef system in the U.S. (Spoto 2006).

“Reef balls” comprise the majority of artificial reefs in use off the coast of New Jersey today. A reef ball is a hollow dome structure generally 1.2 m (4 ft) wide by 0.9 m (3 ft) high weighing about 726 kilograms (kg; 1,600 pounds [lbs]; Borondy 1997; NJDEP 1999; NJDFW 2000). Reef balls are made of specialized concrete that slowly (after 500 yrs) breaks down into sand (Borondy 1997). The concrete has a pH close to that of natural seawater allowing it to last longer than regular concrete (Borondy 1997). The surface of a reef ball is texturized to allow easier settlement for benthos (e.g., mussels, barnacles, sponges, and anemones) and there are multiple holes of varied sizes within the structure to provide shelter to mobile epifauna from predators and fishing gear (Borondy 1997; Steimle and Zetlin 2000).

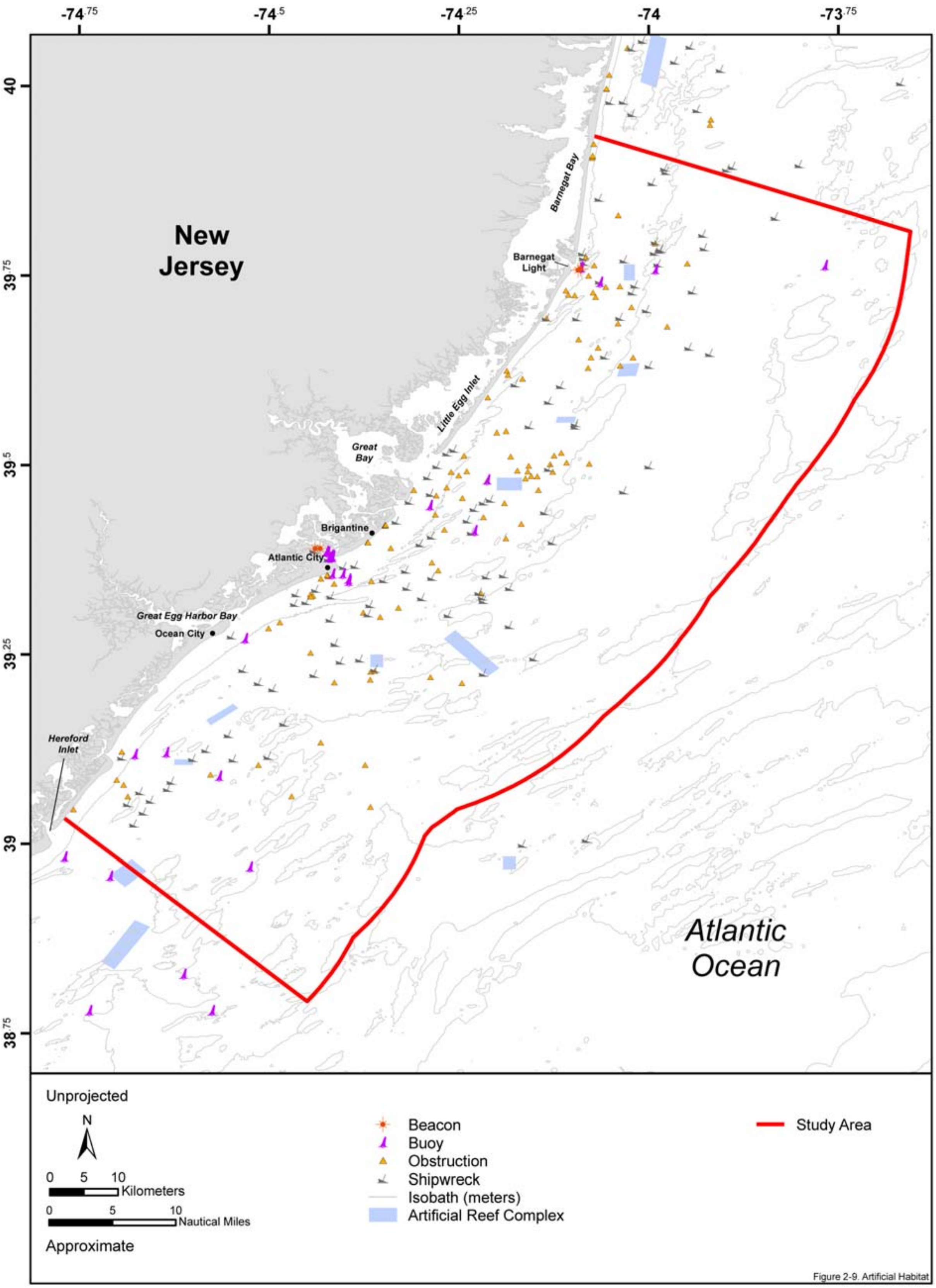

Figure 2-9. Location of artificial habitats found in the New Jersey Study Area. Source data: Veridian Corporation (2001), NOAA/Office of Coast Survey (2008), and NJDEP (2008).

Recruitment to an artificial reef begins immediately and, after only a few weeks, various reef builders can be observed (Borondy 1997). Environmental Protection Agency (EPA) biologists surveyed an artificial reef after the reef had been submerged for 2 yrs. More than 39,900 organisms were counted on a 3-ft by 1-ft structure with blue mussels constituting more than 60 percent of the total organism count. Other fauna included barnacles, worms, snails, crabs, and encrusting organisms (i.e., bryozoans, sponges, and hydroids). Previously, it was thought that organisms associate with artificial reefs because of increased food availability (Steimle Jr. and Ogren 1982); however, Steimle and Ogren (1982) found that most fishes associate with Atlantic artificial reef habitats for shelter and other behavioral needs and are not dependent upon the reef for food.

Reefs provide habitat for many commercially and recreationally important organisms (Spoto 2006). Most reefs off the coast of New Jersey are located at depths of 60 m (197 ft) or more. At this depth, there is not adequate light to support many plants; however, filter feeders (i.e., mussels, barnacles, and tubeworms) can thrive and provide food and hiding places for mobile fauna (NJDEP 2000).

Common sessile reef inhabitants associated with New Jersey artificial reefs include red algae colonies (*Phyllophora* sp.), sponges (*Halichondria* sp. and *Polymastia* sp.), anemones (*Metridium senile*, *Tealia* sp., and *Stomphia careoia*), northern stone coral, mollusks, barnacles, bivalves, bryozoans, and amphipods (Steimle and Zetlin 2000). Some mobile fauna are lobsters, crabs, sea stars, urchins, polychaetes, cod, triggerfish, tautog, sea bass, scup, ocean pout, hake, conger eel, and cunner (Borondy 1997; Steimle and Zetlin 2000).

Reefs, artificial or natural, increase the biological productivity of the local marine environment (NJDEP 2000). Some biological communities are dependent upon or benefit from reef ecosystems; such communities can include from microalgae to megaflora, fishes, and sea turtles (Steimle and Zetlin 2000). Other marine species such as marine mammals, sea turtles, and diving birds are drawn to reef systems, for foraging and shelter. Reef systems can also create a chain of foraging and resting sites for many migrating marine species (e.g., marine mammals and sea turtles).

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3.0 AVIAN SHIPBOARD OFFSHORE SURVEYS

Coastal breeding and migratory/wintering pelagic and non-pelagic avian species utilize New Jersey's offshore waters. Several federal and state-listed threatened, endangered, and species of concern avian species have the potential to occur in the Study Area. The federal species of conservation concern list was developed primarily for terrestrial and coastal birds. Information on population trends of most seabirds is insufficient to determine if they should be on the species of conservation concern list.

The USFWS lists 1 threatened, 1 endangered, and 31 species of conservation concern for the Study Area, which occur within Bird Conservation Region 30 (**Table 3-1**). The State of New Jersey lists 6 threatened, 7 endangered, and several species of concern based on breeding status and/or region for the Study Area (**Table 3-2**).

Table 3-1. Federal avian threatened, endangered, and species of conservation concern for Bird Conservation Region 30 (New England/Mid-Atlantic coast).

Family[1] **Common Name, *Scientific name***	**Status**
Falconidae (falcons)	
Peregrine Falcon, *Falco peregrinus*	SC
Rallidae (rails)	
Black Rail, *Laterallus jamaicensis*	SC
Charadriidae (plovers)	
Wilson's Plover, *Charadrius wilsonia*	SC
Piping Plover, *Charadrius melodus*	T
Haematopodidae (osystercatchers)	
American Oystercatcher, *Haematopus palliates*	SC
Scolopacidae (sandpipers)	
Upland Sandpiper, *Bartramia longicauda*	SC
Whimbrel, *Numenius phaeopus*	SC
Hudsonian Godwit, *Limosa haemastica*	SC
Marbled Godwit, *Limosa fedoa*	SC
Red Knot, *Calidris canutus*	SC
Purple Sandpiper, *Calidris maritime*	SC
Buff-breasted Sandpiper, *Tryngites subruficollis*	SC
Laridae (gulls, terns, and skimmers)	
Least Tern, *Sterna antillarum*	SC
Roseate Tern, *Sterna dougallii*	E
Common Tern, *Sterna hirundo*	SC
Black Skimmer, *Rynchops niger*	SC
Alcidae (auks)	
Razorbill, *Alca torda*	SC
Caprimulgidae (nightjars)	
Whip-poor-will, *Caprimulgus vociferous*	SC
Picidae (woodpeckers)	
Red-headed Woodpecker, *Melanerpes erythrocephalus*	SC
Troglodytidae (wrens)	
Sedge Wren, *Cistothorus platensis*	SC
Marsh Wren, *Cistothorus palustris*	SC

Table 3-1 (*continued*). Federal avian threatened, endangered, and species of conservation concern for Bird Conservation Region 30 (New England/Mid-Atlantic coast).

Family[1] **Common Name, *Scientific name***	**Status**
Turdidae (thrushes)	
Wood Thrush, *Hylocichla mustelina*	SC
Parulidae (warblers)	
Blue-winged Warbler, *Vermivora pinus*	SC
Golden-winged Warbler, *Vermivora chrysoptera*	SC
Prairie Warbler, *Dendroica discolor*	SC
Cerulean Warbler, *Dendroica cerulean*	SC
Worm-eating Warbler, *Helmitheros vermivorum*	SC
Kentucky Warbler, *Oporornis formosus*	SC
Canada Warbler, *Wilsonia Canadensis*	SC
Emberizidae (sparrows)	
Henslow's Sparrow, *Ammodramus henslowii*	SC
Saltmarsh Sharp-tailed Sparrow, *Ammodramus caudacutus*	SC
Seaside Sparrow, *Ammodramus maritimus*	SC
Icteridae (blackbirds, meadowlarks, and orioles)	
Baltimore Oriole, *Icterus galbula*	SC

SC = Species of Concern (Source: USFWS 2007. Birds of Conservation Concern. USFWS, Division of Migratory bird Management. Arlington, Virginia.)
E = Endangered (Source: USFWS website: http://ecos.fws.gov/tess_public//pub/stateListingAndOccurrence.jsp?state=NJ)
T = Threatened (Source: USFWS website: http://ecos.fws.gov/tess_public//pub/stateListingAndOccurrence.jsp?state=NJ)
[1] Scientific Classification based the American Ornithologists Union Checklist of North American Birds, Seventh Edition, including all changes made in Supplements to the 7th Check-List.

Table 3-2. New Jersey state-listed threatened, endangered, and special concern avian species.

Family[1] **Common Name, *Scientific name***	**New Jersey Status**[2]
Podicipedidae (grebes)	
Pied-billed Grebe, *Podilymbus podiceps*	E ^{BR}, SC ^{NB}
Ardeidae (bitterns, egrets, and herons)	
Great Blue Heron, *Ardea herodias*	SC ^{BR}
Black-crowned Night-heron, *Nycticorax nycticorax*	T ^{BR}, SC ^{NB}
Yellow-crowned Night-heron, *Nyctanassa violacea*	T
Accipitridae (eagles and hawks)	
Osprey, *Pandion haliaetus*	T ^{BR}
Bald Eagle, *Haliaeetus leucocephalus*	E ^{BR}, T ^{NB}
Northern Harrier, *Circus cyaneus*	E ^{BR}, SC ^{NB}
Falconidae (falcons)	
Peregrine Falcon, *Falco peregrines*	E
Haematopodidae (oystercatchers)	
American Oystercatcher, *Haematopus palliatus*	SC
Scolopacidae (sandpipers)	
Whimbrel, *Numenius phaeopus*	SC ^{NB}
Sanderling, *Calidris alba*	SC ^{NB}
Semipalmated Sandpiper, *Calidris pusilla*	SC ^{NB}

Table 3-2 (*continued*). New Jersey state-listed threatened, endangered, and special concern avian species.

Family[1] Common Name, *Scientific name*	New Jersey Status[2]
Laridae (gulls, terns, and skimmers)	
Least Tern, *Sterna antillarum*	E
Caspian Tern, *Hydroprogne caspia*	SC ^{BR}, RP ^{NB}
Common Tern, *Sterna hirundo*	SC ^{BR}, RP ^{NB}
Royal Tern, *Thalasseus maximus*	RP ^{NB}
Black Skimmer, *Rynchops niger*	E ^{BR}, T ^{NB}
Parulidae (wood-warblers)	
Northern Parula, *Parula americana*	SC ^{BR}
Black-throated Green Warbler, *Dendroica virens*	SC ^{BR}
Emberizidae (sparrows)	
Vesper Sparrow, *Pooecetes gramineus*	E ^{BR}, T ^{NB}
Icteridae (blackbirds, meadowlarks, and orioles)	
Eastern Meadowlark, *Sturnella magna*	SC

E = Endangered
T = Threatened
SC = Special Concern
RP = Regional Priority
^{BR} = Breeding population
^{NB} = Non-breeding population
[1] Scientific classification based on the American Ornithologists Union Checklist of North American Birds, Seventh Edition, including all changes made in Supplements to the 7th Check-List: http://www.aou.org/checklist/index.php3
[2] State status based on the NJDFW website: http://njfishandwildlife.com/ensp/pdf/spclspp.pdf

3.1 METHODOLOGY

The sampling protocol and the avian survey protocol were developed based on a review of at-sea avian standard survey methods used by U.S. and Europe researchers (e.g., Camphuysen et al. 2004; Ballance 2007). A 300-m x 300-m (984-ft x 984-ft) ship transect survey method was selected to meet the objective of creating an avian predictive model for the Study Area. Field sampling and avian survey methods, data quality control assurance/control procedures, and data analysis methods are presented in this section.

3.1.1 Field Surveys

3.1.1.1 Survey Design

A ‘double saw-tooth’ survey trackline configuration was selected to maximize coverage of the Study Area. Ship survey line transects (tracklines) were generated monthly with the program Distance (Buckland et al. 2001). Tracklines were plotted with double saw-tooth lines running perpendicular to the bathymetry from the 10-m (33-ft) isobath to the Study Area boundary. Start location (north or south, east or west) on the selected trackline was determined by flipping a coin before each survey.

Tracklines were surveyed at approximately 10 kts (5 meters per second [m/s]) during daylight hours when Beaufort Sea State (BSS) was ≤6 and visibility was ≥7 km (4 NM). Between 26 and 28 tracklines, no more than 9 km (5 NM) apart, were scheduled to be surveyed per month. When weather conditions did not allow completion of all tracklines in some of the survey months, tracklines were spaced at intervals greater than 9 km (5 NM) apart to cover the Study Area from north to south.

3.1.1.2 Survey Methods

A computer-based survey program was used to track environmental conditions (weather conditions, sea state, water turbidity, water color, sun strength, and glare) throughout the survey. In addition, the computer recorded the geographic position coordinates of the ship's survey trackline.

The survey area was defined as 300 m (984 ft) ahead of the ship and 300 m (984 ft) perpendicular to one side of the ship's trackline (either the right or left side of the ship depending on which side was selected as having the least glare). When the ship changed course to investigate a marine mammal sighting, avian observers signed "off" and then "on" to separate the avian data collected on tracklines from marine mammal searches. The same procedure was also used to separate avian data collected at stationary water sampling stations at the end of each transect. At the near-shore point for water sample collection, observers focused their survey effort toward shore, glare conditions permitting.

Survey methods were refined and improved based on reviews and subsequent consultations with the USFWS during the first several months of the project. Changes in survey methods were documented in versions of the Avian Observer Packet (GMI 2008a, 2008b, 2008c). The initial and current survey methods are summarized in this section. **Appendices A-1**, **A-2**, and **A-3** provide detailed descriptions of survey methods. All noted changes were continued throughout the remainder of the year.

Initially, the avian survey team consisted of three (3) biologists, one on the bow, one on the port or starboard side (dependant on glare) of the bridge level of the ship (approximately 6 m [20 ft] above the water), and one biologist off-effort. Biologists conducted scans with "naked eye" and binoculars ahead of the ship to spot birds within the designated survey area. Scans occurred beyond this area as far as possible, but birds were only recorded when observed within the survey area. Data were recorded for each bird observation on a hand-held computer that was synchronized to the ship's GPS. Data recorded for each observation included: the position of the observer (i.e., bow, port, or starboard), the observation time and coordinate (location) of the observer, avian identity (lowest practical taxon; family, genus, or species [four letter standard code]), number of individuals (approximate number for flocks), bearing and range (m), estimated flight altitude in ft above sea level (1 [skimming], 25, 50, 100, 200, 300, 500, 1,000+), and behavior (coded numerically; sitting, following the ship, feeding, piracy, other, unknown, directional flight, aimless flight, circling). Cardinal directions were used to designate flight directions (i.e., the ship's bow was considered north).

In January and February 2008, the range to the bird was the perpendicular distance from the ship's track centerline to the bird. Range bins were established and included 1 to 25 m (3 to 82 ft), 26 to 50 m (85 to 164 ft), 51 to 100 m (167 to 328 ft), 101 to 200 m (331 to 656 ft), and 201 to 300 m (659 to 984 ft). In March, range was redefined as the estimated distance from the observer to the bird. Steiner© binoculars equipped with a compass were used to mark bearings (in 10° increments) for each of the observer positions to increase the accuracy of bearing data.

A second survey area was added to the survey protocol in March 2008. The survey areas were defined into two categories: 1) "in-zone": the area 300 m (984 ft) ahead and 300 m (984 ft) to one side of the ship's trackline (either the right or left side of the ship depending on which side was selected as having the least glare) and (2) "out-zone" the area beyond the in-zone (>300 m [984 ft] from the ship). Observers gave priority to recording birds in the in-zone (the primary survey area) and recorded important birds (flocks of birds, rare species) observed in the out-zone after completing in-zone scans. Observer state (a sliding scale that rates avian observation conditions from perfect to poor) was also started in March. Recording of incidental avian behavior was also initiated in March with the creation of a comments section in the hand-held computer program (GMI 2008b; see **Appendix A-2** for additional details). Range estimation sticks specific for each observer were added in June to increase the accuracy of range estimates.

From January through May 2008, the bow biologist was responsible for surveying a 45° area (0° to 45° or 315° to 360°) and the port/starboard biologist was responsible for surveying the remaining 45° area (45° to 90° or 280° to 315°) from the bridge level of the ship (approximately 6 m [20 ft] above the water). From

June through November one biologist (the primary avian observer [PAO]) was responsible for the entire survey strip from the flying bridge (approximately 9 m [30 ft] above the water).

The PAO ensured that the strip transect survey protocols were followed. The PAO was positioned at the front of the flying bridge on the ship's centerline. The PAO was on duty for one-hour periods before being relieved by one of the other survey team members.

The first priority of the PAO was to identify, enumerate, and estimate the bearing to and distance to the bird and to record bird behavior (e.g., flying or sitting, directional or non-directional flight, feeding), flight altitude, and flock composition within the primary survey area (in-zone). The PAO scanned with naked eyes and binoculars the 0° to 90° zone or the 270° to 0° zone (selected and switched as needed to avoid glare) within the survey area while the ship traveled along the trackline. The PAO then pre-scanned beyond this area as far as possible, looking for birds that will potentially be in the in-zone; however, these birds were only recorded when observed within the primary survey area.

The second priority of the PAO was to conduct observations in all visible areas outside of the in-zone for "important" birds. Important birds included large flocks of birds and rare birds such as federal- and state-listed species and federal species of concern. The PAO visually scanned the out-zone area with "naked eyes" for flying birds and then scanned the area with binoculars.

As previously discussed, all data were collected on hand-held computers that were synchronized for time with the field laptop and were connected to the ship's GPS. The computer program allowed for the data entered onto the hand-held computer to be merged with the resultant trackline. Data recorded included:

- identity (lowest identifiable form or taxon; standard four-letter code)
- number of individuals (or best count estimates for large flocks)
- estimated bearing (°) to the bird (the ship bow was designated as 0°)
- estimated range (m) to the bird (based on individual range estimation sticks)
- estimated flight altitude (i.e., identical to those previously discussed)
- behavior category (sitting, directional flight, non-directional flight, piracy, following the ship, and feeding)
- perceived flight direction (the bow of the ship was designated as "designated as north)

All avian data recorded for the primary survey area, with the exception of range, were recorded for out-zone observations. After the out-zone scan was completed observers opportunistically recorded the following data in the comments section:

- dive altitude (ft) of birds, especially Northern Gannets, as DIVA
- submersion time (s) of birds after a dive (i.e., near the ship, sea state conditions permitting) as SUBT
- the life state (age, plumage, morphology) and sex of the bird (e.g., A = adult, J = juvenile, F = female)
- boat traffic observed during the survey, as they often serve as attractants to birds

The PAO contacted the off-effort observer(s) (via the radios carried by all observers) if the environmental conditions needed to be changed on the survey program or additional help was needed to record a large group of birds. When large numbers of birds were encountered, the Senior Seabird Biologist (SSB) on board called on an off-effort observer to assist with recording of zone observations and/or recording observations made by the PAO. When these conditions occurred, each observer was aware of the activity of the other. Unless directed by the PAO, the additional observer did not record data for birds in the survey area or birds on course to enter the survey area.

Because marine mammal surveys occurred simultaneously with the avian surveys, the ship deviated from the tracklines in order to identify sighting of marine mammals. In the event the trackline was broken, the following protocol was followed if an avian observer observed a marine mammal:

- If the boat goes off-transect to investigate a marine mammal sighting, avian data collection continued; however, since the strip-transect methodology was not applicable in such instances, all data collected during this period became incidental (supplemental), with observations no longer being prioritized.
- When the marine mammal team completed a sighting, the ship resumed course on a new heading back toward the trackline. Avian data collection resumed following the strip-transect methodology on this new transect leg.
- If an avian biologist observed a marine mammal, the observer did not point out the animal to the on-watch marine mammal observers until the mammals had passed abeam to either side of the ship.

In addition to marine mammal surveys, oceanographic data were also collected during each survey. Conductivity-Temperature-Depth (CTD) instruments were dropped into the water at the end of each transect line, requiring the ship to stop and remain idle until data collection was complete. During CTD data collection, avian observers continued recording as in the event of a marine mammal sighting until a new transect was started. Additionally, when the ship was at the near-shore point for CTD data collection, observers focused their survey effort toward shore (glare conditions permitting).

Lastly, a weather form was completed prior to initiation of daily surveys, at mid-day, and immediately following final afternoon surveys (**Appendix A-3**). Surveys conditions (e.g., cloud cover, glare, sea state) were checked and changed on the avian computer when necessary by the PAO when the PAO went off-duty.

Based on recommendations made by the USFWS in November, supplemental avian field surveys were added to the study (**Appendix A-4**). These surveys will begin during the winter 2008-2009 season.

3.1.1.3 Data Quality Assurance/Quality Control

The daily survey data were downloaded to a laptop computer and reviewed by the SSB to determine if reporting errors were made; the SSB conferred with the relevant observer to resolve any errors. See **Appendix A-1** for further details.

3.1.2 Data Analysis

3.1.2.1 Avian Occurrence and Abundance

The survey data were checked for errors and merged with the resultant tracklines (in .CSV file format) to match each sighting with its time and location. The merged data file was then processed to provide avian occurrence and abundance data. Survey data was sorted into two categories: In-zone and Incidental. In-zone data included avian observations within the strip survey transect when the ship was traveling ≥4 m/s (13 feet per second [ft/s]) and was not conducting a marine mammal chase. Incidental data included avian observations in the out-zone during ship transect surveys when the ship's speed was ≥4 m/s (13 ft/s) and in the in-zone and out-zone when the ship's speed was <4 m/s (13 ft/s; e.g., during marine mammal chases and while stationary when collecting water samples at the start/end of a survey transect).

In-zone and incidental data were analyzed to create monthly avian occurrence tables (**Appendix B-2**: **Tables B-2.1** to **B-2.4**). The occurrence of federal and state listed avian endangered, threatened, and species of concern during the surveys was determined by comparing federal and state lists with occurrence tables.

In-zone data were used to determine monthly avian abundance in the Study Area (**Tables B-2.5** to **B-2.15**). The total numbers of individuals for each family and each species (for each month) were determined from the in-zone data. Avian family and species abundances were calculated by dividing the total number of each family and the total number of each observed species by the total distance (km) traveled by the ship each month (i.e., total number of individuals/km). Incidental data were reported as the total number of individuals per family and species per month (**Tables B-2.5** to **B-2.15**).

The results section provides a summary of observations made per season. In the results section the grouping of months into the seasons was not based strictly on the calendar dates for the start/end of the season but instead on the overall trends of migration (e.g., northbound migration of waterbirds mostly occurs from March to May and is functionally named "Spring"). June and July were designated as "summer", August through November as "fall"; and December through February as "winter". The five most abundant species within the in-zone are presented for each month and are discussed in the summary tables and accompanying text in **Section 3.2.2**.

3.1.2.2 Avian Density

Baseline Grid Densities

Counts of all birds sampled within the strip transect during shipboard strip-transects were used to determine seabird avian density within the survey area. First, a geospatial database was created to visualize survey effort according to survey type sampled on a monthly basis. Second, for quality assurance and basic data management requirements (i.e., maintenance and updating data), analysts examined expanding symbol plots of total seabird abundance (No./km) and calculated basic spatial and temporal descriptive statistics. Third, the abundances of all birds in relation to survey effort and month were determined.

Densities (birds/km^2) were calculated by dividing the number of birds observed by the amount of area surveyed. Survey effort data used in density calculation were extracted from sighting data for the 300 m x 300 m (984 ft x 984 ft) strip transect when the ship was transiting at ≥4 m/s (13 ft/s). Sightings made during marine mammal chases or greater than 300 m (984 ft) from the ship were excluded from the data set. To maintain consistency over 11 months, the sightings of the bow observer were used in density calculations when observation conditions ranged from Beaufort 1 to 6.

The area surveyed was calculated by multiplying the transect length by the survey width (300 m; 984 ft). Densities estimates were calculated using the standard formula: $D = n / (l \times w)$, where D is density (birds per square kilometer), n is the number of birds observed, l is the transect length, and w is the width of the strip. Baseline total avian density maps were then created for each month.

High-Density Grids

Areas of high-avian density were identified based on a ranking procedure, in which the individual grid boxes with non-zero densities (i.e., those grid boxes with at least one bird sighting) were ranked in the order of highest to lowest total density, and those grid boxes that rank in the top 20 percent of all non-zero-density grid boxes were designated as "high-density" grid boxes (i.e., regions of high avian density).

This procedure was conducted for all birds within the survey area for each individual month and cumulatively (i.e., summed over all months) over the period of January through November 2008. In addition to the all-birds analysis conducted for the Interim Report, this procedure will also be conducted for the five most abundant species for the Draft Final Report.

A system of 72 grid boxes was developed to cover the Study Area. A regular longitude-latitude grid system was used with each square grid box, defined by a maximum and minimum longitude and maximum and minimum latitude. The area of each grid box is approximately 10 km x 10 km (6 mi x 6 mi).

Bird sightings data for the purpose of these calculations consisted of the following parameters recorded for each observation (sighting): Number of birds sighted, date (month, day, and year) of the observation, and the longitude-latitude coordinates of the observation. Each observation was identified and binned spatially into the appropriate grid box as well as temporally according to month. After all bird counts were binned according to month and grid box, the number of bird counts within each grid box for each month was summed to yield a total bird count, which was then divided by the area of the specific grid box to yield total monthly bird density. For the cumulative analysis, the binned bird counts were summed over the number of months for each grid box and then divided by the grid box area to obtain total cumulative bird density.

To identify the high-density grid boxes, a ranking scale of A to F was adopted, in which "A" indicates the highest density, "E" the lowest positive density, and "F" is zero density. For each month and the cumulative total, the zero-density grid boxes were identified and automatically assigned a rank of "F". The remaining grid boxes with positive densities were then ranked from highest to lowest density on a scale of A to E. The top 20 percent of these positive-density grid boxes were assigned a rank of "A", and the grid boxes in the 20 to 40 percentile range were assigned a rank of "B". Similarly, the grid boxes in the 40 to 60, 60 to 80, and 80 to 100 percentile ranges were assigned ranks of "C", "D", and "E", respectively.

For each month (and cumulatively), color-coded spatial maps of the 72 grid boxes encompassing the survey area were generated, with the ranks of A, B, C, D, E, and F represented by red, orange, yellow, green, blue, and white, respectively. Each of the 72 grid boxes was assigned the appropriate color according to its ranking. By definition, high-density grid boxes are identified by the "red" grid boxes (which are ranked "A", corresponding to densities in the top 20 percentile).

3.1.2.3 Altitude Distribution

The counts of all birds within the 300-m x 300-m (984-ft x 984-ft) survey area sampled during the shipboard offshore transect surveys were used to determine altitude distribution within the Study Area. All avian individuals were described as either sitting (on the water) or flying. The altitude for each flying observation was categorized into one of three altitude bands with reference to the potential rotor swept zone (RSZ): (1) below the RSZ (3 to 30 m [1 to 100 ft]); (2) within the RSZ (31 to 152 m [101 to 500 ft]); and (3) above the RSZ (151+ m [501+ ft]). Behavior percentages were calculated for each species (i.e., the percentages of birds sitting and flying). For all of the flying observations, percentages were then calculated for the numbers of individuals within each altitude band. All altitude data are reported in ft above mean sea level (AMSL).

3.1.2.4 Circular Statistical Analysis of Avian Directional Data for the New Jersey Offshore (Ship) Surveys

The objective of the following first-order and second-order circular statistical analyses is to determine the nature of the statistical distribution of avian flight directions and their variability with respect to species, taxonomic group, month, and season. The hypothesis tests are conducted to determine whether the flight directions exhibit circular uniformity (i.e., a random distribution of direction) or exhibits a mean angle (i.e., favoring a particular direction), both overall as well as for a given species, group, month, and season. For example, it may be feasible for one avian species to exhibit circular uniformity, whereas another species may exhibit a mean flight direction that may change from month to month or from season to season, reflecting, for example, seasonal flight migration patterns. This analysis is potentially important for subsequent calculations of avian mortality strikes, since the collision rate of birds with the wind turbine blades depends on the relative directional orientation between the birds and blades.

3.1.2.4.1 Descriptive statistics

Angular (directional) data consist of a sample of "n" measurements of angle (with values ranging from 0° to 360°). Angular measurements (a_i for data point i, where i=1 to n) are often grouped into "J" bins, with each bin "j" defining a (usually equally-spaced) range of angles (e.g., 0° to 10°, 10° to 20°, etc.), such that all J bins encompass the entire angular range 0° to 360°. Each bin "j" is characterized by a midpoint angle b_j (e.g., 5°, 15°, etc.). The number of measured angles (data points) a_i falling into each bin "j" is termed the angular number frequency, occurrence frequency, or number of angular measurements (f_j). Summing f_j across all J bins yields the total sample size n (i.e., SUM (f_j) = n, where the summation is conducted for j=1 to J, where J = total number of bins, which encompass the entire angular range 0° to 360°).

Angular data can thus be individual or grouped:

1. Individual data consist of individual angular values a_i (for measurement "i"), for i=1 to n, where n = sample size or total number of angular measurements.
2. Grouped data consist of an occurrence frequency f_j (a.k.a. number frequency or number of angular measurements) of individual angular measurements a_i occupying bin "j", which is defined by an angular range and a midpoint angle b_j. A total of J bins are defined whose collective ranges cover the entire 0° to 360° range. Each of the a_i individual measurements (for i=1 to n) are distributed into the J bins, such that SUM (f_j) = n.

Individual and grouped angular datasets (i.e., circular distributions) can be characterized based on uniformity and modality. Uniform distributions exhibit a relatively even (or random) distribution of angular measurements over the entire circular range (0° to 360°), whereas a non-uniform (or clumped or aggregated) distribution tends to have a greater relative number of angular measurements concentrated around one or more particular angles or ranges of angles.

Three general types of modal distributions include unimodal, bimodal, and multimodal:

1. Unimodal distributions are characterized by a maximum occurrence frequency at one angular range (i.e., the occurrence frequency for one angular bin is greater than the number frequencies for all other angular bins).
2. Bimodal distributions have a maximum occurrence frequency at 2 angular ranges (i.e., 2 bins exhibit the same maximum occurrence frequency). An example is a diametrically bimodal distribution, which exhibits a maximum occurrence frequency at 2 angles spaced exactly 180° apart (i.e., on opposite sides of the circle).
3. Multi-modal distributions have several angular bins exhibiting the same maximum occurrence frequency.

The angle(s) at which the maximum occurrence frequency occurs is termed the modal angle(s). In addition to the modal angle, circular distributions are also characterized by a mean angle and median angle.

<u>Mean Angle</u>

Angular data take the form of individual angle measurements (a_i) over a sample size n (i.e., i=1 to n). Mean angle (a_{bar}) for a sample of size n is calculated from the summation of the sine and cosine vectors of the individual angle measurements a_i. For each of the n measurements, given a_i (for i=1 to n), $\sin(a_i)$ and $\cos(a_i)$ are calculated and summed over n. The values of X and Y are then calculated as: X = SUM[$\cos(a_i)$]/n and Y = SUM[$\sin(a_i)$]/n, where the summation is from i=1 to n. The length vector r is then calculated as $r = (X^2 + Y^2)^{0.5}$. Knowing X, Y, and r, the cosine and sine components of the mean angle are given by $\cos(a_{bar}) = X/r$ and $\sin(a_{bar}) = Y/r$.

Solving $\cos(a_{bar})$ by itself for a_{bar} yields 2 solutions for a_{bar}. Likewise, solving $\sin(a_{bar})$ by itself for a_{bar} yields 2 solutions for a_{bar}. However, solving both equations simultaneously yields a unique solution for a_{bar}, according to the following geometric and trigonometric guidelines:

1. If $\cos(a_{bar}) > 0$ and $\sin(a_{bar}) > 0$, then $0° < a_{bar} < 90°$.
2. If $\cos(a_{bar}) < 0$ and $\sin(a_{bar}) > 0$, then $90° < a_{bar} < 180°$.
3. If $\cos(a_{bar}) < 0$ and $\sin(a_{bar}) < 0$, then $180° < a_{bar} < 270°$.
4. If $\cos(a_{bar}) > 0$ and $\sin(a_{bar}) < 0$, then $270° < a_{bar} < 360°$.

Grouped angular data take the form of occurrence frequencies (f_i) of the given angle measurement (a_i), recorded over a sample size n (i.e., for i=1 to n). The recorded angular value (a_i) is typically the midpoint of an angular measurement interval (or bin), and f_i is the occurrence frequency (i.e., number of angular measurements) within the angular interval defined by the midpoint angle a_i. For example, for 2 bins defined by the angular ranges 0° to 10° and 10° to 20°, the midpoint angles a_i are 5° and 15°, respectively.

In the case of angular data grouped into "N" bins (or a dataset consisting of an occurrence frequency f_i associated with a distinct angular value a_i), an angle a_i occurring with a frequency f_i is equivalent to repeating the value of a_i, f_i times and recording each individual occurrence of a_i in an expanded table. In this expanded table, the expanded sample size n = SUM(f_i), where the summation is from i=1 to N, where N = number of DISTINCT angular values, and n = total number of angular measurements (sample size). Working with the original data table (consisting of distinct angular values a_i and associated occurrence frequencies f_i), the values of sin(a_i), f_i*sin(a_i), cos(a_i), and f_i*cos(a_i) are calculated for each measurement "i". The values of f_i*sin(a_i) and f_i*cos(a_i) are summed over the number of distinct angular value N. Values of X and Y are then calculated as: X = SUM[f_i*cos(a_i)]/n and Y = SUM[f_i*sin(a_i)]/n, where the summation is from i=1 to N, and n = SUM(f_i). The length vector $r = (X^2 + Y^2)^{0.5}$ is then calculated. Knowing X, Y, and r, the cosine and sine components of the mean angle are given by cos(a_{bar}) = X/r and sin(a_{bar}) = Y/r. Simultaneous solution of these 2 equations yields a unique solution for a_{bar}.

However, calculation of r from grouped data (i.e., data in the form of occurrence frequencies f_i associated with distinct angular values a_i) results in negative bias, generating an underestimate of r. The following correction for this bias is applicable when the distribution is unimodal and does not deviate significantly from symmetry. The r value is multiplied by a correction factor "c" to yield the corrected r value r_c: r_c = c*r, where c = (d*pi/360°)/[sin(d/2)], where the data are grouped into intervals of "d" degrees each.

Measures of Angular Dispersion

Classical measures of dispersion (or spread) of the data include range, standard deviation, standard error, variance, and confidence intervals; and these measures (as well as the mean, median, and mode) are analogously applicable to circular data as well as linear data. Specific circular measures of angular dispersion include range, circular variance, angular variance, variance measure, angular deviation, and circular standard deviation.

Because of the discontinuity in angular value between 0° and 360° (designating the same point on a circle), the range cannot simply defined as the difference between the lowest and highest angular value. Instead, the range in a circular distribution of angular data values is defined as the smallest arc of the circle that contains all of the angular data in the distribution.

In addition to range, other circular measures of angular dispersion include:

1. Circular variance: S^2 = 1-r, ranging from 0 to 1.
2. Angular variance is $s^2 = 2*(1-r) = 2*S^2$, ranging from 0 to 2.
3. Variance measure: s_o^2 = -2*ln(r), ranging from 0 to infinity.
4. Angular deviation: $s = (180/pi)*[2*(1-r)]^{0.5} = (180/pi)*(s^2)^{0.5}$, ranging from 0° to 81.03°.
5. Circular standard deviation: $s_o = (180/pi)*[-2*\ln(r)]^{0.5} = (180/pi)*(so^2)^{0.5}$, ranging from 0 to infinity.
6. Circular mean deviation: CMD = (SUM|a_i - a_{bar}|)/n, where a_i = angular value of measurement "i", a_{bar} = mean angle, and the summation is from i=1 to n.

Confidence Interval for Population Mean

The lower (L_1) and upper (L_2) confidence limits for the mean angle (a_{bar}) are given by $L_1 = a_{bar} - d$ and $L_2 = a_{bar} + d$, where:

$d = \arccos[(1/R)*\{[2*n*(2*R^2 - n*X^2)]/(4*n - X^2)\}^{0.5}]$ for r<=0.9, $R>(n*X^2/2)^{0.5}$, and $n>X^2/4$
$d = \arccos\{(1/R)*[n^2 - (n^2 - R^2)*\exp(X^2/n)]^{0.5}\}$ for r>=0.9

where R = n*r.

Second Order Analysis: The Mean of Mean Angles

If the previously-described procedure of calculating the mean angle a_{bar} (along with length vector r, X, and Y) from a group of measured angles a_i (and their associated occurrence frequencies f_i) is repeated for several groups of measured angular data, then the result is a set of mean angles. For example, for each of "k" samples of circular (angular) data, values of a_{bar}, r, X, and Y are calculated via the above procedure. It is now desired to calculate the grand mean of these "k" mean angles. For each of the "k" samples, given a_{bar} and r, values of X = r*cos(a_{bar}) and Y = r*sin(a_{bar}) are calculated. These values of r*cos(a_{bar}) and r*sin(a_{bar}) are then summed over the "k" samples. The values of X_{bar} and Y_{bar} are then calculated as: X_{bar} = SUM[r*cos(a_{bar})]/k and Y_{bar} = SUM[r*sin(a_{bar})]/k, where the summation is from i=1 to k. Then the length vector r = $(X_{bar}^2 + Y_{bar}^2)^{0.5}$ is calculated. Knowing X, Y, and r, the cosine and sine components of the grand mean angle are given by cos(a_{bar}) = X_{bar}/r and sin(a_{bar}) = Y_{bar}/r. Simultaneous solution of these 2 equations yields a unique solution for a_{bar}.

Confidence Limits for the Second-Order Mean Angle

The precision of the above-calculated second order mean angle (i.e., grand mean angle) can be quantified by the calculation of confidence limits. The following equations are used to calculate b_1 and b_2, which are instrumental in calculating the lower and upper confidence limits:

$A = (k-1)/[SUM(x^2)]$
$B = -[(k-1)*SUM(x*y)]/[SUM(x^2) * SUM(y^2)]$
$C = (k-1)/[SUM(y^2)]$
$D = 2*(k-1)*\{1 - [SUM(x*y)^2]/[SUM(x^2) * SUM(y^2)]\} * F(a(1),2,k-2)/[k*(k-2)]$
$H = A*C - B^2$
$G = A*X_{bar}^2 + 2*B*X_{bar}*Y_{bar} + C*Y_{bar}^2 - D$
$U = H*X_{bar}^2 - C*D$
$V = (D*G*H)$
$W = H*X_{bar}*Y_{bar} + B*D$
$b_1 = (W+V)/U$
$b_2 = (W-V)/U$

where $SUM(x^2) = SUM(X^2) - [SUM(X)]^2/k$, $SUM(y^2) = SUM(Y^2) - [SUM(Y)]^2/k$, and $SUM(x*y) = SUM(X*Y) - [SUM(X*Y)]/k$.

The values of b_1 and b_2 each yields one of the confidence limits (i.e., either the lower limit or the upper limit). An M value is calculated for each of the b_i values as follows: $M = (1+b_i^2)^{0.5}$. Then sine = b_i/M and cosine = 1/M are calculated. A unique angle is obtained from the calculated "sine" and "cosine" value. Then, one of the confidence limits is either this unique angular value or the value of this angle plus or minus 180° (whichever is greater than 0° and less than 360°), whichever is closer to the mean angle.

3.1.2.4.2 Tests for circular uniformity

It is often desired to determine the nature of the distribution of the n angles (a_i) around the circle of 0° to 360°. Are the directional data (either individual or grouped into angular bins) distributed relatively uniformly (i.e., exhibit circular uniformity) around the circle (from 0° to 360°), or do the data exhibit directional bias by favoring one or more particular angles or ranges of angles? This question can be answered via statistical tests for circular uniformity, where the null (H_o) and alternative (H_a) hypotheses are stated as:

H_o: The sample came from a population with a uniform circular distribution (no directional bias).
H_a: The sample came from a population exhibiting bias in one or more directions (i.e., a non-uniform circular distribution).

Among the available parametric tests for circular uniformity, the Rayleigh test and modified Rayleigh test (or V-test) for significance of the mean angle assume a unimodal distribution, whereas the Hodges-Ajne, and Batschelet Omnibus tests for significance of the median angle do not have such a restrictive assumption (i.e., can be applied to unimodal, bimodal, and multi-modal distributions).

Rayleigh Test and V-Test for Significance of the Mean Angle (Unimodal Distributions)

The parametric Rayleigh test is used to test whether the given sampled population is uniformly distributed around a circle (i.e., possesses circular uniformity, having no mean direction), and is valid only for unimodal populations following a von Mises (VM) angular normal distribution. Non-unimodal (e.g., axially bimodal) datasets must first be transformed into unimodal data before Rayleigh's test can be applied to test for circular uniformity. Axially bimodal data, where the two angles with the highest occurrence frequencies are spaced exactly 180° apart, can be transformed into unimodal data by simply doubling all of the angles. “Rao's spacing test” can be used when the circular data are neither unimodal nor axially bimodal (Rao 1976; Batschelet 1981; Russell and Levitin 1994). Populations not following the von Mises distribution must undergo the following procedure before Rayleigh’s test can be applied:

1. Convert the angular data from angular scale to a linear scale.
2. Conduct statistic tests to determine if the data are normal (e.g., Kolmogorov-Smirnov test) and homoscedastic (possess homogeneity of variances) (e.g., Bartlett test).
3. Apply an appropriate data transformation (e.g., logarithmic, arcsin, square root) to the resultant linear data if the data are found to be non-normal or non-homoscedastic.
4. Convert the transformed linear data back to the angular scale.

Once the directional dataset is confirmed to be unimodal and follow the VM angular normal distribution, then the parametric Rayleigh test can be applied to test for circular uniformity. The null (H_o) and alternative (H_a) hypotheses and assumptions of the Rayleigh test are as follows:

H_o: The population has a uniform circular distribution with no mean direction.
H_a: The population has a non-uniform circular distribution with a mean direction.

“Rayleigh’s R”, given by R = n*r (where n = sample size), can be used to test how large a sample r must be to confidently indicate a non-uniform population distribution. “Rayleigh’s z”, given by $z = R^2/n = n*r^2 = R*r$ can be used to test the null hypothesis (H_o). Critical values of z as a function of sample size n and confidence level “a” are tabulated in published statistical tables. An approximation of the probability of Rayleigh’s R is given by $P = \exp([1 + 4*n + 4*\{n^2 - R^2\}]^{0.5} – [1 + 2*n])$. If Rayleigh’s z is greater than the critical z value, then H_o is rejected. Otherwise, H_o is accepted.

The non-parametric V-test (Greenwood and Durand 1955; Durand and Greenwood 1958) is a modification of the Rayleigh test such that a specific mean direction or expected mean angle (e.g., 90°) is specified when testing the null hypothesis (H_o). The H_o and H_a hypotheses are given by:

H_o: The population has a uniform circular distribution with no mean direction, OR has a non-uniform circular distribution with a mean direction that is different from the specified mean direction.
H_a: The population has a non-uniform circular distribution with a specified mean direction.

Because a mean direction is specified, the V-test is more powerful than the Rayleigh test (Batschelet 1972, 1981). For the Rayleigh test, rejection of H_o indicates only that the population has a mean direction, without indicating the specific mean direction. In contrast, for the V-test, rejection of H_o provides additional information on the specific mean direction; however, if the data has an actual mean direction that is different from the specified (tested) mean direction, the test may accept H_o for two reasons:

1. Either the population has a uniform circular distribution, OR,
2. The population has a non-uniform circular distribution with a mean direction that is different from the specified mean direction.

The test statistic for the V-test is given by $V = R*\cos(a_{bar} - u_o)$, where u_o is the predicted mean angle. The significance of V is determined from the “u” statistic: $u = V*(2/n)^{0.5}$. Critical values of u for different values of sample size n and confidence level “a” are tabulated in published statistical tables. As sample size n increases, the “u” statistic approaches a 1-tailed normal deviate $Z_a(1)$. If the data are grouped, then R is calculated from r_c rather than from r. If the u statistic is greater than the critical u value, then H_o is rejected. Otherwise, H_o is accepted.

Parametric 1-Sample Test for Mean Angle

The parametric 1-sample test for mean angle (analogous to the 1-sample t-test for data on a linear scale) is used to test whether the population mean angle (u_a) is equal to a specified value (u_o). The H_o and H_a hypotheses are given by:

H_o: The population has a mean angle (u_a) equal to the specified mean angle (u_o).
H_a: The population's mean angle (u_a) is NOT equal to the specified mean angle (u_o).

This test calculates the (1-a) confidence interval (CI) for u_a and determines whether u_o falls within this CI. H_o is rejected if u_o is outside the CI, and is accepted if u_o falls within the CI.

Hodges-Ajne, and Batschelet Omnibus Tests for Significance of the Median Angle (Unimodal, Bimodal, and Multi-Modal Distributions)

The Hodges-Ajne and Batschelet tests are omnibus tests in that they do not require the assumption of a unimodal data distribution (unlike the Rayleigh and V-tests). That is, these omnibus tests are applicable to unimodal, bimodal, and multimodal distributions; however, for unimodal distributions, the Rayleigh and V-tests are more powerful than these omnibus tests.

The null (H_o) and alternative (H_a) hypotheses for the Hodges-Ajne test are given by:

H_o: The population has a uniform circular distribution.
H_a: The population has a non-uniform circular distribution.

The Hodges-Ajne test (Ajne 1968) is applied by calculating, from the given sample of circular data of sample size n, the smallest number of data (m) falling within a range of 180°. The data are plotted on a circle, a diameter line is drawn through the circle (e.g., connecting 0° and 180°), and the number of data on each side of the line are counted. The diameter line is rotated by a certain angular resolution (e.g., by 1°, so that the new line intersects 1° and 181°), and the above procedure is repeated until all angle pairs (spaced 180° apart) are covered. Thus, for each angle pair defining the diameter line, the numbers of data on each side of the line are counted (with the smaller of these 2 numbers being designated as “m”, and the other number being “n-m”). The smallest “m” value is desired and is used as the “m” test statistic in running the Hodges-Ajne test.

The probability P of an m value at least this small is given by (Hodges et al. 1955): $P = 2^{(1-n)} * (n-2m) *_n C_m$, where $_nC_m = n!/(m! * [n-m]!)$. Critical values for m as a function of sample size n (up to n=50) and confidence level “a” are tabulated in published statistical tables. For larger sample sizes (n>50), P is calculated as $P = ([2*pi]^{0.5}/A)*\exp(-pi^2/[(8*A^2])$, where $A = pi*(n^{0.5})/(2*[n-2*m])$ and pi = 3.1415927. If the m statistic is less than the critical m value, then H_o is rejected. Otherwise, H_o is accepted.

The non-parametric Batschelet test (Batschelet 1981) is a modification of the Hodges-Ajne test such that a specific angle is specified when testing the null hypothesis (H_o). The H_o and H_a hypotheses are given by:

H_o: The population has a uniform circular distribution, OR has a non-uniform circular distribution that is concentrated around an angle that is different from the specified concentration angle.
H_a: The population has a non-uniform circular distribution that is concentrated around a specified concentration angle.

Because a concentration angle is specified, the Batschelet test is more powerful than the Hodges-Ajne test. For the Hodges-Ajne test, rejection of H_o indicates only that the population has a concentration angle, without indicating the specific angle. In contrast, for the Batschelet test, rejection of H_o provides additional information on the specific angle; however, if the data has an actual concentration angle that is different from the specified (tested) concentration angle, the test may accept H_o for two reasons:

1. Either the population has a uniform circular distribution, OR,
2. The population has a non-uniform circular distribution with a concentration angle that is different from the specified concentration angle.

The test statistic for the Batschelet test is given by C = n – m’, where n = sample size and m’ = number of data within 90° of the specified angle. A 2-tailed binomial test is then conducted, with p = 0.50 and with C counts in one category and m' counts in the other.

Critical values for C as a function of sample size n, number of tails (1 or 2), and confidence level “a” are tabulated in published statistical tables. If the C statistic is less than the critical C value, then H_o is rejected. Otherwise, H_o is accepted.

Test for Significance of the Median Angle: Binomial Test

This non-parametric test (Zar 1999) can be used to determine whether the population median angle is equal to a specified value. The H_o and H_a hypotheses are given by:

H_o: The population median angle is equal to the specified value.
H_a: The population median angle is NOT equal to the specified value.

The angular data are plotted on a circle, a diameter line is drawn through the specified angle, and the data on each side of this line are counted. A 2-tailed binomial test is then conducted, with p = 0.50.

Test for Symmetry around the Median Angle: Non-Parametric Wilcoxon Paired-Sampled (Signed-Rank) Test

The non-parametric Wilcoxon paired-sample test (or signed-rank test) is used to test the symmetry of a distribution around the median, using either 1-tailed or 2-tailed tests (Zar 1999). The H_o and H_a hypotheses are given by:

2-tailed test:
H_o: The underlying distribution is symmetrical around the median.
H_a: The underlying distribution is NOT symmetrical around the median.

1-tailed test (with "T-" as test statistic):
H_o: The underlying distribution is NOT skewed clockwise from the median.
H_a: The underlying distribution is skewed clockwise from the median.

1-tailed test (with "T+" as test statistic):
H_o: The underlying distribution is NOT skewed counter-clockwise from the median.
H_a: The underlying distribution is skewed counter-clockwise from the median.

For each angle (X_i), the deviation of X_i from the median angle (X_{median}) is calculated: $d_i = X_i - X_{median}$. The d_i values are ranked over the number of data points (i.e., sample size n), and the ranks are “signed” based on the sign of the deviation (i.e., positive deviations d_i have a positive rank, and negative deviations d_i have a negative rank). All of the positive signed ranks over the sample size n are summed to obtain the “T+” value. Likewise, all of the negative signed ranks are summed, and the absolute value of this sum is calculated, to obtain the “T-” value. Critical values T_{crit} as a function of sample size n (up to n=100) and confidence level “a” for both 1-tailed and 2-tailed tests are tabulated in published statistical tables. For the 2-tailed test, H_o is rejected if either “T+” or “T-” is less than T_{crit}, and is accepted if neither “T+” nor “T-” is less than T_{crit}. For the 1-tailed test, "T+" or "T" was used as the test statistic T_{stat}. H_o is rejected if $T_{stat} < T_{crit}$, and is accepted if $T_{stat} >= T_{crit}$.

1-Sample Second-Order Analysis of Angles: Parametric and Non-Parametric: Species, Group, Month, Season

One-Sample Second-Order Analysis of Angles

A first-order sample (directional dataset) consists of a set of "n" angles with a mean angle a_{bar} and an associated mean length vector r_{bar}, whereas a second-order sample consists of a set of "k" such means. Several parametric and nonparametric statistical tests are available to test for the significance of the mean of a set of mean angles. The validity of application of these various tests depends on assumptions of normality in the directional datasets. Parametric tests require the directional dataset to follow the VM distribution, which is the circular analog of the Gaussian normal distribution for linear datasets. Thus, inherently the directional datasets must exhibit circular non-uniformity (i.e., a mean angle(s) must exist), and the angular distribution around this mean angle must be normal according to the VM distribution, in order to apply parametric tests. If the directional dataset does not follow VM normality, then either the dataset must first be transformed and re-tested for VM normality before applying the parametric tests, or a nonparametric test can be applied to the non-transformed directional dataset.

The statistical significance of the mean of a set of mean angles can be tested parametrically via the Hotelling test (Hotelling 1931) and/or non-parametrically via the Moore test (Moore 1980).

Parametric 1-sample Hotelling Test

The Hotelling test (Hotelling 1931), being parametric, requires the sample of directional datasets (with "k" mean angles a_{bar}, "k" mean length vectors r_{bar}, etc.) to conform to VM normality and homoscedacity. In addition, this test requires that the directional data not be grouped. Assumptions for application of this test can be summarized as follows:

1. Bivariate normality: The second-order sample comes from a bivariate normal distribution (i.e., a population in which the X_j values follow a normal distribution, and the Y_j values are normally distributed).
2. The k X_{bar} values come from a normal distribution.
3. The k Y_{bar} values likewise come from a normal distribution.
4. The data are not grouped.

The H_o and H_a hypotheses are given by:

H_o: There is no mean population direction (angle).
H_a: There is a mean population direction (angle).

The sums of squares and cross-products of the k means are given by $SUM(x^2) = SUM(X_j^2) - [SUM(X_j)]^2/k$, $SUM(y^2) = SUM(Y_j^2) - [SUM(Y_j)]^2/k$, and $SUM(xy) = SUM(X_j*Y_j) - [SUM(X_j)*SUM(Y_j)]/k$, where the summations are from j=1 to k. For Hotelling's test, the test statistic is given by:

$$F = [k*(k-2)/2]*[X_{bar}^2*SUM(y^2) - 2*X_{bar}*Y_{bar}*SUM(xy) + Y_{bar}^2*SUM(x^2)] / \{SUM(x^2)*SUM(y^2) - [SUM(xy)]^2\}$$

where $X_{bar} = SUM(X_j)/k$ and $Y_{bar} = SUM(Y_j)/k$. The critical F value (tabulated in published statistical tables) is given by F[a(1),2,k-2], where a(1) refers to the 1-tailed test at the "a" confidence level (Batschelet 1978, 1981). The 2 degrees of freedom (DF_1, DF_2) relevant to the critical F value are given by $DF_1 = 2$ and $DF_2 = k-2$. If the F statistic is greater than the critical F value, then H_o is rejected. Otherwise, H_o is accepted.

Non-Parametric 1-sample Moore Test

Moore's test (Moore 1980) is a non-parametric modification of the Rayleigh test, which can be used to test a sample of mean angles. Since it is non-parametric, the Moore test, unlike the parametric Hotelling test, does not require the sample of directional datasets to conform to VM normality and homoscedacity. The H_o and H_a hypotheses are given by:

H_o: The population from which the sample of means came has a uniform circular distribution.
H_a: The population from which the sample of means came does NOT have a uniform circular distribution.

Associated with k mean angles, the k vector lengths are ranked from lowest to highest, and the test statistic is calculated as: R' = $[(X^2 + Y^2)/k]^{0.5}$, where X = SUM[i*cos($(a_{bar})_i$)]/k and Y = SUM[i*sin($(a_{bar})_i$)]/k. The test statistic R' is then compared to the critical value R'[a,n], which is tabulated in published statistical tables as a function of sample size n and confidence level "a". If the test statistic R' is greater than the critical R' value, then H_o is rejected. Otherwise, H_o is accepted.

Goodness-of-Fit Testing for Circular Distributions: Non-Parametric Chi-Square (X2) and Watson's 1-Sample U^2 Tests

Goodness-of-fit (GOF) tests are used to test the statistical significance of conformity of a given sample of nominal scale data (e.g., counts, abundances) to a specified or expected frequency distribution. A test statistic is used to quantify the deviation of the sample from the specified theoretical distribution, and is compared to an associated tabulated critical value, the latter of which is a function of the degrees of freedom (DF) and confidence level of interest (e.g., 90 percent, 95 percent, 99 percent). From the comparison between the test statistic and critical value, a probability is calculated along with a decision of whether to accept or reject the null hypothesis (H_o) of no difference. For GOF tests, H_o and the alternative hypothesis (H_a) can be generally stated as follows:

H_o: The sample came from a population that follows the specified theoretical (expected) frequency distribution.
H_a: The sample did NOT come from a population that follows the specified theoretical (expected) frequency distribution.

For the case of testing for uniform circular uniformity, H_o and H_a would be stated as:

H_o: The sample came from a population with a uniform circular distribution.
H_a: The sample did NOT come from a population with a uniform circular distribution.

The critical value is a threshold such that values of the test statistic in excess of the threshold represent sufficiently high deviations from the theoretical distribution to warrant a conclusion that the sample does not come from a population that follows the theoretical distribution (i.e., H_o is rejected). Conversely, if the test statistic is less than the critical value (threshold), then it can be concluded that the deviation of the sample from the theoretical distribution is sufficiently small as to conclude that the sample did indeed come from a population that follows the theoretical distribution (i.e., H_o is accepted, or not rejected). In summary:

1. If test statistic > critical value: H_o is rejected.
2. If test statistic < critical value: H_o is not rejected.

For the circular statistical analysis of bird directional data, the non-parametric chi-square (X^2; Zar 1999) and Watson's 1-sample U^2 tests (Watson 1961, 1962) are used to test the null hypothesis (H_o) of a uniform circular distribution. The H_o and H_a hypotheses are stated as:

H_o: The sample came from a population that follows a uniform circular distribution.
H_a: The sample did NOT come from a population that follows a uniform circular distribution.

Chi-Square (X^2) GOF Test

A typical sample of nominal scale data consists of "k" classes or categories, each of which is quantified by a frequency (or number of counts). In the current application of bird directional data, the nominal directional classes include the 8 directions (i.e., k=8): N (0° or 360°), NE (45°), E (90°), SE (135°), S (180°), SW (225°), W (270°), and NW (315°). The non-parametric chi-square (X^2) GOF test (Zar 1999) uses the following test statistic to measure the deviation of the sample from the specified theoretical distribution: X^2 = SUM[f_i – $f_{hat,i}$] ^{2}/$f_{hat,i}$, where f_i and $f_{hat,i}$ are the actual and expected frequencies, respectively, of class "i", and the summation is conducted over the "k" classes. The f(i) values are obtained directly from the sample, and the $f_{hat,i}$ values are calculated based on the theoretical frequency distribution specified in the null hypothesis (H_o). Two checks on the calculations are the following: 1) SUM[f_i] = n; 2) SUM[$f_{hat,i}$] = n, where n = sample size. The X^2 test statistic is compared to the critical X^2 value (tabulated in published statistical tables) for k-1 degrees of freedom (i.e., DF=k-1) for the desired confidence level (CL; e.g., 90 percent, 95 percent, 99 percent). The critical X^2 value correlates positively with DF and negatively with CL. If the X^2 statistic is greater than the critical X^2, then H_o is rejected. Otherwise, H_o is accepted.

Watson's 1-sample U^2 GOF Test

The non-parametric Watson's 1-sample U^2 GOF test (Watson 1961, 1962) normalizes the angular directional data from a 0° to 360° range to a range of 0 to 1, via the transformation: u_i = a_i/360°, where a_i = angular measurement (degrees) of data point "i", and u_i = normalized value (dimensionless, range=0 to 1). The U^2 statistic (Mardia 1972) is calculated as: U^2 = SUM u_i^2 – (SUM u_i)^2/n – (2/n)*SUM(i*u_i) + (n+1)*u_{bar} + n/12, where n = sample size; the summations are conducted for i=1 to n; and the mean value u_{bar} = SUM(u_i)/n. The U^2 test statistic is compared to the critical $U^2[a,n_1,n_2]$ value (tabulated in published statistical tables) for n_1=n and n_2=n for the desired confidence level "a" (e.g., 90 percent, 95 percent, 99 percent). The critical U^2 value correlates negatively with CL and n_1 and can correlate either positively or negatively with n_2. If the U^2 statistic is greater than the critical U^2, then the H_o is rejected. Otherwise, H_o is accepted.

3.2 RESULTS AND CONCLUSIONS

3.2.1 Shipboard Offshore Survey Effort

Shipboard avian survey lines for the January through November surveys were conducted along the same transect lines as the marine mammal/sea turtle lines but may differ in length and duration due to varying sea state condition requirements between the two efforts.

3.2.1.1 January 2008

Ship avian surveys commenced 12 January 2008. After a day-long delay on 14 January due to poor weather conditions, surveys were reinitiated on 15 January and concluded on 18 January 2008. The ship transects covered 528 km (285 NM; **Appendix B-1**: **Figure B-1.1**). On-effort survey time totaled 30.18 hrs.

3.2.1.2 February 2008

Ship avian surveys commenced on 12 February 2008 and were suspended that night because of poor weather conditions. Poor conditions persisted for the remainder of the week and a decision was made to cancel the February ship surveys. The ship surveys on 12 February 2008 covered 152 km (82 NM; **Figure B-1.2**). On-effort survey time totaled 9.04 hrs.

3.2.1.3 March 2008

Ship avian surveys commenced on 7 March 2008 but were suspended during the afternoon as a result of inclement weather conditions. The surveys resumed on 10 March 2008 and were completed on 14 March

2008. The ship transects covered 887 km (479 NM; **Figure B-1.3**). On-effort survey time totaled 49.15 hrs.

3.2.1.4 April 2008

Ship avian surveys commenced on 09 April 2008. There were four hour-long reductions to the potential survey efforts on 09 and 10 April 2008 because of poor visibility due to dense fog. The ship survey was cancelled on 11 April because of fog. The surveys resumed on 12 April 2008 and were completed on 14 April 2008. The ship transects covered 765 km (413 NM; **Figure B-1.4**). On-effort survey time totaled 41.72 hrs.

3.2.1.5 May 2008

Ship avian surveys commenced on 07 May 2008. There were four hour-long reductions to the potential survey efforts on 07 and 08 May 2008 and no efforts attempted on 09 May due to gale force winds (>20 kts) and high sea states (BSS ≥5). Shipboard surveys resumed on 10 May 2008 and concluded on 11 May 2008. The ship transects covered 576 km (311 NM; **Figure B-1.5**). On-effort survey time totaled 32.38 hrs.

3.2.1.6 June 2008

Ship avian surveys commenced on 13 June 2008 and were completed on 16 June 2008. Survey efforts on 14 June ended early because of poor visibility due to smoke and haze that drifted on southerly winds from forest fires in North Carolina. The ship transects covered 887 km (479 NM; **Figure B-1.6**). On-effort survey time totaled 49.27 hrs.

3.2.1.7 July 2008

Ship avian surveys commenced on 13 July 2008 and were completed on 16 July. The ship transects covered 763 km (412 NM; **Figure B-1.7**). On-effort survey time totaled 42.51 hrs.

3.2.1.8 August 2008

Ship avian surveys commenced on 11 August 2008 and were completed on 14 August. The ship transects covered 848 km (458 NM; **Figure B-1.8**). On-effort survey time totaled 48.50 hrs.

3.2.1.9 September 2008

Ship avian surveys commenced on 12 September 2008 and were completed on 16 September 2008. The ship transects covered 883 km (477 NM; **Figure B-1.9**). On-effort survey time totaled 49.92 hrs.

3.2.1.10 October 2008

Ship avian surveys commenced on 13 October 2008 and were completed on 17 October 2008. The ship transects covered 841 km (454 NM; **Figure B-1.10**). On-effort survey time totaled 44.87 hrs.

3.2.1.11 November 2008

Ship avian surveys commenced on 11 November 2008. Survey efforts ended early on 13 November 2008 due to rain and were delayed for one hour on 14 November 2008 due to fog. Ship surveys were cancelled on 15 and 16 November 2008 due to rain but were resumed and completed on 17 November 2008. The ship transects covered 559 km (302 NM; **Figure B-1.11**). On-effort survey time totaled 31.36 hrs.

3.2.2 Avian Occurrence and Abundance

A total of 110 species was observed during the shipboard offshore surveys from January through November 2008 (**Appendix B-2**: **Tables B-2.1** to **B-2.4**). Birds not identified to species were recorded to the lowest identifiable taxon (genus, family, or unknown). Several species (e.g., Fish Crow and Turkey Vulture) were observed on or over land when the ship was near shore. A total of 6 federal avian species of concern and 17 New Jersey state-listed endangered, threatened, or special concern species were observed.

Monthly species abundances (number per family and species per kilometer) were calculated for in-zone data (**Tables B-2.5** to **B-2.15**). Incidental data were reported as the total number of individuals per family and species per month.

3.2.2.1 Winter 2008

Fifteen species were observed on the January and February shipboard offshore surveys (**Table B-2.1**). The number of in-zone individuals observed in January was 1,350 (**Table B-2.5**) and in February was 251 (**Table B-2.6**). January and February totals are not comparable due to the limited survey effort in February (see **Section 3.1.2**).

The most abundant species observed in January was Northern Gannet (776 individuals), followed by Red-throated Loon (118), Common Loon (83), Herring Gull (71); and Black Scoter (63; **Table 3-3**). Species abundance data for February are not reported because the survey was limited to one day.

One federal species of concern, Razorbill, was recorded in January (37 individuals) and February (11). New Jersey state-listed species were not detected in either month (**Tables B-2.5** and **B-2.6**).

Table 3-3. The most abundant (No./km) avian species within the Study Area during the winter 2008 shipboard offshore transect surveys.

January 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Northern Gannet	776	1.55
Red-throated Loon	118	0.24
Common Loon	83	0.17
Herring Gull	71	0.14
Black Scoter	63	0.13
Total	**1,111**	**2.23**

[1] Includes avian observations within the 300-m x 300-m survey strip transect when the ship was traveling ≥7 kts
[2] No./km

3.2.2.2 Spring 2008

Sixty-two species were recorded during the March through May shipboard offshore surveys (**Table B-2.2**). The total monthly numbers of observed individuals increased from March (3,166; **Table B-2.7**) to April (3,428; **Table B-2.8**), then dropped off drastically in May (1,669; **Table B-2.9**). The increase from March to April was primarily a result of large numbers of northbound scoters. By May, duck and gannet migration had decreased, accounting for the large decline in overall numbers.

Northern Gannet was the most abundant species observed in spring in March (1,497) and May (531). Herring Gull was the second most abundant species in both March and May. In April, scoters (surf, black, and dark-winged) were the most abundant avian group (**Table 3-4**).

Table 3-4. The most abundant (No./km) avian species within the Study Area during the spring 2008 shipboard offshore transect surveys.

March 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Northern Gannet	1,497	1.81
Herring Gull	466	0.56
Long-tailed Duck	306	0.37
Red-throated Loon	180	0.22
Black Scoter	142	0.17
Total	**2,591**	**3.13**
April 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Surf Scoter	1,297	1.80
Northern Gannet	809	1.12
Black Scoter	335	0.46
Scoter, dark-winged (unknown)	204	0.28
Herring Gull	160	0.22
Total	**2,805**	**3.88**
May 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Northern Gannet	531	0.96
Herring Gull	197	0.36
Common Loon	161	0.29
Common Tern	151	0.27
Black Scoter	141	0.25
Total	**1,181**	**2.13**

[1] Includes avian observations within the 300-m x 300-m survey strip transect when the ship was traveling ≥7 kts
[2] No./km

Four federal species of concern were recorded: American Oystercatcher (2 individuals) and Razorbill (29) in March; Common Tern (2) and Razorbill (4) in April; and Least Tern (1) and Common Tern (184) in May. Ten species listed by New Jersey as endangered, threatened, or special concern were recorded: Great Blue Heron (5), American Oystercatcher (2), Eastern Meadowlark (1), and Vesper Sparrow (1) in March; Great Blue Heron (18), Osprey (4), and Common Tern (2) in April; Yellow-crowned Night-heron (1), Osprey (2), Northern Harrier (1), Least Tern (1), Caspian Tern (1), and Common Tern (184) in May (**Tables B-2.7** to **B-2.9**).

3.2.2.3 Summer 2008

Twenty-six species were observed during shipboard offshore surveys from June through July (**Table B-2.3**). The number of observed individuals increased from June (947; **Table B-2.10**) to July (1,032; **Table B-2.11**) due to the influx of foraging breeding birds and austral migrants (e.g., Wilson's Storm-petrel).

Decreasing numbers of Northern Gannet, Common Loon, and Herring Gull account for most of the overall decrease of individuals between May (1,669) and June (947).

Wilson's Storm-petrel was the most abundant species observed during June (338) and July (364), while Laughing Gull or Common Tern were the next most abundant species. Along with Northern Gannet, these species comprised the majority of sightings within the summer season (**Table 3-5**).

Table 3-5. The most abundant avian species within the Study Area during the summer 2008 shipboard offshore transect surveys.

June 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Wilson's Storm-petrel	338	0.41
Common Tern	182	0.22
Laughing Gull	174	0.21
Northern Gannet	132	0.16
Cory's Shearwater	57	0.07
Total	**883**	**1.07**

July 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Wilson's Storm-petrel	364	0.53
Laughing Gull	283	0.41
Common Tern	245	0.36
Cory's Shearwater	42	0.06
Northern Gannet	24	0.03
Total	**958**	**1.39**

[1] Includes avian observations within the 300-m x 300-m survey strip transect when the ship was traveling ≥7 kts
[2] No./km

One federal species of concern, Common Tern, was recorded in June (288 individuals) and July (314). Five species listed by New Jersey as endangered, threatened, or special concern were recorded: Common Tern (288) in June; Black-crowned Night-heron (1) and Common Tern (314) in July (**Tables B-2.10** and **B-2.11**).

3.2.2.4 Fall 2008

A total of 84 species was observed during the August through November shipboard offshore surveys (**Table B-2.4**). The number of observed individuals increased from July (1,032) to August (2,375). Most of the increase was due to increasing numbers of Wilson's Storm-petrels. Total numbers decreased in September (977) as Wilson's Storm-petrels departed (**Table B-2.13**). Total counts increased dramatically from September (977) to November (7,417) because of the arrival of southbound migrants/winter residents. The increase in the total number from September to October was due to an increase in cormorant and tern numbers (**Table B-2.14**) and in November because of the arrival of scoters and Northern Gannet (**Table B-2.15**).

Wilson's Storm-petrel (1,245) was the most abundant species in August. Common Tern (301), Double-crested Cormorant (962), and Surf Scoter (2,101) were the most abundant birds from September through November, respectively (**Table 3-6**). Laughing Gull was the second most abundant species each month during the fall season.

Two federal Species of Concern were recorded: Common Tern (584, 378, and 1 individuals) in August, September, and October, respectively and Peregrine Falcon (3) in October. Nine species listed by New Jersey as endangered, threatened, or special concern were recorded: Great Blue Heron (2), Yellow-crowned Night-heron (1), Sanderling (4), and Common Tern (584) in August Caspian Tern (1) and Common Tern (378) in September; Great Blue Heron (13), Osprey (1), Peregrine Falcon (3), Caspian Tern (1), Common Tern (1), and Black-throated Green Warbler (1) in October; Pied-billed Grebe (1), Great Blue Heron (5), Northern Parula (1), and Eastern Meadowlark (1) in November (**Tables B-2.12** to **B-2.15**).

Table 3-6. The most abundant avian species within the Study Area during the fall 2008 shipboard offshore transect surveys.

August 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Wilson's Storm-petrel	1,245	1.55
Laughing Gull	517	0.64
Common Tern	510	0.63
Great Black-backed Gull	56	0.07
Purple Martin	47	0.06
Total	**2,375**	**2.95**
September 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Common Tern	301	0.36
Laughing Gull	268	0.32
Great Black-backed Gull	203	0.24
Tern, small (unknown)	78	0.09
Herring Gull	36	0.04
Total	**886**	**1.05**
October 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Double-crested Cormorant	962	1.16
Laughing Gull	575	0.69
Forster's Tern	399	0.48
Northern Gannet	281	0.34
Herring Gull	127	0.15
Total	**2,344**	**2.82**
November 2008 Shipboard Offshore In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Surf Scoter	2,101	3.85
Laughing Gull	1,323	2.43
Northern Gannet	1,065	1.95
Black Scoter	1,062	1.95
Scoter, dark-winged (unknown)	510	0.94
Total	**6,061**	**11.12**

[1] Includes avian observations within the 300-m x 300-m survey strip transect when the ship was traveling ≥7 kts

[2] No./km

3.2.3 Density

Baseline avian density figures (maps) were generated (**Appendix B-3a**: **Figures B-3a.1** to **B-3a.10**). Baseline grid density figures for all birds were also generated, with monthly color-coded spatial maps illustrating the 72 grid boxes ranked according to avian density (**Appendix B-3b**: **Figures B-3b.1** to **B-3b.10**). A density map was not produced for February because the survey was limited to one day.

The grid boxes depicted in red (indicating avian densities in the top 20 percentile among the positive-density grid boxes) were designated as high-density grid boxes. These high-density grid boxes were further identified on a month-to-month basis and cumulatively by an "x" (**Table 3-7)**. Only those grid boxes that exhibited an occurrence frequency of 1 or greater (i.e., at least 1 month as a high-density grid box) were listed (**Table 3-7)**.

Each row, corresponding to a particular grid box, was summed over the total number of months of the survey (January through November 2008) to obtain the number of months that the given grid box was designated as a high-density grid box (i.e., "A" ranking). For example, for the offshore surveys, Grid box 1 was a high-density grid box in March and June, for a total of 2 months. Grid box 12 was designated as a high-density grid box in 7 months (January, March, April, May, June, September, and October), giving this grid box the highest monthly occurrence frequency among all 72 grid boxes covering the survey area.

Likewise, each column of table, corresponding to a particular month and the cumulative total, was summed over the number of grid boxes to obtain the total number of high-density grid boxes occurring in the given month and cumulatively. For example, in January, Grid boxes 12, 17, 18, 23, 56, 62, 63, 64, and 65 (9 grid boxes total) were high-density grid boxes. In February there were only 3 high-density grid boxes because of a limited survey effort, (many of the 72 grid boxes exhibited a zero avian density for this month); and there were 9 to 11 high-density grid boxes in each of the other months.

Summing the occurrence frequencies over both the total number of months (last row) and total number of grid boxes (second-to-last column), there were a total of 100 monthly high-density grid box occurrences (**Table 3-7**). The entry on the last line of the last column (13) represents the number of high-density grid boxes (out of 72 possible) for the cumulative or quasi-annual average spatial map (i.e., integrated over the number of months from January through November 2008).

The 2008 cumulative spatial map was generated by summing the abundances over all months (from January to November 2008) for each of the 72 grid boxes and then ranking them from highest to lowest cumulative abundance using the A to F scale (**Figure 3-1**). This quasi-annual average spatial map for the offshore surveys generally exhibits smoother spatial variability (compared to the monthly maps), reflecting a smoothing of the smaller-scale and shorter-term variations in avian abundances between months. Overall, the results for the offshore surveys show a consistent, uniform offshore density gradient (i.e., a decrease in density with increasing offshore distance) that is prevalent along the entire coastline of the Study Area, as reflected by a uniform distribution of 13 high-density (red) grid boxes nearshore (ranging from Barnegat Bay to Hereford Inlet), orange and yellow boxes (medium densities) concentrated near the middle of the Study Area, and green and blue grid boxes (low densities) concentrated along the eastern, northern, and southern offshore boundaries of the Study Area.

The spatial locations of the high-density grid boxes exhibit seasonal variability (**Appendix B-3b**: **Figures B.-3b.1** to **B-3b.10**). Generally, high-density grid boxes were concentrated more nearshore than offshore, indicating a gradient of decreasing avian densities as offshore distance increases. The high-density grid boxes in winter (January) were concentrated in the southernmost region of the survey area (off Hereford Inlet) and also nearshore in northern regions between Little Egg Inlet and Barnegat Bay. During the spring months (March, April, May), the high-density grid boxes changed from the southern region to the central and northern regions. There was also a subtle shoreward movement of high-density grid boxes between April and May. By May, high-density grid boxes were observed along the entire coastline of the survey area, from Barnegat Bay to Hereford Inlet. In early summer (June), the high-density grid boxes were congregated in the northern regions both nearshore and offshore (north of Little Egg Inlet). This northern concentration of high-density grid boxes then dissipated during July and August.

Table 3-7. Identification of avian high-density grid boxes (quartile rank = A) by month for the shipboard offshore surveys.

Grid No.[1]	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Total
1			x			x						2
2		x	x		x				x	x		5
7				x	x		x		x	x	x	6
8					x	x			x			3
9						x				x		2
12	x		x	x	x	x			x	x		7
13			x			x						2
14						x						1
17	x	x		x					x			4
18	x			x		x		x	x	x		6
19						x		x				2
20							x					1
22								x				1
23	x	x	x	x	x				x			6
24				x			x					2
25								x				1
29					x						x	2
30			x	x		x		x				4
31								x				1
32						x						1
35								x				1
36			x					x	x			3
37							x					1
38				x								1
42				x	x				x	x		4
43			x						x		x	3
46				x								1

Table 3-7 (*continued*). Identification of avian high-density grid boxes (quartile rank = A) by month for the shipboard offshore surveys.

Grid No.[1]	Jan-08	Feb-08	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Total
49					x							**1**
50										x	x	**2**
51					x					x	x	**3**
55			x							x	x	**3**
56	x		x				x				x	**4**
57							x					**1**
62	x		x		x							**3**
63	x						x			x	x	**4**
64	x						x				x	**3**
65	x											**1**
68							x	x				**2**
Total	**9**	**3**	**11**	**10**	**10**	**10**	**9**	**9**	**10**	**10**	**9**	**100**

[1] Non-zero grid boxes within the shipboard offshore survey area are not included.

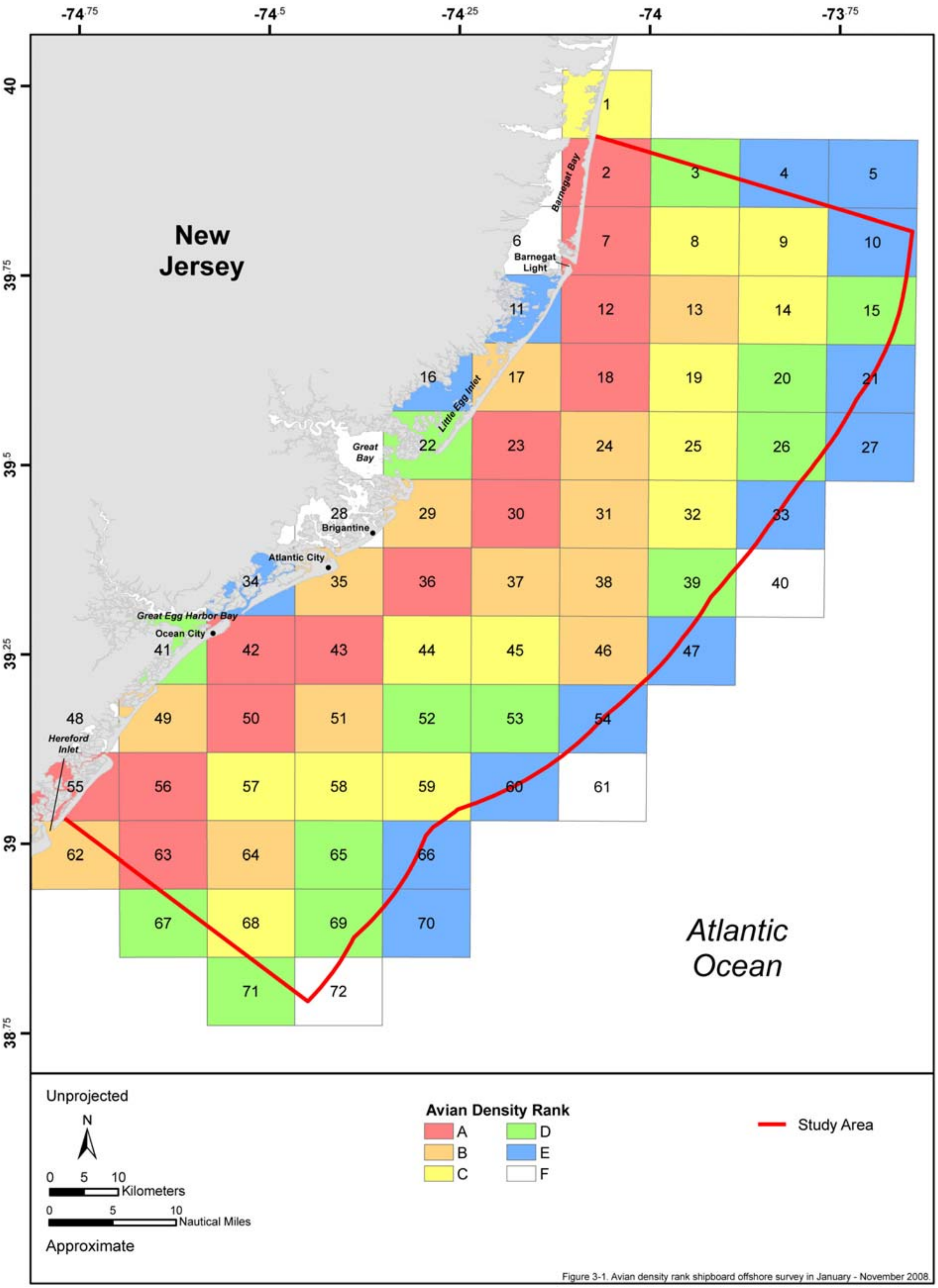

Figure 3-1. Cumulative avian high-density grids for the shipboard offshore surveys from January through November 2008 (excluding February).

For example, all 10 high-density grid boxes occurred in the northern region in June, whereas in July there were 5 high-density grid boxes in the southern region and only 4 high-density grid boxes in the northern region. Between July and August the northern high-density grid boxes moved slightly southward to the central region between Atlantic City and midway between Little Egg Inlet and Barnegat Light. In September the high-density grid boxes were concentrated nearshore in the central region (between Ocean City and Brigantine) and northern region (from Little Egg Inlet to Barnegat Bay). From September to November, the high-density grid boxes generally shifted southward: High-density grid boxes occurred in the northern and south-central regions in September and October, and with the exception the area adjacent to Barnegat Light, in the central and southern regions in November.

3.2.4 Offshore Altitude Distribution

In June and August no birds were observed flying in the RSZ (total numbers of flying birds were 838 and 2,220, respectively). February survey results were not reported because the survey effort was limited to one day. During the remaining months, the cumulative percentage of birds flying in the RSZ was 11.29 percent (**Table 3-8**; **Appendix B-4a**: **Tables B-4a.1a** to **B-4a.11b**). The monthly percentage of birds flying in the RSZ ranged from 3.91 to 25.06 percent (for months with birds flying in the RSZ and at least 100 flying individuals). May had the both the highest number of species and the highest percentage of birds flying in the RSZ.

Northern Gannet, Double-crested Cormorant, and Herring Gull were the most abundant species flying within the RSZ (**Table 3-8**). From January through November (excluding February), 10.75 percent of the Northern Gannets, 11.95 percent of the Double-crested Cormorants, and 10.55 percent of the Herring Gulls were flying in the RSZ. As a group, flying scoters were also abundant (1,178 individuals), with 16.81 percent flying in the RSZ. Terns were observed monthly from April through November, but were seen within the RSZ in May only (**Appendix B-4a**). One of the species, the Common Tern, is a federal species of concern for the region, and the Northern Harrier, a New Jersey state-listed endangered species, was observed once and flew within the RSZ.

3.2.5 Circular Statistics

The descriptive circular statistics of the avian shipboard offshore surveys off the New Jersey coast were summarized (**Appendix B-5a**: **Table B-5a.1)**, and show the sample size (n), X and Y values, length vector r, Rayleigh's R, Rayleigh's z, deviation, circular deviation, circular standard deviation (SD), mean angle, and the 95 percent CI for the mean angle for the top 10 most abundant species, the top 10 most abundant taxonomic groups, all months, all seasons, and all species combined. For example, for all species combined (n = 36695), length vector r = 0.0675, and mean angle = 148.20° (with a 95 percent CI ranging from 142.05° to 154.34°).

The first-order mean angle for each individual species, taxonomic group, month, and season was calculated based on the number of bird observations as sample size (n) (**Table B-5a.1**). The second-order mean angle (i.e., the mean of mean angles) for all species, groups, months, and seasons was then calculated by averaging the respective first-order mean angles over the number of species, groups, months, and seasons, respectively, as sample size (n). Only those species for which the length vector r>0 and first-order mean angle >0 were included in the calculations of second-order mean angle.

Second-order mean angles for all species, groups, months, and seasons were summarized (**Table B-5a.2**), along with the results of the parametric 1-sample second-order analysis (Hotelling test). Results show that, for the ship surveys, the null hypothesis (H_o) of no mean population direction was accepted in all four cases (i.e., species, group, month, and season).

Results of the non-parametric 1-sample second-order analysis (Moore test) were summarized (**Table B-5a.3**). Results show that, for the ship surveys, the null hypothesis (H_o) of no mean population direction was accepted in all four cases (i.e., species, group, month, and season).

Table 3-8. Avian species observed flying within the RSZ (31 to 152 m; 101 to 500 ft) during the 2008 shipboard offshore surveys. The first number reflects the individuals within the RSZ, and the number in parenthesis reflects the total number of birds observed flying.

Family Common Name	Month										Total	Percent Flying in RSZ
	Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Anatidae (geese and sea ducks)												
Gadwall								2 (2)			2 (2)	**100.00%**
American Black Duck										9 (12)	9 (12)	**75.00%**
Surf Scoter	1 (4)		26 (662)								27 (666)	**4.05%**
Black Scoter	1 (40)		10 (228)	140 (140)							151 (408)	**37.01%**
Black Scoter			20 (104)								20 (104)	**19.23%**
Gaviidae (loons)												
Red-throated Loon	5 (110)	2 (164)	11 (126)	3 (20)							21 (420)	**5.00%**
Common Loon	2 (20)		11 (40)	15 (76)							28 (136)	**19.12%**
Sulidae (gannets)												
Northern Gannet	109 (582)	15 (853)	73 (510)	106 (441)						21 (628)	324 (3,014)	**10.75%**
Phalacrocoracidae (cormorants)												
Double-crested Cormorant									115 (962)		115 (962)	**11.95%**
Ardeidae (herons)												
Great Blue Heron									5 (10)		5 (10)	**50.00%**
Accipitridae (hawks and eagles)												
Northern Harrier				1 (1)							1 (1)	**100.00%**
Laridae (gulls and terns)												
Laughing Gull				9 (106)					6 (483)		15 (589)	**2.55%**
Herring Gull	33 (66)	28 (387)	14 (150)	18 (179)		1 (8)			1 (110)		95 (900)	**10.55%**
Great Black-backed Gull	9 (32)	10 (46)	1 (50)	7 (87)		1 (14)					28 (229)	**12.23%**
Gull, large (unknown)		2 (6)	1 (3)								3 (9)	**33.33%**
Common Tern				5 (151)							5 (151)	**3.31%**
Forster's Tern				6 (43)							6 (43)	**13.95%**
Royal Tern				1 (6)							1 (6)	**16.67%**
Tern, small (unknown)				14 (41)							14 (41)	**34.15%**
Hirundinidae (swallows)												
Barn Swallow				1 (10)							1 (10)	**10.00%**
Total Flying	**160 (854)**	**57 (1,456)**	**167 (1,873)**	**326 (1,301)**	**0 (838)**	**2 (22)**	**0 (2,220)**	**2 (2)**	**127 (1,565)**	**30 (640)**	**871 (7,713)**	**-**
Percent Flying in RSZ	**18.73%**	**3.91%**	**8.92%**	**25.06%**	**-**	**9.09%**	**-**	**100.00%**	**8.11%**	**4.69%**	**11.29%**	**-**

Following the format of **Table B-5a.1**, the descriptive circular statistics for the all-species, all-groups, all-months, and all-seasons cases were summarized (**Table B-5a.4**). Due to space limitations, the tests for circular uniformity were applied to the all-species, all-groups, all-months, and all-seasons results rather than to each individual species, group, month, and season. Results are shown in **Table B-5a.5** (Rayleigh test), **Table B-5a.6** (V-test), **Table B-5a.7** (Hodges-Ajne test), **Table B-5a.8** (Batschelet test), **Table B-5a.9** (Binomial test), **Table B-5a.10** (Wilcoxon paired-sample or signed-rank test), **Table B-5a.12** (non-parametric X^2 GOF test), and **Table B-5a.12** (non-parametric Watson's 1-sample U^2 GOF test).

Consensual agreement was obtained among the various tests for circular uniformity for the ship surveys: At the 95 percent CL, the null hypothesis (H_o) of circular uniformity was accepted for all four cases (i.e., species, group, month, and season). For example, Rayleigh test probabilities are P=0.3862 (species), P=0.7027 (group), P=0.3418 (month), and P=0.6490 (season) (**Table B-5a.5**); V-test probabilities are P=0.0777 (species), P=0.3146 (group), P=0.0643 (month), and P=0.2336 (season) (**Table B-5a.6**); and Batschelet test probabilities are P=0.20 (species), P=0.80 (group), P=0.50 (month), and P=0.00 (season) (**Table B-5a.8**). For the species, group, month, and season cases, the 1-tailed Binomial test probabilities are P=0.0918, 0.2617, 0.1133, and 0.3125; the 2-tailed Binomial test probabilities are P=0.1837, 0.5235, 0.2266, and 0.6250 (**Table B-5a.9**); and Watson's 1-sample U^2 non-parametric GOF test yielded P=0.2394, 0.7974, 0.2417, and 0.7823, respectively (**Table B-5a.12**).

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4.0 AVIAN SMALL BOAT COASTAL SURVEYS

4.1 METHODOLOGY

4.1.1 Field Surveys

Small boat surveys were conducted to capture nearshore coastal bird activity that may have been missed during offshore surveys due to depth limitations of the shipboard offshore survey. A strip-transect method was used to conduct the small boat coastal survey. The survey method was identical to the method used for the avian shipboard surveys (**Section 3.1.1**) except that a “single saw-tooth” sample design was implemented to adequately survey the area. Initially, the small boat transects were designed to cover the area between the coast and the 10-m (33-ft) isobath. Beginning in March, the offshore survey ship proceeded beyond the 10-m (33-ft) isobath to the nearest safe location near the shoreline (i.e., depending on tide and wave conditions). Nearshore ship waypoints were plotted and the small boat tracklines were then generated to complete the shipboard tracklines to the shore and to the next ship survey waypoint(s). Transect length varied between months and was dependent on the tide and water depth during both the shipboard and small boat survey days.

The starting location for each survey was randomly determined among two starting points (north end and south end) by the toss of a coin. If daylight, weather, and sea state conditions allowed, the entire coastal area was surveyed in one day. All other field survey methods were identical to the methods described in **Section 3.1.1**.

4.1.1.1 Observer Training and Efficiency

The method used to conduct observer training and efficiency was identical to that described for the shipboard surveys in **Section 3.1.1.1**.

4.1.1.2 Data Quality Assurance/Quality Control

The daily survey data were downloaded to a laptop computer and reviewed by the SSB to determine if reporting errors were made; if so, the SSB conferred with the relevant observer to resolve any errors. See **Appendix A-1** for further details regarding quality assurance/quality control (QA/QC) for avian survey data.

4.1.2 Data Analysis

4.1.2.1 Avian Occurrence and Abundance

The data analysis methods were identical to those previously described in **Section 3.1.2**. In-zone data were analyzed and are discussed in **Section 4.2.2**. Incidental data were analyzed and can be found in **Appendix B-2**: **Tables B-2.5** to **B-2.15**.

4.1.2.2 Avian Density

Methods were the same as described in **Section 3.1.2.2**.

4.1.2.3 Altitude Distribution

The counts of all birds recorded during the coastal small boat transect surveys were used to determine altitude distribution within the Study Area. Methods were the same as described in **Section 3.1.2.3**.

4.1.2.4 Circular Statistical Analysis of Avian Directional Data

The statistical methods used to analyze the data were identical to those used for the avian shipboard offshore survey (**Section 3.1.2.4**).

4.2 Results and Conclusions

4.2.1 Small Boat Coastal Survey Effort

4.2.1.1 January 2008

The small boat coastal survey was conducted on 23 January 2008 covering 115 km (62 NM; **Appendix B-1**: **Figure B-1.1**). Survey effort was continuous; the total daily effort was 6.46 hrs.

4.2.1.2 February 2008

The small boat coastal survey was cancelled in February 2008. Ship coastal waypoints, which determine the coastal survey waypoints (trackline), were not generated in February because shipboard surveys were not completed that month due to poor weather conditions: Wind >10 m/s (33 ft/s) out of the east creating sea conditions of BSS >5; seas were 2 to 3 m (8 to 10 ft).

4.2.1.3 March 2008

The small boat coastal survey was conducted on 21 March 2008, covering 130 km (70 NM; **Figure B-1.3**). Survey effort was continuous; the total daily effort was 6.76 hrs.

4.2.1.4 April 2008

The small boat coastal survey was conducted on 18 April 2008, covering 109 km (59 NM; **Figure B-1.4**). Survey effort was continuous; the total daily effort was 5.75 hrs.

4.2.1.5 May 2008

The small boat coastal survey was conducted on 23 May 2008, covering 115 km (62 NM; **Figure B-1.5**). Survey effort was continuous; the total daily effort was 6.11 hrs.

4.2.1.6 June 2008

The small boat coastal survey was conducted on 20 June 2008, but the most northerly transects of the survey were not completed due to rain. The small boat transects covered 104 km (56 NM; **Figure B-1.6**). Survey effort was continuous; the total daily effort was 5.86 hrs.

4.2.1.7 July 2008

The small boat coastal survey was conducted on 21 July 2008 but was cancelled after 2 hours due to fog. The survey was finished on 27 July 2008. The small-boat transects covered 93 km (50 NM; **Figure B-1.7**). The total effort was 5.00 hrs.

4.2.1.8 August 2008

The small boat coastal survey was conducted on 18 August 2008, covering 117 km (63 NM; **Figure B-1.8**). Survey effort was continuous; the total daily effort was 6.18 hrs.

4.2.1.9 September 2008

The small boat coastal survey was conducted on 30 September 2008, covering 124 km (67 NM; **Figure B-1.9**). The survey ended one half-hour early due to rain; the total daily effort was 6.56 hrs.

4.2.1.10 October 2008

The small boat coastal survey was conducted on 30 October 2008, covering 131 km (71 NM; **Figure B-1.10**). Survey effort was continuous; the total daily effort was 6.86 hrs.

4.2.1.11 November 2008

The small boat coastal survey was conducted on 23 November 2008, covering 131 km (71 NM; **Figure B-1.11**). Survey effort was continuous; the total daily effort was 6.86 hrs.

4.2.2 Avian Occurrence and Abundance

A total of 69 species was observed during the small boat coastal surveys from January through November 2008 (**Appendix B-2**: **Tables B-2.1** to **B-2.4**). Birds not identified to species were recorded to the lowest identifiable taxon (genus, family, or unknown). Monthly species abundances (number of each family and each species per square kilometer) were calculated (**Tables B-2.5** to **B-2.15**). A total of 11 New Jersey State endangered, threatened, or special concern species were observed.

4.2.2.1 Winter 2008

A total of 19 species were observed during the January small boat coastal survey (**Table B-2.1**). The February 2008 small boat coastal survey was cancelled due to adverse weather conditions. The total number of individuals observed in January was 4,188 (**Table B-2.5**). Black Scoter (1,245) and Herring Gull (782) were the most abundant species observed during January, followed in abundance by scaup (Greater, Lesser, and unknown), Long-tailed Duck, and Ring-billed Gull (**Table 4-1**).

Two federal species of concern were recorded in January: American Oystercatcher (63 individuals) and Razorbill (15). Three species listed by New Jersey as endangered, threatened, or special concern were recorded in January: Bald Eagle (1), American Oystercatcher (63), and Sanderling (206; **Tables B-2.5** and **B-2.6**).

Table 4-1. The most abundant (No./km) avian species within the Study Area during the winter 2008 small boat coastal transect surveys.

January 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Black Scoter	1,245	11.04
Herring Gull	782	6.93
Scaup (unknown), *Aythya* (unknown)	750	6.65
Long-tailed Duck	427	3.79
Ring-billed Gull	400	3.55
Total	**3,604**	**31.96**

[1] Includes avian observations within the 300 m x 300 m (984 ft x 984 ft) survey strip transect when the ship was traveling ≥4 m/s (13 ft/s)
[2] No./km

4.2.2.2 Spring 2008

A total of 46 species was observed during the March through May 2008 small boat coastal surveys (**Table B-2.2**). The total monthly number of observed individuals decreased from March (2,644 **Table B-2.7**) through April (866; **Table B-2.8**) to May (246; **Table B-2.9**), because of a large decrease in the number of scoters and Herring Gulls observed from March to April. By May, duck and Northern Gannet migration had ceased, accounting for much of the decrease in overall numbers from April to May. Surf Scoter was the most abundant species in March (1,014) and April (301). Laughing Gull was the most abundant species in May (54; **Table 4-2**).

Four federal species of concern were recorded: American Oystercatcher (2 individuals) and Razorbill (1) in March; American Oystercatcher (1) in April; and Least Tern (1) and Common Tern (76) in May. Seven species listed by New Jersey as endangered, threatened, or special concern were recorded: American Oystercatcher (2) and Sanderling (449) in March; Great Blue Heron (1), Osprey (9), Northern Harrier (2), and American Oystercatcher (1) in April; and Great Blue Heron (1), Osprey (25), Sanderling (31), Least Tern (1), and Common Tern (76) in May (**Tables B-2.7** to **B-2.9**).

Table 4-2. The most abundant (No./km) avian species within the Study Area during the spring 2008 small boat coastal transect surveys.

March 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Surf Scoter	1,014	7.92
Herring Gull	947	7.40
Northern Gannet	256	2.00
Great Black-backed Gull	117	0.91
Long-tailed Duck	113	0.88
Total	**2,447**	**19.11**
April 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Surf Scoter	301	2.78
Northern Gannet	176	1.63
Herring Gull	92	0.85
Black Scoter	58	0.54
Great Black-backed Gull	47	0.43
Total	**674**	**6.23**
May 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Laughing Gull	54	0.47
Common Tern	43	0.38
Double-crested Cormorant	37	0.32
Great Black-backed Gull	34	0.30
Forster's Tern	22	0.19
Total	**190**	**1.66**

[1] Includes avian observations within the 300 m x 300 m (984 ft x 984 ft) survey strip transect when the ship was traveling ≥4 m/s (13 ft/s)
[2] No./km

4.2.2.3 Summer 2008

A total of 21 species was observed during the June and July 2008 small boat coastal surveys (**Table B-2.3**). Overall diversity and abundance were low during these surveys. Local coastal breeding birds and small numbers of migrating shorebirds accounted for most of the individuals counted during the season. The total monthly number of observed individuals decreased slightly from June (375; **Table B-2.10**) to July (306; **Table B-2.11**). Laughing Gull was the most abundant species observed during June (197) and July (169). Great Black-backed Gull was the second most abundant species observed in June (76), and Common Tern was the third most abundant species. Whimbrels were presumed to be early migrants and Common Tern were the second and third most abundant birds in July (**Table 4-3**).

Two federal species of concern were recorded: Common Tern (51 individuals) in June; and Common Tern (52) and Whimbrel (49) in July. Four species listed by New Jersey as endangered, threatened, or special concern were recorded: Osprey (21) and Common Tern (51) in June; and Osprey (6), Whimbrel (49), Sanderling (14), and Common Tern (52) in July (**Tables B-2.9** and **B-2.10**).

Table 4-3. The most abundant (No./km) avian species within the Study Area during the summer 2008 small boat coastal transect surveys.

June 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Laughing Gull	197	1.94
Great Black-backed Gull	44	0.43
Common Tern	41	0.40
Forster's Tern	32	0.31
Northern Gannet	14	0.14
Total	**328**	**3.22**
July 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Laughing Gull	169	1.84
Whimbrel	49	0.53
Common Tern	28	0.31
Forster's Tern	17	0.19
Great Black-backed Gull[3]	14	0.15
Total	**277**	**3.02**

[1] Includes avian observations within the 300 m x 300 m (984 ft x 984 ft) survey strip transect when the ship was traveling ≥4 m/s (13 ft/s)
[2] No./km
[3] Tied with Sanderling (14 individuals; abundance = 0.15)

4.2.2.4 Fall 2008

Forty-nine species were observed during the August through November 2008 small boat coastal surveys (**Table B-2.4**). The number of observed individuals decreased from August (1,140) to September (617; **Tables B-2.12** and **B-2.13**) and increased from October (1,418; **Table B-2.14**) to November (3,529; **Table B-2.15**), due to the large numbers of migrating waterbirds in the region at this season. Abundance among the fall months varied greatly among species. Fewer observations of Laughing Gulls accounted for much of the decrease in overall numbers between August and September. Laughing Gull was the most abundant species in August (579) and September (157; **Table 4-4**). Common Tern (214) and Great-blacked Gull (110) were the second most abundant species in August and September, respectively. Northern Gannet was the most abundant species in October (540) and November (1,311). Laughing Gull (211) was the second most abundant species observed in October and Canada Goose (646) was the second most abundant species observed in November. All gull species except Laughing Gull increased in number between October and November (**Tables B-2.12** to **B-2.15**).

Table 4-4. The most abundant (No./km) avian species within the Study Area during the fall 2008 small boat coastal transect surveys.

August 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Laughing Gull	579	5.03
Common Tern	214	1.86
Great Black-backed Gull	73	0.63
Tern, small (unknown)	63	0.55
Sanderling	62	0.54
Total	**991**	**8.61**
September 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Laughing Gull	157	1.27
Great Black-backed Gull	110	0.89
Herring Gull	73	0.59
Forster's Tern	63	0.51
Ring-billed Gull	44	0.36
Total	**447**	**3.62**
October 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Northern Gannet	540	4.21
Laughing Gull	211	1.64
Great Black-backed Gull	154	1.20
Double-crested Cormorant	94	0.73
Herring Gull	59	0.46
Total	**1,058**	**8.24**
November 2008 Small Boat Coastal In-Zone[1]		
Common Name	**Number**	**Abundance[2]**
Northern Gannet	1,311	10.01
Red-throated Loon	646	4.93
Ring-billed Gull	398	3.04
Bonaparte's Gull	339	2.59
Canada Goose	231	1.76
Total	**2,925**	**22.33**

[1] Includes avian observations within the 300 m x 300 m (984 ft x 984 ft) survey strip transect when the ship was traveling ≥4 m/s (13 ft/s)
[2] No./km

Two federal species of concern were recorded: Common Tern (214 and 14) in August and September, respectively; and American Oystercatcher (17) in October. Seven species listed by New Jersey as endangered, threatened, or special concern were recorded: Osprey (1), Sanderling (79), and Common Tern (214) in August; Great Blue Heron (12), Osprey (1), Sanderling (6), Caspian Tern (5), and Common Tern (14) in September; Great Blue Heron (7), American Oystercatcher (17), and Sanderling (211) in October; and Sanderling (201) in November.

4.2.3 Density

Baseline avian density figures (maps) were generated (**Appendix B-3a**: **Figures B-3a.1** to **B-3a.10**). Baseline grid density figures (maps) for all birds identified during the coastal surveys were also generated, with monthly color-coded spatial maps illustrating the 72 grid boxes ranked according to avian density are given (**Appendix B-3b**: **Figures B-3b.11** to **B-3b.20**) for the coastal small boat surveys. Density results do not include February because the coastal survey was not conducted.

The grid boxes depicted in red (indicating avian densities in the top 20 percentile among the positive-density grid boxes) were designated as high-density grid boxes. These high-density grid boxes are further identified on a month-to-month basis and cumulatively by an “x” (**Table 4-5**). Only those grid boxes that exhibited an occurrence frequency of 1 or greater (i.e., at least one month as a high-density grid box) were listed in the tables.

Each row, corresponding to a particular grid box, was summed over the total number of months of the survey (January through November 2008) to obtain the number of months that the given grid box was designated as a high-density grid box (i.e., “A” ranking). For example, for the coastal surveys, grid boxes 42 and 49 each exhibited the highest monthly occurrence frequency (four months) as a high-density grid box.

Likewise, each column, corresponding to a particular month and the cumulative total, was summed over the number of grid boxes to obtain the total number of high-density grid boxes occurring in the given month and cumulatively. For the coastal surveys, there were no high-density grid boxes in February (because of limited survey effort) and either two or three high-density grid boxes in each of the other months.

Summing the occurrence frequencies over both the total number of months (last row) and total number of grid boxes (second-to-last column) produced a total of 27 monthly high-density grid box occurrences for the coastal surveys (**Table 4-5**). Because of the restricted spatial range of the survey effort, there were significantly fewer high-density grid boxes for the coastal surveys than for the offshore surveys. Indeed, as shown on the color-coded monthly spatial maps, all of the offshore grid boxes for the coastal surveys were colored white, indicating zero avian density (i.e., no bird sightings due to zero survey effort offshore). Among the grid boxes with positive densities, the top 20 percent with the highest densities were designated as high-density grid boxes. Thus, the number of high-density grid boxes generally decreases as the number of grid boxes with zero densities increases.

The 2008 cumulative spatial map (obtained by summing abundances over all months from January to November 2008 and then applying the A to F ranking scale) for the coastal surveys show three high-density grid boxes occurring quasi-annually: Atlantic City, Ocean City, and south of Ocean City (**Figure 4-1**). In contrast, low-to-moderate densities occurred in the northern and central regions north of Atlantic City and also in the southern region around Hereford Inlet. The offshore grid boxes for the cumulative spatial map are predominantly white due to limited survey effort (since the coastal surveys were concentrated nearshore).

Table 4-5. Identification of avian high-density grid boxes (quartile rank = A) by month for the small boat coastal surveys.

Grid No.[1]	Jan-08	Feb-08[2]	Mar-08	Apr-08	May-08	Jun-08	Jul-08	Aug-08	Sep-08	Oct-08	Nov-08	Total
2									x		x	2
7					x			x		x		3
11			x									1
12			x									1
17					x				x			2
29				x	x							2
35	x					x	x					3
41	x			x								2
42			x				x	x			x	4
49				x					x	x	x	4
55						x				x		2
56								x				1
Total	**2**	**0**	**3**	**3**	**3**	**2**	**2**	**3**	**3**	**3**	**3**	**27**

[1] Non-zero grid boxes within the coastal survey area are not included.
[2] The coastal survey was not conducted in February because of inclement weather conditions.

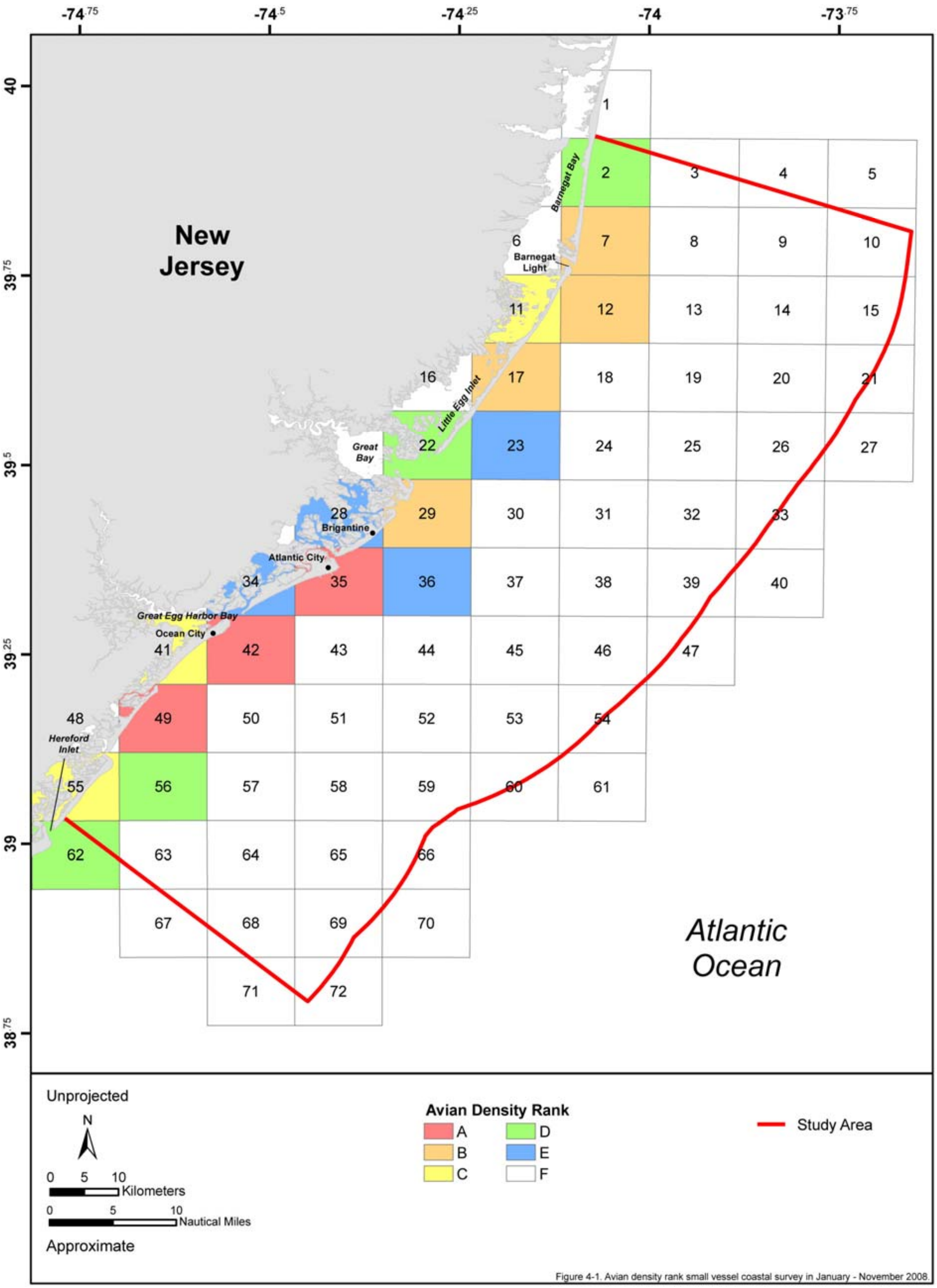

Figure 4-1. Cumulative avian high-density grids for the small boat coastal surveys from January through November 2008 (excluding February).

During the monthly coastal surveys two or three high-density grid boxes occur in any given month (except for February, when no coastal surveys were conducted; **Figures B-3b.11** to **B-3b.20**). In January, two high-density grid boxes occurred in the central and south-central region (Atlantic City and just south of Ocean City). Ocean City high-density grid boxes remained through March and April, whereas the Atlantic City high-density grid box dissipated and was replaced by high-density grid boxes further north (between Little Egg Inlet and Barnegat Light in March, and between Brigantine and Little Egg Inlet in April). Three high-density grid boxes were distributed nearshore from the central to northern regions in May. In the early summer months (June and July) the northern high-density grid boxes dissipated; high-density grid boxes reappeared in the central region (from Atlantic City to Ocean City in June and July) and southern region (Hereford Inlet in June). In the fall, high-density grid boxes occurred at Ocean City and north of Hereford Inlet in August, while a northern high-density grid box re-appeared off Barnegat Bay. During September, October, and November the high-density grid boxes remained relatively constant and prevalent in the northern region (Barnegat Bay) and southern regions (south of Ocean City and Great Egg Harbor Bay).

4.2.4 Altitude Distribution

In January and June birds were not observed flying within the RSZ (total numbers of flying birds were 810 and 293, respectively). From January through November, 18.95 percent of the birds flying were within the RSZ (31 to 152 m [101 to 500 ft] AMSL; **Table 4-6**). The monthly percentage of all birds flying in the RSZ from January through November ranged from 0 to 10.34 percent.

Sample sizes were low for most species. Northern Gannet and Laughing Gull were the most numerous species recorded flying. Overall, 6.67 percent of the Northern Gannets and 1.58 percent of the Laughing Gulls were flying in the RSZ from January through November. The greatest number of species observed in the RSZ occurred in October (**Appendix B-4b**; **Tables B-4b.1a** to **B-4b.10b)**. No state-listed or federal Species of Concern were observed flying within the RSZ (**Appendix B-4b**).

Some notable exceptions to the low RSZ percentages were identified: In November all of the 231 Canada Geese flew within the RSZ. Northern Gannets flying within the RSZ comprised approximately 12 percent of total flying gannets in March and April, and 4 percent in October (**Table 4-6**).

4.2.5 Circular Statistical Analysis of Avian Directional Data for the New Jersey Small Boat Coastal Surveys

The descriptive circular statistics of the avian coastal (boat) surveys off the New Jersey coast are summarized in **Table B-5b.1**, which lists the sample size (n), X and Y values, length vector r, Rayleigh's R, Rayleigh's z, deviation, circular deviation, circular SD, mean angle, and the 95 percent CI for the mean angle for each species, taxonomic group, month, season, and for all species combined. For example, for all species combined (n=18532), length vector r=0.5846, and mean angle = 200.75° (with a 95 percent CI ranging from 199.84° to 201.66°).

The first-order mean angle for each individual species, taxonomic group, month, and season was calculated based on the number of bird observations as sample size (n) (**Table B-5b.1**). The second-order mean angle (i.e., the mean of mean angles) for all species, groups, months, and seasons was then calculated by averaging the respective first-order mean angles over the number of species, groups, months, and seasons, respectively, as sample size (n). Only those species for which the length vector r>0 and first-order mean angle >0 were included in the calculations of second-order mean angle (**Table B-5b.1**).

Table 4-6. Avian species observed flying within the RSZ (31 to 152 m [101 to 500 ft]) during the 2008 small boat coastal surveys. The first number reflects the individuals flying within the RSZ, and the number in parenthesis reflects the total number of birds observed flying.

Family Common Name	Month										Total	Percent Flying in RSZ
	Jan	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov		
Anatidae (geese and sea ducks)												
Canada Goose										231 (231)	231 (231)	**100.00%**
American Black Duck									12 (20)		12 (20)	**60.00%**
Mallard									1 (1)		1 (1)	**100.00%**
Northern Pintail									1 (4)		1 (4)	**25.00%**
Greater Scaup									3 (13)		3 (13)	**23.08%**
Black Scoter			1 (28)								1 (28)	**3.57%**
Duck (unknown)									1 (1)		1 (1)	**100.00%**
Gaviidae (loons)												
Red-throated Loon									9 (21)		9 (21)	**42.86%**
Common Loon			2 (16)						2 (15)		4 (31)	**12.90%**
Sulidae (gannets)												
Northern Gannet		23 (200)	9 (72)						16 (448)		48 (720)	**6.67%**
Pelecanidae (pelicans)												
Brown Pelican							2 (4)				2 (4)	**50.00%**
Phalacrocoracidae (cormorants)												
Double-crested Cormorant									17 (93)		17 (93)	**18.28%**
Laridae (gulls and terns)												
Laughing Gull						2 (161)	6 (313)	1 (100)			9 (574)	**1.58%**
Herring Gull			2 (28)								2 (28)	**7.14%**
Great Black-backed Gull		2 (34)		2 (22)							4 (56)	**7.14%**
Gull, large (unknown)			1 (1)								1 (1)	**100.00%**
Total Flying	**0 (810)**	**25 (234)**	**15 (145)**	**2 (22)**	**0 (293)**	**2 (161)**	**8 (317)**	**1 (100)**	**62 (616)**	**231 (231)**	**346 (1826)**	**-**
Percent Flying in RSZ	**-**	**10.08%**	**10.34%**	**9.09%**	**-**	**1.24%**	**2.52%**	**1.00%**	**10.06%**	**100.00%**	**18.95%**	**-**

Second-order mean angles for all species, groups, months, and seasons were summarized (**Table B-5b.2)** along with the results of the parametric 1-sample second-order analysis (Hotelling test). Results show that, for the boat surveys, the null hypothesis (H_o) of no mean population was rejected for the species, group, and month cases, and was accepted for the season case (**Table B-5b.1**).

Results of the non-parametric 1-sample second-order analysis (Moore test) were summarized (**Table B-5b.3)**. Results show that, for the boat surveys, the null hypothesis (H_o) of no mean population direction was rejected. Comparing these results for the boat surveys with those for the ship surveys (**Section 3.2.2**), it is observed that, with respect to accepting or rejecting H_o, the Hotelling and Moore tests generated the same conclusions for all four cases for both the ship surveys and boat surveys.

Following the format of **Table B-5b.1**, the descriptive circular statistics for the all-species, all-groups, all-months, and all-seasons cases were summarized (**Table B-5b.4)**. Due to space limitations, the tests for circular uniformity were applied to the all-species, all-groups, all-months, and all-seasons results rather than to each individual species, group, month, and season. Results are shown in **Table B-5b.5** (Rayleigh test), **B-5b.6** (V-test), **B-5b.7** (Hodges-Ajne test), **B-5b.8** (Batschelet test), **B-5b.9** (Binomial test), **B-5b.10** (Wilcoxon paired-sample or signed-rank test), **B-5b.11** (non-parametric X^2 GOF test), and **B-5b.12** (non-parametric Watson's 1-sample U^2 GOF test).

For the boat surveys, the various tests generated conflicting results in some cases (probably due to a smaller sample size for the boat surveys compared to the ship surveys). For example, the V-test rejected H_o for all four cases (i.e., species, group, month, and season), whereas the Rayleigh test rejected H_o for all cases except the season case. For the species, group, month, and season cases, P=0.0000, 0.0093, 0.0248, and 0.1981 for the Rayleigh test (**Table B-5b.5**), and P=0.0000, 0.0010, 0.0030, and 0.0359 for the V-test (**Table B-5b.6**), respectively. The Hodges-Ajne test rejected H_o for the species and month cases only (**Table B-5b.7**), whereas the Batschelet test and binomial test rejected H_o for the species case only (**Table B-5b.8**). For the species, group, month, and season cases, the Batschelet test probabilities are P=0.00, 0.20, 0.20, and 1.00 (**Table B-5b.8**); the 1-tailed Binomial test probabilities are P=0.0000, 0.0592, 0.0547, and 0.3125; and the 2-tailed Binomial test probabilities are P=0.0000, 0.1185, 0.1094, and 0.6250, respectively (**Table B-5b.9**). The Wilcoxon test accepted H_o for all cases (**Table B-5b.10**), and Watson's 1-sample U^2 non-parametric GOF test rejected H_o for all cases except the season case (**Table B-5b.12**). For the species, group, month, and season cases, the Watson test probabilities are P=0.0000, 0.0011, 0.0110, and 0.4112, respectively (**Table B-5b.12**).

5.0 AVIAN AERIAL SURVEYS

This section describes the avian aerial survey conducted for the NJDEP Baseline Studies Project on 16 April 2008. Methodology, results, and conclusion are presented.

5.1 METHODOLOGY

Avian aerial survey methods were based primarily on recommendations made by Camphuysen et al. (2004). A strip transect survey sampling design was selected to collect avian data. Transect lines were spaced 2 NM apart and orientated perpendicular to the coastline (**Figure 5-1**). The 34 transect lines were divided (even or odd numbered) and flown during separate morning and afternoon sessions (i.e., half were flown in the morning and half in the afternoon). This design provided comparable spatial and temporal coverage of the entire Study Area. On the day of the survey, a coin toss determined whether the surveys started at the north or south end of the survey area. Another coin toss determined whether the odd or even numbered survey transects were flown in the morning. After a mid-day break, the remaining transects were flown.

The survey aircraft was a twin-engine Cessna Skymaster 337. Surveys were flown at approximately 76.2 m (250 ft) altitude at a speed of ~220 kilometers per hour (kph; 110 kts). Two avian biologists/observers conducted the avian strip transect surveys. A third scientist observer was responsible for ensuring the operational status of computer that was connected to the plane's GPS to accurately record the transect sighting coordinates and transect start and end times. The data acquisition computer was interfaced with the aircraft GPS system. Automated data acquisition included the time, date, latitude, longitude, speed, and heading of the aircraft, and GPS signal strength; data were collected at 10-s intervals.

The two avian biologists were stationed at each of the back side windows; the other (third) observer was stationed in the front seat next to the pilot. Avian observers recorded: transect number; transect start/end times (to the nearest second); transect side; identity (lowest practical taxon [four-letter standard code]; number of individuals (approximate number for flocks); distance bin (based on perpendicular distance from the aircraft's heading) and behavior (flying, foraging, etc) with a digital voice recorder. The three distance bins were: A = 44 to163 m (144 to 535 ft); B = 164 to 432 m (538 to 1417 ft); and C = 433 to 1,000 m (1420 to 3281 ft). The declination in the degrees from the horizon were 60° to 25° for Bin A, 25° to 10° for Bin B, and 10° to 4° for Bin C for an aircraft flying at 76 m (250 ft) AMSL. Prior to initiating the survey the biologists used an inclinometer to mark these bin lines on the aircraft window to aid in sorting observations into these distance bins. The avian biologists completed QA/QC protocols (see New Jersey Department of Environmental Protection Quality Assurance Work Plan Revision **III**; GMI 2008a) prior to take-off and after landing.

The avian aerial survey was conducted on 16 April 2008. Weather conditions during the survey were nearly perfect. Skies were clear, wind speeds were low (0 to 5 miles per hour [mph]), and the BSS ranged from 0 to 1. All 34 proposed transects were flown on 16 April (**Figure 5-2**). Transects were flown in an alternating pattern to provide data on temporal variation. The aerial survey was initiated at 8:52:13 AM Eastern Daylight Time (EDT) on Transect 1 (south end of the Study Area; see **Figure 5-2**). The morning flight ended at Transect 33 at 12:27:35 PM EDT. The afternoon flight started on Transect 2 at 2:12:32 PM EDT and ended at Transect 34 at 5:51:50 PM EDT. The total survey effort for the avian aerial survey was 7:04:54 hr. The total length of all transects was 593 NM.

Transect data were transcribed from the digital voice recorders into an Excel spreadsheet. The voice recordings were not audible on one of the two recorders. An attempt was made to reduce background noise; however, the voice recordings were still inaudible. Therefore, this report only includes data from one of the two avian observers (i.e., from one side of the aircraft).

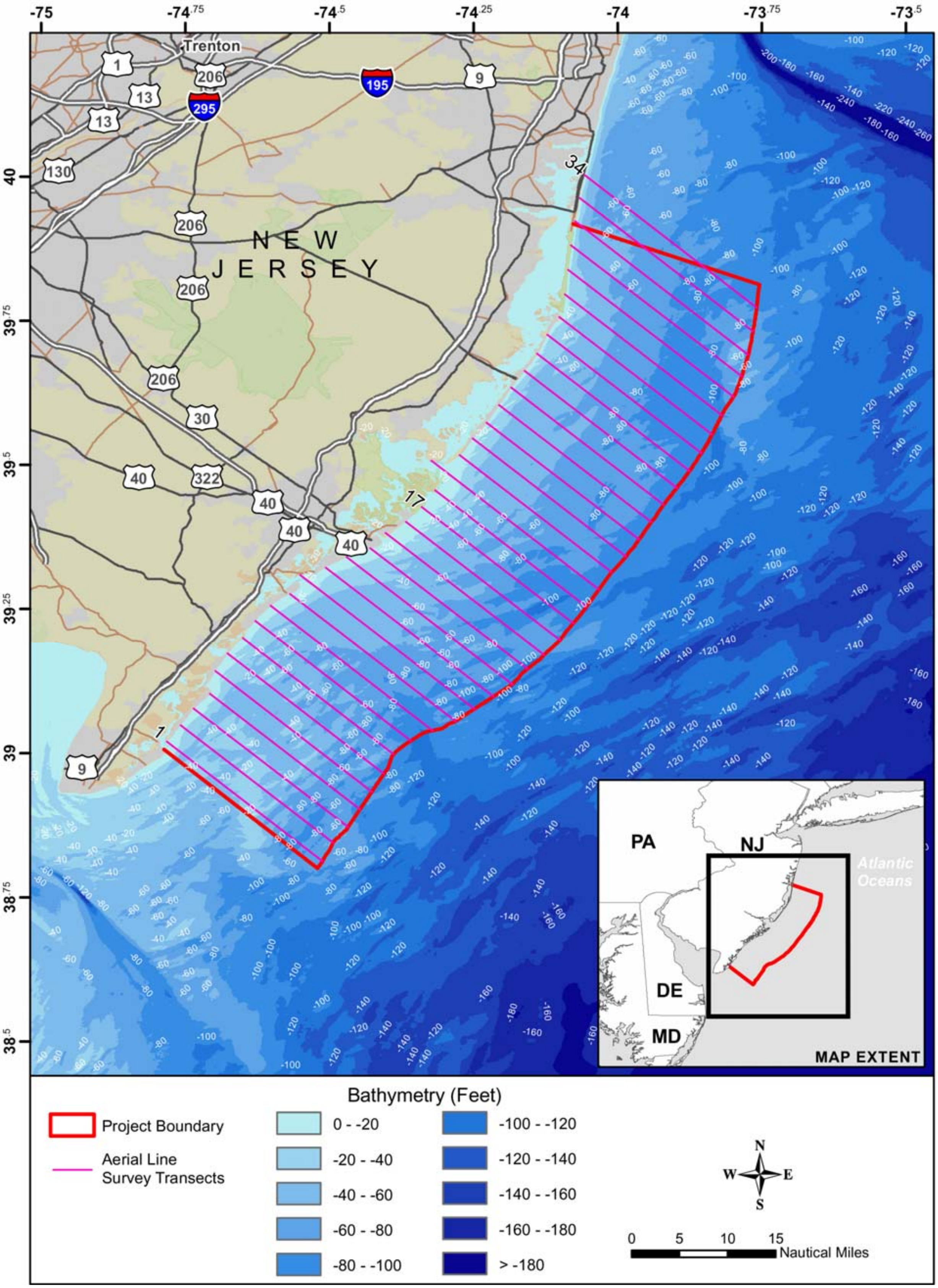

Figure 5-1. Proposed avian aerial survey transects.

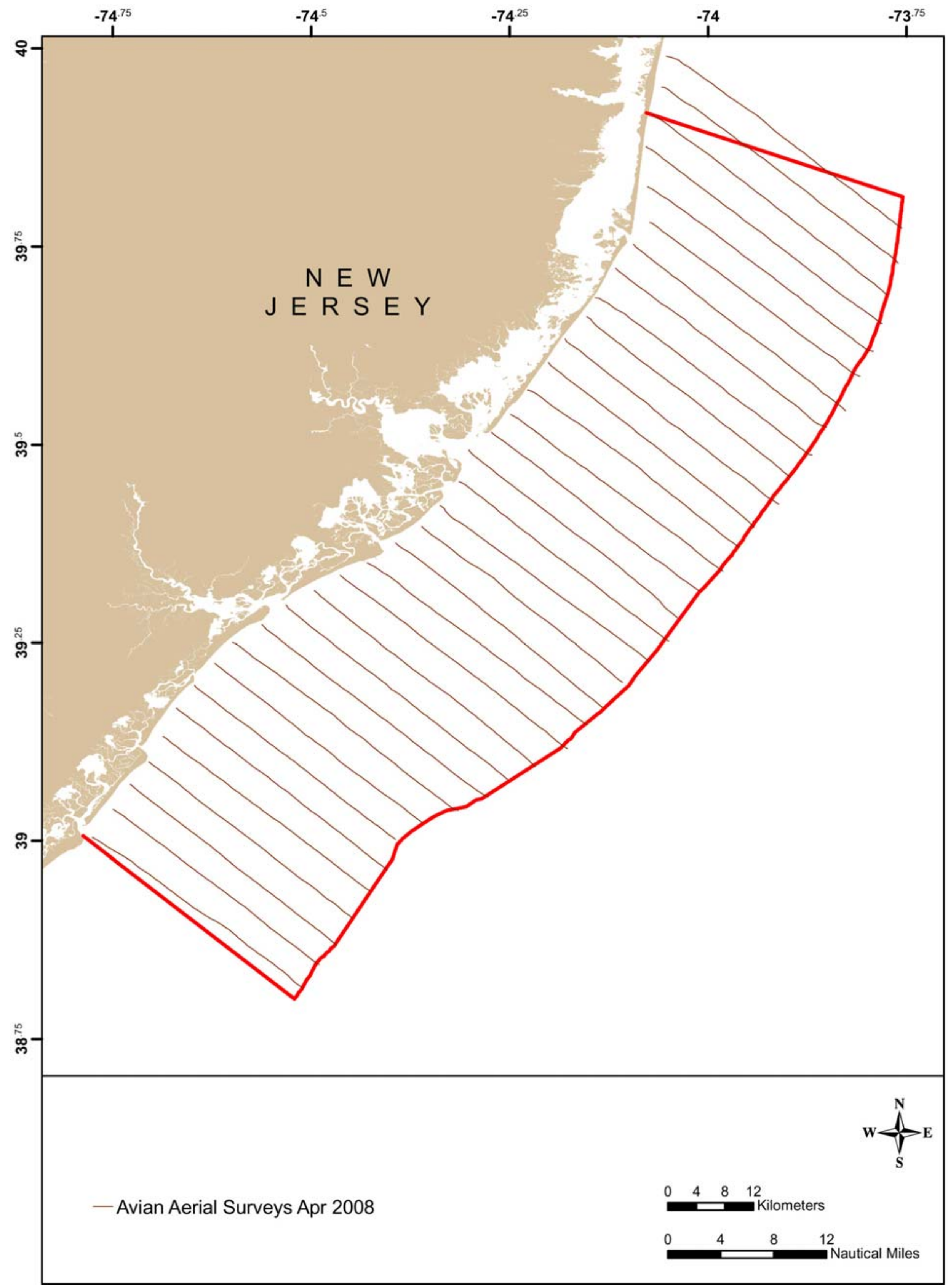

Figure 5-2. Actual avian aerial survey tracklines for 16 April 2008.

5.2 RESULTS AND CONCLUSIONS

Ten avian species were identified during the aerial survey (**Table 5-1**). Five categories were used to designate birds that could not be identified to species. No federal or state listed bird species were observed. Ten bird species were identified in the morning and eight were detected in the afternoon (**Table 5-1**).

Table 5-1. Avian species observed during the 16 April 2008 aerial survey.

Family Common Name	Full-Day Survey	Morning	Afternoon
Anatidae (sea ducks)			
Surf Scoter	X		X
Black Scoter	X	X	
Scoter (unknown)	X	X	
Gaviidae (loons)			
Red-throated Loon	X	X	X
Common Loon	X	X	X
Loon (unknown)	X	X	X
Sulidae (gannets)			
Northern Gannet	X	X	X
Laridae (gulls, terns)			
Bonaparte's Gull	X	X	
Laughing Gull	X	X	X
Herring Gull	X	X	X
Great Black-backed Gull	X	X	X
Gull, small (unknown)	X	X	
Gull (unknown)	X	X	
Forster's Tern	X	X	
Unidentified			
Passerine	X	X	

Northern Gannet, Red-throated Loon, and Common Loon were the most abundant species detected during the aerial survey (**Table 5-2**). Temporal variation in abundance occurred between the morning and afternoon surveys; more birds were detected in the morning (332) than in the afternoon (199; **Table 5-2**).

Many variables affect bird activity and behavior. For example, differences in morning and afternoon abundance may have resulted from birds migrating over the Study Area in the morning, birds foraging in the Study Area during the morning and migrating north out of the Study Area by early afternoon, and decreased avian foraging activity as a result of lower prey abundance in the afternoon. The primary differences between morning and afternoon counts were decreased numbers of red-throated and common loons detected in the afternoon. The peak of red-throated loon migration occurs from early March through mid-April, and common loon migration peaks from early April to mid-May (Walsh et al. 1999). It is possible that migrating loons (both flying and/or foraging) were detected in the morning but were no longer present in the afternoon.

Table 5-2. Abundance and percent composition of birds observed during the 16 April 2008 aerial survey.

Family Common Name	Morning		Afternoon	
	Number	**% Composition**	**Number**	**% Composition**
Anatidae (sea ducks)				
Surf Scoter			15	7.5
Black Scoter	1	0.3		
Scoter (unknown)	1	0/3		
Gaviidae (loons)				
Red-throated Loon	67	20.2	18	9.1
Common Loon	59	17.8	9	4.5
Loon (unknown)	11	3.3	3	1.5
Sulidae (gannets)				
Northern Gannet	152	45.8	138	69.4
Laridae (gulls, terns)				
Bonaparte's Gull	2	0.6	3	1.5
Laughing Gull	2	0.6		
Herring Gull	25	7.5	5	2.5
Great Black-backed Gull	4	1.2	8	4.0
Gull, small (unknown)	1	0.3		
Gull, large (unknown)	3	0.9		
Forster's Tern	3	0.9		
Unidentified				
Passerine	1	0.3		
TOTAL	**332**		**199**	

The total number of birds detected per transect (T) varied from 9 to 31 during the morning survey and from 6 to 43 during the afternoon survey (**Tables 5-3** and **5-4**). The highest number of individuals were detected on transects 25 and 27 in the morning and on transect 28 in the afternoon. More birds were detected in the northern half of the Study Area during the morning; 201 birds were present on the morning northern transects (odd-numbered transects 19 through 33) compared to 131 on the morning southern transects (odd-numbered transects 1 through 17). During the afternoon the number of individuals on the northern half (even-numbered transects 20 through 34) of the Study Area was 108; the southern half (even-numbered transects 2 through 18) had 91 individuals.

During the 16 April 2008 avian aerial survey a total of 531 birds were detected. In contrast the average daily number of birds observed during the April offshore ship surveys (9, 10, 12 to 14 April) was 2,322. In April, offshore ship surveys had a total of 250.7 birds per on-effort hour compared to 75.9 birds per on-effort hour observed during the 16 April aerial survey (**Table 5-5**). Offshore ship and aerial survey data were compared to determine if differences existed in species diversity and the detection of species.

Table 5-3. Morning avian species abundance by transect during the 16 April 2008 aerial survey.

Family Common Name	Transect Number																
	T1	**T3**	**T5**	**T7**	**T9**	**T11**	**T13**	**T15**	**T17**	**T19**	**T21**	**T23**	**T25**	**T27**	**T29**	**T31**	**T33**
Anatidae (sea ducks)																	
Surf Scoter																	
Black Scoter						1											
Scoter (unknown)											1						
Gaviidae (loons)																	
Red-throated Loon	1	1	1	1		19	3	6	5	3		2	9	1	3	6	6
Common Loon	1	2	9	5	4		4	1	1	2	8	1	1	8	4	5	3
Loon (unknown)				1	1	1	1	1	1			1		2		1	1
Sulidae (gannets)																	
Northern Gannet	4	10	8	5	4	6	3	15	10	6	4	17	15	19	14	5	7
Laridae (gulls, terns)																	
Bonaparte's Gull						1					1						
Laughing Gull													1		1		
Herring Gull	3	3	2	2				1		2			4	1	3	3	1
G. Black-backed Gull		1										1	1				
Gull, small (unknown)		1															
Gull, large (unknown)				1											1		1
Forster's Tern		2	1														
Unidentified																	
Passerine																	
TOTAL	**9**	**20**	**21**	**15**	**9**	**28**	**12**	**24**	**17**	**13**	**14**	**22**	**31**	**31**	**26**	**21**	**19**

T = Transect

Table 5-4. Afternoon avian species abundance by transect during the 16 April 2008 aerial survey.

Family Common Name	Transect Number																
	T2	T4	T6	T8	T10	T12	T14	T16	T18	T20	T22	T24	T26	T28	T30	T32	T34
Anatidae (sea ducks)																	
Surf Scoter				15													
Black Scoter																	
Scoter (unknown)																	
Gaviidae (loons)																	
Red-throated Loon	1	1		1	2	1		1	1	1	1	3		2		1	2
Common Loon		2	1				1		2			1	2				
Loon (unknown)	2					1											
Sulidae (gannets)																	
Northern Gannet	5	2	7	9	5	6	15	8			2	13	10	37	8	6	5
Laridae (gulls, terns)																	
Bonaparte's Gull														3			
Laughing Gull																	
Herring gull		1											2			2	
G. black-backed Gull			1									1	2	1		3	
Gull,small (unknown)																	
Gull (unknown)																	
Forster's Tern																	
Unidentified																	
Passerine																	
TOTAL	**8**	**6**	**9**	**25**	**7**	**8**	**16**	**9**	**3**	**1**	**3**	**18**	**16**	**43**	**8**	**12**	**7**

T = Transect

Table 5-5. Avian abundance and average number of individuals per on-effort hour during the April 2008 offshore ship and aerial surveys.

Family Common Name	April Offshore Ship[1]		April Aerial	
	Number	Avg. No./Hour	Number	Avg. No./Hour
Anatidae (geese, ducks)				
Atlantic Brant	54	1.2		
Canada Goose	4	0.1		
Snow Goose	10	0.2		
American Black Duck	96	2.1		
Gadwall	1	<0.1		
Northern Pintail	25	0.5		
Green-winged Teal	1	<0.1		
Duck (dabbling)	34	0.7		
Scaup (unknown), Lesser Scaup, Greater Scaup	4	0.1		
Duck (diving)	6	0.1		
Surf Scoter	2408	52.0	15	2.1
Black Scoter	484	10.4	1	0.1
White-winged Scoter	8	0.2		
Scoter (dark-winged)	1650	35.6		
Scoter (unknown)	1425	30.8	1	0.1
Long-tailed Duck	3	0.1		
Bufflehead	2	<0.1		
Red-breasted Merganser	19	0.4		
Duck (unknown)	102	2.2		
Gaviidae (loons)				
Red-throated Loon	564	12.2	85	12.1
Common Loon	271	5.8	68	9.7
Loon (unknown)	20	0.4	14	2.0
Podicipedidae (grebes)				
Horned Grebe	2	<0.1		
Sulidae (gannets)				
Northern Gannet	2793	60.3	290	41.4
Phalacrocoracidae (cormorants)				
Double-crested Cormorant	296	2.5		
Ardeidae (herons)				
Great Blue Heron	18	0.4		
Accipitridae (hawks, eagles)				
Osprey	3	<0.1		
Laridae (gulls, terns)				
Little Gull	1	<0.1		
Bonaparte's Gull	391	8.4	5	0.7
Laughing Gull	74	1.6	2	0.3
Ring-billed Gull	5	0.1		
Herring Gull	386	8.3	30	4.3
Lesser Black-backed Gull	1	<0.1		
Great Black-backed Gull	100	2.2	12	1.7
Gull, large (unknown)	179	3.9	3	0.4
Royal Tern	1	<0.1		
Common Tern	2	<0.1		

Table 5-5 (*continued*). Avian abundance and average number of individuals per on-effort hour during the April 2008 offshore ship and aerial surveys.

Family Common Name	April Offshore Ship[1]		April Aerial	
	Number	Avg. No./Hour	Number	Avg. No./Hour
Forster's Tern	108	2.3	3	0.4
Tern, small (unknown)	3	0.1		
Gull, small/tern	33	0.7	1	0.1
Alcidae (auks)				
Dovekie	2	<0.1		
Razorbill	4	0.1		
Other				
Non-passerine[2]	14	0.3		
Passerine[3]	5	0.1	1	0.1
Unknown				
TOTAL	**11,612**		**531**	

[1] GMI 2008b
[2] Represents vultures and other non-water bird, non-passerine spp.
[3] Represents passerine spp. recorded over land, on shore, offshore, and/or on the survey vessel
Avg. = Average
No. = Number

As expected, April avian species diversity was higher during the four-day offshore ship survey than the one-day aerial survey because of the difference in survey effort. Average on-effort hourly numbers for scoters, small gulls, and small terns were noticeably lower on the aerial survey than on the April offshore ship surveys. It is possible that the scoters observed on the offshore ship survey had left the Study Area prior to the aerial survey or that the dark-bodied scoters could not be distinguished during the aerial survey. Small gull and tern species (e.g., laughing gull, common tern) that are resident in the Study Area beginning in April may also occur as migrants throughout the spring. Small gulls and terns resting on the water at moderate distances from the ship can be difficult to see during the offshore survey, and unless they are flying, would be easy to miss on an aerial survey. Another possible explanation for the lower hourly on-effort bird numbers for the aerial survey was the difference in weather conditions; the weather on 16 April (BSS of 0 to 1) was unusual for New Jersey coastal and offshore waters in April and differed from the weather for the offshore surveys (GMI 2008b).

Avian aerial surveys were initially scheduled for three separate occasions: once each in spring 2008, fall 2008, and spring 2009. After the April survey the efficacy of such limited surveying was discussed by the committee members, and the pros and cons of conducting aerial surveys were compared. Benefits consisted of better detection of peak activity (if conducted during peak activity) and a “snapshot” collection of avian data over the whole day. The negatives consisted of limited detection of small and darker-colored birds, the temporal variation of migration, the small number of planned surveys (considering the limited data already gathered), the safety of flying at low altitudes, and the cost involved. A vote was taken and it was decided to discontinue aerial surveys and instead increase radar ground-truthing observations.

5.3 REFERENCES

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6.0 AVIAN RADAR SURVEYS

This section discusses radar and radar parameters in relationship to biological target detection, a description of the Mobile Avian Radar System (MARS®) including standard operations and capabilities, and an explanation of real-time data processing performed by the MARS®.

Radar is an acronym for RAdio Detection and Ranging. All radars transmit a radio signal, and then receive the reflected signals (echoes) from objects in the atmosphere. The farther away a target, the longer it takes for an echo to return to the receiver and the weaker that echo is. Almost any object reflectss radar signals; the strength of the echo is dependent upon the object's composition, the wavelength of the radar signal, the power of the signal, and the distance from the radar to the object. Metal objects reflect radar energy strongly; water and land reflect less strongly. A bird has approximately the same reflectivity as a similar mass of water. Bird echoes are small and weak relative to those of larger metal objects (e.g., boats, airplanes). Therefore, radars are only capable of detecting birds at shorter ranges. Empirical evidence shows that the strength of echoes, or "signals", from birds is generally related to: the wavelength of the radar signal (10 cm [4 in] for S-band radars); 3 cm (1 in; for X-band radars), the distance from the radar to the bird, the size of the bird, and the profile the bird presents towards the radar.

Bird targets are generally more difficult to detect at increasing distance from the radar because the size (reflectivity) of the return signal is smaller. The smaller the target (small reflective surface or cross-section), the more difficult it is for the radar to detect. Therefore, low numbers of small targets are more likely to be detected at 3 km (2 mi) from the radar than at 6 km (4 mi); larger targets (i.e., flocks or large birds) can be detected at greater distances (i.e., throughout the radar coverage area). There is no reliable way to discriminate between echoes produced by small birds and echoes produced by large birds, because several small birds in a radar pulse volume can have a combined mass similar to a single large bird and will produce a similar radar echo.

Radars work primarily along line-of-sight, and scan in a circular sweep; therefore, radars cannot detect targets behind other objects. Obstructions, such as towers or large vessels, create a shadow, which obscures objects behind them. Such obstructions, as well as the ground or sea (i.e., waves), also reflect energy back to the radar; these echoes are known as clutter echoes. Wave echoes are of similar, or greater strength, than bird echoes, while tower and or vessel echoes are usually much stronger than bird echoes. Combinations of topographic features (static and/or dynamic) and obstructions can block radar coverage and create "blind spots."

When the center of the beam of marine radar is horizontal, half of the radar energy is directed below the horizontal and toward the sea. Sea state is directly affected by wind speed, and as the wind speed increases so does the amount of clutter from waves (**Section 6.2.1.3**). Increased returned reflectivity from waves can obscure returned reflectivity from birds flying low above the surface of the water, because the returned signals from birds may not be distinguished from returned signals from the crest of waves. Birds flying behind and below a wave crest may not be detected, because of blockage of the radar signal.

6.1 MOBILE AVIAN RADAR SYSTEM (MARS®)

6.1.1 Mobile Avian Radar System (MARS®)Configuration and Capability

The GMI MARS® is used to monitor airborne biological targets (i.e., flight activity) in the Study Area. This section describes a typical MARS® configuration and its capabilities.

The MARS® consists of two radar systems:

- VerCat (X-band, 3-cm [1-in] wavelength) determines the altitude and range of targets of different size and is used to measure the flux of targets (the number of birds that passes through the vertical sample volume in a given unit of time).
- TracScan (S-band, 10-cm [4-in] wavelength) determines the range, flight direction, speed, and heading of targets in a horizontal sample volume.

Both VerCat and TracScan use commercially available marine-band radars to transmit radio signals and listen for echoes. **Table 6-1** provides the VerCat and TracScan radar specification parameters. These radars transmit for a very short duration (pulse length) and then listen for echoes until it is time to transmit the next pulse. The number of times per second that radar transmits a pulse and listens is the pulse repetition frequency (PRF). Radar manufacturers fix combinations of pulse length and PRF in the radar hardware. Commercially available marine-band radars effectively see in two dimensions, using the time between pulse and detection to determine the distance to the target, and the orientation of the radar antenna to determine bearing of the target.

Table 6-1. MARS® Radar Parameters.

Radar Parameters	VerCat (Furuno FR-2155)	TracScan (Furuno FR-2165)
Band Type	X-band	S-band
Transmit Peak Power	50 kilowatts (kW)	60 kW
Transmit Frequency	9415 megahertz (MHz)	3040 MHz
Transmit Pulse Length	80 nanosecond (ns)	80 ns
Pulse Repetition Frequency	2200 hertz (Hz)	1900 Hz
Beamwidth	20° Horizontal	2.2° Horizontal
Beamwidth	0.95° Vertical	25° Vertical
Maximum Study Range	2.8 km downrange (1.5 NM) both directions; 5.5 km (18,200 ft; 3.0 NM) altitude	7.4 km (4 NM)
Antenna Polarization	Vertical	Horizontal
Wave Length	3 cm (1 in)	10 cm (4 in)

6.1.1.1 VerCat Radar (X-band)

The MARS® VerCat radar scans a circular pattern in a vertical plane from the horizon, through an arc into the sky, to the opposite horizon (**Figure 6-1**). While the antenna is pointing below horizontal (i.e., toward the ocean), no signal is transmitted; however, given the 0.95° vertical resolution of the antenna, when the radar transmits a pulse horizontally, almost one half of the energy is projected in an approximate 0.5° arc below the horizon towards the water. The radar scans at 24 revolutions per minute (rpm), completing one scan (a full 360° rotation) every 2.5 s. Given a PRF of 2,200 times a second, VerCat can transmit 15.27 pulses for every degree of radar rotation. The radar signal is transmitted through an 2.4-m (8-ft) long array (T-bar) antenna (**Figure 6-2**). The antenna focuses the signals into a fan-shaped beam, which is 0.95° wide in the vertical scanning plane and extends 10° to either side of the scanning plane (20° total). Radar antennas are designed to operate scanning horizontally, not vertically. When the antenna is pointing at the sky, some radio energy leaks out the backside of the standard antenna and bounces off the ground. MARS® VerCat antenna has been fitted with a custom-designed shield to minimize the impact of this ground-bounce clutter. **Figure 6-1** illustrates the coverage of the VerCat beam.

The VerCat scan pattern results in a "radar curtain," that samples targets as they fly through the 20° by 180° scanning volume within 3 km (1.5 NM) of radar (horizontal) and up to 6 km (3 NM; vertical). The radar determines target altitude and downrange distance from the MARS® site. The VerCat scanning beamwidth of 0.95° provides fine angular resolution from which estimates of echo size can be determined. Targets flying along the axis of the VerCat scan can be tracked and accurate ground speeds measured; however, targets crossing perpendicular to the sweep of the beam appear stationary, and targets crossing the sweep at angles between parallel and perpendicular have ground speeds reduced from true ground speeds.

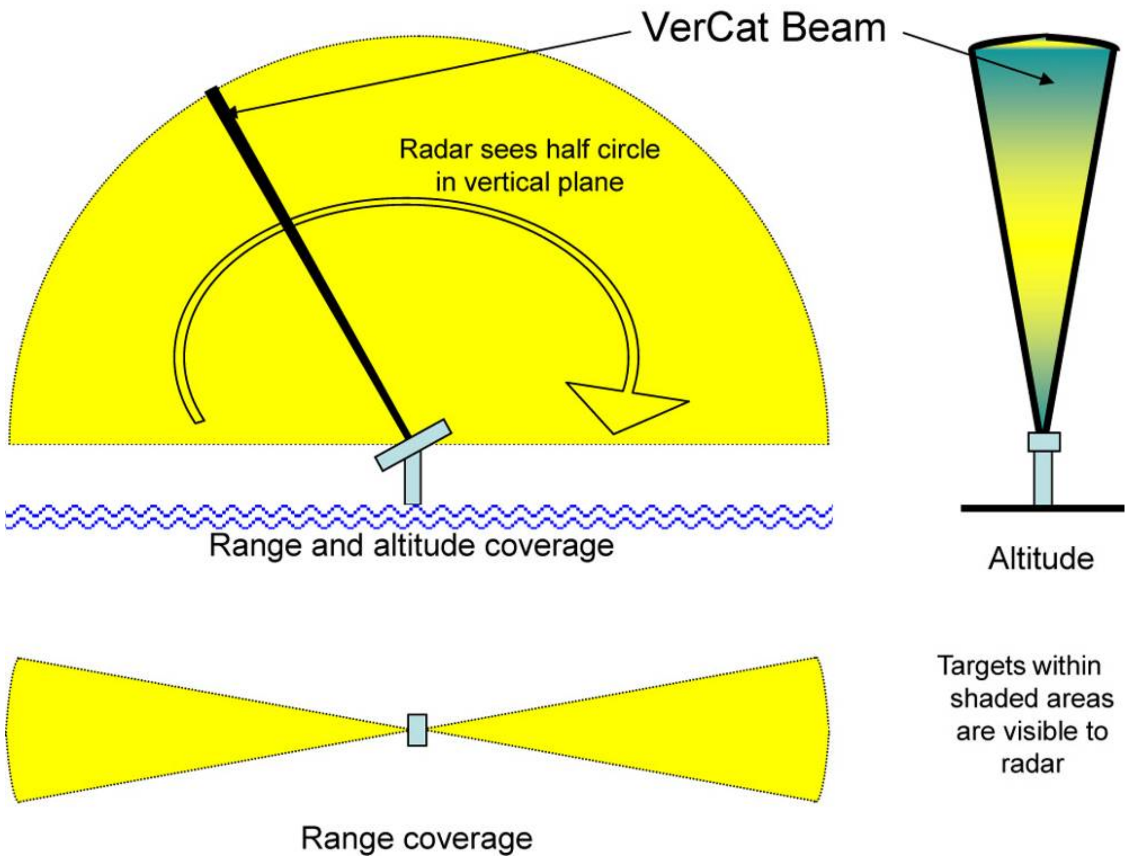


Figure 6-1. VerCat Coverage Pattern.

Because of the nature of X-band signal propagation in the atmosphere, and the generally smaller returns of targets in X-band, the operational range is limited to 3 km (1.5 NM). Furthermore, X-band is quite sensitive to precipitation (e.g., rain and high moisture content in the atmosphere) which obscures targets of interest. Wind speeds in excess of 15 to 18 m/s (49 to 59 ft/s) along the VerCat's scan axis will trip the VerCat's motor safety breaker. By shutting down operation, the radar protects itself from damage.

6.1.1.2 TracScan Radar (S-band)

The MARS® TracScan radar scans in the horizontal plane at 24 rpm, completing one scan (a full 360° rotation) every 2.5 s (**Figure 6-3**). Given a PRF of 1,900 pulses per second, TracScan can transmit 13.19 pulses for every degree of radar rotation. The radar signal is transmitted through an array (T-bar) antenna (**Figure 6-2**). This antenna focuses the signals into a fan-shaped beam, which is 2.2° wide in the horizontal plane and extends 12.5° above and below the horizontal plane (25° vertical beam width).

TracScan data are used to determine target position (range and bearing), speed, and heading. With its relatively wide beam width of 2.3°, TracScan is not the best radar to determine target size; however, S-band signals propagate very well in the atmosphere because they are attenuated less by precipitation, thus enabling the radar to detect targets beyond the precipitation.

Figure 6-2. GMI MARS® System showing both VerCat and TracScan antennae and transmitter/ receiver units.

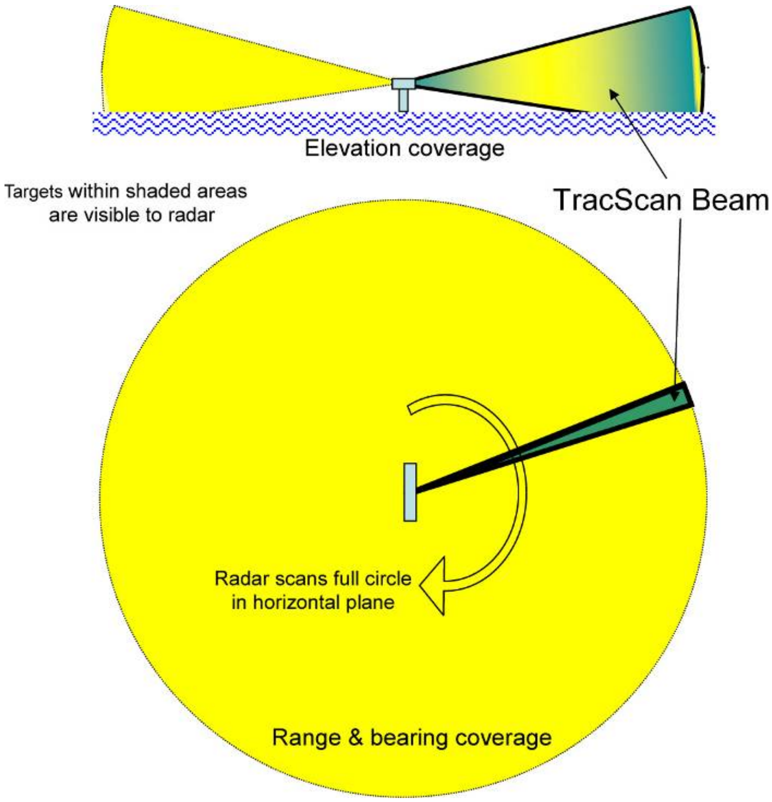
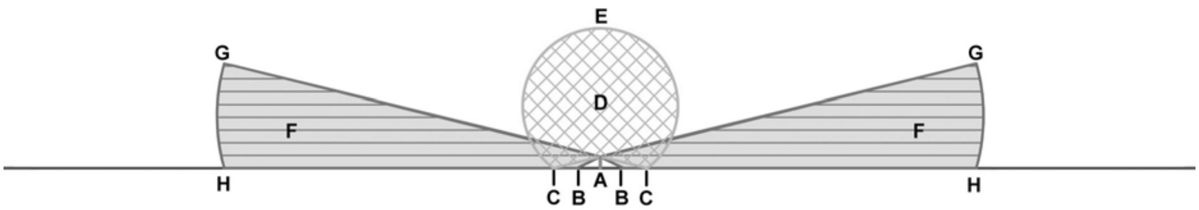


Figure 6-3. TracScan Coverage Pattern.

6.1.1.3 Summary

With VerCat and TracScan operating simultaneously, MARS® provides both horizontal and vertical coverage (**Figure 6-4**). The coverage for the TracScan range of 7.4 km (4 NM) is illustrated below. Concurrent radar coverage occurs in the overlapping areas of the cross hatching of the VerCat and TracScan ranges. As such, targets detected by one radar are not necessarily detected by the other.



KEY TO FEATURES:

A. Radar unit
B. TracScan's horizontal beam meets ground level at approximately 61 m (200 ft) from unit
C. VerCat's vertical beam meets ground at approximately 1 km (0.5 NM) from unit
D. VerCat coverage
E. Maximum altitude of VerCat coverage at 5.5. km (18,000 ft)
F. 7.4 km (4 NM) TracScan coverage
G. Maximum altitude of 4 nm TracScan coverage at 1,629 m (5,346 ft)
H. 7.4 km (4 NM) from unit

Figure 6-4. Typical MARS® Coverage Pattern.

6.1.2 MARS® On-Site Data Capture and Processing

The GMI MARS® replaces commercial marine radar processors with high-resolution processors. Radar echoes are digitally captured and sampled at 4,096 levels of resolution. After each radar scan, the MARS® software processes this high-resolution data to generate dynamic maps of background clutter and exploit the small differences between clutter and targets.

GMI proprietary algorithms attempt to exploit the distinction between background clutter (even temporary clutter like a rain cloud) and moving targets in order to detect small radar echoes in the presence of background clutter. The MARS® software maintains a real-time clutter map that incoming radar echoes are compared against. A "detection" is any echo with a reflectivity that is sufficiently above the real-time background clutter. After making the detection, MARS® automatically archives information about each detection in a track (range bearing, bearing, size, and strength) to a database for future analysis. The definition of "sufficient" is complicated by the variable nature of radar echoes. Target echo strength depends upon the target's reflective area (radar cross-section) and this is dependent on the size of the bird, flight orientation relative to the radar, and even wing position. These variables can change greatly and rapidly between successive 360° radar scans.

6.1.3 TI-VPR

Recent visual studies of migration have incorporated passive infrared (IR) cameras (Buurma 1988, Winkelman 1992, Bruderer and Liechti 1994) that detect the heat generated by a target. The passive IR cameras make it possible to distinguish between birds, insects, and foraging bats (Zehnder et al. 2001); however, IR cameras do not provide accurate information on the distance to target or altitude of flight. According to Liechti et al. (1995), the proportion of birds detected by tracking radar and IR camera did not change with distance between 0.5 and 3 km (0.31 and 1.86 mi), and the "very rough grouping of birds into three size classes by moonwatchers and IR-operators is closely related to the distances measured by the tracking radar."

Migration traffic rate (MTR, the number of birds crossing 1.6 km [1 mi] of front per hour) is a standard metric of bird migration studies. Using a rough grouping of birds into three size classes to estimate altitude does not permit accurate determination of MTRs because the altitude of individual birds is unknown. For accurate MTR measurements, precise information about the bird's altitudes crossing the vertical field of view is necessary since sample space increases with altitude.

The TI-VPR (thermal imaging camera-vertically pointing radar) system consists of two components (**Figure 6-5**):

- TI, pointed up vertically to obtain target identification, behavior, and X/Y dimensional information.
- VPR, pointed up vertically to obtain altitude (Z dimension) of targets within the TI field of view.

The TI was a fixed focus, uncooled thermal imaging camera (FLIR SR-35, FLIR Systems, Inc., Goleta, California) with a 35-millmeter (mm; 1.4 in) lens and a 20° field of view. This camera is well-suited for short range surveillance use (i.e. monitoring activity within the potential RSZ) with a minimum focus distance of only 1 m (3 ft). It has a standard resolution focal plane array (FPV) of 320 x 240 pixels with a pixel pitch of 38 microns (µm) and a spectral range of 7.5 to 13 µm. The camera is able to operate in temperatures ranging from -32°C to 54°C (-25°F to 130°F).

The VPR was a commercially available marine-band radar (FURUNO FR-1525 Mark-3, FURUNO Electric Co, LTD., Nishinomiya, Japan) coupled to a standard gain horn antenna (WR-90, Pasternack Enterprises, Inc., Irvine, California) with a beam width of 15°. A right angle waveguide elbow was used to point the horn antenna up parallel with the TI. The transmitter frequency was 9410 ±30 megahertz (MHz; X-band, 3-cm [1-in] wavelength) with peak power output of 25 kilowatts (kW) and a minimum range detection of 35 m (115 ft). The 463-m (0.25-NM) radar range setting was chosen to observe activity aloft within the rotor swept zone. Additional settings were 0.07 microseconds (µs) pulse length, 3000 hertz (Hz) pulse repetition frequency, and 92.6-m (0.05-NM) range rings.

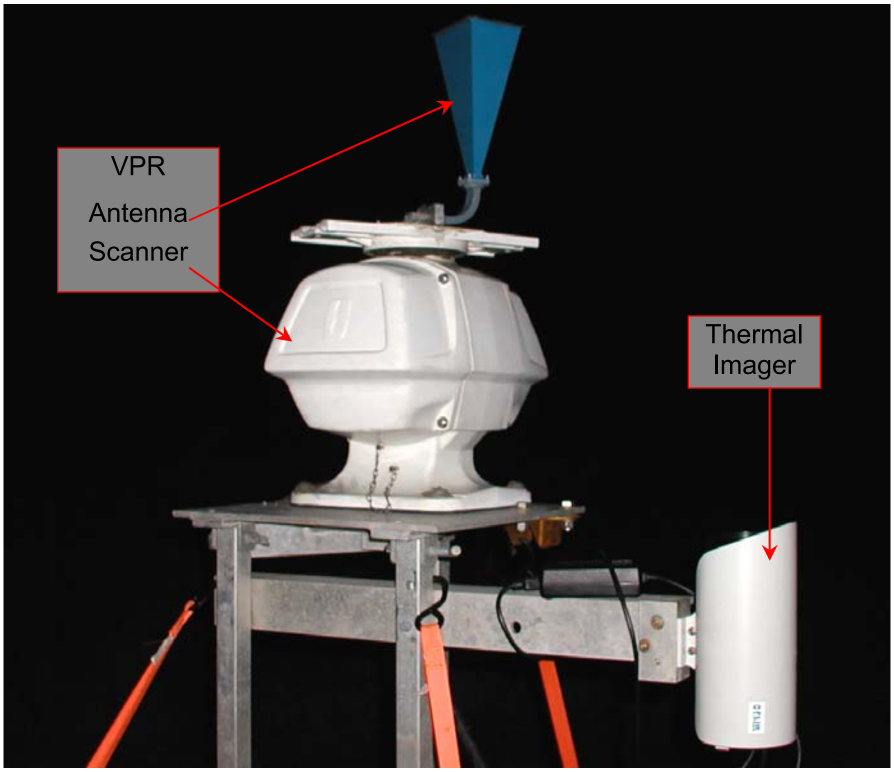


Figure 6-5. MARS® TI/VPR.

6.2 SURVEY METHODOLOGY

6.2.1 Offshore Avian Monitoring Radar Surveys

6.2.1.1 MARS® Survey Site Setup and Data Collection Schedule

The MARS® was mounted on a jack-up barge on 13 March 2008, deployed on the morning of 14 March, and on station at Grid 1 that night (**Figure 6-6**). Initial set up and ground truthing occurred on 15 March; avian radar surveys commenced the same day and continued until barge demobilization on 21 March.

The barge was relocated to Grid 7 on 21 March. Set up and ground truthing occurred on 22 March and radar surveys continued until 27 March. On 27 March the barge moved to Grid 13 (**Figure 6-6**), waited for 2 hrs, and then navigated to port in Atlantic City, New Jersey, as it was unable to jack up due to excessive sea state conditions.

The month of April began with the barge and avian radar system in port at Atlantic City due to bad weather. On April 3, the barge was able to return to sea and the avian radar was on station and collecting data at Grid 13 that afternoon. The avian radar remained at Grid 13 until the morning of April 13, at which time the barge moved to Grid 19 (**Figure 6-6**). The avian radar collected data at Grid 19 from April 13 through April 19. A ground truthing survey was conducted on April 19. After completion of the ground truthing survey, the barge moved to Grid 26.

The barge attempted to jack up on station at Grid 26 on April 19, but was prevented from doing so because of rough seas at the site and had to take shelter at Cape May to await calmer seas. The barge remained at Cape May until April 24, when it was able to successfully jack up at Grid 26. The avian radar system operated at Grid 26 from April 24 through 30.

On April 30, the barge was moved to Grid 23, and the radar began collecting data at the site. The barge collected data at Grid 23 from April 30 through May 7. On May 3 a ground truthing exercise was conducted. On May 7 the avian radar system was turned off and the barge moved to Grid 17.

On May 7, the barge and avian radar system was moved to Grid 17 and began collecting data. The avian radar remained operational at Grid 17 through 11 May, at which time the barge had to return to port in Atlantic City due to an approaching weather system. The barge had to remain in port at Atlantic City until the end of the spring survey period.

6.2.1.2 Offshore Ground Truthing Methods

The purpose of the avian radar ground truthing (ARGT; radar validation) events is to verify MARS® performance against the essential requirements and desired characteristics as related to target detection. The ARGT protocol employed the cued visual ground truthing of 1) MARS® detections from the avian radar operator (ARO) to the ground truth observers (GTOs) and 2) GTO observations to the ARO. Field team members were comprised of at least two GMI biologists; one observer and a radio communicator/recorder. The ARGT consisted of multiple observation periods scheduled over the radar season at each offshore radar site.

Boat-based field observations were necessary to validate the offshore radar. The field team navigated to multiple oceanic sites at varying distances within the barge-based MARS® coverage area. Prior to, and during, each ARGT event, field observers requested, from the ARO, distances to nearby vessels to establish distance estimation with the MARS®; passing and stationary ships were used to orient field observers.

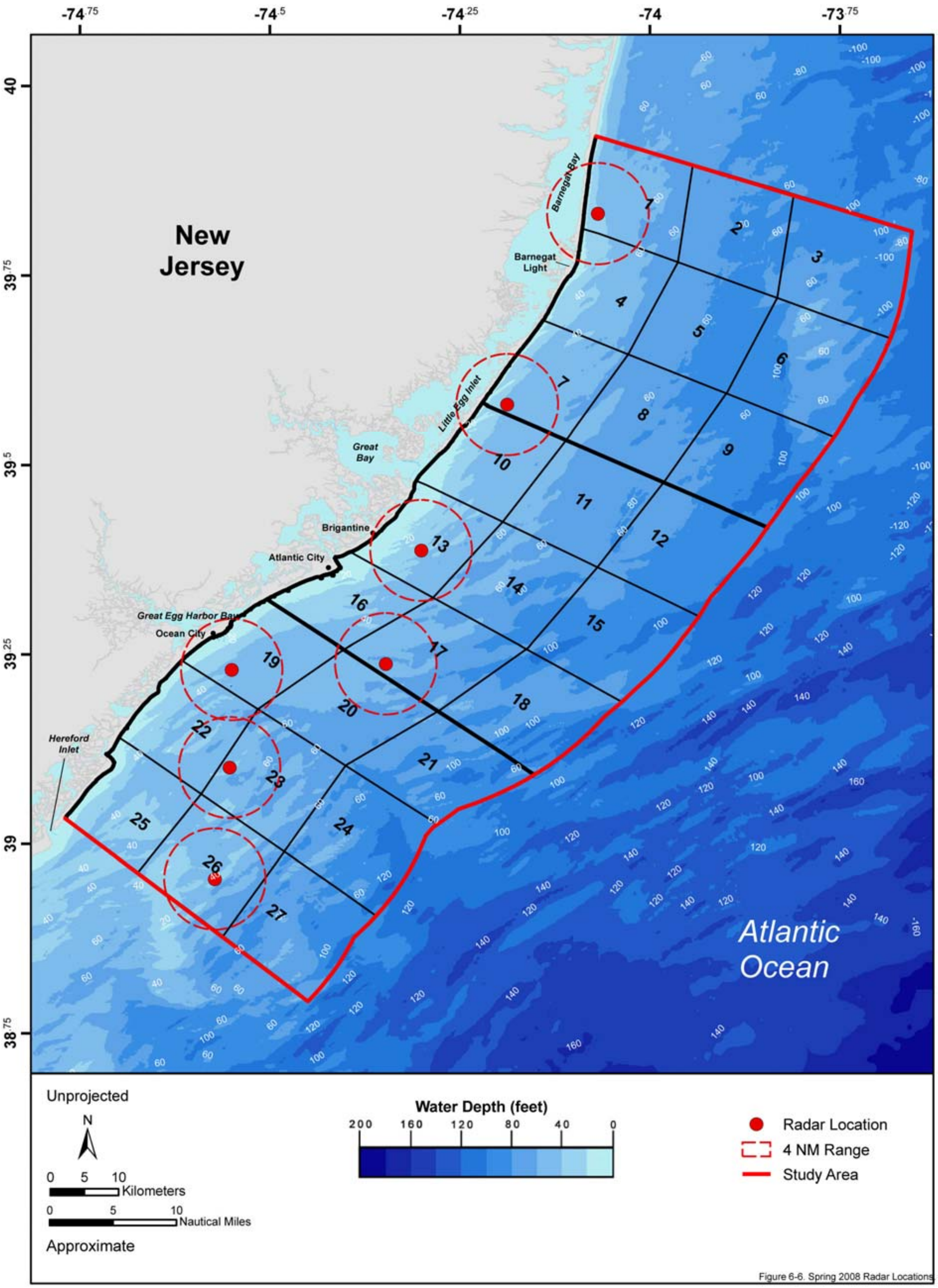


Figure 6-6. Locations of offshore radar in the New Jersey Study Area during Spring (March through May) 2008.

The first offshore survey site was assigned to the team during the pre-event briefing. The ARO reviewed the radar clutter image at varying distances from MARS® and determined an area where both the ARO and field team could detect/observe birds. The ARO then directed the field team to traverse to the first ARGT location (e.g., navigate northwest 5 km [2.5 NM; from the barge]). Subsequent offshore survey sites were established immediately prior to commencement of each ARGT based on the radar clutter image and sea state conditions.

At the arrival of each survey site, the field team recorded pertinent data on the “Ground Truth Data Sheet” (**Figure 6-7**). Data recorded included: date, time, team number, event number, observer name(s), recorder name, and location information (latitude, longitude). After the initial data was recorded, the field team reported “ready” on-station status via radio. The ARO subsequently radioed to the field team when the event would begin, which was recorded on the datasheet by the field recorder. The ARO in the MARS® began observing the radar displays surrounding the designated survey site, which encompassed a 2- to 4-km (1- to 2-NM) radius from the boat.

GROUND TRUTH SURVEY DATA SHEET

Date:___________

Team No: ________ Event No: ________ Observer: ___________ Recorder: ___________

Lat(dd:mmmmm)______________Long(-dd:mmmmm)____________ Location:_____________________

Time on Station: Begin: _____________End: _____________

Weather conditions/visibility/comments:

____

____

____

Time	C/U	U by (Radar or Observer)	Bearing from observer	Range/m	Flight heading	Altitude/ft	Count	Species

Figure 6-7. Ground truth survey data sheet.

When the ARO saw a tracked target on the radar screen (or when the field team saw a bird/flock) within the survey site, the following detection/observation information was reported: the approximate range and bearing of the detection/observation relative to the field team location, bird/target heading (using eight cardinal compass points), and the location of bird/target as it moved across the landscape/radar display. A typical radio call during each event was: “Target East (bearing 90°), range 2 km (1 NM), heading west (i.e., towards you)”. The field team recorded time, detection bearing (or quadrant), and confirmed (C) or unconfirmed (U). The following data were recorded for all confirmed tracks: estimated range (m), heading, flight altitude (ft), number of birds in the tracked target/flock, species/group (e.g., Northern Gannet), and any other comments.

As workload permitted, field observers recorded observations of bird activity that were not called out by the ARO since the MARS® (or ARO) may not have been able to see all the visual observations. All bird species/groups of varying sizes, flight altitudes, and behaviors were relevant to qualifying MARS® (TracScan and VerCat) performance. Therefore, resident and migratory bird activities were recorded during ARGT events. In addition, visual observations were limited to areas without radar clutter and within the boundaries of the observer’s vision (aided by binoculars). For each of the non-cued observations, the field team recorded observation time, observation bearing, estimated (m) range, heading, flight altitude (ft), count, and species/group. Events ended when the field team was notified by the ARO, and the event end time was recorded on the field data sheet by the recorder. The ARGT events were approximately 1 to 2 hrs in duration. After each ARGT event, the field data recorder verified that all field event data sheets were completed. The field team members and the ARO discussed ARGT event methods and made improvements if necessary. Significant observations were discussed and locations of successive field events were determined.

6.2.1.3 Data Analysis

On land, ground clutter is much more consistent than target echoes, although ground clutter may vary slowly over multiple scans. If the reflectivity from a target of interest is not much above the reflectivity of background clutter, then the target is eliminated when background clutter is eliminated. At sea, clutter varies greatly from scan to scan, and although the MARS® algorithms take the nature of the target and the clutter variations into account when determining whether to record the detection as a moving target, the dynamic reflectivity of waves often makes this task impossible. In high sea clutter conditions targets of interest may be eliminated or false targets (wave reflectivity instead of bird reflectivity) may be treated as legitimate detections. Rain also produces undesirable dynamic clutter, and in VerCat, echoes from rain may greatly inflate the number of detections. QA/QC procedures have been developed to minimize this possibility.

6.2.1.3.1 False detections, weather, and weather effects

European radar studies of local and migratory bird movements in offshore areas selected for wind development projects have noted that rain and waves affect marine radar performance when the radar is operated in the conventional horizontal scan mode (Tulp et al. 1999, Christensen et al. 2004). Off-the-shelf marine radars with array antennas project half of their radiation below the horizontal, and even slight wave action can generate sea clutter echoes that make tracking echoes from birds difficult to impossible. This problem has resulted in some studies conducting bird movement studies only when the sea is relatively calm. In a study of bird movements and collision risks at the offshore wind farms at Horns Rev, North Sea, and Nysted, Baltic Sea, in Denmark, Blew et al. (2006) used marine radar in a horizontal scanning mode with a range of 2,780 m (1.5 NM). They stated that “A prerequisite for the use of horizontal radar is a calm sea state (wind speeds less than 2 m/s [3.9 kts]). Otherwise the signals will be concealed by sea clutter, caused by the reflection of the radar waves by a rough water surface” (Blew et al. 2006). Marine radar has a sea clutter filter but use of this filter may decrease the detection of small birds.

At least one European offshore radar study has reported results from a horizontally scanning marine radar (S-band, 30 kW, 25° beam width, 11-km [6-NM] range) with digital processing similar to MARS® TracScan (Kreijgsveld et al. 2005). The authors noted that sea clutter produced 85 percent of the tracks (false tracks) and cautioned readers that even after the application of a clutter removing procedure, the data still contained an unknown number of false tracks within the ranges affected by sea clutter. MARS® TracScan also produces false detections and tracks when sea clutter is present. The false detections are particularly evident when the velocity measured between two detections is plotted in a histogram (**Figure 6-8**). The excessively high ground speeds (100+ kts) are not representative of biological targets and are classified as false targets. It is unknown how the plotting algorithms produce these false detections, but sea clutter may is responsible, because the histograms of velocity measured between detections with MARS® VerCat do not contain the abnormally fast velocities (**Figure 6-9**).

Filtering rules have been developed to eliminate false detections and tracks from sea clutter and these rules are discussed next in **Section 6.2.1.3.2**.

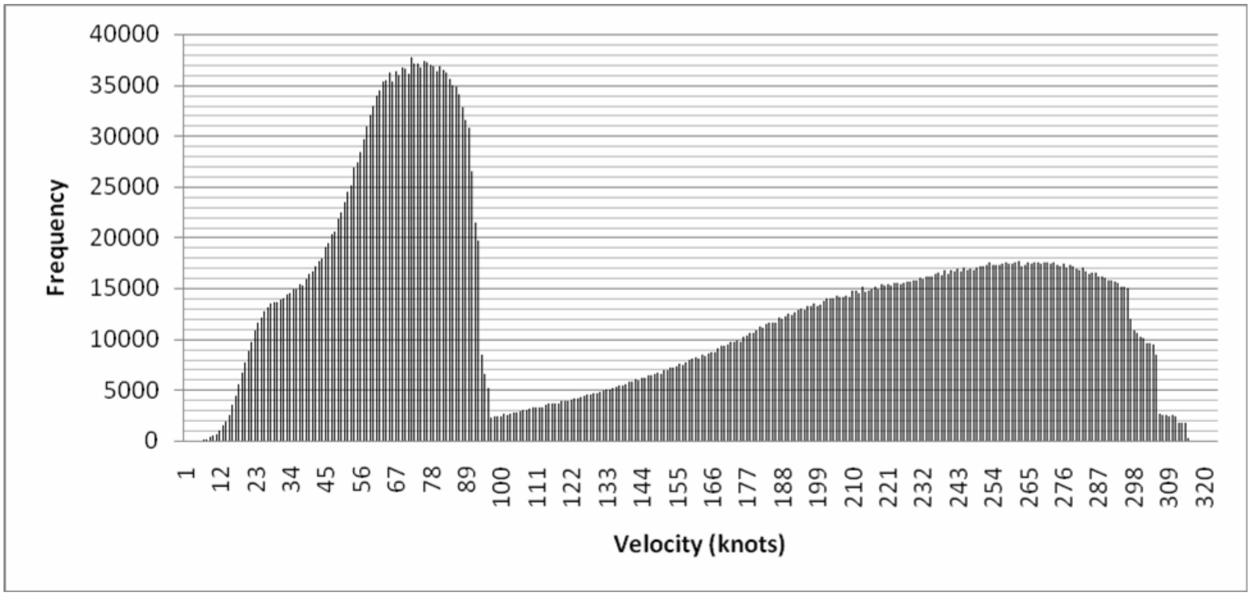


Figure 6-8. Histogram of total ground speeds between detections for 15 March 2008 from MARS® TracScan. Note the extraordinary number of detections and the extremely high velocities with no filtering.

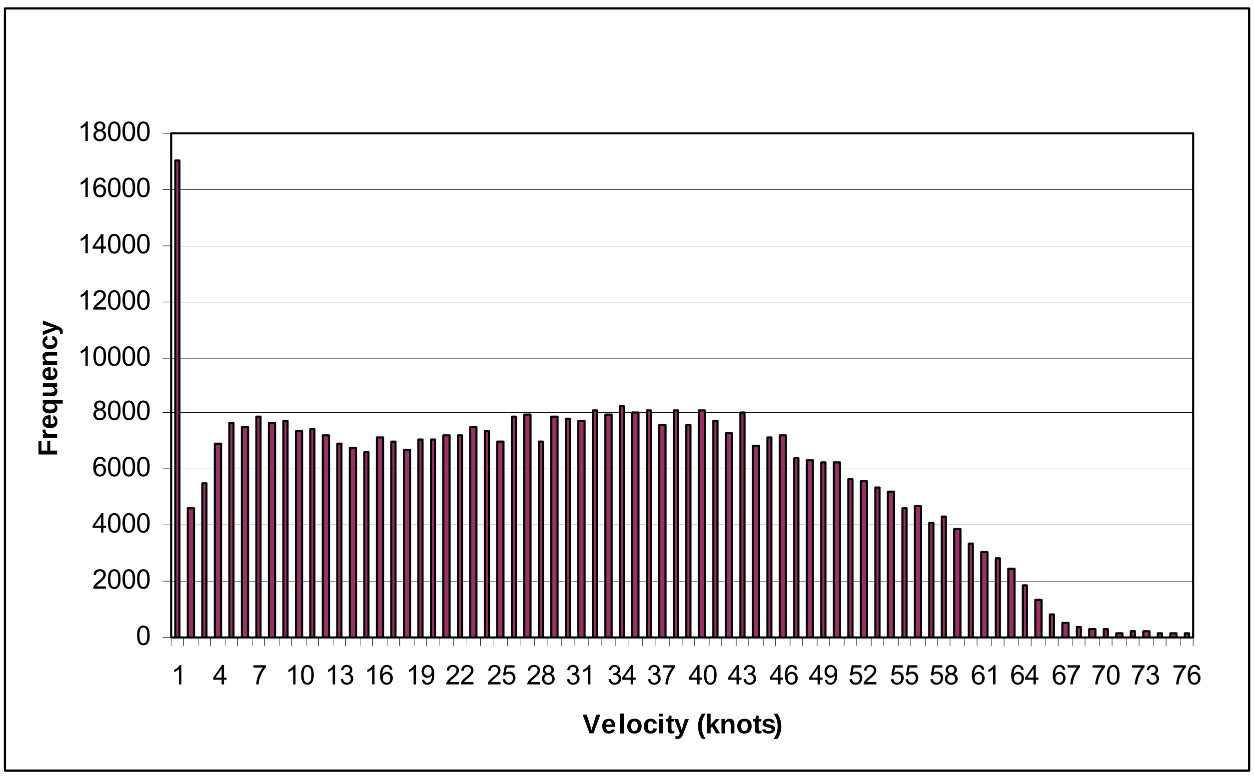


Figure 6-9. Histogram of total ground speeds between detections for 15 March 2008 from MARS® VerCat. Note the absence of a second mode of velocities and the lower frequency of velocities above 46 knots (24 m/s or 79 ft/s).

6.2.1.3.2 Analysis of MARS® TracScan data

The radar data from the first nine days of radar surveillance in this study (spring 2008) have been analyzed to examine the influence of sea clutter on MARS® TracScan data. The distribution and density of processed detections have been plotted for each day. Examples are given (**Figure 6-10)**. To examine the relationship between the extent of sea clutter and wind velocity the maximum range of detections was determined by inspecting the daily plots of all detections. The density of detections is greatest near the radar (red colored targets) and decreases as a function of range (orange>yellow>green>light blue>dark blue; **Figure 6-10**). The range at which the outer edge of the dark blue targets occurred was recorded. These measures were then correlated with the mean wind velocity at the 1000-millibar level (approximately 91 m [300 ft] above the sea) from data posted at http://vortex.plymouth.edu/upcalc-u.html. The resulting relationship (**Figure 6-11**) indicates that about 83 percent of the variation in maximum range of detections can be explained by mean wind velocity. Because 85 percent of the recorded data from TracScan type radar can be attributed to sea clutter (Kreijgsveld et al. 2005) and sea clutter conditions are related to mean wind speed, it is possible to predict sea clutter conditions in the TracScan data from data on wind conditions. This is important because false detections from sea clutter (and rain) must be removed in data processing to assure that the results of the analyses relate to biological targest and not to false detections.

The following procedures were completed during the analyses of TracScan data to reduce the number of false detections produced by sea clutter:

1) Eliminated tracks with distances greater than 0.06 NM between successive detections (i.e., tracks with velocities above 100 kts).

This procedure eliminated the detections with speeds greater than 100 kts (51 m/s; 167 ft/s) and eliminated the mode of velocities between 100 and 315 kts (51 m/s; 167 ft/s and 162 m/s; 531 ft/s) (compare **Figures 6-8** and **6-12**).

2) All tracks with gaps in detections were treated as separate tracks to avoid treating two unrelated tracks as one and generating false tracks.

This procedure changed the histogram of velocities between detections very little, suggesting that this source of false echoes was not important (compare **Figures 6-12** and **6-13**).

3) Selected only tracks with nine or more continuous detections (number of echoes per track).

This procedure had a tremendous effect on the frequency of velocities. The highest velocity counts dropped from nearly 37,000 to approximately 3,000 and the histogram showed a bimodal distribution (compare **Figures 6-13** and **6-14**).

4) Only used tracks beyond the sea clutter range (tracks equal to or greater than 3 km [1.5 NM]—see **Figure 6-11**). If a portion of a track occurred at 3 km (1.5 NM) the entire track was included in the analysis.

This procedure also had a tremendous effect on the frequency of velocities. The second mode of higher velocities was eliminated and the highest frequencies of velocities in the mode of slower speeds dropped from 2,700-2,800, to 1,600-1,700 (compare **Figures 6-14** and **6-15**) and are in closer agreement with velocities measured with MARS® VerCat (**Figures 6-9**) to MARS® TracScan (**Figure 6-15**).

Although the above measures likely eliminated some real bird tracks, it is better to follow a more conservative approach and avoid the possibility of having a large number of false tracks generated by sea clutter. MARS® TracScan data were processed using all four procedures. Since receiving comments on the Draft Interim Report filtering rules have been further refined and now TracScan data may be processed and used within 3 km (1.5 NM) of the radar.

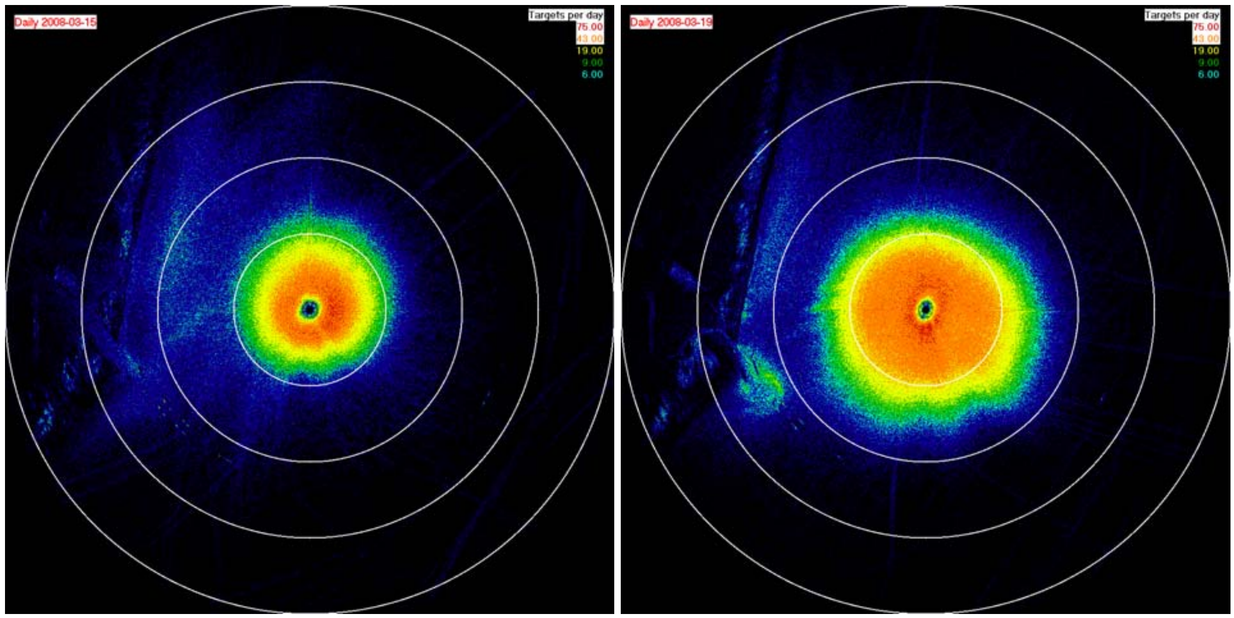


Figure 6-10. Total TracScan detections per day for 15 March 2008 (left) and 19 March 2008 (right). Maximum winds on 15 March were 7 to 8 knots and on 19 March were 18 to 19 kt.

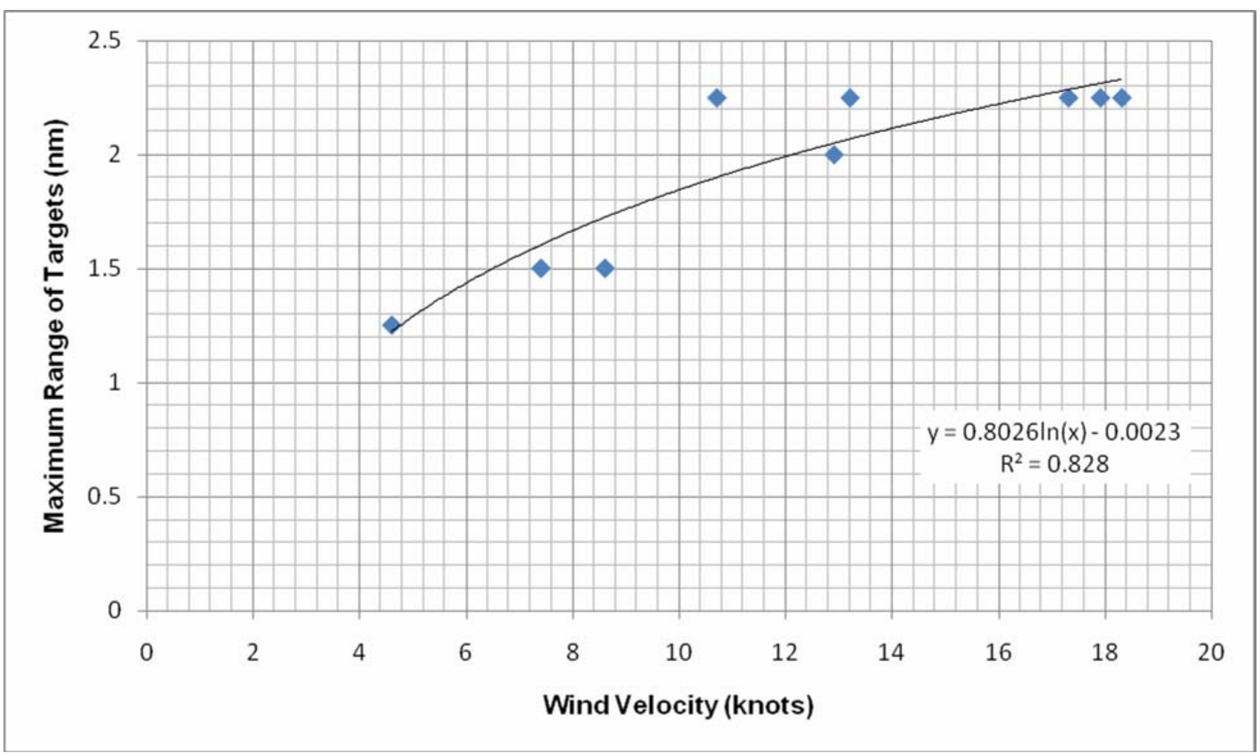


Figure 6-11. Relationship between mean wind velocity and maximum range of targets (sea clutter) in TracScan. Note that 82 percent of the maximum range of targets can be explained by wind velocity.

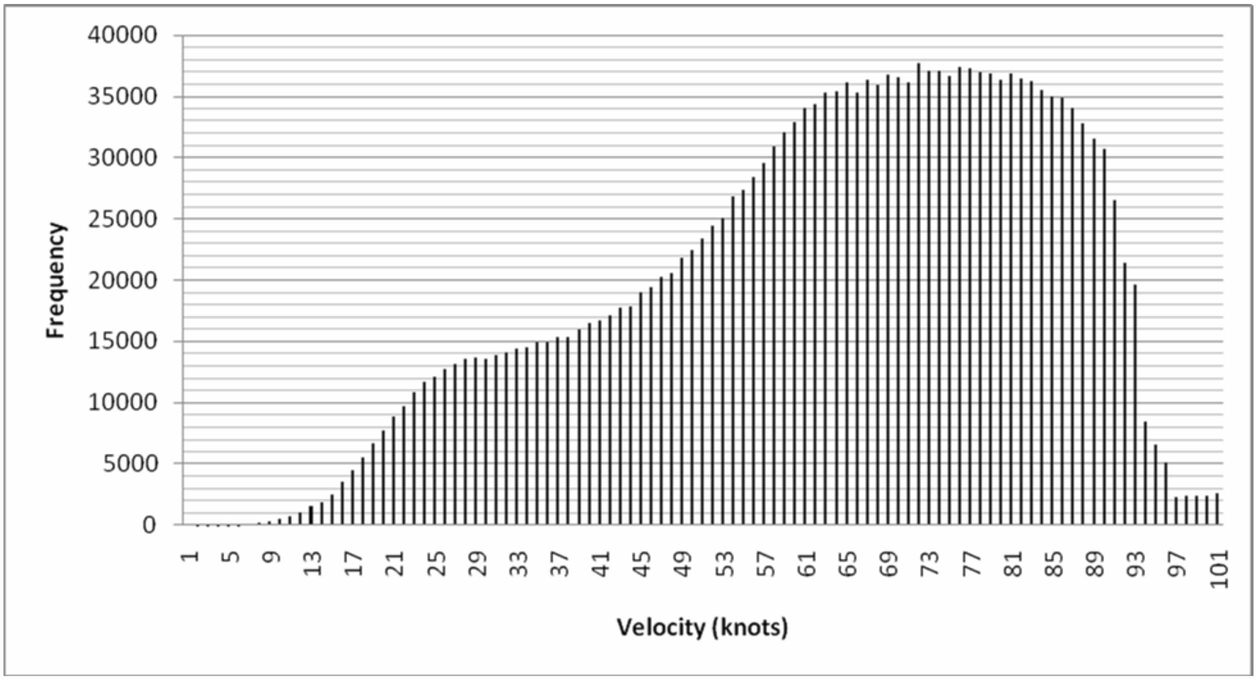


Figure 6-12. Histogram of total ground speeds between detections for 15 March 2008 with velocities greater than 100 knots (51 m/s or 167 ft/s) removed for MARS® TracScan.

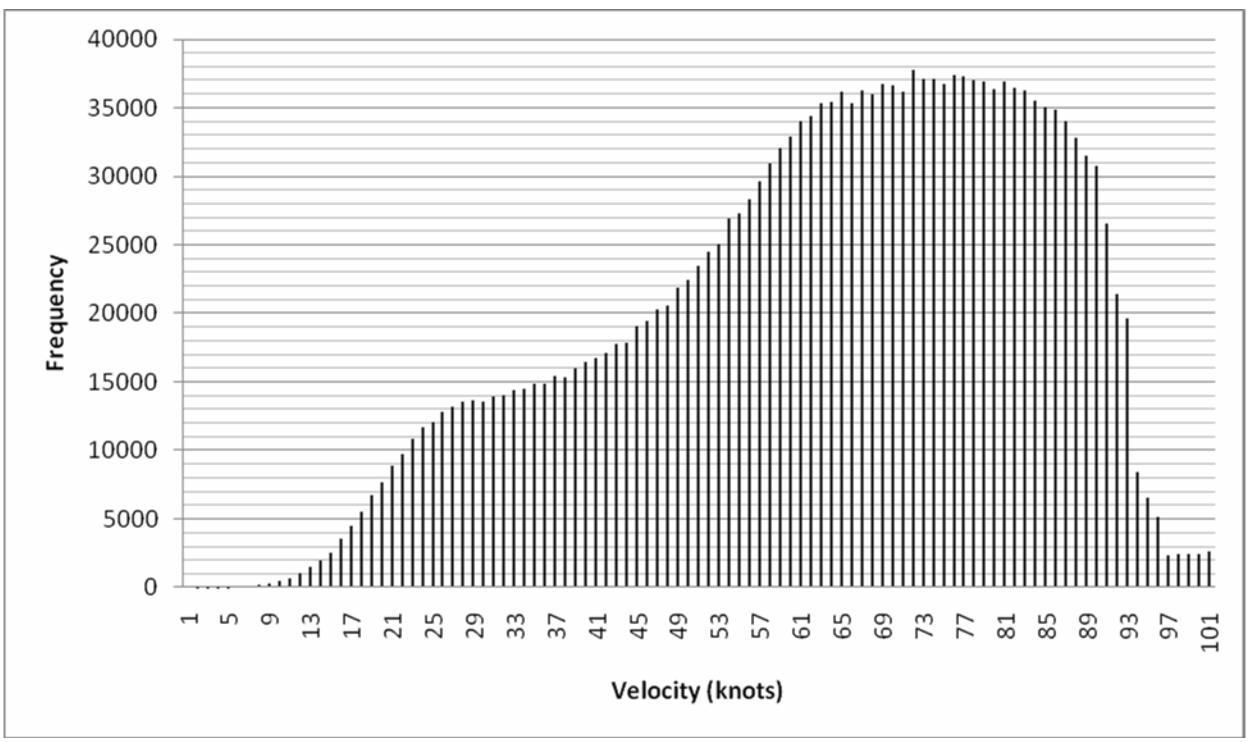


Figure 6-13. Histogram of total ground speeds between detections for 15 March 2008 after treating tracks with gaps (missing detections) as separate tracks for MARS® TracScan.

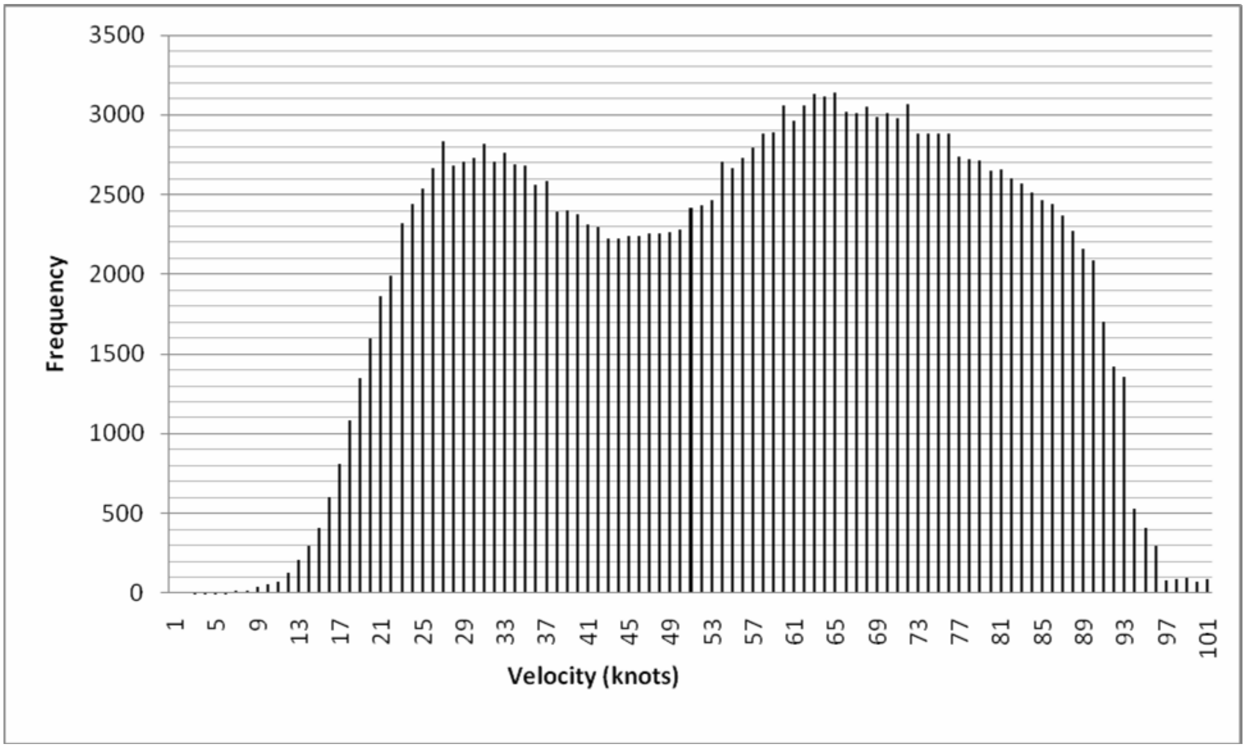


Figure 6-14. Histogram of total ground speeds between detections for 15 March 2008 after eliminating tracks that did not have nine continuous detections in a track for MARS® TracScan.

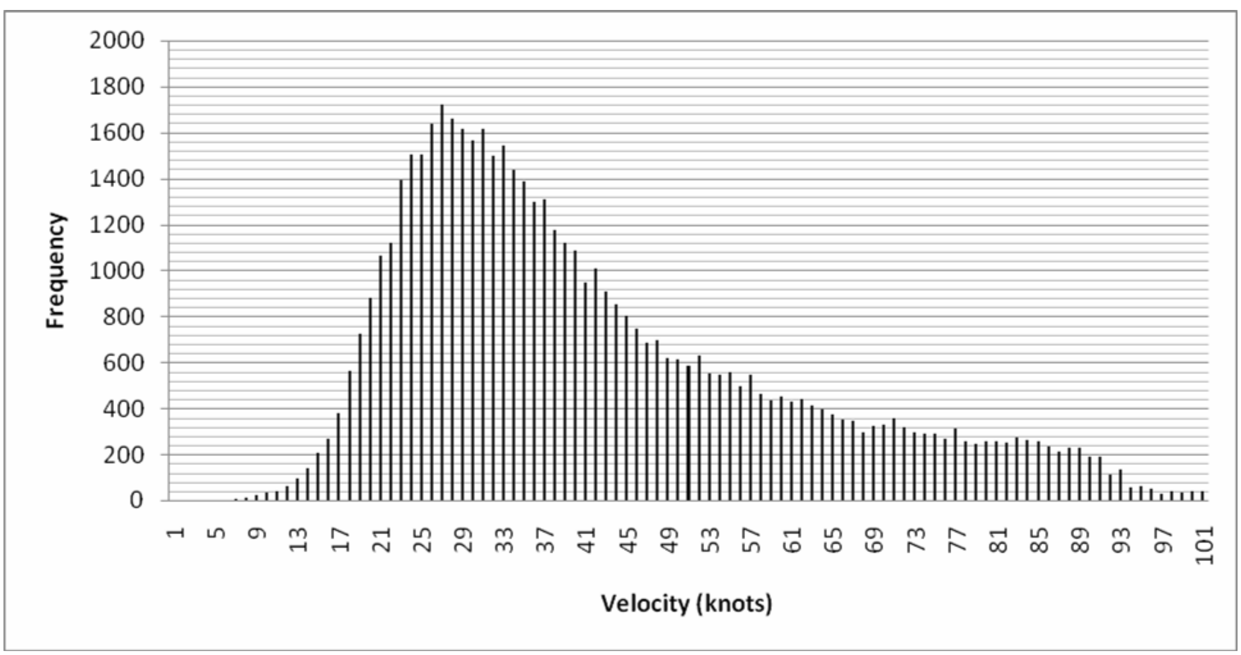


Figure 6-15. Histogram of total ground speeds between detections for 15 March 2008 after eliminating tracks within 3 km (1.5 nautical miles) of the radar for MARS® TracScan.

Because all horizontal surveillance marine radars have serious sea clutter issues, the data from these units are best used to determine directional information on targets and not density information (Kreijgsveld et al. 2005).This recommendation was followed, and the direction of target movement (direction of movement between two detections) for the TracScan data is reported. The results are presented as directional rose diagrams with 16 possible directions, and there is one diagram for each of the four quadrants of horizontal surveillance around the position of the TracScan unit. The number of movements between detections (that met the above criteria) is indicated for each direction in each quadrant.

6.2.1.3.3 Analysis of MARS® VerCat data

VerCat data are used for calculating the altitudinal distribution of targets and migration traffic rate (MTR; the number of biological targets crossing a given line in a given unit of time [e.g., birds per kilometer per hour]). After the auto capture and on-site processing of the data were completed, the data were removed from the host computer for further analysis. Because VerCat can detect precipitation (i.e., rain, sleet, snow) which may be recorded as bird targets thereby inflating VerCat counts and increasing the median altitude distribution, a QA/QC check was conducted by an avian biologist to examine data with precipitation.

Initially, the biologist checked the VerCat data for excessively high diurnal and nocturnal flight counts. If a count was higher than expected based on count totals during the preceding and/or subsequent days, data from regional and local weather stations or observer notes, or both, were examined to determine if certain weather conditions (rain, mist, snow) existed on that date and time period.

If rain was present during the higher than expected VerCat count period, then the altitude distribution during clear conditions and during rain on the same and/or subsequent days were compared graphically. If the rain altitude distribution differed noticeably from the clear conditions, an altitude scatter plot was created to determine if precipitation was present in the data (spiking indicates precipitation). The VerCat data were then replayed to determine presence or absence of precipitation. If precipitation was present and resulted in inflated VerCat counts, the VerCat data during the precipitation period was not analyzed. If rain was not present, the data were replayed and analyzed to determine if the unusual target counts were bird targets or other biological/non-biological targets (e.g., insects/chaff). Since receiving comments on the Draft Interim Report, additional filtering rules have been developed that allow the separation of bird tracks from false tracks generated when rain is present. These rules will be applied to the VerCat data containing virga (light rain evaporating before it hits the ground). This will allow for an assessment of the amount of bird migration occurring under these conditions.

If counts were lower than expected, field weather forms and weather station summaries were reviewed to identify the reason for the lower than expected VerCat count(s), because weather conditions may reduce bird activity and flight behavior (e.g., some birds will not fly in fog or high winds). If weather conditions did not explain the lower than average counts, then equipment operational records were checked for equipment problems that might explain the low counts. Low count data that result from equipment problems were eliminated from further analysis. If the low counts were not weather related or could not be explained (i.e., absence of avian activity cannot always be explained), no action was taken and the data were included for analysis.

The protocols for analysis of VerCat data are the same as those for analyzing TracScan data (**Section 6.2.1.3.2**) with one addition. When the velocity between two detections is plotted in a histogram for VerCat data, a large number of velocities are classified as zero knots (**Figure 6-9**). If a target flies through the radar beam perpendicular to the sweep of the beam, the target would have zero velocity, because its echo would appear at the same position in subsequent sweeps of the radar beam; however, the number of zero velocity entries is far too high in comparison with targets passing through the beam at angles slightly different from perpendicular. It is unknown why the number of zero velocities is so high and the algorithms are generating these velocities are continuing to be studied. Corrected algorithms will be applied to the data included in the Draft Final Report. For the Interim Report the VerCat data was processed using the following steps:

1) Compute velocity between detections from raw detection data from VerCat
2) Eliminate all velocities between detections less than 4 nautical miles per hour (knots)
3) Split tracks with a missed detection
4) Eliminate tracks with less than 9 detections
5) Compute velocity between detections with above filters.

The resulting data contained information on the number of tracks within three altitudinal zones: below 30 m (100 ft), between 31 to 152 m (101 to 500 ft), and above 153 m (501 ft; tracks per hour by altitude in relation to the MARS® site) and MTR (tracks per hour per kilometer by altitude [in relation to the MARS® unit]). Analysis of the filtered target data depended on the normality of distribution of the data.

6.2.1.3.4 Descriptive statistics and hypothesis testing for normality for the VerCat altitude distribution data

Relevant descriptive statistics for the observed diurnal and nocturnal altitude distributions include the mean, median, and the 25 and 75 percent quartiles. The 25 and 75 percent quartiles are calculated in order to assess the potential presence of altitudinal outliers at the two extremes of the altitude distribution. For example, the presence of high-altitude outliers (e.g., several anomalously high-flying birds) will tend to increase the altitude value of the 75 percent quartile relative to the value that would occur if no outliers were present. Likewise, the presence of low-altitude outliers (or a greater number than the usual or expected number of low-flying birds) will tend to decrease the altitude value of the 25 percent quartile. The median altitude (or, equivalently, the 50 percent quartile) is defined as that altitude at which half the total number of birds observed are flying below the median, and half are flying above the median.

Comparisons of the mean and median are conducted to obtain a rough estimate of the deviation of the given altitude data from a normal distribution and also the direction of any skewness in the data. Generally, the greater the difference between mean and median, the greater is the deviation from normality and the greater is the skewness. If the mean altitude is greater than the median altitude, then the given altitude distribution is skewed upward (i.e., toward higher altitudes) due to the presence of several outliers with anomalously high altitudes. Conversely, if the mean altitude is less than the median altitude, then the given altitude distribution is skewed downward (i.e., toward lower altitudes) due to the presence of an anomalously high number of bird counts with low altitudes. If the mean and median are equal, then there is no skewness, and the given altitude distribution is (probably) normal.

A further, more conclusive statistical test for normality is the Kolmogorov-Smirnov GOF test (Kolmogorov 1933; Smirnov 1939a,b; Zar 1999). According to this test, a cumulative frequency distribution (CFD) is calculated from the observed (altitude) distribution; and the GOF of this observed CFD to an expected CFD (i.e., the normal CFD) is assessed. A test statistic for each sample "i" (for i=1 to sample size n) is calculated as the absolute magnitude of the difference between the cumulative observed frequency and the cumulative expected (i.e., normal) frequency. The maximum test statistic calculated is compared to the critical value (tabulated in published statistical tables) for the given sample size (n) and desired confidence level (e.g., a=0.05). If the test statistic is less than the critical value, then the null hypothesis (H_o) that the given distribution is normal is accepted. Otherwise, H_o is rejected.

To assess whether the observed altitude data follow a normal distribution, the Kolmogorov-Smirnov test is run. If the data is not normal, the data is placed into a linear transformation model (logarithmic) to determine if the data can be normalized. If the data cannot be normalized, the only remaining alternative is to use a quartile system for reporting the altitudinal distribution data. Non-transformed datasets can be subject to non-parametric statistical tests, such as the Mann-Whitney test, or Kruskal-Wallis test, which are the non-parametric equivalents of the 2-sample test t-test, paired-sample t-test, and the Analysis of Variance (ANOVA) test, respectively to test for example to assess the differences in diurnal and nocturnal altitude distributions.

The Kolmogorov-Smirnov test was run for the diurnal and nocturnal altitude distributions of all spring 2008 radar offshore and radar onshore data. The data was found to be not normally distributed. A logarithmic linear transformation model was then run to determine if the datasets could be normalized; the datasets could not be transformed to normal. Therefore, a quartile data reporting system (cumulative and daily median with 25 and 75 percent quartiles) was selected to report altitudinal data.

6.2.2 Onshore Avian Monitoring Radar Surveys

The hardware, software, data collection, and analysis of the MARS® system used for onshore avian surveys were similar to the offshore MARS® system.

6.2.2.1 MARS® Survey Site Setup and Data Collection Schedule

Three sample sites were chosen based on location relative to the coastline, availability, and radar line of sight coverage of the coastline and ocean from the location (**Figure 6-16**). The first site (northern most) was located at Island Beach State Park. The second was originally located behind an observation tower in North Brigantine Beach. The third, southernmost location was at Corson's Inlet State Park.

The onshore MARS® system is trailer mounted and was stationed at Island Beach State Park on 13 May 2008. Set up and initial ground truthing occurred on 15 May 2008; avian radar surveys commenced the same day and continued through 23 May. The onshore MARS® system was deployed and operational at Brigantine Beach from 29 May through 8 June, and at Corson's Inlet from 9 June through 19 June.

6.2.2.2 Onshore Ground Truthing Methods

For the onshore radar ground truth surveys both boat-based and land-based observation sites were used. Boat-based protocols were identical to the offshore ship methods (**Section 6.2.1.2**). Onshore methods were slightly different than boat-based methods.

To validate the onshore coastal radar, land-based field observers were positioned in areas (e.g., beach dune, overpass berm) that were within direct sight of known bird activity. Observer locations were chosen based on the field team's best ability to have an unobstructed view (up to a 3-km [2-mi] radius) with an emphasis on a clear view over the ocean. Prior to commencement of each ARGT event, field observers became acquainted with the site landmarks (i.e., distance landmarks) established with the MARS®.

During the daily pre-event briefing, survey sites were assigned to the team. The ARO and field team members reviewed the radar clutter image in the immediate area surrounding the assigned survey sites to determine areas where both the ARO and field team could detect/observe birds. One of two survey methods was employed to determine the areas where the ARO/field team would concentrate their observation effort. Observations occurred along a predetermined transect line as birds/targets intersected the line, or a broader scale approach was used to verify targets/birds at any bearing from the field team station location. The survey method, either transect or quadrant, was selected by the team. After the team was onsite and the survey method was chosen, the protocol occurred as previously discussed in **Section 6.2.1.2**.

6.2.2.3 Data Analysis

Data analysis methods and protocols were identical to those discussed previously in **Section 6.1.2.3**.

6.2.3 TI-VPR Surveys

6.2.3.1 Data Collection

Output from the TI and VPR was combined into a single video display before being recorded. The MARS® VPR signal was converted from a video graphics array (VGA) output into composite video (personal computer [PC] to television [TV] converter). This output was then sent to a video multiplexer (Colorado Video, Boulder, Colorado) and combined with the video output from the TI into a single video display. The combined output was recorded on digital versatile disc (DVD) via a Sony Model VRD-MC5. Approximately 2 hours of data were recorded per DVD for later analysis.

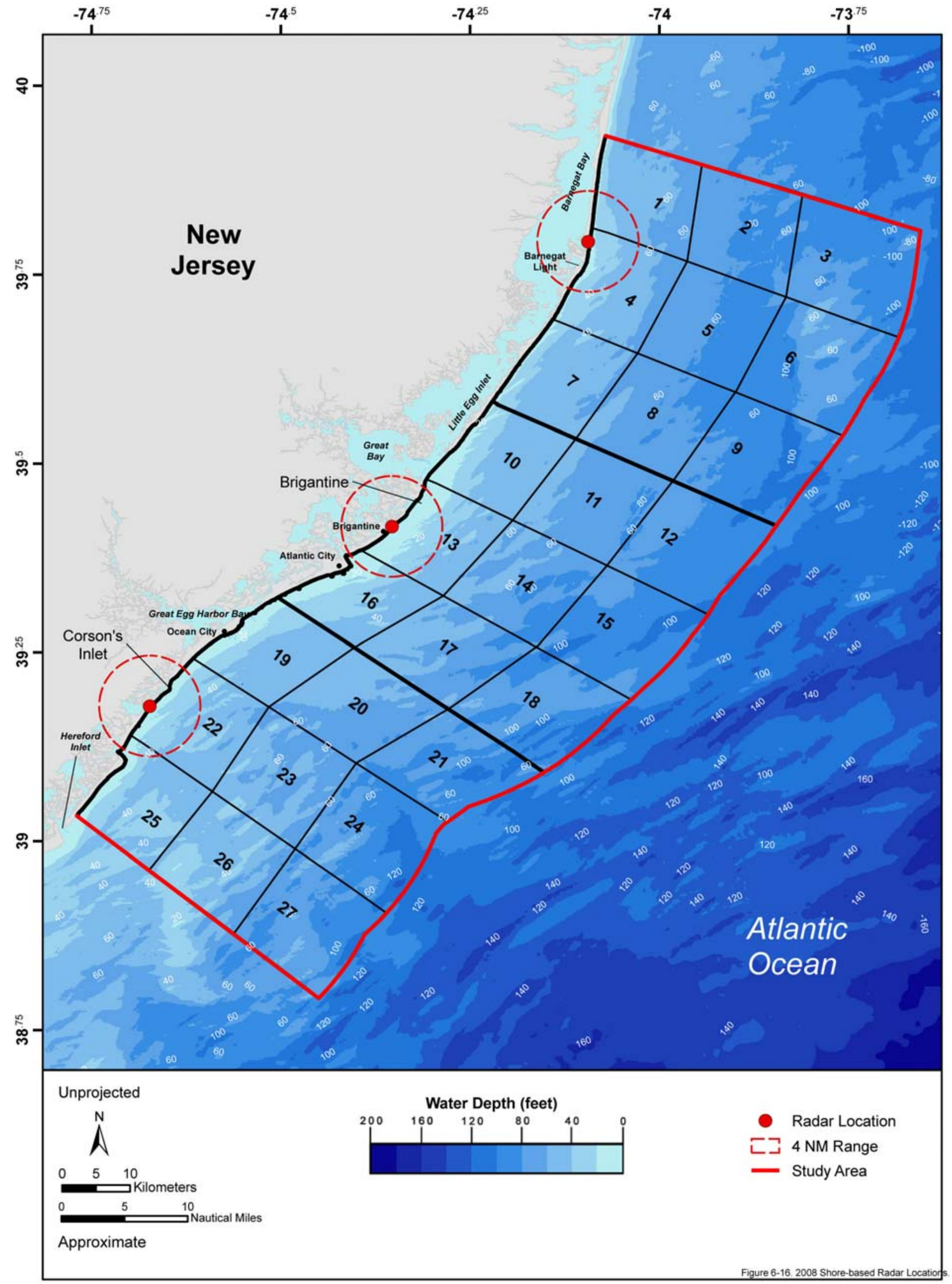


Figure 6-16. Locations of onshore radar in the New Jersey Study Area during Spring (March through May) 2008.

This system works well in clear, low humidity weather conditions, but may experience reduced target detection in partly to mostly cloudy conditions. During periods of precipitation, the VPR becomes saturated with returns and the TI is unable to function safely.

The proposed TI-VPR sampling scheme was chosen to enable every hour of the day to be sampled twice during a 5-day period. Each sampling session was conducted over a 4-hr period, with two DVDs used during one 4-hr sampling period. Dr. Sid Gauthreaux set up and tested the TI-VPR during the first deployment of the system to the project site, and determined that a modification of the TI-VPR methodology was appropriate to reduce radar operator fatigue. Per recommendations, the methodology was amended to: record 4 hrs, off 4 hrs, record 4 hrs, off 16 hrs, and repeat. This schedule was adequate to record hourly data at least once for each hour in a day at each site. Sampling was not conducted during periods of rain, drizzle, or heavy fog, and the sampling schedule was adjusted as required by weather conditions.

After ground truthing was completed at Grid 1 on 15 March, DVD recording of the TI-VPR began. Equipment problems with the multiplexer prevented simultaneous recording of both camera and radar systems, preventing the intended functionality of the system. A new multiplexer was ordered and arrived in New Jersey approximately one week later; however, weather conditions prevented transport of the new multiplexer to the radar. The new multiplexer was installed in the radar system when the barge returned to port (due to sea conditions) on 27 March.

Only TI images could be recorded at Grids 1 and 7, not VPR images. Due to bad weather and the inability to record TI and VPR images simultaneously, TI images were recorded to DVD only at times of high target activity in the VerCat radar. Ten DVDs (20 hrs) of TI images were recorded at Grids 1 and 7.

The offshore conditions during the months of April and May included large periods of heavy fog and/or rain at each site. This prevented following the proposed TI-VPR recording schedule of 4 hrs recording, 4 hrs off, 4 hrs recording, 16 hrs off, and repeat. During April, recording at site 13 was conducted for approximately 26.5 hrs, at site 19 for approximately 36 hrs, and at site 26 for approximately 28 hrs. In May, recording was conducted at site 23 for approximately 51 hrs and at site 17 for approximately 21.5 hrs.

6.2.3.2 Data Analysis

To analyze the data, the combined TI and VPR recorded image was separated using a model 497-2C demultiplexer (Colorado Video Inc., Boulder, Colorado). The TI image was then sent to a Model 443CS video peak store (VPS; Colorado Video, Inc., Boulder, Colorado) to analyze tracks and the VPR image was sent to a monitor to view target altitudes and times. The VPS functions by storing a new incoming pixel if it is brighter than the corresponding pixel already stored in frame memory. This results in a visible track being displayed on the screen for a bright target moving against a dark background (i.e., a warm biological target against a cold sky). This enables the visual extraction of track characteristics which are used in determining target identifications. The classification criteria from Gauthreaux and Livingston (2006) were used to determine target identification. Using this method: (1) bright targets with mostly straight tracks showing modulation (wing beats) were classified as birds, (2) dimmer targets with minimal to no modulation along the track at low altitudes were classified as insects, and (3) bright targets showing irregular tracks (e.g., sharp turns, pauses) with minimal modulation were classified as foraging bats. It is impossible to distinguish between birds and bats in linear flight unless they are flying at very low altitudes and can be identified by their shape. Although foraging birds are possible, all of the low level foraging targets were bats. The speed at which a target crossed the TI screen and its altitude provided additional information that could be used to identify the type of target. It is important to note that the direction of movement is not evident from a completed VPS image; therefore the scientist must also observe the movement in time lapse to determine the direction of movement. Also, in some instances when multiple targets are present in a completed VPS image, it is difficult to determine target-altitude associations; thus observations must be made as the VPS image is generated.

TI-VPR data from Grid 17 on the night of 11 May 2008 were analyzed for this report (10 hrs from 00:00 Coordinated Universal Time [UTC] to 10:00 UTC). This is only a sample of the total dataset and the remaining analyses are ongoing. GMI analyzed 5-minute (min) samples for every 15 min for each hour of data collected. Each 5-min sample analysis period was randomly chosen within the 15-min blocks for each hour, for a total of 20 min total sample data analyzed for each hour. This protocol was derived from a preliminary analysis of 4 hrs of data.

In this preliminary analysis, all targets were counted for the entire duration and two sampling protocols were tested against the total count. The first method was to use a 5-minute (min) sample for each 10 min time block for each hour and the second was the 5-min sample within each 15 min time block for each hour. The results of the preliminary analysis showed the second method (i.e., 5/15) to be more exact when compared to the total count. For each data point GMI recorded the following information: date, time, target identification (bird [BD], insect [I], foraging bat [BT], or unknown [U]), direction (degrees), altitude (ft) and comments (e.g., flight behavior; see **Appendix C-4**).

To obtain the percentage birds per hour, a total count corrected for time sampled is first calculated. This was done by extracting the total number of targets for each 5-min sample of each hour (raw count) and then multiplying that number by 3 to obtain the total count for an hour (corrected count for time sampled). Then the total corrected count for time sampled was divided by the corrected count for birds (raw count of birds/hour multiplied by 3) yielding a percentage of birds for each hour.

Altitudinal distributions for birds were obtained in 15-m (50-ft) bands of elevation up to 244 m (800 ft). Correction factors were calculated and applied to each bird based on its altitudinal band to account for the increase in the sample area of the beam with altitude. In this analysis the corrected count for birds for time sampled was multiplied by the sample size correction factor to obtain the final count within each altitudinal band. This enables a comparison of the amounts of migration in and out of the RSZ. Directional analyses were conducted using circular statistics (Oriana 2, Kovach Computing Services, Pentraeth, Wales, United Kingdom [U.K.]) applied to analyze straight track data to determine mean direction of migration. In the directional analyses irregular flight tracks were not used because of the unknown heading.

6.3 Results and Conclusions

This section presents radar operational hours, target altitudinal distribution in the radar survey area and within the potential RSZ; the MTR and target flight direction, TI-VPR data; and radar ground truth data. All data analyses presented in this section are considered preliminary. Additional processing of radar data is in progress to improve report quality.

Radar operational hours summaries are based on the total number of hours (rounded) for clear and rain (including mist and fog) weather conditions. Cumulative and daily diurnal and nocturnal altitude quartiles are used to report altitudinal distribution because the altitude data are non-normal and could not be normalized (**Section 6.2.1.3**). The selected quartile system reports the median track altitude, and track altitude at 25 and 75 percent levels. The median value means that 50 percent of the tracks are above the median value and that 50 percent are below the median value. The mean traffic rate is a measure of the number of tracks over a set distance and time span. Target flight direction analysis is based on the number of detections by cardinal direction (e.g., north, south).
TI-VPR data are analyzed to provide information on target identity, target altitude distribution, and target flight direction. Radar ground truth data provide information on the number of radar confirmations for guilds (i.e., ducks, gannets) of birds.

6.3.1 Offshore Radar Surveys – Spring 2008

Altitude distribution, mean traffic rate, and altitude band composition data are based on VerCat track counts. The “best” detection within each track is counted. Flight direction counts are based on TracScan detections.

6.3.1.1 MARS® Altitudinal Distribution

Cumulative and daily altitude quartiles (median track altitude and altitude range for 25 and 75 percent of the diurnal and nocturnal VerCat tracks) are discussed for each radar survey grid (**Figure 6-6**). Cumulative diurnal and nocturnal track altitude data at each survey grid are presented for three altitude bands with reference to the potential RSZ (101 to 500 ft): (1) below the RSZ (1 to 100 ft), (2) within the RSZ (101 to 500 ft), and (3) above the RSZ (501+ ft). All altitude data are reported in feet AMSL.

VerCat records flight altitudes (behaviors) of biological targets. Within the survey area, Northern Gannets may land on the water and fly up to plunge dive (forage) from varying altitudes many times a day. A gull may fly a short distance and land several times a day. The same flock of birds (e.g., scoters, gulls) may fly through the survey area every day to reach a foraging area and return through the same area on their way to a roosting site. During post processing, frequency of track occurrence is determined for each altitude band. Since a single target may occur in multiple altitude bands, total VerCat tracks cannot be used as a measure of biological target abundance.

QA/QC post-processing analysis determined that VerCat data collected during periods of rain (including drizzle and fog/mist) were inflated by false detections of rain (radar sometimes recorded rain as biological targets). Biological target tracks were visible but could not be separated (filtered) from rain without the significant loss of biological targets. Avian radar data collected during rain periods were eliminated from data processing. However, additional data processing steps are currently being investigated and tested to develop a method for filtering out rain while retaining biological targets.

<u>Grid 1</u>

VerCat surveys started on 14 March 2008 and ended on 22 March 2008 (**Table 6-2**). VerCat operated for 153.4 of the 178.8 (85.79 percent) on-grid hours. VerCat automatically shut down on 20 and 21 March because of high winds (>64 kph [40 mph]). During operation, clear conditions occurred 56.45 percent of the survey time and rain was recorded 43.55 percent of the survey time.

The cumulative diurnal median track altitude for 14 to 22 March 2008 was 44 m (144 ft) AMSL (range: 26 to 78 m [84 to 255 ft] AMSL [25 and 75 percentile altitudes]; **Appendix C-1a**: **Table C-1a.1)**. Daily diurnal median target altitudes ranged from 32 to 122 m (103 to 399 ft) AMSL (**Figure 6-17**).

The cumulative nocturnal median track altitude for 14 to 22 March 2008 was 239 m (783 ft) AMSL (range: 55 to 855 m [182 to 2,805 ft] AMSL [25 and 75 percentile altitudes]; **Table C-1a.1)**. Daily nocturnal median track altitudes ranged from 49 to 910 m (162 to 2,985 ft) AMSL (**Figure 6-18**).

The cumulative count (number) of diurnal tracks within the RSZ was slightly greater than the count below the RSZ (**Table 6-3**). The altitudes above the RSZ had the lowest number of tracks. Cumulative nocturnal counts above the RSZ were greater than within and below the RSZ.

6.3.1.2 Mean Traffic Rate

MTR is a metric used to determine fluxes or changes in the number of targets over the Study Area. MTR is defined as the number of tracks through a set distance for a given period of time. For this study, MTR is expressed as the number of tracks per kilometer per hour within a specified time period (i.e., diurnal, nocturnal). Cumulative and daily mean diurnal and nocturnal MTRs are presented in this section. VerCat operational hours are reported in **Section 6.3.1.1**.

As previously discussed, QA/QC VerCat data analysis determined a discernable inflation of track counts during rain events. Therefore, MTR data are reported only for clear weather conditions.

Table 6-2. Grid 1, VerCat operational hours, 14 to 22 March 2008.

Date	Diurnal[1]			Nocturnal[2]			Total Hrs
	Hrs Clear	Hrs Rain	Total Hrs	Hrs Clear	Hrs Rain	Total Hrs	
3/14/2008		-		1.0	4.4	5.4	5.4
3/15/2008	10.6	0.9	11.5	2.4	8.5	10.9	22.4
3/16/2008	5.5	7.4	12.9	5.5	5.7	11.1	24.0
3/17/2008	12.9	-	12.9	11.1	-	11.1	24.0
3/18/2008	7.2	5.1	12.3	5.5	5.6	11.0	23.3
3/19/2008	2.4	10.6	13.0	0.2	10.8	11.0	24.0
3/20/2008	2.2	0.5	2.7	2.4	3.1	5.5	8.2
3/21/2008	11.1	-	11.1	5.3	0.1	5.4	16.4
3/22/2008	-	-	-	1.3	4.1	5.4	5.4
Total	**51.9**	**24.5**	**76.4**	**34.7**	**42.3**	**77.0**	**153.4**

[1] Diurnal occurs from Civil Sunrise to Civil Sunset
[2] Nocturnal occurs from Civil Sunset to Civil Sunrise
Hrs = hours

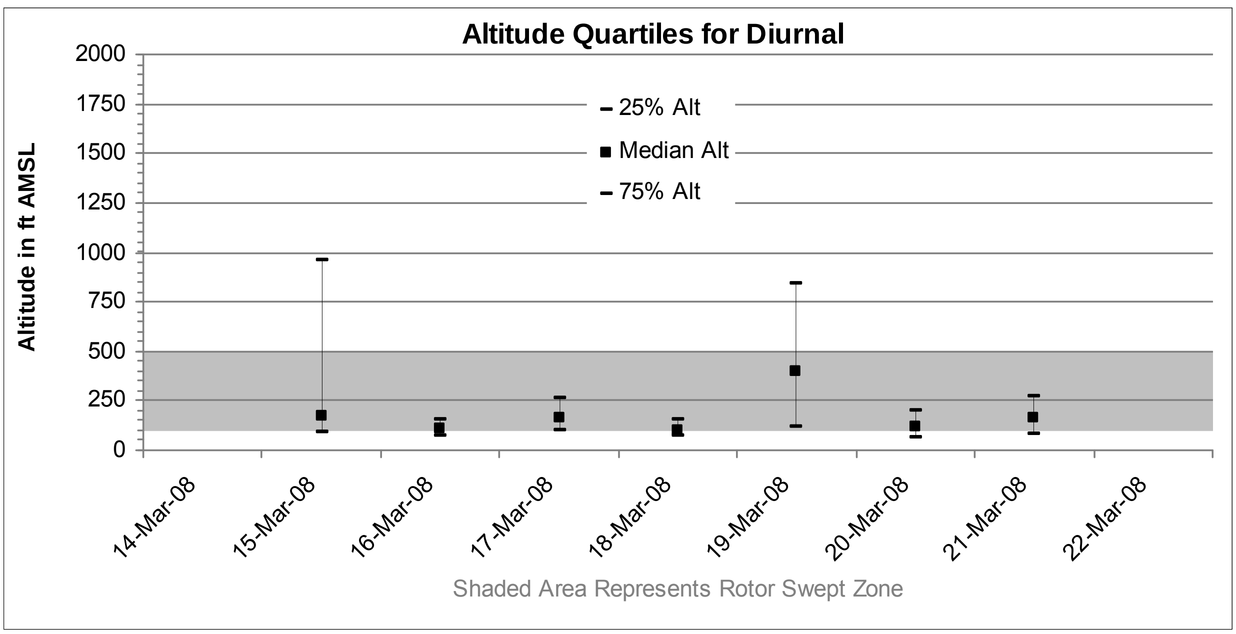


Figure 6-17. Grid 1 diurnal (clear weather) altitude quartiles, 14 to 22 March 2008.

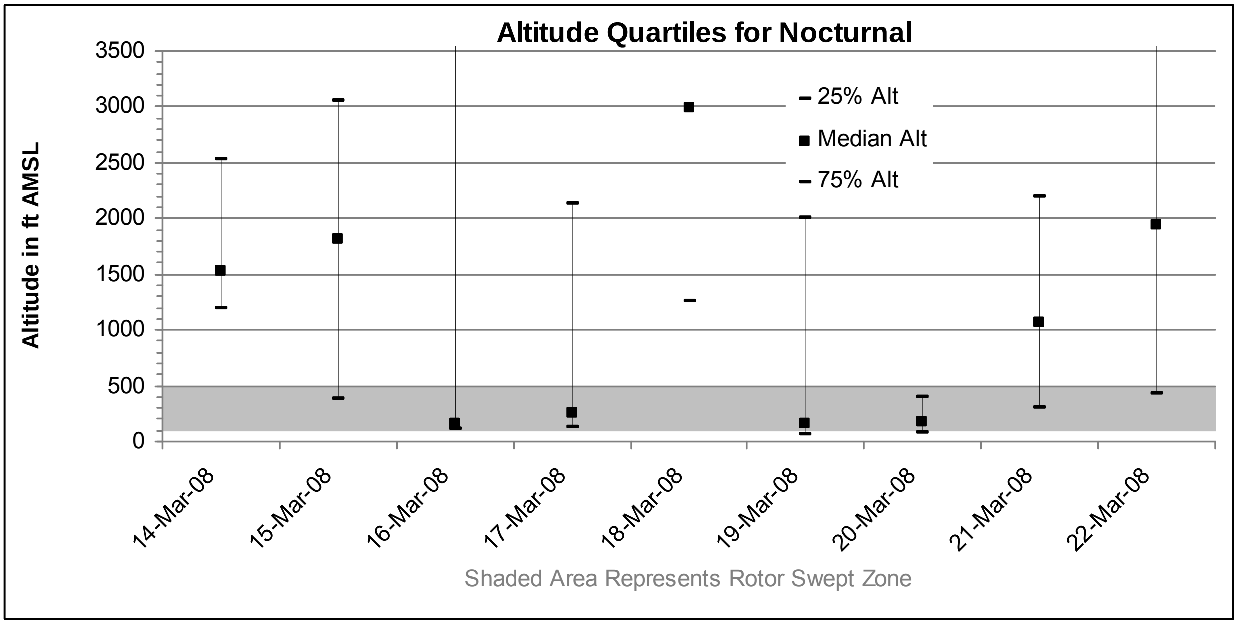


Figure 6-18. Grid 1 nocturnal (clear weather) altitude quartiles, 14 to 22 March 2008.

Table 6-3. Grid 1, cumulative diurnal and nocturnal (clear weather) target tracks by altitude band, 14 to 22 March 2008.

Altitude Band	Total Tracks	Percent Composition
Diurnal[1]		
1-100 ft AMSL	2,717	40.05
101-500 ft AMSL	3,314	48.85
501+ ft AMSL	753	11.10
Subtotal	6,784	-
Nocturnal[2]		
1-100 ft AMSL	637	19.90
101-500 ft AMSL	1,082	33.80
501+ ft AMSL	1,482	46.30
Subtotal	3,201	-
Total Dataset	9,985	-

[1] Diurnal occurs from Civil Sunrise to Civil Sunset
[2] Nocturnal occurs from Civil Sunset to Civil Sunrise

Grid 1

The cumulative diurnal MTR for 14 to 22 March 2008 was 16.2. Daily diurnal MTRs ranged from 6.2 to 35.1 (**Appendix C-2a**: **Table C-2a.1**). Most of the diurnal MTRs were between 10.6 and 19.5. The highest diurnal MTRs were on 16 and 19 March 2008 (25.2 and 35.1, respectively); these tracks may have been diurnal migrants. The cumulative nocturnal MTR was 13.6 (range: 0.7 to 76.7). Most of the nocturnal MTRs were between 0.7 and 7.0. The highest nocturnal MTRs (30.0 to 76.7) on 20 to 22 March 2008 were probably nocturnal migrants.

6.3.1.3 Flight Direction by Quadrant

TracScan data were analyzed to determine flight direction by quadrant. Heading (flight direction) is reported for all targets during all weather conditions (clear, rain, fog). A given target detection may have been detected more than once and therefore can be counted more than once. Avian target detection count and direction information are illustrated as flight compass roses, where the directions are represented by "spokes" radiating from a center. The length of each spoke represents the number of targets flying in that direction; the greater the number of targets flying in a particular direction, the longer the spoke. The total detections for each flight direction are plotted in 16 categories (cardinal directions): N, North-northeast (NNE), Northeast (NE), East-northeast (ENE), East (E), East-southeast (ESE), Southeast (SE), South-southeast (SSE), South (S), South-southwest (SSW), Southwest (SW), West-southwest (WSW), W, West-northwest (WNW), Northwest (NW), and North-northwest (NNW). Cumulative diurnal and nocturnal flight directions for each radar survey station are illustrated in **Appendices C-3a** and **C-3b**.

Grid 1

The dominant diurnal flight direction in Quadrants 1 and 3 was to the NNE and the targets were thought to be diurnal migrants (**Appendix C-3a**: **Figure C-3a.1**). Diurnal flight direction in Quadrant 2 was to the NNE, NE, ESE, and SE. In Quadrant 4 the dominant flight directions were NNE, SSW, N, and S. Because the numbers in both of these directions (i.e., NNE and SSW and N and S) were similar, it is thought that these targets traveled in one direction to forage in the morning and returned via the same route during the afternoon on the way back to their roost site.

The dominant nocturnal target flight direction in all quadrants was to the NE and/or NNE (**Figure C-3a.2**). These targets were probably nocturnal migrants or targets detected just after dark flying to a roost site.

6.3.1.4 TI-VPR Target Identification

The TI-VPR system readily detects birds, bats, and insects aloft. During analysis of the sample data over Grid 17 on 17 May 2008, 52 percent of all observations were identified as birds (**Table 6-4**), indicating that this was not a heavy migration night. In the first hour (00:00) and the last hour (09:00) only one target was found for each hour. Both targets were birds, which yielded a rate of 100 percent of detections being birds during those two hours. Hours 7 and 8 showed the highest percent-composition of birds outside of the first and last hours (83 percent and 69 percent, respectively). Overall, few foraging bats were detected over this sample period (3 of 168, or 2 percent).

6.3.1.5 TI-VPR Altitudinal Distribution

Over Grid 17 on the evening of 11 May 2008, the raw count of birds in each 15-m (50-ft) altitudinal band showed that 55 percent were at altitudes at or above 152 m (500 ft; **Table 6-5**, **Figure 6-19**). A total of 6 birds were detected below 30 m (100 ft) and 33 birds were detected between 30 to 152 m (100 to 499 ft; i.e., within the RSZ). Occasionally, detections appeared in the VPR and not in the TI and these may represent insects too high to be detected by the TI but reflective enough to generate an echo on the VPR.

Corrected altitude counts adjust for the varying sample size of the TI-VPR field of view at different altitudes. Corrected counts indicate an inverse altitude distribution from the raw counts, with 90 birds below 30 m (100 ft), 73 birds within the RSZ (i.e., 30 to 152 m [100 to 499 ft]), and 67 birds from 152 to 244 m (500 to 799 ft).

6.3.1.6 TI-VPR Flight Direction

The directional tendencies of birds over Grid 17 are given in **Table 6-6** and illustrated in **Figure 6-20**. The mean direction for the movement was 11.30 degrees. There was some variability in directions, as indicated by the length of the mean vector (0.54) and the circular standard deviation (63.60 degrees).

Table 6-4. Number of birds, insects, and foraging bats observed in TI-VPR samples over Grid 17 on the night of 11 May 2008.

Date (hour)	Birds	Insects	Foraging Bats	Total Targets	% Birds
11 (0)	3	0	0	3	100
11 (1)	6	3	0	9	67
11 (2)	6	6	3	15	40
11 (3)	0	12	0	12	0
11 (4)	6	12	0	18	33
11 (5)	3	6	0	9	33
11 (6)	18	24	0	42	43
11 (7)	15	3	0	18	83
11 (8)	27	12	0	39	69
11 (9)	3	0	0	3	100
Total	**87**	**78**	**3**	**168**	**52**

Table 6-5. Number of birds (raw and corrected) within 15-m (50-ft) altitudinal bands for TI-VPR samples over Grid 17 on the night of 11 May 2008.

Altitudinal Band (ft)	Raw Count	Corrected Altitudinal Count
0-49	0	0
50-99	6	90
100-149	0	0
150-199	0	0
200-249	0	0
250-299	6	18
300-349	6	16
350-399	0	0
400-449	12	24
450-499	9	15
500-549	18	30
550-599	9	12
600-649	12	16
650-699	0	0
700-749	6	6
750-799	3	3
Total	**87**	**230**

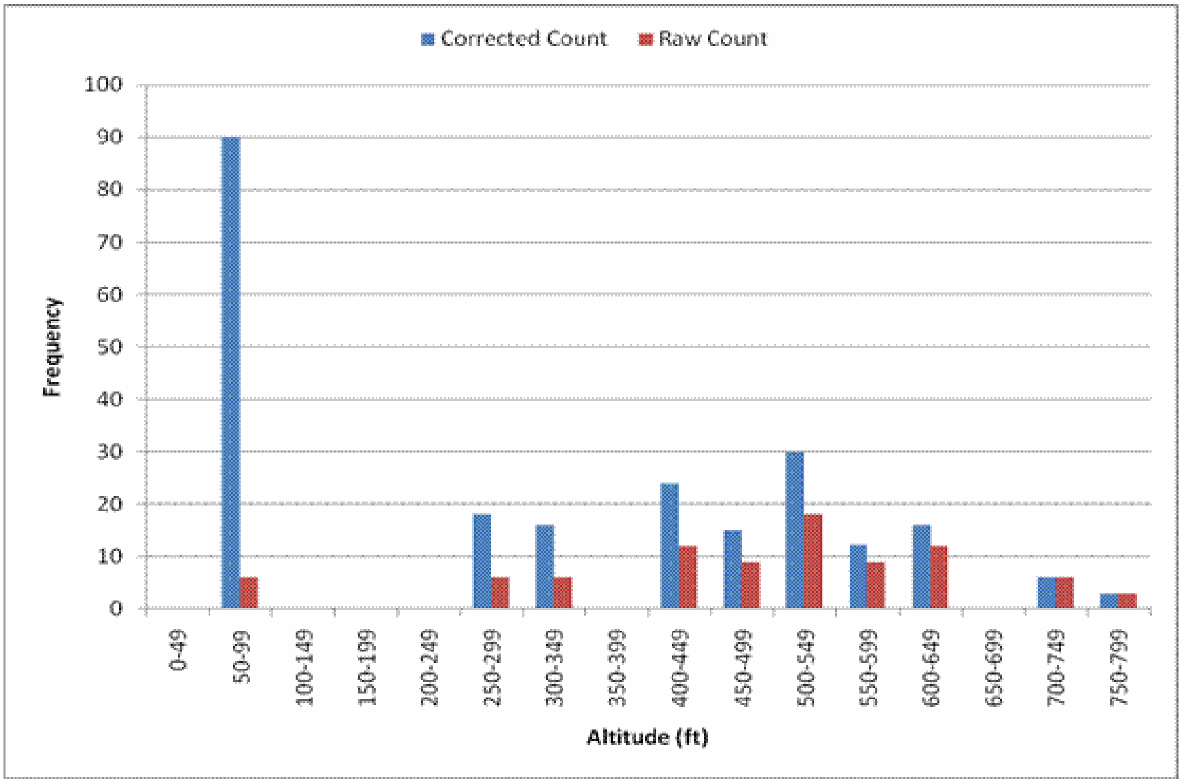


Figure 6-19. Altitudinal distribution of birds (raw count and corrected count) aloft over Grid 17 during the night of 11 May 2008.

Table 6-6. Statistical analysis of direction of nightly migrations over Grid 17 on 11 May 2008.

Number of Observations (Corrected Altitudinal Count)	230
Mean Vector (μ)	11.30°
Length of Mean Vector (r)	0.54
Median	0°
Concentration	1.29
Circular Variance	0.46
Circular Standard Deviation	63.60°
Standard Error of Mean	4.53°
Rayleigh Test (Z)	67.10
Rayleigh Test (p)	<1E-12
Rao's Spacing Test (U)	322.44
Rao's Spacing Test (p)	<0.01

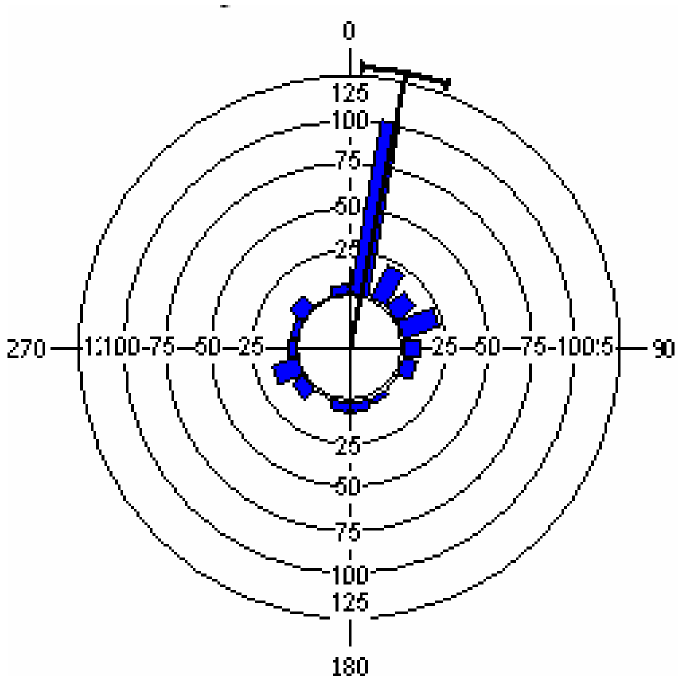


Figure 6-20. Circular diagram showing the direction of nocturnal bird movements through the TI/VPR field of view in Grid 17 on 11 May 2008. The dark line is the mean angle and the arc at the end shows the 95 percent confidence limits of the mean.

6.3.2 Onshore Surveys – Spring 2008

6.3.2.1 MARS® Altitudinal Distribution

Island Beach State Park

VerCat surveys occurred at Island Beach State Park from 15 to 23 May 2008 (**Table 6-7**). VerCat operated for 187.1 hrs (98.32 percent) of the total 190.3 on-station hours. During operation, clear conditions occurred 80.12 percent of the survey time and rain was recorded for 19.88 percent of the survey time.

The cumulative diurnal median track altitude for 15 to 23 May was 47 m (155 ft) AMSL, with a range of 21 to 141 m (68 to 461 ft) AMSL (25 and 75 percent quartiles, respectively; **Appendix C-1b**: **Table C-1b.1**). Daily diurnal median track altitudes ranged from 24 to 204 m (80 to 669 ft) AMSL (**Figure 6-21**).

The cumulative nocturnal median track altitude was 118 m (386 ft) AMSL, with a range of 60 to 204 m (198 to 669 ft) AMSL (25 and 75 percent quartiles, respectively; **Table C-1b.1**). Daily nocturnal median track altitudes ranged from 40 to 195 m (132 to 641 ft) AMSL (**Figure 6-22**).

The cumulative number of diurnal tracks within and below the RSZ was nearly equal (**Table 6-8**). The lowest number of diurnal tracks was above the RSZ. Nocturnal tracks were almost evenly distributed within and above the RSZ. Tracks within and above the RSZ were probably migrants.

Table 6-7. Island Beach State Park, VerCat operational hours, 15 to 23 May 2008.

Date	Diurnal[1]			Nocturnal[2]			Total Hrs
	Hrs Clear	Hrs Rain	Total Hrs	Hrs Clear	Hrs Rain	Total Hrs	
5/15/2008	3.9	-	3.9	4.4	-	4.4	8.3
5/16/2008	7.2	7.7	14.8	4.1	4.4	8.6	23.4
5/17/2008	13.5	-	13.5	3.9	4.6	8.5	22.0
5/18/2008	10.0	5.0	15.0	7.1	1.4	8.5	23.5
5/19/2008	14.8	0.7	15.6	8.4	0.1	8.5	24.0
5/20/2008	5.4	10.2	15.6	8.2	0.3	8.4	24.0
5/21/2008	14.5	1.2	15.6	7.3	1.1	8.4	24.0
5/22/2008	14.7	0.5	15.2	8.4	-	8.4	23.5
5/23/2008	10.0	-	10.0	4.1	-	4.1	14.0
Total	**94.0**	**25.3**	**119.3**	**55.9**	**11.9**	**67.8**	**187.1**

[1] Diurnal occurs from Civil Sunrise to Civil Sunset
[2] Nocturnal occurs from Civil Sunset to Civil Sunrise
Hrs = hours

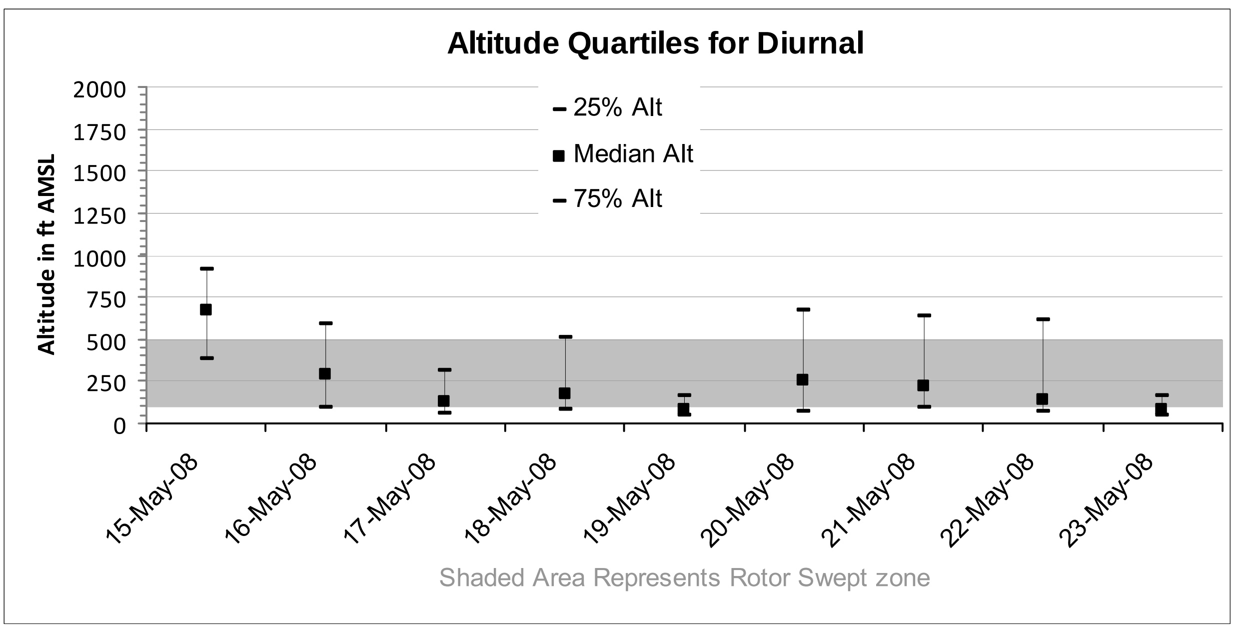


Figure 6-21. Island Beach State Park diurnal (clear weather) median altitude quartiles, 15 to 23 May 2008.

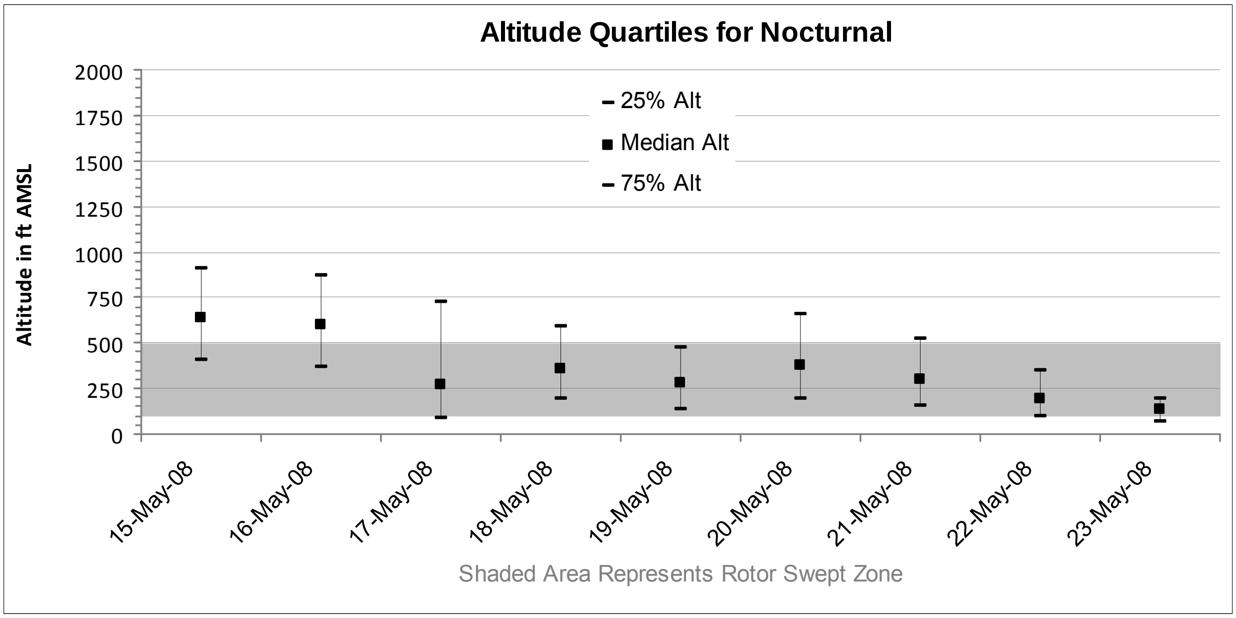


Figure 6-22. Island Beach State Park nocturnal (clear weather) altitude quartiles, 15 to 23 May 2008.

Table 6-8. Island Beach State Park cumulative diurnal and nocturnal (clear weather) track counts, 15 to 23 May 2008.

Altitude Band	Total Tracks	Percent Composition
Diurnal[1]		
1-100 ft AMSL	3,057	37.84
101-500 ft AMSL (RSZ)	3,331	41.24
501+ ft AMSL	1,690	20.92
Subtotal	8,078	-
Nocturnal[2]		
1-100 ft AMSL	5,866	18.33
101-500 ft AMSL (RSZ)	13,530	42.29
501+ ft AMSL	12,600	39.38
Subtotal	31,996	-
Total	40,074	-

[1] Diurnal occurs from Civil Sunrise to Civil Sunset
[2] Nocturnal occurs from Civil Sunset to Civil Sunrise

6.3.2.2 Mean Traffic Rate

Island Beach State Park

The cumulative diurnal MTR for Island Beach State Park was 21.9; daily diurnal MTRs ranged from 13.0 to 30.6 (**Appendix C-2b**: **Table C-2b.1**). Little variance in diurnal MTRs was noted and most of the targets were probably residents. During the nighttime, the cumulative MTR for the study period was 120.1 (range: 18.0 to 245.9). Two nights had MTRs of 200+ and two nights had MTRs over 100; most of these targets were probably nocturnal migrants.

6.3.2.3 Flight Direction by Quadrant

Heading (flight direction) is reported for all target detections during all weather conditions (clear, rain, fog). A given target may have been detected more than once and therefore was counted more than once. The total detections for each flight direction are plotted on a compass rose in 16 categories: N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW. Cumulative diurnal and nocturnal flight directions for each radar survey station are illustrated in **Appendix C-3b**: **Figures C-3b.1** and **C-3b.2**.

Island Beach State Park

During the daytime, the dominant flight direction was to the NNE in Quadrants 1 and 2 and to the NE in Quadrants 3 and 4 (**Figure C-3b.1**). Sub-dominant flight directions were to NE in Quadrants 1 and 2 and to the NNE and ENE in Quadrants 3 and 4 (**Figure C-3b.2**). The larger number of flights in the dominant and sub-dominant flight directions indicates that most of these targets were probably diurnal migrants.

At night, the dominant flight direction was to the NE in Quadrants 2, 3, and 4 and to the NNE in Quadrant 1. The sub-dominant flight direction in Quadrants 2, 3, and 4 was to the NNE. Most of the targets during the night were probably nocturnal migrants.

6.3.3 Radar Ground Truth Surveys

Radar target detection is affected by many variables including the size of the target, the location of the target within the beam, flight direction of the target with reference to the radar, flight behaviors (e.g., flapping, gliding, soaring), and weather conditions. Detection of all targets decreases with increasing distance from the radar because of a decrease in target reflectivity; therefore smaller targets are more difficult to detect at increasing distances from the radar than larger targets. Large flocks are easier to detect than single individuals throughout the radar's range because of the higher reflectivity of a large flock. The upper and lower sections of the radar beam have less power than the central portion of the beam; targets in the upper and lower sections of the beam may or may not be detected at increasing distances from the radar. A small target in the center of the radar beam at 4.6 km (2.5 NM) from TracScan may be detected while the same target near the lower or upper edge of the beam at the same distance may not be detected.

Each flight profile (e.g., flapping, gliding, diving) produces a different reflectivity which may have an effect on its detection. Flight direction with reference to the radar also affects a target's reflectivity. A target flying toward or away from the radar is more likely to have a lower reflectivity than a target flying tangential (broadside) to the sweep of the radar beam. Weather conditions (e.g., wind speed) may increase sea state and sea clutter and limit detection capabilities of the radar. Even with these limitations, radar provides the best available data on flying targets in the vicinity of the radar site at night.

6.3.3.1 Offshore Spring 2008

Four barge radar ground truth surveys were conducted during the spring season (**Appendix D-1**). Survey results are summarized for the spring season by species (Northern Gannet) or guild (ducks, loons, cormorants, gulls), flight altitude, and location with reference to the radar site. Both TracScan and VerCat radars were ground truthed. When the radar operator reported a radar echo track to the ground truth team and a biologist located and identified the source of the echo, the entry was recorded as confirmed.

TracScan ground truth survey data are limited; only general trends regarding TracScan detection of Northern Gannet were determined. Data for other guilds are presented (**Tables 6-10** through **6-13**). Insufficient data are available to identify any general trends in radar detections of these guilds at varying altitudes and distances from the radar site.

Based on the limited data, TracScan target confirmation of Northern Gannets decreased with increasing distance from the radar site. At 2 km (1.00 NM) from the radar 88.23 percent of the Northern Gannet observations (n=17) were confirmed, and at 4 km (2.00 NM), 63.64 percent of the Northern Gannet observations (n=33) were confirmed (**Table 6-9**). At (6 km (3.00 NM), 28.57 percent of the Northern Gannet observations (n=7) were confirmed. The decrease in Northern Gannet detections results from decreased detection capabilities in lower flight altitudes (<31 m [101 ft] ASL) at increasing distances from the radar (see **Section 6.3.3.2**: **Onshore Radar** for additional Northern Gannet data**)**.

VerCat ground truth data were analyzed. No general trends were identified for VerCat ground truth data because of the very limited survey data (**Tables 6-14** through **6-16**).

Table 6-9. Confirmation status of Northern Gannet observations by flight altitude for TracScan offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 07	1.00	0	2	3	0	4	0	4	0	2	0	13	2
Station 19	1.00	-	-	1	0	1	0	-	-	-	-	2	0
Subtotal	**1.00**	**0**	**2**	**4**	**0**	**5**	**0**	**4**	**0**	**2**	**0**	**15**	**2**
Station 23	1.75	2	1	1	0	-	-	-	-	-	-	3	1
Station 01	2.00	-	-	-	-	-	-	2	3	2	0	4	3
Station 07	2.00	2	1	0	2	3	0	2	0	2	1	9	4
Station 19	2.00	1	0	1	1	2	3	-	-	1	0	5	4
Subtotal	**2.00**	**5**	**2**	**2**	**3**	**5**	**3**	**4**	**3**	**5**	**1**	**21**	**12**
Station 23	**3.00**	**1**	**4**	**0**	**1**	**1**	**0**	**-**	**-**	**-**	**-**	**2**	**5**
Total		**6**	**8**	**6**	**4**	**11**	**3**	**8**	**3**	**7**	**1**	**38**	**19**

NM = nautical miles; ft AMSL = feet mean above sea level; C = Confirmed; U = Unconfirmed

Table 6-10. Confirmation status of duck (Anatidae) observations by flight altitude for TracScan offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 07	1.00	1	0	-	-	-	-	-	-	-	-	1	0
Station 19	1.00	0	1	-	-	-	-	-	-	-	-	0	1
Subtotal	**1.00**	**1**	**1**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**1**
Station 01	2.00	-	-	1	0	0	1	1	0	-	-	2	1
Station 07	2.00	1	1	-	-	-	-	-	-	-	-	1	1
Station 19	2.00	3	0	-	-	-	-	-	-	-	-	3	0
Subtotal	**2.00**	**4**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**-**	**-**	**6**	**2**
Total		**5**	**2**	**1**	**0**	**0**	**1**	**1**	**0**			**7**	**3**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-11. Confirmation status of loon observations by flight altitude for TracScan offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 19	1.00	3	0	-	-	1	1	-	-	1	0	5	1
Total		**3**	**0**			**1**	**1**			**1**	**0**	**5**	**1**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-12. Confirmation status of cormorant observations by flight altitude for TracScan offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 19	1.00	-	-	-	-	2	0	-	-	-	-	2	0
Total						**2**	**0**					**2**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-13. Confirmation status of gull observations by flight altitude for TracScan offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 07	1.00	-	-	-	-	-	-	-	-	-	-	-	-
Station 19	1.00	3	0	1	0	-	-	-	-	-	-	4	0
Subtotal	**1.00**	**3**	**0**	**1**	**0**	**-**	**-**	**-**	**-**	**-**	**-**	**4**	**0**
Station 23	1.75	3	1	-	-	-	-	-	-	-	-	3	1
Station 01	2.00	-	-	-	-	1	0	-	-	0	2	1	2
Station 07	2.00	0	1	1	0	-	-	-	-	-	-	1	1
Station 19	2.00	-	-	-	-	2	0	-	-	1	0	3	0
Subtotal	**2.00**	**3**	**2**	**1**	**0**	**3**	**0**	**-**	**-**	**1**	**2**	**8**	**4**
Total		**6**	**2**	**2**	**0**	**3**	**0**			**1**	**2**	**12**	**4**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-14. Confirmation status of Northern Gannet observations by flight altitude for VerCat offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 07	0.50	-	-	1	0	3	0	1	0	-	-	5	0
Subtotal	**0.50**	**-**	**-**	**1**	**0**	**3**	**0**	**1**	**0**	**-**	**-**	**5**	**0**
Station 01	1.00	-	-	-	-	-	-	-	-	1	0	1	0
Subtotal	**1.00**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**1**	**0**	**1**	**0**
Total				**1**	**0**	**3**	**0**	**1**	**0**	**1**	**0**	**6**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-15. Confirmation status of cormorant observations by flight altitude for VerCat offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 01	1.00	-	-	-	-	-	-	-	-	1	0	1	0
Total										**1**	**0**	**1**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-16. Confirmation status of gull observations by flight altitude for VerCat offshore ground truth surveys, spring 2008.

Station #	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Station 01	1.00	-	-	0	1	-	-	3	0	2	0	5	1
Total				**0**	**1**			**3**	**0**	**2**	**0**	**5**	**1**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

6.3.3.2 Onshore Spring 2008

Ground truth surveys were conducted at three sites: Island Beach State Park, Brigantine Beach, and Corson's Inlet from May to June (**Appendix D-2**). All of the radar data are TracScan; VerCat ground truth surveys were not conducted.

No general trends were identified except for gulls. Although data are limited, gulls were confirmed at all altitude bands (**Table 6-17**). Data for the other guilds are presented (**Table 6-18** through **6-20**). Insufficient data are available to identify any general trends in radar detections of these guilds at varying altitudes and distances from the radar site.

Table 6-17. Spring 2008 confirmation status of gull observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	1	-	-	2	0	2	0	0	1	2	0	6	1
Absecon	1	-	-	5	0	2	0	3	0	-	-	10	0
Corson's Inlet	1	2	0	4	0	3	0	4	0	3	0	16	0
Total		**2**	**0**	**11**	**0**	**7**	**0**	**7**	**1**	**5**	**0**	**32**	**1**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-18. Spring 2008 confirmation status of tern observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	1	-	-	-	-	-	-	1	0	-	-	1	0
Brigantine	1	-	-	1	0	-	-	-	-	-	-	1	0
Corson's Inlet	1	-	-	1	0	1	0	-	-	-	-	2	0
Total				**2**	**0**	**1**	**0**	**1**	**0**			**4**	**0**

NM = nautical miles; ft AMSL = feet above sea level; C = Confirmed; U = Unconfirmed

Table 6-19. Spring 2008 confirmation status of cormorant observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	1	-	-	-	-	-	-	-	-	-	-	-	-
Absecon	1	-	-	-	-	-	-	-	-	-	-	-	-
Corson's Inlet	1	-	-	-	-	2	0	-	-	-	-	2	0
Total						**2**	**0**					**2**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-20. Spring 2008 confirmation status of wader observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	1	-	-	-	-	-	-	-	-	-	-	-	-
Absecon	1	-	-	-	-	-	-	-	-	-	-	-	-
Corson's Inlet	1	1	0	-	-	3	0	2	0	3	0	9	0
Total		**1**	**0**			**3**	**0**	**2**	**0**	**3**	**0**	**9**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

6.3.3.3 Onshore Fall 2008

Ground truth surveys were conducted at three sites: Island Beach State Park, Sea Isle City, and Brigantine Beach from September through November (**Appendix D-3**). At Brigantine Beach ground truth observations were conducted both onshore and offshore, and the data are presented separately. All of the radar data are from TracScan; VerCat ground truth surveys were not conducted.

Land-based Observations

Survey results are summarized for the land-based observation sites by species (Northern Gannet) or guild (ducks, cormorants, gulls, and terns), flight altitude, and location with reference to the radar site (**Tables 6-21** to **6-25**). At all three sites surveying was constrained by access, view, and communication; as a result, all of the observations were conducted at 2 km (1.00 NM) or less from the radar.

One hundred percent of the tern sightings (n=49) were confirmed by radar. Ninety-nine percent of the gull sightings (n=182), 97.80 percent of the duck sightings (n=182), 97.92 percent of the cormorant sightings (n=96) sightings, and 95.52 percent of the Northern Gannet sightings (n=67) were confirmed by radar. Confirmation rate for onshore radar is much higher than those for offshore radar (**Section 6.3.3.1**); however, onshore and offshore radar observation results cannot be effectively compared given the disparity in sample sizes.

Offshore Observations

The observations taken offshore from Brigantine Beach were conducted at 3, 4, and 5 km (1.67, 2.00, and 2.75 NM) and are summarized by species (Northern Gannet) or guild (gulls, ducks, and cormorants). At all distances from the radar 100 percent of the Northern Gannet (n=70) and gull (n=26) sightings were confirmed (**Tables 6-26** and **6-27**); however, one individual, either a Northern Gannet or a Herring Gull, was unconfirmed by radar at a distance of 3.7 km (2.75 NM) and an altitude of 14 m (45 ft; **Appendix D-2**). It is not listed in either of these tables since it was not definitively identified to species. Insufficient data for ducks and cormorants (**Tables 6-28** and **6-29**) prevent any generalizations in radar detection trends. Consistent with the land-based surveys, unconfirmed observations across all altitude levels are low.

Table 6-21. Fall 2008 confirmation status of Northern Gannet observations by flight altitude for onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	0.03	4	0	2	1	1	0	3	1	3	0	13	2
Sea Isle City	0.03 to 0.20	0	1	8	0	5	0	-	-	1	0	14	1
Brigantine Beach	0.10	5	0	21	0	7	0	3	0	1	0	37	0
Total		**9**	**1**	**31**	**1**	**13**	**0**	**6**	**1**	**5**	**0**	**64**	**3**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-22. Fall 2008 confirmation status of duck (Anatidae) observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	0.03	6	0	1	0	-	-	-	-	1	0	8	0
Sea Isle City	0.03 to 0.40	105	0	22	1	2	0	8	0	14	2	151	3
Brigantine Beach	0.10	8	0	2	0	-	-	0	1	9	0	19	1
Total		**119**	**0**	**25**	**1**	**2**	**0**	**8**	**1**	**24**	**2**	**178**	**4**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-23. Fall 2008 confirmation status of cormorant observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to Radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	0.03	3	0	2	0	-	-	-	-	-	-	5	0
Sea Isle City	0.03 to 0.40	2	0	2	1	1	0	5	0	70	0	80	1
Brigantine Beach	0.10	1	0	2	0	-	-	1	1	5	0	9	1
Total		**6**	**0**	**6**	**1**	**1**	**0**	**6**	**1**	**75**	**0**	**94**	**2**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-24. Fall 2008 confirmation status of gull observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	0.03 to 1.00	22	0	53	1	11	1	21	0	37	0	144	2
Sea Isle City	0.03 to 0.40	3	0	4	0	3	0	5	0	4	0	19	0
Brigantine Beach	0.10	1	0	8	0	4	0	2	0	2	0	17	0
Total		**26**	**0**	**65**	**1**	**18**	**1**	**28**	**0**	**43**	**0**	**180**	**2**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-25. Fall 2008 confirmation status of tern observations by flight altitude, onshore ground truth surveys. All radar data are TracScan.

Location	Distance to radar (NM)	Altitude (ft AMSL)											
		1-25		26-50		51-75		76-100		101+		Total	
		C	U	C	U	C	U	C	U	C	U	C	U
Island Beach State Park	0.03	6	0	9	0	3	0	13	0	13	0	44	0
Sea Isle City	0.03	-	-	4	0	-	-	-	-	-	-	4	0
Brigantine Beach	0.10	-	-	1	0	-	-	-	-	-	-	1	0
Total		**6**	**0**	**14**	**0**	**3**	**0**	**13**	**0**	**13**	**0**	**49**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-26. Confirmation status of Northern Gannet observations by flight altitude, offshore Brigantine Beach on 11 November 2008. All radar data are TracScan, and radar was based onshore.

Distance to Radar (NM)	Altitude (ft AMSL)											
	1-25		26-50		51-75		76-100		101+		Total	
	C	U	C	U	C	U	C	U	C	U	C	U
1.67	-	-	7	0	4	0	5	0	2	0	18	0
2.00	4	0	12	0	3	0	2	0	-	-	21	0
2.75	15	0	16	0	-	-	-	-	-	-	31	0
Total	**19**	**0**	**35**	**0**	**7**	**0**	**7**	**0**	**2**	**0**	**70**	**0**

NM = nautical miles; ft AMSL = feet above sea level; C = Confirmed; U = Unconfirmed

Table 6-27. Confirmation status of gull observations by flight altitude, offshore Brigantine Beach on 11 November 2008. All radar data are TracScan, and radar was based onshore.

Distance to Radar (NM)	Altitude (ft AMSL)											
	1-25		26-50		51-75		76-100		101+		Total	
	C	U	C	U	C	U	C	U	C	U	C	U
1.67	4	0	5	0	1	0	3	0	1	0	14	0
2.00	2	0	6	0	1	0	-	-	-	-	9	0
2.75	1	0	2	0	-	-	-	-	-	-	3	0
Total	**7**	**0**	**13**	**0**	**2**	**0**	**3**	**0**	**1**	**0**	**26**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-28. Confirmation status of duck (Anatidae) observations by flight altitude, offshore Brigantine Beach on 11 November 2008. All radar data are TracScan, and radar was based onshore.

Distance to Radar (NM)	Altitude (ft AMSL)											
	1-25		26-50		51-75		76-100		101+		Total	
	C	U	C	U	C	U	C	U	C	U	C	U
1.67	1	0	-	-	-	-	-	-	-	-	1	0
2.00	-	-	-	-	-	-	-	-	-	-	-	-
2.75	1	2	1	1	-	-	-	-	-	-	2	3
Total	**2**	**2**	**1**	**1**							**3**	**3**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

Table 6-29. Confirmation status of cormorant observations by flight altitude, offshore Brigantine Beach on 11 November 2008. All radar data are TracScan, and radar was based onshore.

Distance to Radar (NM)	Altitude (ft AMSL)											
	1-25		26-50		51-75		76-100		101+		Total	
	C	U	C	U	C	U	C	U	C	U	C	U
1.67	-	-	-	-	-	-	-	-	1	0	1	0
2.00	-	-	-	-	-	-	-	-	3	0	3	0
2.75	-	-	-	-	-	-	-	-	-	-	-	-
Total									**4**	**0**	**4**	**0**

NM = nautical miles; ft AMSL = feet above mean sea level; C = Confirmed; U = Unconfirmed

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7.0 AVIAN PREDICTIVE MODEL

This section provides a preliminary review of potential modeling methods that could be used as components of the avian predictive model and for modeling avian radar data. Other components that may be incorporated into the avian predictive model include existing data sources and databases (USFWS offshore aerial/boat survey data, habitat maps [shoals], and other physical and water data [chlorophyll, salinity, temperature]). These components are currently being reviewed for potential incorporation into the overall avian predictive model.

This section discusses distance modeling and kernel density (i.e., potential components of the avian predictive model), and kriging methods for avian radar data modeling. Distance modeling and kernel density modeling results are presented for avian offshore surveys.

7.1 SPATIAL AND TEMPORAL MODELING LITERATURE REVIEW

7.1.1 Background

At sea, surveys for mapping bird density is routinely used to estimate spatial distribution, population size, habitat use, predator-prey interactions and potential changes due to human disturbances and climate change (Santora et al. 2009; Zador et al. 2008; Certain et al. 2007; Karpouzi et al. 2007; Desholm et al. 2006; Clarke et al. 2003; Hyrenbach and Veit 2003; Veit et al. 1996). Here, the focus is on relating changes in bird density collected during ship surveys along the New Jersey coast to develop predictive models to examine how changes in spatial distribution of birds is related to seasonality, environmental predictors (e.g. bathymetry), and avian community composition. There are a number of statistical models available to examine changes in bird density at sea, such as spatial interpolation (e.g. kriging or kernel density), Generalized Linear Models, and Generalized Additive Models (GAMs; Certain et al. 2007; Zador et al. 2008; Karpouzi et al. 2007; Redfern et al. 2006; Kaschner et al. 2006; Clarke et al. 2003). Our preliminary modeling investigation is to examine spatial variability of bird density using spatial interpolation methods. For example, hotspot mapping and kernel density are used to examine changes in bird density at specific cells through time in the Study Area. Although these methods are useful for determining the presence of spatial patterns and trends, they are not predictive in the sense of explaining specific species habitat associations through time and space. To predict changes in avian density, information regarding the environment needs to be related to sampled distribution of bird species using a geo-statistical approach. Generalized linear and additive models are particularly useful for predicting the response of avian density at sea in terms of environmental predictors and survey effort (Zador et al. 2008; Certain et al. 2007; Clarke et al. 2003). Clarke et al. (2003) used at sea survey data and a GAM, to predict population size of birds and spatial distribution in the Central California region. GAMs are also useful for examining the influence and shape of explanatory variables for predicting changes in predator density at sea. Redfern et al. (2006) discussed the usefulness of GAMs for describing changes in the sighting rate of marine mammals based on distance from shore and changes in bathymetry. Understanding and predicting potential risk from human perturbations (e.g. wind farms, vessel traffic) in the marine environment to birds and mammals is also a problem that geospatial models are useful for investigating. For example, Vanderlann et al. (2008) investigated the probability of ship strikes and whale distribution in the Bay of Fundy by developing probability of occurrence functions to generate predicted spatial distribution of whales and vessels in order to minimize the encounter of vessel striking a whale. These already developed generalized linear and additive models will be expanded by adding a geospatial context that incorporates spatially explicit information regarding the coastal environment off New Jersey. Once all data have been collected, an avian predictive model will be developed and tested using multivariate statistical models that incorporate aspects of avian density (e.g. presence/absence, spatial point patterns, kernel density and hotspot mapping) and environmental predictors (e.g. Bathymetry, sediment, SST, distance from shore, etc…) to predict the probability of occurrence for bird species along the New Jersey coastal environment.

Counts of birds sampled during shipboard strip-transect are used to determine seabird avian density within the survey area. First, a geo-spatial database will be maintained to visualize survey effort according to survey type sampled on a monthly basis. Secondly, for quality assurance and basic data management requirements (i.e. maintenance and updating data), the expanding symbol plots of total seabird abundance (No./km) will be examined for inspection of data, and basic spatial and temporal descriptive statistics will be calculated. Thirdly, the most abundant species will be plotted in relation to survey effort and month.

The objective of modeling at-sea bird density is essentially to determine the probability of being able to detect a specified change in bird numbers in relation to time (i.e. month) and spatial scale (e.g., 1 km x 1 km [0.62 mi x 0.62 mi] and 5 km x 5 km [3.1 mi x 3.1 mi]). All aspects of statistical modeling will pass through a rigorous series of tests and statistical power analyses. Furthermore, explicit consideration will be given to different species and how their densities vary accordingly to life history constraints. For example, species specific attributes such as timing of migration events and seasonal habitat requirements (e.g., affinity for shoals) will be considered during all aspects of statistical modeling procedures.

Modeling temporal variability of bird density is basically constrained to survey type (nearshore or offshore), effort (No./km), month and season. Temporal modeling will be conducted using a generalized linear model. To fit the model, a log-likelihood ratio is used along with a link function specified as a Poisson distribution to account for over-dispersion in the bird response variable (i.e., seabird counts tend to be patchily distributed). Moreover, a power analysis will be conducted by using the observed data distribution to simulate a series of distributions with similar means and variances to the observed dataset, and then the proportion of times that the statistical tests are significant will be calculated. The model output will be a tabulation of effects via contribution of explanatory variables for estimating and predicting bird density on a temporal basis.

Modeling spatial variability of at-sea bird density requires explicit consideration of space and scale dependency. Seabird spatial variability will be described, estimated, and predicted using spatial autocorrelation (Moran's I), generalized linear models, spatial regression models and spatial interpolation (e.g., conditional simulation and kernel density methods). In addition, spatial covariates are used to aid in estimation and prediction of seabird spatial variability. Examples of spatial covariates include bathymetry (depth), distance to land, location and distance to shoals, and hydrodynamic properties (e.g., sea-temperature).

The visual product of statistical spatial modeling is a density map that incorporates aspects of spatial structure (i.e., patchiness) and the variance or error in predicting spatial usage by seabirds. For example, seabird counts are used to generate spatial density maps using the kernel density spatial interpolation method. This method inputs measured attribute values (e.g., avian abundance) collected at sampled longitude-latitude locations to obtain estimates at un-sampled sites positioned on a regular longitude-latitude grid system. Kernel methods generally spread the mass of each observation around the observed value, with a relative weighting being inversely related to the separation distance between the un-sampled site and a neighboring sampled site. Attribute values generated at each sampled site are estimates rather than exact values, since interpolation is required. This method is relatively accurate for sampled data that are evenly spaced and exhibit smooth spatial gradients, but is less accurate for clustered data exhibiting sharp gradients or "spikes" (e.g., hot-spots). In addition, the presence of anomalies significantly skews the data, introducing inaccuracies in the interpolation process. The standard error in the estimates at a given un-sampled site generally varies directly with the magnitude of the spatial gradient (difference) in observed values in proximity to that site.

7.1.2 Kernel Density Spatial Interpolation

The kernel density (smoothing) spatial interpolation method is a non-parametric (e.g., distribution-free) method of discerning structure or relationships in the data, by estimating the probability density function of a random variable. Kernel density estimation, like any spatial interpolation method, involves estimating an attribute value (e.g., avian density) at an unsampled site given measurements at neighboring sampled sites. An algorithm is used that incorporates a weighting function that prescribed relative contributions of individual sampled values as a function of the distance between the un-sampled and sampled sites.

The kernel density method operates on the premise (principle) that spatial autocorrelation between two points decreases (e.g., their semivariance increases) asymptotically as their separation distance increases. For example, in the estimation of bird density at a given unsampled site, bird count data at neighboring sites that are very close to the unsampled site are given more weight than data at neighboring sites that are a further distance away (as parameterized by the kernel function K). Bird densities generated at each unsampled site are estimates rather than exact values, since interpolation is required. The standard error in the estimates at a given unsampled site generally varies directly with the magnitude of the spatial gradient (difference) in observed values in proximity to that site. The presence of anomalies can significantly skew the data, introducing inaccuracies in the interpolation process.

The kernel density method disperses the mass of each observation around the observed value, with the amount of dispersion being governed by the kernel function K and bandwidth h (a.k.a. smoothing parameter). The kernel function K is typically symmetric, such that the point mass is dispersed equally toward higher and lower values (Burt and Barber 1996). For example, narrow kernels (small h) concentrate mass more tightly around the central (observed) values than wide kernels (large h). The h value also governs the amount of detail in the estimated point density function g(x,y) and probability density function f (x,y): A large h value generates a broad, smooth density function with little fine structure, whereas a small h value generates a narrow density function with fine-scale variability.

This method is often used when relationships between variables are thought to be non-linear and complex and requires fewer statistical assumptions than standard linear regression. Kernel smoothing is also commonly used for estimating the probabilities of occurrence of organisms across a two-dimensional landscape.

7.1.3 Kriging Spatial Interpolation

In addition to Distance sampling and kernel density spatial interpolation currently being applied to the transect survey data, another feasible spatial interpolation method, which can potentially be applied to estimate avian density from transect data and radar data, is kriging. An advantage of kriging is the wealth of statistical information provided by this method's standard output: A spatially continuous density map of the given attribute (i.e., bird density), and an analogous spatial map of standard error (or variance).

The feasibility of kriging is currently being assessed by examining the nature of the temporal/spatial resolutions and variability of the avian density data from the strip transects and radar. For example, kriging is generally more accurate for data exhibiting small spatial gradients (e.g., smoothly varying densities over space) than large spatial gradients (e.g., sharply varying densities over small spatial scales, such as "hot spots"). In addition, significant differences in spatial and temporal resolutions exist between the radar datasets and the line-transect surveys. Radar coverage is essentially continuous temporally but, due to time and effort constraints and water-depth constraints, provides relatively poor spatial resolution: Several radar platform locations are quasi-randomly located throughout the Study Area but are constrained by water depth. In contrast, the transect lines of the aerial surveys and the double sawtooth transect lines of the shipboard surveys provide complete spatial coverage but only a temporal "snapshot" (e.g., at one point in time, corresponding to the time the plane or ship is at the given location). Recognizing the spatial and temporal differences between the radar data and the strip transect data, these two types of datasets will potentially be analyzed via kriging to generate a similar product: A spatially continuous avian density map with a corresponding spatial map of standard error (or variance).

7.1.3.1 Kriging Concepts

Kriging is an optimal geospatial interpolation method involving Bayesian inference that uses a set of linear least squares weighted regression estimation algorithms (routines) that minimize estimation variance (error) from a predefined covariance or semivariance model. These algorithms utilize spatial correlation structure to provide a best linear unbiased estimate (BLUE) of the average attribute value at unsampled sites based on known attribute values at neighboring sampled sites. Kriging interpolates attribute values at unsampled sites on a regular grid with a finer spatial resolution than the spacing between sampled sites, thereby generating spatial maps (interpolated surfaces) of the average attribute estimate and of the (minimized) estimation variance (error) over the Study Area. Thus, kriging estimates interpolation weights and provides information about errors, resulting in maps of interpolated values and estimation variances (errors) at each of the unsampled sites (interspersed among the sampled sites). Unlike trend surface methods, kriging is an exact interpolator, such that the interpolated average attribute value calculated at a sampled site coincides with its known attribute value (i.e., the kriged surface passes through the data points), provided that the spatially uncorrelated random residual variation ("noise") is zero.

Kriging is quasi-random in that it contains both deterministic and random components. Spatial variation models generally contain three components: 1) A major deterministic structural component representing the average (mean) value of the attribute (or a constant trend) within a defined area or mapping unit; 2) A spatially correlated gradual random variation; 3) Spatially uncorrelated random residual variation ("noise"). The noise component arises due to measurement error and microstructure (where spatial variations occur at scales too small to be resolved by the sampling network), and is quantified by the semivariogram's nugget parameter (non-zero semivariance at zero separation distance). This residual term is assumed to be stationary, spatially independent, and normally (Gaussian) distributed with zero mean and constant variance. Due to the presence of both deterministic and random components, the given attribute being interpolated via kriging is termed a regionalized variable (i.e., intermediate between a truly random variable and a completely deterministic variable). Sampling and estimation (interpolation) of regionalized variables are conducted to generate a spatial pattern (map) of variation in the average value of the attribute and associated (minimized) estimation variance (error).

Five general components of kriging include detrending, semivariogram modeling, neighborhood search, interpolation, and cross-validation. Kriging is a valid and accurate model only when applied to stationary data. The stationarity principle states that the average attribute value at the sampled sites is relatively constant among the various regions in the sampled dataset (i.e., no spatial deterministic trend exists). That is, stationary data is spatially random, containing no deterministic trend. As a precursor to kriging, detrending is applied if the attribute cannot be assumed to be stationary. In the detrending process: 1) The data are regressed via a polynomial regression function, separating the data into a deterministic (trend) component and a random component; 2) The deterministic component is subtracted from the random component, leaving the residual. 3) Kriging is applied only to the residual component, to generate a model-estimated (interpolated) residual error; 4) The deterministic component is added to the model-estimated residual error to obtain the model-estimated (interpolated) mean attribute value. Since the residuals are stationary, kriging can be applied to the residuals (obtained during the detrending process).

Spatial correlation structure among sites in a Study Area is quantified by a model-fitted semivariogram (e.g., plot of semivariance versus separation distance between pairs of points). Semivariogram analysis is a precursor to the kriging process and is a multivariate extension of principal components analysis (PCA) ordination. The semivariance model, using least-squares and maximum-likelihood criteria and incorporating three parameters (range, sill, and nugget), quantifies positive spatial correlation structure (spatial autocovariance), which recognizes greater similarity in attribute values between two closely spaced sites than between two sites spaced further apart. Thus, sites close together have high spatial correlation, which decreases (e.g., semivariance increases) with increasing separation distance. Within the range of spatial autocorrelation, semivariance generally increases asymptotically with increasing separation distance between the two sites. Sites located outside the range of a given site are spatially uncorrelated with (e.g., statistically spatially independent of) that site. As separation distance increases from zero to the range value, semivariance increases from the nugget value to approach an asymptote (sill), equal to the variance around the average value of the attribute in the Study Area. The nugget parameterizes the "noise" component (arising from measurement error and microstructure).

If the range value (obtained from the model-fitted semivariogram) is significantly less than the spatial extent of the Study Area, then kriging is a local application process, such that not all sampled sites ("j") in the Study Area are used to interpolate the attribute value at a given unsampled site ("i"). That is, the kriging neighborhood search is restricted to only those sampled sites within the unsampled site's range. Sampled sites outside this range are considered spatially uncorrelated with the unsampled site and hence are given a weighting factor w (i,j) of zero. Within the range, sampled sites closer to the unsampled site are given relatively stronger weighting (since their spatial correlation is stronger) than sampled sited further from the unsampled site, to reflect their spatial autocorrelation structure (quantified by the model-fitted semivariogram). To fine-tune the kriging process, the neighborhood search can be further controlled by the user via specification of a minimum and maximum number of nearest neighbors (sampled sites), sector search method (1, 4, or 8 sectors), angle direction and tolerance, bandwidth (to assess anisotropy versus isotropy), lag size, and number of lags. Isotropy occurs if autocorrelation depends solely on separation distance and not on their relative position or angle. In contrast, anisotropy occurs if autocorrelation depends on relative position or angle.

After kriging interpolation is applied to the dataset, cross-validation is conducted to assess the kriging model's accuracy. Cross-validation uses all of the sampled data sites to estimate the autocorrelation (semivariance) model. Then each sampled site is removed one at a time, and the kriging model is used to estimate the attribute value at the omitted site. The model-estimated and known (measured) attribute values at the omitted site are compared; and this omission-comparison procedure is repeated for each sampled site in the Study Area. Thus, validation first removes part of the data (i.e., the test or validation dataset) and then uses the rest of the data (e.g., the training or calibration dataset) to develop the trend and autocorrelation (semivariance) models to be used for prediction. Common statistical metrics calculated in cross-validation include: Mean prediction error (MPE), root mean square prediction error (RMSPE), average kriging prediction (estimation) standard error (AKPSE), mean standardization prediction error (MSPE), and root mean square standardized prediction error (RMSSPE).

7.1.3.2 Advantages of Kriging vs. Other Spatial Models

Advantages of kriging over other spatial modeling methods (e.g., Distance sampling, kernel density estimation) arise from its features as a BLUE, an exact interpolator, and its functional dependence on spatial autocorrelation structure. Like trend surface models, kriging uses interpolation to generate an estimate of an attribute value at unsampled sites based on known attribute values at neighboring sampled sites. Unlike trend surface models, however, kriging is based on the spatial autocorrelation structure (semivariogram) among these sites. Disadvantages of trend surface models (e.g., empirical, often physically unrealistic regression polynomials; long-range nature of the surfaces due to modeling of gradual long-range spatial variations in the attribute; potentially large effect of outliers on local estimates) are overcome by the kriging method. Furthermore, based on matrix algebraic relationships, a spatial map of the (minimized) estimation variance (error) is generated alongside the map of the average value of the attribute estimate. This feature provides an advantage to kriging compared to other methods (e.g., Distance modeling), which rely on repeated random data generation processes (e.g., bootstrapping) to generate the standard errors. Kriging has been shown to be superior to other interpolation methods such as Inverse Distance Weighting (IDW) and Triangulated Irregular Networking (TIN).

Another advantage of kriging is its superior abundance of spatial output information over other spatial modeling methods. Four type of spatial maps can be generated by the kriging process: 1) “Prediction Map” of the average value of the estimated (interpolated) attribute; 2) “Prediction Standard Error Map” of the (minimized) estimation variance (error); 3) “Probability Map”: Each site has a mean attribute value and a variance (and hence a normal Gaussian probability distribution curve) associated with it. The bell-shaped curve is theoretically symmetrical about the mean, with a spread governed by the standard error. For a given site and user-specified threshold value, the probability that the attribute is greater than the threshold is given by the area under the Gaussian curve to the right of the threshold value. This probability is calculated for each site and is plotted on the probability map; 4) “Quantile Map”: Alternatively, for a given site and user-specified quantile (e.g., 5 percent, or the probability that the attribute value is greater than some unknown value is 5 percent), this unknown value is calculated from the normal Gaussian probability distribution curve for each site and is plotted on the quantile map.

7.1.3.3 Sensitivity and Optimization Analyses of Kriging Models

Sensitivity analysis of impacts of various user-specified parameters on the kriging model output (spatial maps and cross-validation parameters) can be conducted by repeating the above general procedure for different parameter values, for example: 1) Selection of kriging method (e.g., ordinary, simple, universal, indicator, probability, or disjunctive kriging); 2) Selection of spatial map product (prediction, minimized standard error, probability, or quantile maps); 3) Detrending (e.g., separation of deterministic component from the random component) versus no detrending of the data; 4) Selection of semivariogram model (circular, spherical, tetraspherical, pentaspherical, exponential, Gaussian [normal], rational quadratic, hole effect, K-Bessel, J-Bessel, or stable models); 5) Examination of isotropy versus anisotropy; and selection of major/minor ranges, angle direction and tolerance, bandwidth, lag size, and number of lags; 6) Selection of neighborhood search method (1, 4, or 8 sectors), maximum and minimum number of nearest neighbors, and major/minor semiaxes.

Optimization analysis involves identifying the set of parameter values that minimizes the estimation variance (error) on the standard error spatial map and/or optimizes the cross-validation parameters. For example, several kriging methods and semivariance models can be compared with each other with respect to overall performance, by comparing their output standard error spatial maps. The model with an optimized standard error map showing the smallest standard error residuals (compared to other models), reflecting superior fit of the measured data, is identified as the best model. In addition, model accuracy and validity are governed by the following cross-validation parameter criteria:

1) Mean prediction error (MPE): Should be near zero if the prediction errors are unbiased.

2) Root mean square prediction error (RMSPE): Should be near zero if there is good agreement between the predicted and measured attribute values.

3) Average kriging prediction (estimation) standard error (AKPSE): Should be close to the RMS prediction error if the kriging prediction (estimation) standard errors are valid/accurate (e.g., if the variability in the kriging prediction is being correctly assessed). If the AKPSEs are greater (less) than the RMSPEs, then the variability in the predictions are being overestimated (underestimated).

4) Mean standardized prediction error (MSPE): Should be near zero if the prediction errors are unbiased. The mean standardized prediction error is the ratio of the mean prediction error to the average kriging prediction (estimation) standard error: MSPE = MPE/AKPSE.

5) RMS standardized prediction error (RMSSPE): Should be near unity if the kriging prediction (estimation) standard errors are valid/accurate (e.g., if the variability in the kriging prediction is being correctly assessed). The RMS standardized prediction error is the ratio of the RMS prediction error to the average kriging prediction (estimation) standard error: RMSSPE = RMSPE/AKPSE. Thus, if the RMSSPEs are greater (less) than unity, then the variability in the predictions are being underestimated (overestimated).

To account for differences in scale of the data, standardized prediction errors are calculated as the prediction errors divided by the prediction standard errors (e.g., MSPE = MPE/AKPSE and RMSSPE = RMSPE/AKPSE). The cross-validation criteria used to select the optimal model include: 1) MSPE nearest to zero; 2) Smallest RMSPE; 3) AKPSE nearest to the RMSPE; 4) RMSSPE nearest to 1.

7.2 MODEL DEVELOPMENT

7.2.1 Hotspot Mapping

A hotspot mapping method to determine avian "hotspots" for all birds is provided in this section. Block-averaging and tracking grid cells are an effective means for exploring the persistence of regions through space and time. The objective was to assess the repeatability of detecting similar concentrations of birds on a fixed grid. It is important to note that the resulting maps are not estimates of absolute density, but are rather an index for locating regions where similar concentrations of birds were observed over the year, and for comparison among seasons.

By definition, a "hotspot" is a region whereby the gridded value (avian density) exceeds the mean by 1.96 SD. The total avian density for all birds is calculated, weighted by survey effort (number of km sampled) per 10 km^2. Avian density for all birds is determined for each of 72 grid cells placed over the Study Area for the periods of: January through November (February had only one survey day); January to April; May to July; August to November. An avian density range, displayed as percent of total, is determined for January through November by identifying the minimum and maximum densities and developing a color-coded range for six categories, with red as the highest and dark blue being the lowest categories.

7.2.2 Kernel Density

For a sample size n, point density g(x,y; e.g., bird density) at an unsampled site (x,y; e.g., longitude-latitude [lon-lat] location) is estimated by summing the kernel values $K(d_i/h)$ of all n data points or neighboring sampled sites around the unsampled site (Burt and Barber 1996):

$$g(x,y) = (1/h^2)*SUM[K(d_i/h)]$$

and probability density f(x,y) is given by: f(x,y) = g(x,y)/n, where d_i = spatial distance between the unsampled site and sampled site "i"; n = number of neighboring sampled sites (in the vicinity of the unsampled site); h = bandwidth or smoothing parameter; K is the kernel weighting function that generally decreases with increasing distance between the unsampled and sampled sites. For example, a normal kernel is given by:

$$K(d_i/h) = \{[1/(2*pi)]^{0.5}\}*exp[-0.5*(d_i/h)^2]$$

where pi=3.1415927. This function describes a Gaussian normal curve with a maximum value of $(1/[2*pi])^{0.5}$ at zero distance (d_i=0) and decreases with increasing distance d_i. The rate of decrease in K with increasing d_i is governed by the value of h: As h decreases, the rate of drop-off becomes more rapid, effectively concentrating the mass more tightly around the central (observed) value. The summation in the above equation for g(x,y) is conducted over the number of neighboring sampled sites n around the unsampled site.

For the bird count data collected on the coastal and offshore surveys, the sampled sites are the lon-lat locations at which bird count data were collected; and the unsampled sites are the 100 gridpoints in the above-mentioned regular lon-lat grid system.

The Gaussian kernel estimator for point location data (Silverman 1986) was modified for continuous data by multiplying values of bird density (the continuous variable) by kernel weights and computing a weighted average:

$$\hat{\mu}(y \mid x) = \frac{\sum_{i=1}^{n} w(x, X_i, h) y_i}{\sum_{i=1}^{n} w(x, X_i, h)}$$

where y_i is the observed density (birds per square kilometer per visit) for each sub-segment represented by the coordinate pair $\boldsymbol{X}_i$, $\hat{\mu}(y \mid x)$ is the estimated mean density at grid location $\boldsymbol{x}$, h is the bandwidth or smoothing parameter, and

$$w(x, X_i, h) = exp\left[-\frac{1}{2h^2}(x - X_i)^T (x - X_i)\right]$$

where $(x – X_i)$ is a vector of length n. In vector notation, the superscript "T" denotes transpose of the vector, such that $(x – X_i)$ is a vector with n rows and 1 column, whereas $(x – X_i)^T$ is the transposed vector with 1 row and n columns. The pre-multiplication of the vector $(x – X_i)$ by its transpose results in a scalar (Bailey and Gatrell 1995). The smoothing parameter h dictates the degree of smoothing. The weighted average, $\hat{\mu}(y \mid x)$, was computed at each intersection of a longitude-latitude regular grid.

General assumptions made in the kernel density spatial interpolation analysis include:

1) Only birds observed within 300 m (984.3 ft) of the observer (in-zone observations), and only those data that were collected with vessel speeds less than 7 kts (8.1 mph) were included in the analysis.

2) Given the observation date and time as well as the starting/ending times and starting/ending lon-lat locations of each transect on which the given observation occurred was identified. Then, to a first order approximation, the lon-lat locations were interpolated with respect to the times to estimate the lon-lat location of the observation.

3) Given the range, heading, and lon-lat location of the observation (e.g., observer location), the approximate location (in longitude-latitude coordinates) of the actual birds was calculated. The accuracy of this value may vary, and the variability may be significant if the magnitude of the ship's spatial deviation from the trackline is on the order of the range of the observation.

Given these assumptions, the ship and boat transect survey data were combined with GPS longitude-latitude information to generate spatial density maps using the kernel density spatial interpolation method. Input data for this method includes measured avian abundance (bird counts, z) collected at sampled longitude-latitude locations (x, y). The abundance data were spatially interpolated to obtain estimates of bird density (number per km^2) at unsampled sites positioned on a regular lon-lat grid system.

The regular lon-lat grid system was developed for both the coastal and offshore survey types to encompass the spatial range of minimum-maximum longitudes and minimum-maximum latitudes for which bird count data were collected in the given month. Spatial lon-lat resolutions were adopted such that 10 equally-spaced intervals were generated in both the longitude and latitude dimensions, by simply dividing the difference between the minimum-maximum longitudes by 10, and repeating the process in the latitude dimension. Thus, a grid of 10x10=100 gridpoints were generated for each month (over the period January-November 2008) for both the offshore (ship) and coastal (boat) surveys. Estimates of bird density were obtained for all birds (i.e., integrated over all species observed) at these 100 gridpoints using the kernel density method. Base maps illustrating the results were prepared with longitude and latitude as spatial references.

7.2.3 Kriging

In order to apply kriging to the sampled avian radar data, the Study Area, a sampling scheme, and a regular lon-lat grid must first be defined. Sites for radar platform locations in the survey area (both coastal and offshore) were quasi-randomly chosen (via stratified random sampling using a random number generator), subject to the following constraints: the water depth at each site must be shallower than 60 ft (to satisfy the depth criteria of the barge-supported radar platform); and all pairwise distances between sites must be greater than 4 NM (to avoid overlapping of radar ranges at adjacent sites). The radar is designed in this study to detect bird densities and flight migration patterns within a 4-NM range of its location. For each radar detection, the attribute value (f; e.g., bird density) is measured and recorded along with the range (and the calculated lon-lat location [x,y]) of the sighting. The accuracy of the kriging model in estimating the average attribute value at unsampled sites (quantified by the [minimized] estimation variance [error]) depends on the size, shape, orientation, and spatial arrangement of the sampled sites.

A regular lon-lat grid, characterized by lon-lat ranges and resolutions, should span the entire range over which sampled data are collected, and is to contain the unsampled sites at which the attribute value (f) is to be estimated/interpolated via kriging. To enhance the information content, the lon-lat resolution should be finer than the 4-NM spacing of the radar sites; and the spatial extent of the grid should not deviate too far outside the range of the spatially extreme radar locations (i.e., spatial distances between all pairwise combinations of sampled and unsampled sites should be on the order of 4 NM or less), to avoid edge effects.

Kriging is based on spatial autocorrelation structure, hence it is recommended to conduct preliminary tests for spatial autocorrelation and associations of the attribute (bird density) data among the sampled sites to assess the feasibility and accuracy of application of kriging to the data. Any of the following statistics can be calculated:

a) Moran's I: Standardizes the spatial autocovariance by the variance of the data.
b) Geary's C: Uses the sum of squared differences between pairs of data attribute values to measure covariation.
c) General G(d): A multiplicative measure of overall spatial association of attribute values occurring within a given distance (d) of each other.
d) Local Moran's I (LISA): Is calculated individually for each sampled site and measures the extent of spatial clustering of similar values around the site; and the sum of all LISA indicators (i.e., summed over all sampled sites) is proportional to the global Moran's I (the global indicator of spatial association).
e) Local Gi(d): Is calculated individually for each sampled site and measures the extent of spatial clustering of high or low values around the site.

Since kriging is based on autocorrelation structure (semivariogram), positive autocorrelation (e.g., that attribute values are more similar between closely spaced sites than between sites spaced further apart) is an important preliminary criteria for accurate interpolation via kriging. A t-statistic is calculated as the difference between the given spatial statistic and its expected value, divided by the standard error. A t-test is applied to test for autocorrelation and its direction (positive or negative). If a significant positive autocorrelation exists in the data, then the kriging model can safely be applied to the dataset.

Kriging spatial interpolation and analysis will be conducted using the ArcGIS (ArcMap v9.0) Geostatistical Analyst/Geostatistical Wizard. The following general procedure is used to generate spatial density maps:

1) **Input Dataset Generation**: Generate a sightings per unit effort (SPUE) input data file ("*.dbf"), a SPUE seasonal shape file ("*_spue.shp"), and a Global geographic shape file ("bo_world.shp").

2) **Geostatistical Method Selection**: Select the desired kriging method (e.g., "Ordinary Kriging", "Universal Kriging") and the desired spatial map for output. Four types of spatial maps are available: Prediction Map, Prediction Standard Error Map, Probability Map, and Quantile Map.
3) **Detrending**: Remove the deterministic trend component from the data, leaving behind the residual component (which will be kriged, followed by adding back in the trend component).

4) **Semivariogram/Covariance Modeling**: Select the desired semivariance model (e.g., circular, spherical), decide whether to examine isotropic (directionally uniform) or anisotropic (direction-dependent) effects, enter the desired lag size and number of lags, decide whether to conduct error modeling, and enter the desired angle direction, angle tolerance, and bandwidth (lags).

5) **Neighborhood Search**: Enter the number of neighbors (sampled locations) to include in the interpolation of the attribute value at the unsampled location, and enter the sector method, number of sectors, and spatial dimensions (i.e., angle, major and minor semiaxes) of the sector.

6) **Cross-Validation**: The program automatically repeats the kriging interpolation process while removing one sampled data point at a time. The total number of runs is equal to the number of sampled data points, with each data point removed from the pool of others. The accuracy of the kriging model is assessed at each omitted data point by comparing the model-predicted attribute value with the measured (sampled) attribute value. Four graphs are generated: a) "Predicted" plot of predicted versus measured attribute; b) "Error" plot of the residual (= predicted - measured) versus measured attribute; c) "Standardized Error" plot of standardized error [= (predicted – measured)/(estimated standard error)] versus measured attribute; d) "Q-Q Plot" of quantiles of standardized error versus the corresponding quantiles from a standard Gaussian normal distribution. If the errors of predictions from the true values are normally distributed, the points on the Q-Q plot should fall on the 1:1 line, reflecting confidence in using methods that rely on

normality (e.g., spatial probability maps and quantile maps). These 4 graphs can be viewed by clicking on their respective tabs. In the "Prediction Errors" section, the various cross-validation statistical parameters (MPE, RMSPE, AKPSE, MSPE, and RMSSPE) are reported.

7) **Generate Spatial Maps**: Save the cross-validation results in an Excel file, and save the spatial map ("*.mxd") by providing a file name and directory.

7.3 RESULTS

7.3.1 *Hotspot Mapping*

Total avian density across the Study Area from January through November 2008 was determined (**Figure 7-1**). Bird "hotspots" (red, orange, and/or yellow) were clustered primarily along the coast. Total bird density was highest along the New Jersey coastline with densities generally decreasing with increasing distance offshore. The only exceptions were near the southeast boundary of the Study Area (e.g., grids 68 and 71). Although this analysis effectively showed locations where the probability of encountering high and low bird densities occur, it is complicated by the strong seasonal variability (**Figure 7-2** through **Figure 7-4**) due to changes in avian species composition (see **Section 3.2.2**).

The highest densities from January through April (spring) were clustered along the coast (i.e., Grid 2 off Barnegat Bay, Grid 17 near Little Egg Inlet, Grid 42 off Ocean City, and Grid 55 near Hereford Inlet). Offshore densities were generally lower than coastal densities, with the exception of Grids 36 and 41. In comparison to the January to November period, avian densities were generally lower throughout the Study Area (**Figure 7-2**).

In general, avian density was more evenly distributed from May to July (**Figure 7-3**) than from January to April (**Figure 7-2**). With the exceptions Grids 2, 13, 17, 23, 30, 42, and 55, avian densities were generally higher than January to April.

Bird "hotspots" from August through November were present along almost the entire coastline (**Figure 7-4**). Coastal avian habitat use was higher this period than in January to April (**Figure 7-2**). Additionally, the highest densities were found further north along the coast rather than near the southern boundary of the Study Area. Coastal avian densities were similar between the August through November and May through July timeframes (**Figures 7-3** and **7-4**); however, May through July showed higher densities throughout the entire study area than those in August through November.

In summary, the highest number and connectivity of bird hotspots occurred in May through July (**Figure 7-3**; illustrated in red, orange, yellow). Future modeling effort will combine habitat attributes (presence and distance to shoals) and species composition to predict spatial and temporal changes in avian "hotspots".

7.3.2 *Kernel Density*

Temporal and spatial distributions of avian densities off the New Jersey coast for the period January-November 2008 were estimated from the offshore (ship) surveys and coastal (boat) surveys using kernel density spatial interpolation. Monthly spatial density maps of all observed birds (e.g., integrated over all species) were generated for each month and are shown in **Appendix E**. Point estimates of avian densities were generated on a lon-lat regular grid encompassing the entire lon-lat range of avian density data collection, and the spatial resolution in both the longitude and latitude dimensions is 10 percent of the respective ranges, thus generating a maximum of 10x10=100 point density estimates on the regular lon-lat grid; however, only those points contained within the survey area are shown on the spatial maps.

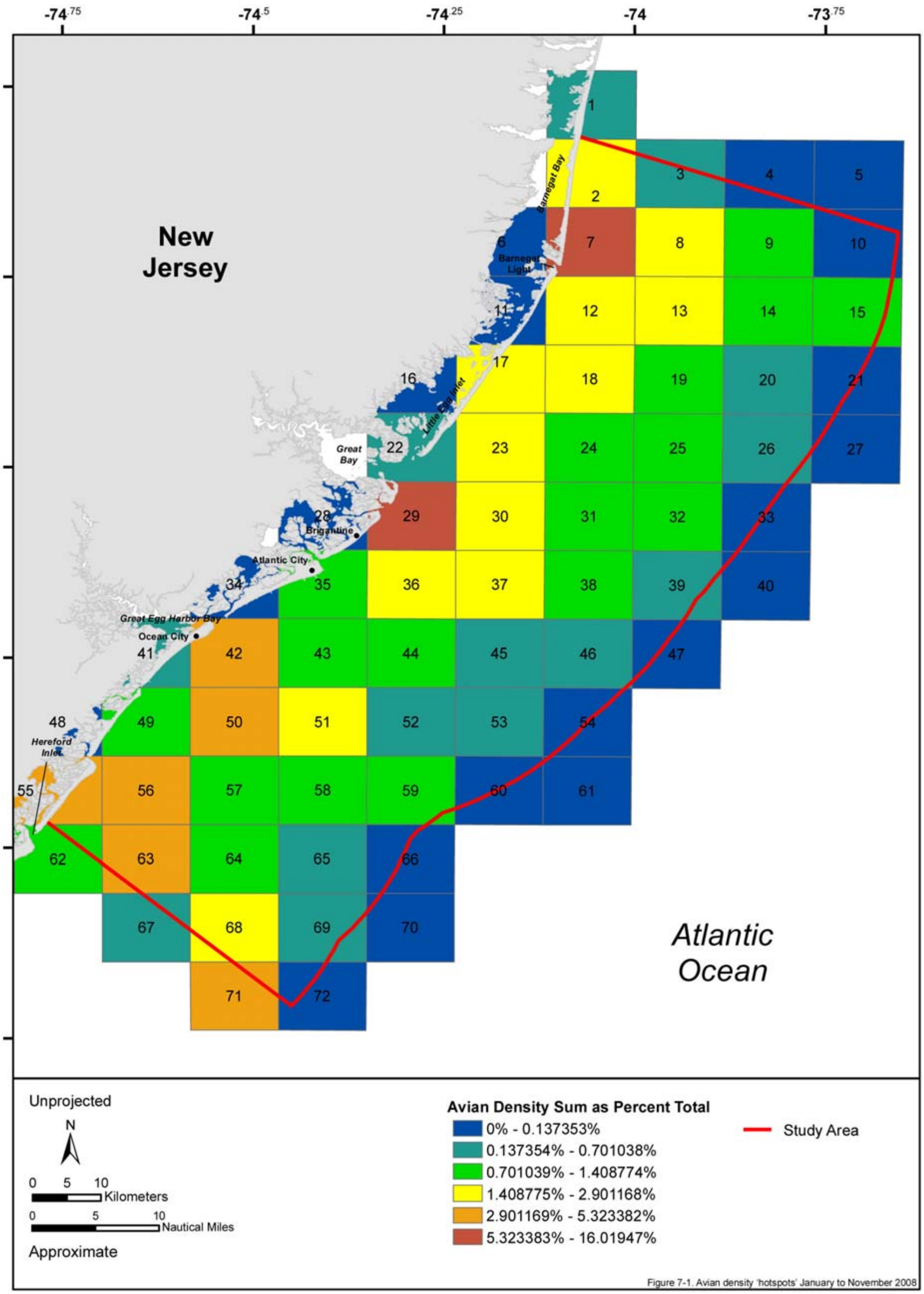

Figure 7-1. Avian density 'hotspots' in the New Jersey Study Area during the shipboard offshore surveys from January through November 2008. Cell size is ~10 km.[2]

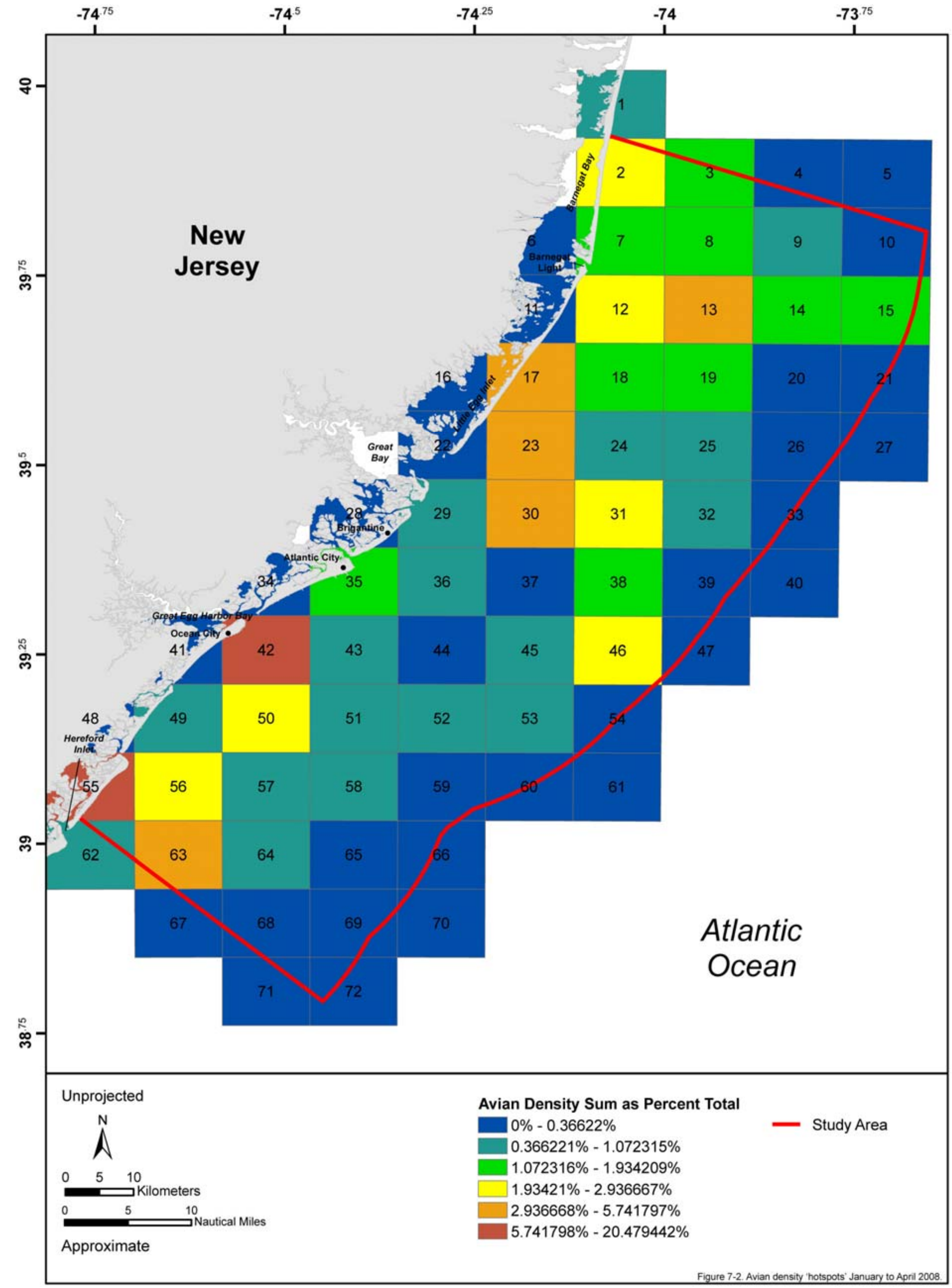

Figure 7-2. Avian density 'hotspots' in the New Jersey Study Area during the shipboard offshore surveys from January through April 2008. Cell size is ~10 km.[2]

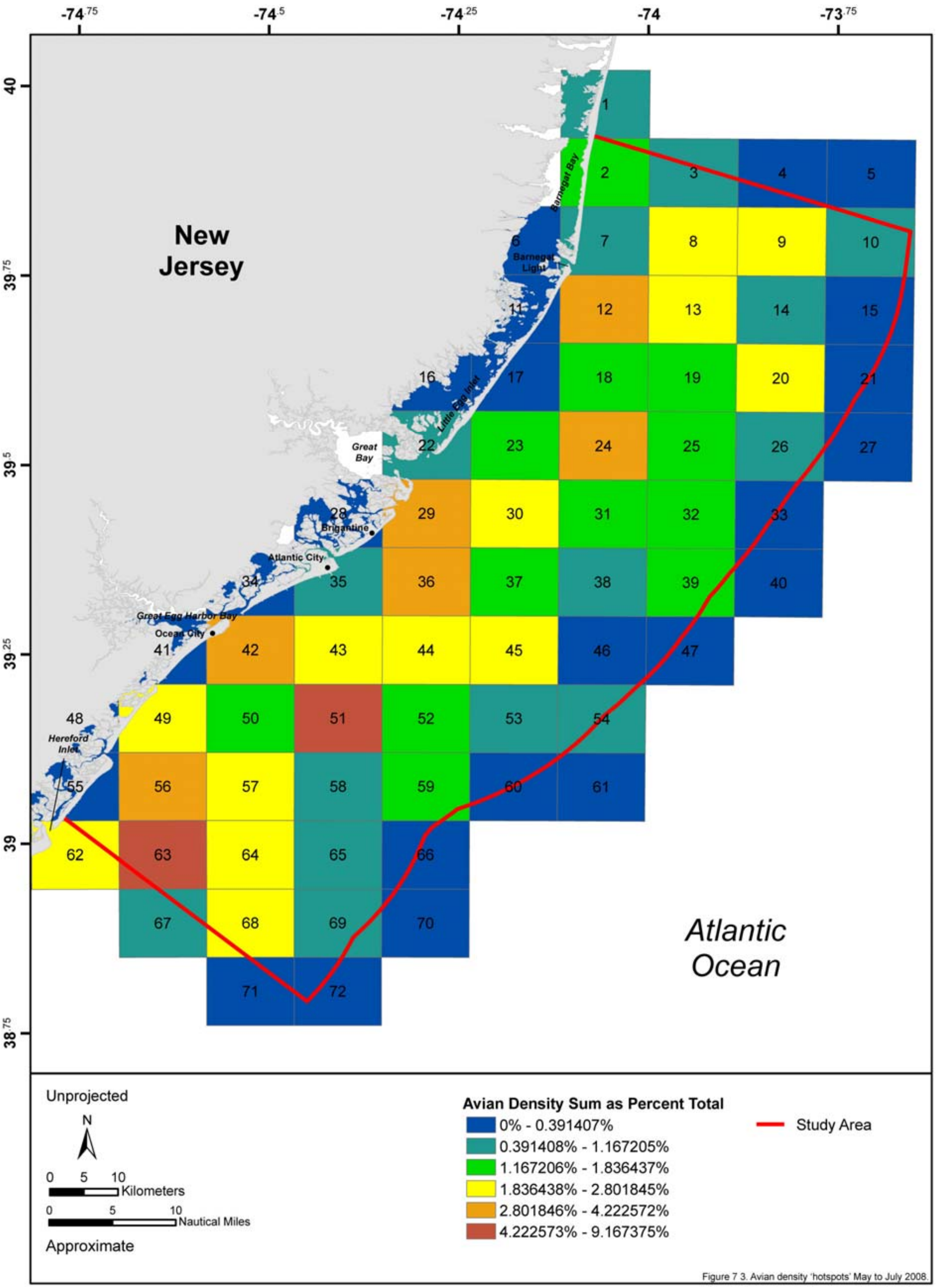

Figure 7-3. Avian density ‘hotspots’ in the New Jersey Study Area during the shipboard offshore surveys from May through July 2008. Cell size is ~10 km.²

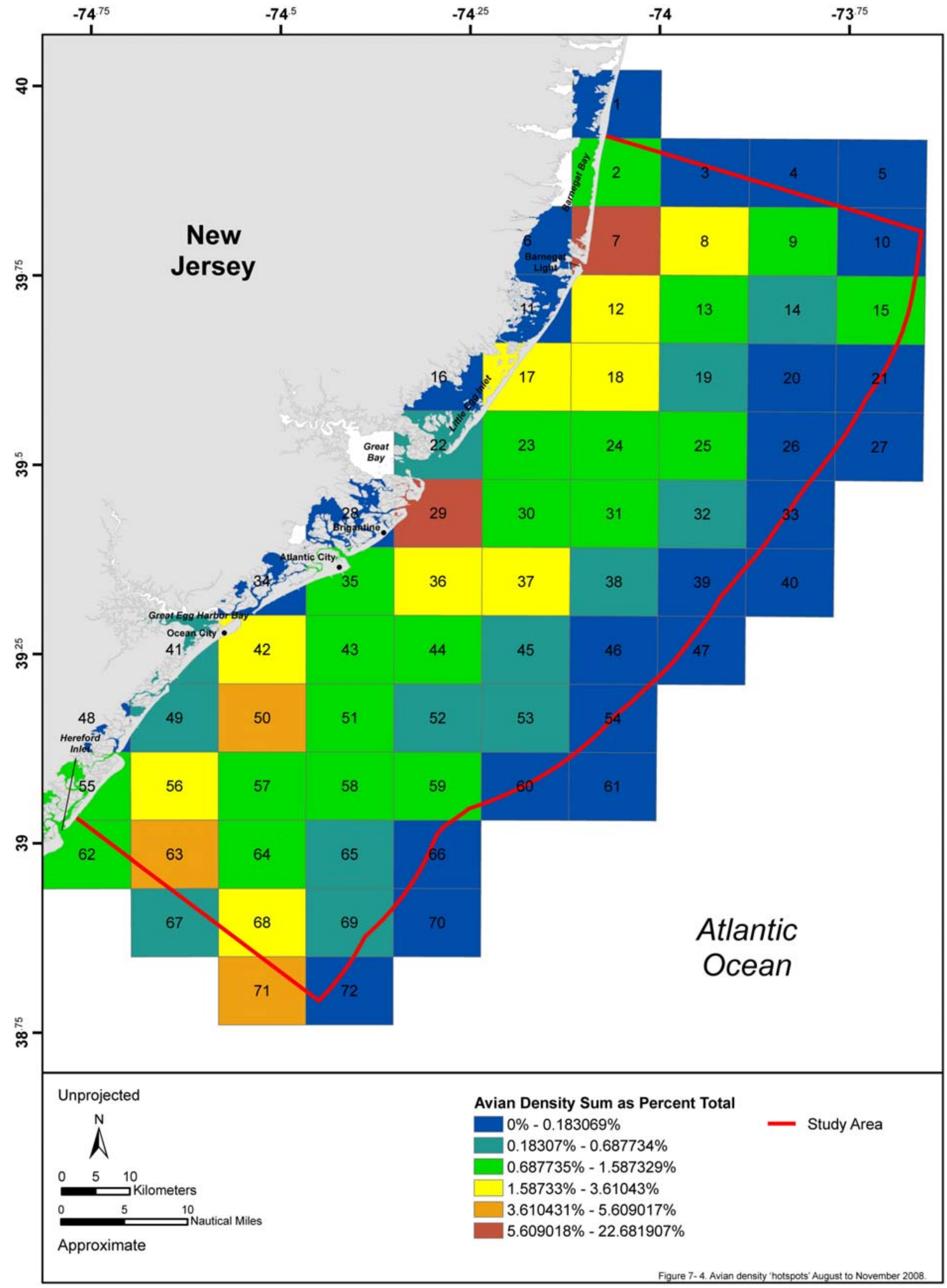

Figure 7-4. Avian density 'hotspots' in the New Jersey Study Area during the shipboard offshore surveys from August through November 2008. Cell size is ~10 km.[2]

For the ship surveys, during the composite period January-November 2008, avian densities were highest in the southeastern region of the survey area approximately 10 NM offshore, between Ocean City and Hereford Inlet (**Appendix E**: **Figure E-1a**). Maximum density for the region as a whole was 27.15 birds per km^2, which occurred approximately 10 NM offshore from Ocean City. Densities were moderate in the northern regions near the coast (Barnegat Bay) and lowest in the central regions and offshore (out to 20 NM offshore). These relative spatial trends in avian density are also reflected in the January-November 2008 composite map for the boat surveys (**Figure E-1b**): High avian densities (in excess of 72 birds per km^2 alongshore at Great Egg Harbor Bay (just north of Ocean City) and Barnegat Bay (along the northern coastal boundary of the survey area). Densities were generally greater nearshore than offshore, reflecting a decrease in densities with increasing offshore distance.

During January 2008 for the ship survey, the highest densities (from 3.77 up to a maximum of 27.15 birds per km^2) occurred nearshore in the central region of the Study Area (from Atlantic City to just north of Little Egg Inlet), and moderate densities occurred in the southern regions (around Hereford Inlet). Densities were generally highest nearshore and decreased moving offshore. Offshore densities were generally less than 0.50 birds per km^2 (**Figure E-2a**). For the boat survey, the highest (nearshore) densities (ranging from 13.88 to 31.78 birds per km^2) were likewise in the central region of the Study Area, spanning from Atlantic City to Brigantine to the inlet to Great Bay (**Figure E-2b**).

In February the spatial range of available ship survey data was restricted to the northern region of the survey area (from Little Egg Inlet to Barnegat Bay). Densities in this region were generally highest in the region just north of Little Egg Inlet, and were relatively higher nearshore than offshore, with a maximum February density of 16.57 birds per km^2 (**Figure E-3**). No boat surveys were conducted in February.

The ship survey avian densities as a whole generally increased between January and March, with a maximum density of 98.36 birds per km^2 in March (off the coast of Hereford Inlet in the southern region of the Study Area). Regions of relatively high and low densities were relatively dispersed throughout the Study Area, with high densities occurring over the entire range of latitudes from Barnegat Bay to Hereford Inlet. On average, densities were higher nearshore than offshore, especially in the southern region (between Ocean City and Hereford Inlet). Offshore densities generally ranged from 0.66 to 3.77 birds per km^2 in March (**Figure E-4a**). Nearshore avian densities from the boat survey in March were moderate to high (4.00 to 13.88 birds per km^2) off the coast of Barnegat Light and south of Ocean City, and were lower along the rest of the coast (**Figure E-4b**).

The general pattern of decreasing densities with increasing offshore distance continued into April, for the ship surveys, whereas the densities for the survey area as a whole generally increased between March and April, with a maximum density of 11.26 birds per km^2 in April. The highest densities within the Study Area occurred nearshore south of Ocean City and nearshore between Barnegat Light and Great Bay. Offshore densities in April were generally 1.13 birds per km^2 or less (**Figure E-5a**). Nearshore avian densities from the boat survey in April were similarly high along Little Egg Inlet (between Great Bay and Barnegat Light) and moderate at Great Egg Harbor Bay (**Figure E-5b**).

Maximum density for the survey area as a whole increased from 11.26 birds per km^2 in April to 27.15 birds per km^2 in May, according to the ship survey. The highest densities occurred in the central region (between Little Egg Inlet and Ocean City), and the densities in this region remained relatively high from nearshore to offshore (out to 20 NM). Both nearshore and offshore densities decreased moving northward and southward from this central region, toward values of 3.77 birds per km^2 or less (**Figure E-6a**). Nearshore avian densities from the boat survey in May were moderate (4.00 to 13.88 birds per km^2) at Barnegat Light and Ocean City and lower along the rest of the coast (**Figure E-6b**).

The densities for the ship survey area as a whole generally decreased from May to June and then increased from June to July, with maximum densities of 27.15, 3.77, and 27.15 birds per km^2 in May, June, and July, respectively. Onshore-offshore gradients in June and July were relatively negligible, and densities were generally higher in the northern and southern regions than in the central region. For example, densities (both nearshore and offshore) were higher in the southern region (Hereford Inlet) and in the northern region (between Little Egg Inlet and Barnegat Light) than in the region between Ocean

City and Atlantic City (**Figures E-7a** and **E-8a**). Nearshore densities from the boat surveys were relatively high (4.00 to 13.88 birds per km^2) at Great Bay, Atlantic City, and Hereford Inlet in June (**Figure E-7b**), and at Hereford Inlet, Ocean City, Atlantic City, and the region south of Barnegat Light in July (**Figure E-8b**).

The trend of higher densities in the northern and southern regions (compared to the central region) continued into August and September, and the maximum density for the ship survey area as a whole decreased from 27.15 birds per km^2 in July (midshore between Little Egg Inlet and Barnegat Light) to 98.36 birds per km^2 in August (an anomalously high density estimate 20NM offshore in the southeastern corner of the Study Area) and 27.15 birds per km^2 in September (nearshore at Barnegat Light). In August, densities (both nearshore and offshore) were higher off Hereford Inlet than off Ocean City and Atlantic City. In the north-central region (Little Egg Inlet), densities were relatively high nearshore out to 10-15 NM offshore and then decreased with increasing offshore distance out to 20 NM. Similarly, off Barnegat Light and Barnegat Bay in both August and September, densities were relatively high nearshore and decreased moving offshore. Between August and September, nearshore densities in the southern (Hereford Inlet) and central (Little Egg Inlet) regions decreased, whereas nearshore densities in the northern region (Barnegat Light and Barnegat Bay) increased (**Figures E-9a** and **E-10a**). Nearshore densities from the boat surveys were similarly high (13.87 to 31.78 birds per km^2) between Ocean City and Hereford Inlet in August (**Figure E-9b**) and at Barnegat Bay (north of Barnegat Light) in September (**Figure E-10b**).

Both the overall densities and spatial variability in densities increased in magnitude from September to October and November. For the ship survey area as a whole, maximum densities were 27.15, 98.36, and 98.36 birds per km^2 for September, October, and November, respectively. For October and November, densities were relatively higher nearshore than offshore, with offshore densities being less than 3.77 birds per km^2 (reflecting a very strong onshore-offshore gradient). In October, the highest nearshore densities occurred in the northern region (Barnegat Bay and Barnegat Light) and in the south-central region (between Ocean City and Atlantic City; **Figure E-11a**), whereas in November, the highest nearshore densities occurred in the central region (off Great Bay and Little Egg Inlet), with moderate densities between Ocean City and Hereford Inlet (**Figure E-12a**). Nearshore densities from the boat surveys were relatively high (13.88 to 31.78 birds per km^2) at Barnegat Bay and lower along the rest of the coast in October (**Figure E-11b**), whereas in November, nearshore densities were high (greater than 13.88 birds per km^2) along the entire coast, spanning Barnegat Bay to Hereford Inlet (**Figure E-12b**).

7.3.3 Kriging

The feasibility of kriging as an accurate spatial interpolation method is currently being assessed by examining the nature of the variability of the avian density data from the transect and radar surveys. Because of this ongoing model assessment process, the short radar survey season in fall 2008, and the uncertain availability of radar data for spring 2009, the modeling results of temporal and spatial interpolation statistical analysis of avian survey data using the kriging method are being assessed and are not included in the Interim Report.

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8.0 MARINE MAMMAL AND SEA TURTLE SURVEYS AND MONITORING

Marine mammals and sea turtles are important marine resources found in the Study Area. Forty-seven species have confirmed or potential occurrence in the Study Area based on known ranges of distribution and habitat associations (**Tables 8-1** and **8-2**). Known or potential species include 35 cetaceans (whales, dolphins, and porpoises), 6 pinnipeds (seals), 1 sirenian (manatee), and 5 sea turtles. Seven of the marine mammal species and all of the turtle species are designated as threatened or endangered under the Endangered Species Act (ESA). All marine mammal species are afforded protection under the Marine Mammal Protection Act (MMPA).

Table 8-1. Marine mammal species with known or potential occurrence in the Study Area. ESA status is denoted. Naming conventions are consistent with the NOAA Stock Assessment Report (SAR; Waring et al. 2008).

Common Name	Scientific Name	ESA Status
Order Cetacea		
Suborder Mysticeti (baleen whales)		
Family Balaenidae (right whales)		
North Atlantic right whale	*Eubalaena glacialis*	Endangered
Family Balaenopteridae (rorquals)		
Humpback whale	*Megaptera novaeangliae*	Endangered
Minke whale	*Balaenoptera acutorostrata*	
Bryde’s whale	*Balaenoptera edeni*	
Sei whale	*Balaenoptera borealis*	Endangered
Fin whale	*Balaenoptera physalus*	Endangered
Blue whale	*Balaenoptera musculus*	Endangered
Suborder Odontoceti (toothed whales)		
Family Physeteridae (sperm whale)		
Sperm whale	*Physeter macrocephalus*	Endangered
Family Kogiidae		
Pygmy sperm whale	*Kogia breviceps*	
Dwarf sperm whale	*Kogia sima*	
Family Monodontidae		
Beluga	*Delphinapterus leucas*	
Family Ziphiidae (beaked whales)		
Cuvier's beaked whale	*Ziphius cavirostris*	
Northern bottlenose whale	*Hyperoodon ampullatus*	
Blainville's beaked whale	*Mesoplodon densirostris*	
Sowerby's beaked whale	*Mesoplodon bidens*	
Gervais' beaked whale	*Mesoplodon europaeus*	
True's beaked whale	*Mesoplodon mirus*	

Table 8-1 (*continued*). Marine mammal species with known or potential occurrence in the Study Area. ESA status is denoted. Naming conventions are consistent with the NOAA Stock Assessment Report (SAR; Waring et al. 2008).

Common Name	Scientific Name	ESA Status
Order Cetacea		
Suborder Odontoceti (toothed whales)		
Family Delphinidae (dolphins)		
Rough-toothed dolphin	*Steno bredanensis*	
Bottlenose dolphin	*Tursiops truncatus*	
Pantropical spotted dolphin	*Stenella attenuata*	
Atlantic spotted dolphin	*Stenella frontalis*	
Spinner dolphin	*Stenella longirostris*	
Clymene dolphin	*Stenella clymene*	
Striped dolphin	*Stenella coeruleoalba*	
Common dolphin	*Delphinus delphis*	
White-beaked dolphin	*Lagenorhynchus albirostris*	
Atlantic white-sided dolphin	*Lagenorhynchus acutus*	
Fraser's dolphin	*Lagenodelphis hosei*	
Risso's dolphin	*Grampus griseus*	
False killer whale	*Pseudorca crassidens*	
Melon-headed whale	*Peponocephala electra*	
Killer whale	*Orcinus orca*	
Long-finned pilot whale	*Globicephala melas*	
Short-finned pilot whale	*Globicephala macrorhynchus*	
Family Phocoenidae (porpoises)		
Harbor porpoise	*Phocoena phocoena*	
Order Carnivora		
Suborder Pinnipedia (seals, sea lions, walruses)		
Family Phocidae (seals)		
Harbor seal	*Phoca vitulina*	
Gray seal	*Halichoerus grypus*	
Harp seal	*Pagophilus groenlandica*	
Hooded seal	*Cystophora cristata*	
Bearded seal	*Erignathus barbatus*	
Ringed seal	*Pusa hispida*	
Order Sirenia		
Family Trichechidae (manatees)		
West Indian manatee	*Trichechus manatus*	Endangered

Table 8-2. Sea turtle species with known or potential occurrence in the Study Area and their status under the ESA. Taxonomy follows Pritchard (1997).

Common Name	Scientific Name	ESA Status
Order Testudines (turtles)		
Suborder Cryptodira (hidden-necked turtles)		
Family Dermochelyidae		
Leatherback turtle	*Dermochelys coriacea*	Endangered
Family Cheloniidae (hard-shelled turtles)		
Loggerhead turtle	*Caretta caretta*	Threatened
Kemp's ridley turtle	*Lepidochelys kempii*	Endangered
Green turtle	*Chelonia mydas*	Threatened*
Hawksbill turtle	*Eretmochelys imbricata*	Endangered

*Although this species as a whole is listed as threatened, the Florida nesting stock of green turtles is listed as endangered. Since the nesting area for green turtles encountered at sea often cannot be determined, a conservative approach to management requires the assumption that all green turtles found in the Study Area are endangered.

Marine mammal and sea turtle distribution in New Jersey's nearshore waters is not well known. Besides providing possible habitat for nearshore toothed whales [e.g, bottlenose dolphins (*Tursiops truncatus*)] and seals [e.g., harbor seals (*Phoca vitulina*)], the waters of the Study Area are also likely important to baleen whales, particularly the North Atlantic right whale (*Eubalaena glacialis*) which migrates through the nearshore waters of the eastern U.S. coast between feeding and breeding areas.

The NMFS and other organizations have been conducting marine mammal and sea turtle surveys along the U.S. east coast for many years. Although several of these surveys have included waters of the Study Area, none have concentrated efforts specifically in New Jersey's nearshore waters. In addition, no year-round survey efforts have been conducted in this region. The following is a list of the main surveys which have effort that overlaps with at least part of the Study Area. Note that most of these surveys were conducted only during the summer months.

<u>Aerial Surveys</u>

- The NMFS-Southeast Fisheries Science Center (SEFSC) conducted the Mid-Atlantic *Tursiops* Surveys (MATS) to determine the distribution and abundance of bottlenose dolphins in nearshore waters of the U.S. east coast. During the summer of 1994, NMFS-SEFSC conducted a pilot study which consisted of an aerial survey to count the bottlenose dolphins along the shoreline and a line transect aerial survey from Long Island, New York to Vero Beach, Florida (Blaylock 1995). During the following summer, a line transect aerial survey from Sandy Hook, New Jersey to Cape Hatteras, North Carolina from the shoreline to the 25-m (82-ft) isobath (around 0-81 km [0-44 NM] from shore; Garrison and Yeung 2001). The MATS surveys flown during the summer of 2002 covered coastal waters out to the 40-m (131-ft) isobath between Sandy Hook, New Jersey and Vero Beach, Florida (Hoggard 2002; Waring et al. 2006). Additional surveys were flown in the summer of 2004 between Atlantic City, New Jersey and Fort Myers, Florida (Fertl and Fulling 2007).

- The NMFS-NEFSC conducted aerial (DeHavilland Twin Otter) line transect surveys to estimate cetacean and sea turtle abundance off the mid-Atlantic and northeast coasts. These surveys were flown during the summer in 1995, 1998, and 2004 from the Gulf of St. Lawrence to Virginia (NMFS-NEFSC 1998a; Quintal and Smith 1999; Palka et al. 2001).

- Right Whale Sighting Advisory System (SAS) aerial surveys are currently being flown over a broad region of the western North Atlantic Ocean from just south of Long Island, New York to the U.S./Canada border and out to the 200-NM Exclusive Economic Zone (EEZ).[1] Although the primary focus of these surveys is North Atlantic right whales, other species of marine mammals and also sea turtles are documented. Opportunistic sighting information is also provided to the SAS by other organizations, including state, federal, and non-profit organizations (NMFS-NEFSC 2008).

Shipboard Surveys

- The NMFS-NEFSC conducted a two-week shipboard survey (*Delaware II* 97-05 cruise) in March 1997 to determine the spatial distribution and relative abundance of cetaceans in mid-Atlantic waters between Long Island, New York and just south of Cape Hatteras, North Carolina (NMFS-NEFSC 1997). Additional surveys (*Delaware II* 98-04 cruise) in this same region were conducted in March 1998 (NMFS-NEFSC 1998b).

- The NMFS-SEFSC conducted a shipboard marine mammal survey (*Oregon II* 99-05 cruise) in August and September 1999 from the 10-m (33-ft) isobath to 185 km (100 NM) offshore from Cape Canaveral, Florida to just north of Delaware Bay (NMFS-SEFSC 1999).

Aerial/Shipboard Surveys

- The University of Rhode Island conducted systematic seasonal surveys (aerial and shipboard) during the Cetacean and Turtle Assessment Program (CETAP) from October 1978 through January 1982. These surveys covered waters of the U.S. continental shelf [from the coast to 9.26 km (5 NM) seaward of the 2,000-m (6,562-ft) isobath from Cape Hatteras, North Carolina to the northern Gulf of Maine (CETAP 1982).

This EBS includes the first year-round, systematic survey effort in nearshore waters of New Jersey between Stone Harbor and Seaside Park. The objective of this study was to determine the spatial distribution and estimate the abundance/density of marine mammals and sea turtles in the Study Area (shoreline to around 20 NM [37 km] offshore). Shipboard and aerial surveys were conducted to collect data on marine mammal and sea turtle species found in the Study Area. Passive acoustic monitoring was also conducted to determine the presence of cetaceans in the Study Area.

8.1 Aerial and Shipboard Survey Methodology

8.1.1 Aerial Survey Design

8.1.1.1 Survey Effort

Aerial surveys were conducted monthly after the shipboard surveys between February and May 2008 under NOAA Permit #10014. In May 2008, while conducting aerial surveys, the aircraft tragically crashed on-shore in New Jersey killing the pilot, one observer, and seriously injuring the others on board. As a result, aerial surveys were suspended until Geo-Marine was able to develop new, more stringent safety protocols, find a suitable and experienced aviation company that could meet the new safety requirements, and find new, experienced marine mammal observers. Aerial surveys resumed in January 2009 and two surveys will be completed each month (weather permitting) to supplement missing data.

The aerial surveys were designed to estimate marine mammal and sea turtle distribution and abundance using line transect methods (see Buckland 2001). The survey aircraft was a twin-engine, high-winged Cessna Skymaster 337 with two bubble windows on each side of the aircraft to allow unobstructed views

[1] NOAA (National Oceanic and Atmospheric Administration) and MDMF (Massachusetts Division of Marine Fisheries). Right whale aerial survey track. Accessed 24 December 2008. http://whale.wheelock.edu/whalenet-stuff/reportsRW_NE/rw_aerialsurvey98.html.

of the trackline directly beneath the plane. Surveys were flown at ~229 m (750 ft) altitude and a speed of ~220 kph (110 kts) during daylight hours when there was at least 3.7 km (2 NM) visibility and a BSS of less than 5.

For the February survey, pre-determined transect lines (tracklines) were spaced 3.7 km (2 NM) apart and orientated perpendicular to the coastline. The 34 tracklines were divided (even or odd numbered) and flown during separate morning and afternoon sessions (i.e., half were flown in the morning and half in the afternoon). New transect protocol following NOAA survey methodology was initiated for the March survey. The tracklines were flown in a double saw-tooth pattern. This design provided comparable spatial and temporal coverage of the entire Study Area. On the day of the survey, a coin toss determined whether the surveys would start at the north or south end of the Study Area. Another coin toss determined whether the odd or even numbered survey transects were flown in the morning. After a mid-day break, the remaining transects were flown. This design allowed the entire Study Area to be surveyed in one day, thereby minimizing the temporal variation.

Additional strip transects were flown along the coastline (at low tide) when possible to assess the presence/absence of seals in the Study Area. Seals at haulout sites were recorded and groups photographed to assist with species identification and group size estimation. No flights were purposefully flown directly over haulout sites in accordance with NMFS requirements.

Visual observations were recorded by a team of three people. Two experienced observers searched for animals at the surface from directly beneath the aircraft out to a perpendicular distance of ~1,500 m. The third person acted as data recorder and was stationed in the co-pilot seat.

8.1.1.2 Data Logging

The aircraft's position along the trackline (in addition to all other survey information) was collected every 10 s on a computer interfaced with the aircraft's GPS via a custom data acquisition program. Environmental conditions which affect sightability of the animals (sea state, solar glare, water color, and transparency) were recorded prior to the start of each trackline and updated as needed while on-effort. All sighting data, including time, position, group size, species, and behavior, were recorded in the data entry program Voice Operated Recording (VOR).

8.1.1.3 Recording Sightings

When an animal was sighted perpendicular to the aircraft along the trackline, the angle to the sighting (≤60°) was determined either using a digital inclinometer or 10° intervals (bins) marked on the aircraft windows for calculation of perpendicular sighting distance. Observers went into off-effort mode at that time to verify species identification and estimate group sizes. The species identification, best estimate of group size, behavior, time, position, and associated animals were also recorded. This information was relayed to the data recorder. The circle-back procedure was used if necessary to verify species identification. Attempts were made to photograph all the animals in a sighting to compare with other photo-identification databases.

8.1.2 Shipboard Survey Design

8.1.2.1 Survey Effort

Shipboard survey effort was conducted on the University of Delaware's R/V *Hugh R. Sharp* (146 ft) under NOAA Permit #10014. Surveys were conducted monthly between January and December 2008, and protocols followed the standard systematic line transect methodology (Buckland 2001). The surveys were conducted along predetermined tracklines at ~10 kts along the designated trackline. Before each monthly survey, tracklines were randomly generated in a double saw-tooth pattern using the program Distance (Buckland et al. 2004) to cross the bathymetry gradient and to maximize uniform coverage of the Study Area. The starting point and time of each cruise was chosen based on the timing of high tide and weather conditions due to the docking criteria of the R/V *Hugh R. Sharp*. Tracklines were altered only if sea state, glare, or weather inhibited the survey effort. In these cases, the vessel diverted off the established trackline up to 30° from the established course. This deviation continued only until the ship was 10 NM (18.5 km) from the original trackline; at this point the ship turned back toward the waypoint of the original trackline.

Visual observations were recorded from the flying bridge (10 m [32.81 ft] above water) during daylight hours (roughly sunrise to sunset) when weather permitted. The marine mammal/sea turtle observer team consisted of six individuals; three observers were actively on duty at any one time. On-duty observers consisted of one observer searching with 25x150 power Fujinon binoculars ("bigeyes") mounted on a pedestal on the port side of the vessel while another observer searched through bigeye binoculars mounted on the starboard side. The third observer served as the data recorder and also searched the water with unaided eyes and 7x hand-held binoculars between the port and starboard bigeye observers. Each observer scanned out to the horizon from abeam (90°) on his/her side of the ship to 10° to the opposite side of the bow (100° in all). The 20° along the ship's trackline thus received overlapping coverage by the two bigeye observers. Observers rotated through these three stations every 40 min. At least one of the on-duty observers was highly experienced in survey techniques and marine mammal identification.

Survey operations were suspended when wind conditions reached a 6 or higher on the Beaufort scale since visibility was too poor for survey effort to continue. Survey effort was also suspended when rain or fog reduced visibility to a mile or less along the trackline or when greater than 50 percent of the horizon was obscured.

8.1.2.2 Data Logging

The data recorder entered a log of weather conditions [e.g., BSS, wind speed, swell height, etc.], visual effort (on or off), sightings, and other survey information into the computer mounted on the flying bridge. All data were recorded using WinCruz, a computer program developed by NMFS-Southwest Fisheries Science Center (SWFSC). The GPS position of the vessel, as well as the vessel's course and speed, was automatically recorded every 2 min via an integrated, stand-alone GPS unit on the flying bridge. Detailed paper forms were completed for each marine mammal sighting to supplement and expand upon information recorded in WinCruz. The initial time of the sighting and the angle (bearing) and reticle (distance) of the sighting (recorded from the bigeye binoculars) were listed on each sighting form as a backup to the computer file. Other information on taxonomic identification (including a sketch showing diagnostic features) and the behavior of the animals observed was also documented on the sighting form and used to verify species identification. Each observer maintained a log book which was used primarily to record estimates of the number of individuals and taxonomic composition (in percentages) for each sighting documented by the observer. Three estimates of group size (best, maximum, and minimum) were recorded for all sightings observed. Estimates of group size and the percent taxonomic composition were made independently by each observer without discussion among other observers so that the data were not observer-biased. At the end of the day, the chief scientist was responsible for collecting the log books and adding the estimates of group size and composition to the sighting records in the WinCruz dataset.

8.1.2.3 Recording Sightings

When a marine mammal was sighted, the observer team went into off-effort mode so that all observers could stop actively searching and focus on the sighting. The reticle and angle of the sighting was verbally relayed to the recorder. The vessel remained in passing mode if species identification and group estimates could be obtained while remaining on the trackline. If necessary, the vessel turned off the trackline to approach the individual or group (closing mode) to obtain this information. The vessel's speed and course were altered as necessary to obtain sighting data. A balance was kept between spending time off-effort approaching animals and spending time searching on-effort. Attempts were made to photograph all the animals in a sighting to document species identification and to obtain photographs that can be compared to other photo-identification databases for possible matches.

Once all the necessary data were collected for the sighting, the vessel resumed the same course and speed as prior to the sighting. If the vessel had to turn off the trackline for the sighting, then the vessel would resume a course parallel to the original trackline and the team would go back on-effort as long as the distance from the planned trackline was less than 5 NM (9 km). If the vessel was farther than 5 NM (9 km) from the original trackline, it would either angle back to the original trackline at 20° or plot a new course to the original waypoint.

Sightings that were made while the survey team was off-effort were also recorded. In some cases, another marine mammal or turtle sighting was observed while the vessel was in off-effort mode approaching the first sighting. Also, an occasional sighting was made by off-duty personnel; these sightings were only reported after the animal(s) passed abeam of the ship and were recorded as off-effort sightings. All off-effort sightings are included in this report but were not used in the calculation of abundance and density estimates.

8.1.3 Data Processing

Data collected from the aerial and shipboard line transect surveys were reviewed daily for accuracy. Data QA/QC procedures included verifying that weather conditions, viewing conditions, observer information, species identification, group size, and location information were all correctly recorded. The sighting sheets were also checked for completeness and readability. The chief scientist compared digital data with data captured through sighting sheets, daily sighting logs, behavior data sheets, and error correction logs. All corrections found either through notes logged on the computer or on the aerial survey error logs were documented and confirmed by the chief scientist. These QA/QC procedures allowed any flaws in the data to be corrected immediately and prevented errors from progressing through data analysis. All data files were backed up on external hard drives, DVDs, and GMI's network.

8.1.3.1 Seasons

The following three-month periods were used as seasonal designations in the analysis of marine mammal and sea turtle sightings data:

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

Data from the December 2008 shipboard survey are summarized in this report but were not available for inclusion in the abundance and density analyses. Due to the suspension of the marine mammal/sea turtle aerial surveys in May, no aerial survey data were collected between May and December.

8.1.3.2 Calculation of Survey Effort

Shipboard survey data were collected as a series of latitude and longitude points every 2 min while a series of latitude and longitude points were collected every 10 s on the aerial surveys. Daily survey effort was calculated as a summation of the distance between each successive point after the coordinates were converted from degrees to radians. After converting to radians, the coordinates were 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 survey. All of the daily effort estimates were summed to obtain a total estimate of effort for all days and surveys combined.

8.2 DENSITY ESTIMATE MODELING ANALYSIS

Only sightings data collected during the shipboard surveys were used in the density model because the aerial survey data did not meet the sample size requirement discussed below.

8.2.1 Input Sightings Data Assumptions and Adjustments

An ideal estimate of density (with as low a variance as possible) requires the collection of accurate sightings data, modification of the data to account for spurious data (outliers) at both short distances (potential "left truncation") and long distances (potential "right truncation"), sound criteria for selection of the "optimal" model that best fits the data, and accurate estimation (with low variance) of the optimal model's parameters. The accuracy of a model in estimating density is only as good as the input data being modeled. If the data do not conform to the characteristics favorable for, and/or required by, model fitting, the resultant selection of the "optimal" model, estimation of model parameters, and ultimately estimation of density may be inaccurate and associated with a high degree of uncertainty (as quantified by high variance).

Input data are modeled as a probability detection function g(y), a plot of sightings versus distance between the sighting and (for line transect surveys) the perpendicular distance from the sighting to the trackline on which the ship/plane is traveling. Sightings data recorded during the shipboard surveys included the number of animals sighted (n), the distance between the ship and the animal (R), and the angle (b) between the animal and the trackline. The perpendicular distance (y) between the animal and trackline is calculated as y = R*sin(b) (Lerczak and Hobbs 1998). The bearing and reticle recorded for each sighting were used in combination with the height of the observer platform above the water's surface to calculate the perpendicular distance of each sighting.

At zero perpendicular distance y=0 (e.g., when the animal is on the trackline), the detection probability should be at or near 100 percent (e.g., all or nearly all animals on the trackline should be detected). Over a moderate range of short distances, the detection probability should be ideal (100 percent) or near ideal (i.e., a broad shoulder in the detection function), meaning that all animals that are actually present are detected by the observer. Instruments that aid in detection at short distances (such as high-power binoculars) can increase the distance range of the "broad shoulder". Naturally, as sighting distance increases over longer distances, the number of sightings/detections should begin to decrease, and at a given distance, large animals and animal clusters are more likely to be sighted/detected than smaller animals and animal clusters. Thus, an ideal probability detection function has the following characteristics:

1) An intercept of g(0)=1.0 (100 percent probability of detection) at zero perpendicular distance y=0 (where g(0) is the probability of detecting an animal on the trackline)
2) A broad shoulder over a range of short distances before beginning to taper off
3) A monotonically decreasing function g(y) with increasing perpendicular distance y
4) An upward shift in the detection function g(y) as animal/cluster size increases (when animal size or cluster size is included in the modeling)

However, the actual collected data may deviate from this "ideal" (from a modeling standpoint) detection function behavior at both short and long distances, which may require left and right truncation, respectively. Truncation deletes spurious data and outliers and facilitates modeling of the data. For example, spurious data (or outliers) at large distances may include anomalous sightings (due to the presence of very large animals or large clusters of animals), overestimation of distance for a given observation, or underestimation of the number of individuals or group size at a given distance. Such situations may potentially result in fewer sightings at moderate distances and more sightings at longer distances, generating a detection function with a minimum at moderate distances (thus violating the "monotonically decreasing" criteria at long distances). Such a situation can be remedied via "right truncation", which involves removing sightings data at the longest distances to omit spurious data and outliers from further analysis. Typically, right truncation involves removing 5-10 percent of the data from the right-hand tail of the detection function, or removing data at distances beyond which the detection probability g(y) falls below 0.15 (15 percent).

Spurious data at short distances may include perception bias (i.e., failure of an observer to detect an animal on the trackline), availability bias (e.g., animal is submerged or otherwise hidden from view while on the trackline and hence are unable to be detected), and animal movement prior to detection (due to attraction/avoidance behavior). Perception bias and availability bias can lead to negative departures of g(0) below 1. In the case of animal movement prior to detection, if the observer (e.g., person, ship, plane) is too close to the animal, the animal may respond either positively or negatively, thereby moving from its original location before being detected by the observer. Animal attraction toward the observer prior to detection will cause the observer to underestimate the detection distance, thus causing more animals to be detected at shorter distances and fewer animals to be detected at longer distances (which is often the case with bottlenose and common dolphins). This can lead to an upward spike (heaping) in the detection function at short distances, hence eroding the breadth of the shoulder at short distances. Conversely, animal avoidance away from the observer prior to detection will lead to overestimation of the detection distance, causing more animals to be detected at longer distances and fewer animals to be detected at shorter distances (which is often the case with harbor porpoises). This can lead to a maximum in the probability detection function at short distances (thus violating the “monotonically decreasing” criteria at short distances). Such a situation can be remedied via “left truncation”, which involves removing sightings data at the shortest distances to omit spurious data (arising from perception bias, availability bias, and animal movement prior to detection) from further analysis. Typically, left truncation involves removing data that are within a given specified distance of the trackline (e.g., 100 m). This “truncation distance” should be wide enough to account for animal movement prior to detection but not too wide as to eliminate data with a near-100 percent detection probability at short distances.

Actual data that do not conform to the above “ideal” criteria for the detection function may adversely affect modeling of the data via poor definition of a broad shoulder and poor estimation of g(0) (and hence the probability density function [PDF] at zero perpendicular distance f_o, which is directly proportional to the density estimate). Due to propagation of errors and variance, poor estimation (and associated high variance) of g(0) will lead to a poor estimation (and high variance) of the model parameters and of density. Thus, it is important to process the raw sightings data prior to model-fitting (such as by left and/or right truncation to remove spurious data and outliers) so that the above “ideal” criteria for the detection function are satisfied, and hence the model parameters and animal density can be estimated with as high a precision (i.e., as low a variance) as possible; however, truncation may also have the undesirable effect of reducing the same size (i.e., number of sightings) below the minimum threshold value (set equal to 20 sightings in this analysis) required for adequate, accurate modeling, which can have the effect of increasing variance. Thus, when considering truncation of some of the data, trade-offs must be weighed between the benefits of removing spurious data (which can reduce variance) and the costs of a reduced sample size (which can increase variance).

Assumption of g(0)=1 (e.g., overestimation of the actual g[0], especially if the actual g[0] is significantly less than 1) can lead to bias and underestimation of abundance and density (since density is inversely related to g[0]). This assumption rarely holds true during marine mammal and sea turtle surveys due to availability bias and perception bias. Accurate estimation of g(0) involves accounting for the following factors that can affect availability bias and perception bias:

1) Animal sightability (detectability)—species-specific behavior, group size, blow and dive characteristics, and dive interval
2) Viewing conditions—sea state, windspeed and direction, sea swell, and glare
3) Observer condition—experience, fatigue, and concentration
4) Platform characteristics—pitch, roll, yaw, speed, and altitude (for aerial surveys)

A discussion of g(0), factors affecting animal detectability, and methods of accounting for detection bias are discussed in Thomsen et al*.* (2005). Estimates of g(0) for shipboard and aerial surveys are used to calculate less biased estimates of population size. For the purposes of this report, g(0) was assumed to be 1 because estimates of g(0) were not able to be calculated due to the short duration of the aerial survey. The g(0) estimates that were calculated from other similar surveys were not chosen since detection probability has been shown to vary substantially among observers, platforms, weather conditions, etc. (Borchers 2005). Therefore, the density and abundance estimates calculated for this report are likely underestimated for most species.

The g(0) for each survey technique will be addressed during future surveys, and the g(0) results will be compared with those in the published literature. For shipboard surveys, there are two methods that can be used. The first uses a two-team approach where two independent teams of observers scan the same trackline simultaneously. This approach is very costly in personnel and equipment and requires a ship large enough to accommodate four sets of bigeye binoculars and twelve observers. The second method utilizes a survey aircraft to survey the ship's trackline three to four times during a single day. This method has been used by NMFS (Palka 2005) successfully and is the most cost effective method that could be used given the restrictions with the budget. This technique involves simultaneous ship and aerial surveys that cover the same spatial and temporal area. The sightings from the ship and aircraft are then compared to estimate the number sightings missed by the ship but seen from the aircraft. This method is normally used to estimate g(0) for aircraft but can be used to approximate this metric in reverse.

To estimate g(0) for aerial surveys, the Hiby circle-back data collection method will be used (Hiby 1999). This method is comparable to the two-team shipboard data collection method that can result in an estimate of g(0) but is a much more cost-effective method than using a two-team approach. The Hiby circle-back method will be used to estimate g(0) in accordance with NOAA/NMFS/NEFSC protocols on select surveys throughout the study period. Briefly, this method uses a "mark-recapture" method whereby once a group of animals is sighted, the aircraft will continue to fly the trackline for 30 s; break trackline and fly the reciprocal heading past the sighting for another 30 s; and then rejoin the trackline. This trackline segment is then repeated and the presence/absence of the animals is recorded. The ratio of initial sightings to resighting events will provide an estimate of g(0).

Accurate modeling of data with high precision (low variance) requires an adequate sample size (n). Generally, as sample size increases, variance decreases and precision improves. In this analysis, a minimum sample size of 20 sightings was used for each species in order to reduce the variability associated with the ultimate density estimates. In addition to modeling (estimating) global density (e.g., by pooling or combining all species), post-stratifications by species and taxonomic group were conducted. In the post-stratification runs, modeling to estimate density was conducted only for those individual species (and individual groups and individual months) for which there were at least n=20 sightings. Species with fewer than 20 sightings were pooled (combined) into their taxonomic groups when possible. Modeling to estimate density for the resultant group was then conducted (provided that the total number of sightings for all member species in that group was at least 20).

In addition, observations that were made under poor visibility conditions have a high degree of variance. For example, the estimated sighting distance, animal size, or (in the case of clusters) the number of animals in the cluster may not be accurate under these conditions. Thus, in this analysis, only those sightings associated with a BSS of 5 or less were included in the modeling analysis in order to reduce the variability that is propagated through the calculations leading ultimately to density and abundance estimates.

After these key assumptions and modifications to the data (e.g., g[0]=1, specifying a minimum sample size n, and removing poor-visibility sightings) were made, preliminary modeling analysis of the modified dataset was conducted to determine if it was necessary to remove spurious data and outliers (via left/right truncation) to conform to the conditions of the "ideal" probability detection function. The detection function of the data can be fit using several models (available in Distance) including the uniform, half-normal, and hazard-rate key functions, modulated by series expansion terms including the cosine, simple polynomial, and Hermite polynomial series. In a preliminary model optimization analysis, the following nine detection function models were tested:

1-3) Uniform key function with cosine series, simple polynomial series, and Hermite polynomial series

4-6) Half-normal key function with cosine series, simple polynomial series, and Hermite polynomial series

7-9) Hazard-rate key function with cosine series, simple polynomial series, and Hermite polynomial series

In this model optimization analysis using Program Distance (Thomas et al. 2006), with no truncation of the data and with and without stratification, a warning message was generated for some of the models: "Parameters constrained to obtain monotonicity", which indicates that the unprocessed data suggested an extreme in the detection function (thus violating the "monotonically decreasing" criteria). Thus, some form of left-truncation and/or right-truncation was required for these models. The same warning message appeared after the data was left-truncated only and right-truncated only. Using both left-truncation and right-truncation removed the warning message. However, for other models, this warning message did not appear, indicating that truncation of the sightings data was not necessary when running these models. Hence, any spurious data points in the dataset were not serious. It was decided not to truncate the data for the main modeling analysis in order to maximize the sample size available for modeling. Thus, as part of the model optimization analysis, those models that required truncation of the data were removed from further consideration. Of the remaining models, the optimal model was chosen at that model which yielded the smallest value of the Akaike's Information Criterion (AIC), as discussed below.

In summary, the following assumptions and modifications of (adjustments to) the input sightings data were conducted:

1) g(0) was assumed to be 1.0.
2) A minimum sample size of n=20 was specified in order to conduct modeling for density estimation. Species with fewer than 20 sightings were pooled into taxonomic groups when possible, and modeling of group density was then conducted provided that sample size was at least 20 for that group.
3) Poor-visibility sightings data (e.g., with BSS of 6 or higher) were removed from the modeling analysis.
4) Truncation was not applied to the sightings data in order to maximize the sample size available for modeling.

At this point, the input sightings data were deemed sufficiently reliable to proceed with the full modeling analysis in order to estimate density and abundance.

8.2.2 Modeling and Density/Abundance Estimation

According to line transect theory outlined in Program Distance (Thomas et al. 2006), density (abundance per unit area) is estimated as a function of:

1) Encounter rate n/L (where n = sample size or number of sightings and L = line transect length or effort).
2) Probability density function at zero perpendicular distance (f_o).
3) Mean group size or cluster size E(s).
4) Probability detection function at zero perpendicular distance (g[0], availability bias).

The estimated density is given by: $D = N/A = 0.5*(n/L)*f_o*E(s)/g(0)$, where N = abundance; A = survey area; E(s) = expected cluster size (= 1 for individual animals); and the other parameters are as defined previously. The error or uncertainty associated with each estimated parameter [D, n/L, f_o, E(s), g(0)] can be quantified by the variance (Var), coefficient of variation (CV), and the 95 percent CI. The CV is the ratio of the square root of variance to the value of the parameter estimate. For example, $CV(x) = Var(x)^{0.5}/x$, where x = D, n/L, f_o, E(s), or g(0). According to the Delta method, the squared coefficient of variation for density (D) is equal to the sum of the squared CVs for encounter rate (n/L), f_o, cluster size E(s), and g(0):

$$CV(D)^2 = CV(n/L)^2 + CV(f_o)^2 + CV[E(s)]^2 + CV[g(0)]^2$$

In this analysis, if it is assumed that g(0)=1.0 and E(s)=1 (i.e., ungrouped data, individual animal sightings), then the above equation simplifies to:

$$CV(D)^2 = CV(n/L)^2 + CV(f_o)^2$$

Once CV(D) is calculated, then, for the 100*(1 - 2*a) CI, the lower (D_l) and upper (D_u) confidence limits for estimated density D are given by D_l = D/C and D_u = D*C, where C = exp(z_a*[ln{1 + CV(D)^2}]), where z_a is the critical z value of the Gaussian normal distribution for the "a" confidence level (Buckland et al. 2001, 2004). For example, for the 95 percent CI, a = 0.025 and z_a = 1.96.

In summary, in addition to the estimates of density (D) and abundance (N), the model reports the CV, DF, and the 95 percent CI statistics associated with each density and abundance estimate. In addition, the optimal model parameters (of the optimal model used in the density estimates) are reported along with associated variances. Statistics on the components of density (i.e., n/L and f_o) are also reported. In addition, model output includes the percentages of the variance associated with the global density estimate that is attributed to the encounter rate (n/L) and detection function (f_o).

8.2.3 Criteria for Optimal Model Selection

In a model optimization analysis, several model combinations (including the previously-listed nine models) were run to generate density estimates. Selection of the optimal model from these runs was conducted via minimization of the AIC index (Buckland et al. 2001, 2004), given by: AIC = -2*ln(L) + 2*q, where ln(L) is the log-likelihood function evaluated at the maximum likelihood estimates of the model parameters, and q = number of estimated model parameters. AIC quantifies the bias-variance trade-off. The first term quantifies how well the model fits the data, which can also be quantified via the X^2 GOF test. The second term quantifies the penalty (increased variance) associated with addition of model parameters. Model parameter addition (increase in q) improves model fit and reduces bias, at a cost of increasing variance and model complexity. To aid in model selection, the model with the lowest AIC is identified as the optimal model, which has the best combination of a good fit to the data without too many parameters (parsimony principle). For smaller samples, a second order criterion (AIC_c) was developed by Hurvich and Tsai (1989, 1995): AIC_c = AIC + 2*q*(q+1)/(n-q-1), where n = sample size (i.e., number of sightings). As the ratio n/q increases, AIC_c approaches AIC.

Proceeding with the modeling analysis, the following runs were using the optimal model selected from the group of nine models:

1) No stratification
2) Post-stratification by species
3) Post-stratification by taxonomic group
4) Post-stratification by month (optional)

The first run generated global density and abundance estimates (e.g., with all species pooled together). Runs 2 and 3 yielded density estimates for individual species (only for those species for which there are at least 20 sightings) and for taxonomic groups (generated by pooling all species belonging to the given group), respectively. Optional Run 4 yielded global density and abundance estimates (i.e., pooling all species) for each individual month. A total of 11 months of shipboard survey sightings data (January through November 2008) were modeled for density and abundance estimation.

8.3 PASSIVE ACOUSTIC MONITORING METHODOLOGY

8.3.1 Array Configuration – Placement Variation between Deployments

A cross configuration was selected for placement of five marine autonomous recording units (i.e., popups) from the Bioacoustics Research Program, Cornell Laboratory of Ornithology (BRP) with roughly 45 mi (72.42 km) between the southern and northern stations and about 15 mi (24.14 km) between the eastern and western deployment coordinates (**Figure 8-1**). The first deployment of these five popups was March 2008. In June 2008, one popup was not recovered; therefore, the four remaining popups were deployed in a diamond pattern (i.e., Station #3 was not deployed). The third deployment occurred in September 2008 with four units recovered, refurbished, and a replacement unit delivered to allow for five units

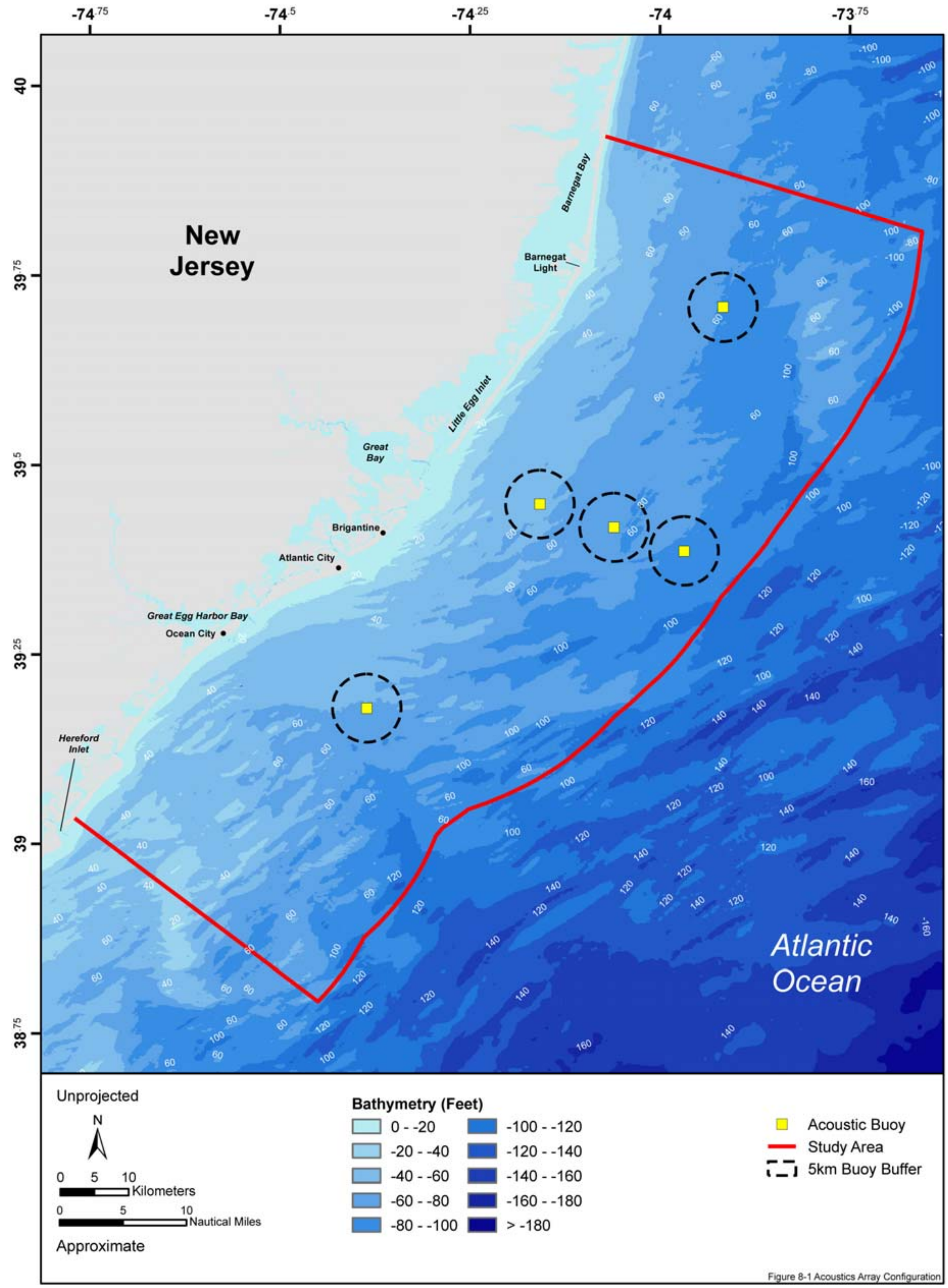

Figure 8-1. Locations of acoustic popup buoys in the New Jersey Study Area from March to September 2008. The popups were deployed in a cross-configuration in an attempt to record whale and dolphin sounds over as much of the Study Area as possible.

deployed in the cross configuration pattern. The fourth deployment covered the first two weeks of December 2008 with weather and equipment issues factoring into the extended time frame for recovery, refurbishment, and redeployment. Two popups (PU063 at Station #1 and PU081 at Station #2) were not found and did not return to the surface when called. It is likely they were somehow removed from the area. Two replacement units from BRP were provided and redeployment included five units. Because of the loss of two units over the course of the project from Station #1, new coordinates were identified slightly to the northwest of the original Station #1 location for this drop. The new GPS coordinates place Station #1 in an area marked with obstruction on the chart; it was the consensus of the crew and chief scientist that this area would be relatively free from trawler activity.

Popups were consistently placed within 20 ft (6.10 m) of the GPS coordinates identified for deployment. Depths for deployed popups ranged from 58 to 90 ft (17.68 to 27.43 m) with the shallowest units at Station #1 and Station #2 in the array configuration (new and original coordinates not withstanding).

8.3.2 Acoustic Sampling Rates and Duty Cycles for Recording

The March 2008 deployment had five popups each with a 2-kilohertz (kHz) sample rate and continuous duty cycle for recording. This protocol would yield roughly 2,000 hrs of data per popup unit recovered; four popups recovered translates to 8,000 hrs of data for processing. A 2-kHz sample rate is biased towards capturing baleen whale calls only; thus, two popups were equipped with a modified sample rate and duty cycle for each deployment from June 2008 forward. The popups at Stations #1, #3, and #5 retained the 2 kHz sample date and continuous duty cycle for each deployment. Popups at Stations #2 and #4 were given a 32 kHz sample rate with a 5 min on/25 min off duty cycle. The increased sample rate provides a significantly larger amount of data for each frequency/time period and enables examination of the data for toothed whale calls (e.g., dolphin whistles). Roughly 240 min (5 min per half hour over 24 hrs) of data are collected per 24-hr period.

8.4 AERIAL AND SHIPBOARD SURVEY AND ACOUSTIC MONITORING RESULTS

8.4.1 Aerial and Shipboard Survey Results

8.4.1.1 Aerial Survey Effort

The total aerial survey covered 2,186 km (1,180 NM) of on-effort trackline between February and April 2008 (**Figure 8-2**). The aerial surveys were scheduled to begin in January; however, poor weather conditions delayed the start of the surveys until February. The BSS ranged from 0 to 5. Survey effort was usually stopped when conditions reached a BSS of 4; however, effort was continued in some cases when it was thought that there would be a lower BSS on the following trackline due to the change in the direction of the aircraft (inshore or offshore). Survey days, effort, and BSS ranges are summarized in **Table 8-3**. In February, an additional shoreline survey was flown to record hauled out seals. The plane crashed on May 17, and aerial surveys have not been flown since.

On- and off-effort sightings from the aerial surveys are discussed in this report; however, due to the low number of sightings, none of the aerial survey data were used in the calculation of abundance and density estimates.

8.4.1.2 Shipboard Survey Effort

The total shipboard survey covered 7,090 km (3,896 NM) of on-effort trackline between January and December 2008 (**Figure 8-3**). The BSS ranged from 0 to 6. Survey effort was usually stopped when conditions reached a BSS of 6; however, effort was continued in some cases when the BSS was shifting between a 5 and 6. The majority of survey effort was conducted in a BSS between 2 and 4. Bad weather conditions prevented survey effort mainly during the winter months. For example, survey effort in February was terminated after only one day of surveying. Survey days, effort, and BSS ranges are summarized in **Table 8-4**.

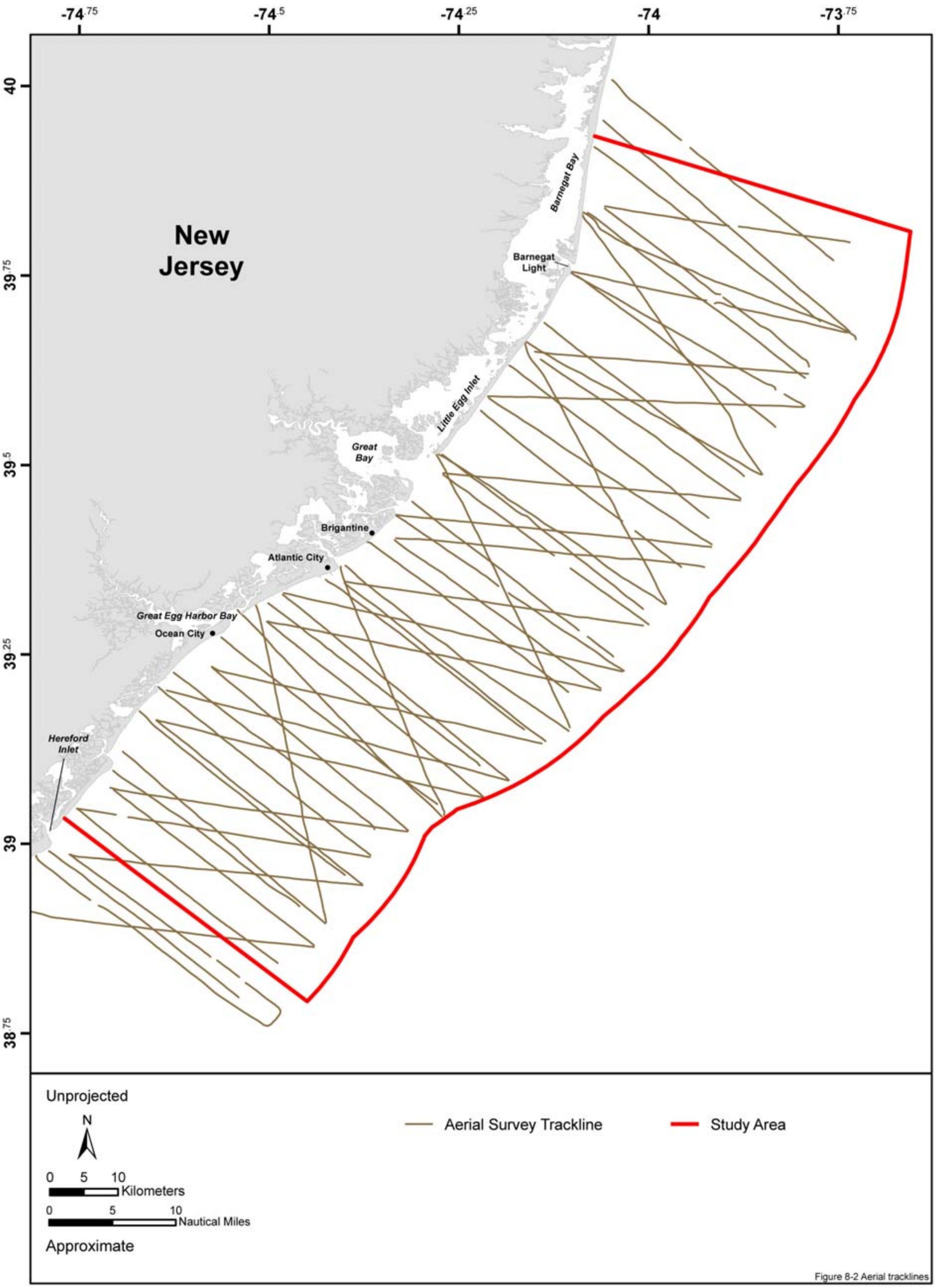

Figure 8-2. Marine mammal and sea turtle aerial survey tracklines in the New Jersey Study Area for February through April 2008.

Table 8-3. Summary of dates, effort, and BSS range for the aerial survey for marine mammals and sea turtles.

Month	Day	Survey Effort (km)	BSS Range
February 2008	2/3-2/4	583.544	1-3
March 2008	3/3, 3/6	749.819	2-4
April 2008	4/18	852.569	0-5
May 2008	5/15, 5/17	N/A	N/A

Only on-effort sightings and on-effort portions of the tracklines surveyed in a BSS of ≤5 were used in the analysis of abundance and density estimates. On-effort means that the observers were in place and actively searching for marine mammals and/or sea turtles and that the observation platform was on its trackline. Off-effort sightings are discussed in this report but were not included in the calculation of abundance and density estimates.

8.4.1.3 Sightings and Distribution

During the aerial and shipboard surveys, a total of 282 sightings were recorded between January and December 2008 (**Figure 8-4**). A total of 237 of these sightings were recorded while the survey teams were on-effort (i.e., observers were actively searching for marine mammals and turtles on the trackline). Seven cetacean species, one pinniped species, and two sea turtle species were found in the Study Area. In some cases, the animal(s) in a sighting could not be identified to the species level; therefore, a generalized taxonomic grouping, such as small cetacean, was used. The bottlenose dolphin was the most frequently sighted species (142 sightings); however, most of these sightings were recorded in the summer months. The fin whale was the only species sighted throughout the year. The only pinniped species recorded in the Study Area was the harbor seal. Two species of sea turtle, the loggerhead turtle and leatherback turtle, were sighted in the Study Area.

Table 8-5 provides a summary of on-effort and off-effort sightings for each species or group. Note that one sighting may consist of one or multiple animals; therefore, the mean group size and range of group sizes for each species and taxonomic group are included in **Table 8-5**. Group size varied by species and ranged from one to 108 animals.

More information on marine mammal and sea turtle distribution and the sightings recorded during the shipboard and aerial surveys is discussed below. Information on the other species which may occur in the Study Area but which were not sighted during these surveys will be discussed in the final report.

♦ **North Atlantic Right Whale (*Eubalaena glacialis*)**

Right whales occur in sub-polar to temperate waters (Jefferson et al. 2008). North Atlantic right whales occur mainly in continental shelf waters along the east coast of North America between Florida and Nova Scotia (Winn et al. 1986). Most sightings of this species are concentrated within five high-use habitat areas: the coastal waters of the southeastern U.S. off Georgia and Florida, Massachusetts Bays (such as Cape Cod Bay), the Great South Channel, the Bay of Fundy, and the Scotian Shelf (Winn et al. 1986; NMFS 2003). The feeding grounds of Cape Cod Bay, which have the greatest number of individuals from February through April (Hamilton and Mayo 1990; Nichols et al. 2008), and the Great South Channel east of Cape Cod, with most frequent use from April through June (Winn et al. 1986; Kenney et al. 1995), are designated as critical habitat for the North Atlantic right whale under the ESA (NMFS 1994; NMFS 2003). The waters off Georgia and northern Florida are the only known calving grounds for North Atlantic right whales in the western North Atlantic basin and are designated critical habitat. North Atlantic right whale use in this area is concentrated in the winter (as early as November and through March; Winn et al. 1986).

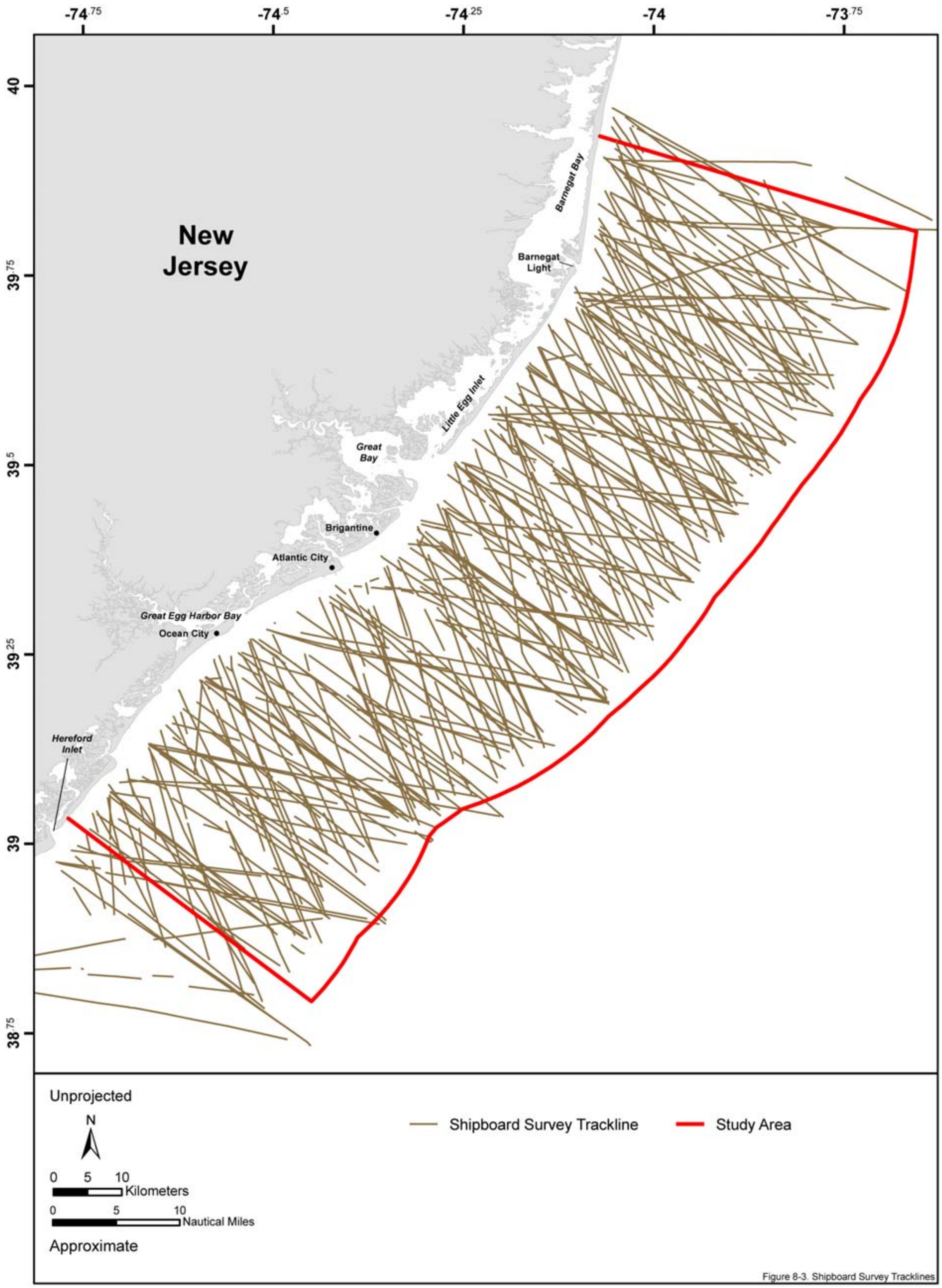

Figure 8-3. Marine mammal and sea turtle shipboard survey tracklines in the New Jersey Study Area for January through December 2008.

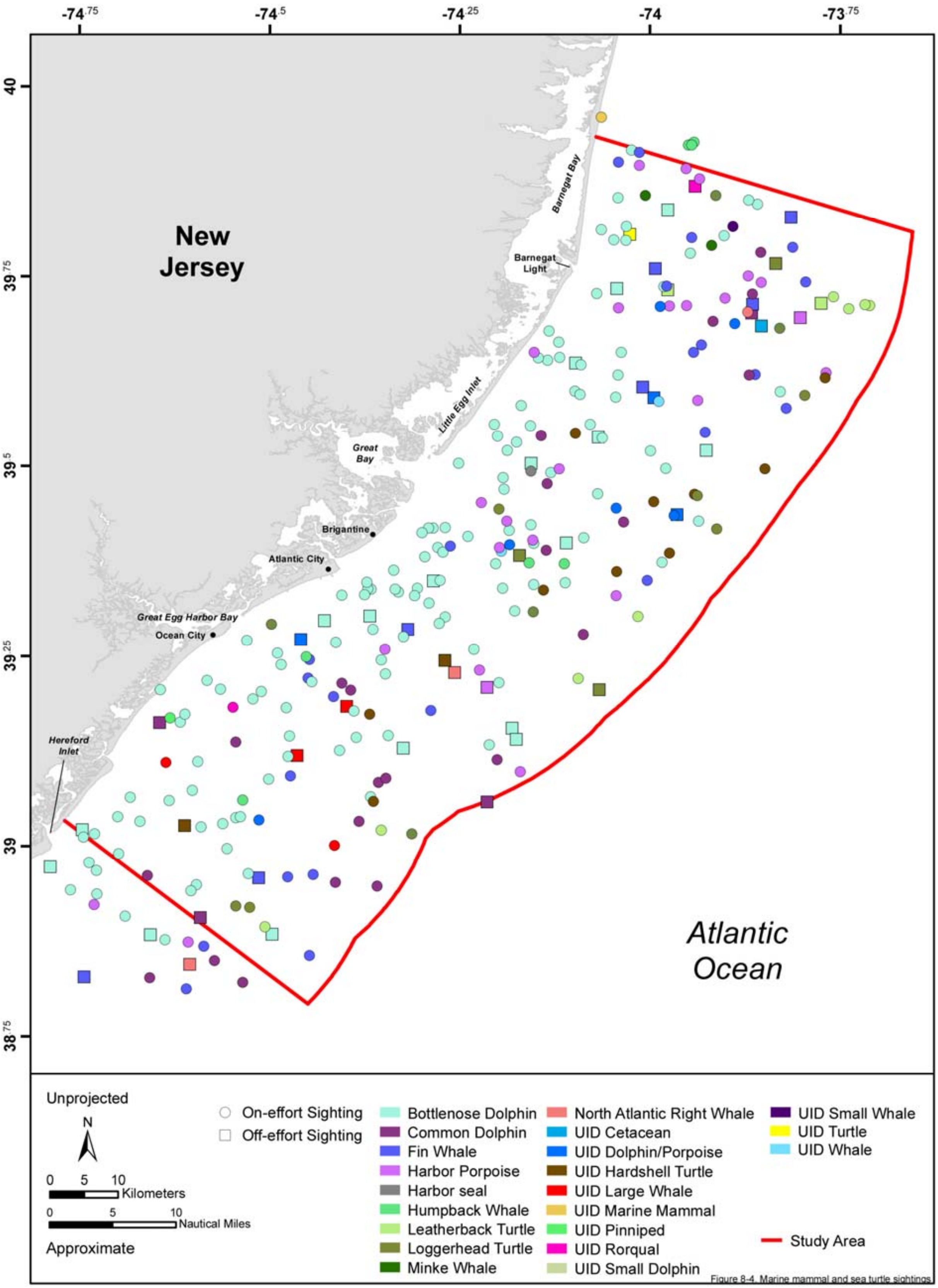

Figure 8-4. Marine mammal and sea turtle sightings (on-effort and off-effort) from shipboard and aerial surveys in the New Jersey Study Area for January through December 2008.

Table 8-4. Summary of dates, effort, and BSS range for the shipboard survey for marine mammals and sea turtles.

Month	Dates	Survey Effort (km)	BSS Range
January 2008	1/15-1/18	451.371	2-6
February 2008	2/12	117.061	1-4
March 2008	3/7, 3/10-3/14	683.292	1-6
April 2008	4/9-4/10, 4/12-4/14	547.357	2-6
May 2008	5/7-5/8, 5/10-5/11	499.649	2-6
June 2008	6/13-6/16	602.408	0-5
July 2008	7/13-7/16	773.069	1-4
August 2008	8/11-8/14	892.478	1-5
September 2008	9/12-9/16	817.600	1-5
October 2008	10/13-10/17	838.548	2-5
November 2008	11/11-11/17	504.4626	1-4
December 2008	12/9, 12/13-12/14	362.914	2-6

Table 8-5. Summary of sightings (combined aerial and shipboard survey data) by species.

Common Name	Scientific Name	On-effort Sightings	Off-effort Sightings	Total Sightings	Mean Group Size	Group Size Range
North Atlantic right whale	*Eubalaena glacialis*	0	2	2	1.5	1-2
Humpback whale	*Megaptera novaeangliae*	7	0	7	1.3	1-2
Minke whale	*Balaenoptera acutorostrata*	2	0	2	1	1
Fin whale	*Balaenoptera physalus*	20	6	26	1.6	1-4
Bottlenose dolphin	*Tursiops truncatus*	123	19	142	15	1-108
Common dolphin	*Delphinus delphis*	19	2	21	13.6	1-65
Harbor porpoise	*Phocoena phocoena*	22	1	23	1.6	1-4
Harbor seal	*Phoca vitulina*	1	0	1	1	1
Unidentified cetacean		0	1	1	3	3
Unidentified small cetacean		1	0	1	1	1
Unidentified small dolphin		5	0	5	2	1-4
Unidentified dolphin/porpoise		6	3	9	9.3	2-40
Unidentified whale		2	0	2	1	1
Unidentified large whale		2	2	4	1	1
Unidentified rorqual*		0	1	1	1	1
Unidentified pinniped		1	0	1	2	2
Unidentified marine mammal		1	0	1	1	1
Leatherback turtle	*Dermochelys coriacea*	8	2	10	1	1
Loggerhead turtle	*Caretta caretta*	7	3	10	1	1
Unidentified turtle		0	1	1	1	1
Unidentified hardshell turtle		10	2	12	1	1

***** A rorqual is a whale from the family Balaenopteridae (e.g., humpback whale, fin whale, minke whale, etc.).

Most North Atlantic right whale sightings follow a well-defined seasonal migratory pattern through several consistently utilized habitats (Winn et al. 1986; Kenney et al. 2001). It should be noted, however, that some individuals may be sighted in these habitats outside the typical time of year and that migration routes are poorly known (Winn et al. 1986; Kenney et al. 2001). Knowlton et al. (2002) analyzed sightings data collected in the mid-Atlantic from northern Georgia to southern New England and found that the majority of right whale sightings occurred within approximately 56 km (30 NM) from shore; however, North Atlantic right whales do range widely; trans-Atlantic migrations of North Atlantic right whales between the eastern U.S. coast and Norway have been documented (Jacobsen et al. 2004) which suggests a possible offshore migration path.

North Atlantic right whales are known to occur off the coast of New Jersey. New Jersey waters are within the known migratory route taken by right whales as they travel between their feeding areas in the north and their breeding/calving grounds off the southeastern U.S. Previous research efforts have recorded right whales in nearshore waters off New Jersey in spring and fall (CETAP 1982). Few sightings near Delaware Bay have been recorded in October, December, May, and July (Knowlton et al. 2002). One satellite-tagged cow and her calf were tracked from the Bay of Fundy to New Jersey and back within a six-week period in September (Knowlton et al. 2002). Another satellite-tagged individual fed in the shelf waters east of the Study Area as it traveled south from the waters off Maine (Bowman et al. 2001). One right whale mortality incident due to entanglement was recorded off the coast of New Jersey in October (Knowlton et al. 2002). While many right whales make long-distance movements to southern breeding and calving areas, not all individuals leave high latitudes. North Atlantic right whales are known to occur regularly throughout the year in the mid-Atlantic and may occur in the Study Area year-round.

Only two sightings of North Atlantic right whales were recorded during the 2008 surveys; both of these were off-effort sightings. One of the sightings included a cow-calf pair and was recorded in waters near the 17-m (56-ft) isobath southeast of Atlantic City in May (**Figure 8-5**). The other sighting was of a single individual and was recorded just near the southern boundary of the Study Area (water depth of 25 m [82 ft]) while the ship was in transit to the southernmost trackline in November (**Figure 8-5**). In both cases the location, time, date, and group size were reported to the U.S. Coast Guard (USCG) and NMFS immediately after the sighting was recorded. Photographs of the right whales were also submitted to NMFS for inclusion in the New England Aquarium's North Atlantic right whale catalog (http://www.neaq.org/conservation_and_research/projects/endangered_species_habitats/right_whale_research/ north_atlantic_right_whale_catalog.php).

- **Humpback Whale (*Megaptera novaeangliae*)**

Humpback whales are globally distributed in all major oceans and most seas (Jefferson et al. 2008). They are generally found during the summer on high-latitude feeding grounds and during the winter in the tropics and subtropics around islands, over shallow banks, and along continental coasts, where calving occurs. Most humpback whale sightings are in nearshore and continental shelf waters; however, humpback whales frequently travel through deep water during migration (Clapham and Mattila 1990; Calambokidis et al. 2001; Reeves et al. 2004).

During spring and summer in the western North Atlantic, the largest numbers of humpback whales are found off the northeast and mid-Atlantic coasts of the U.S. (CETAP 1982; Whitehead 1982; Kenney and Winn 1986; Weinrich et al. 1997; Hamazaki 2002; Stevick et al. 2008). Distribution in this region has been largely correlated to prey species and abundance, although behavior and bottom topography are factors also (Payne et al. 1986; Doniol-Valcroze et al. 2007; Doniol-Valcroze 2008; Stevick et al. 2008). A large proportion of the North Atlantic population of humpback whales is believed to migrate during the winter to calving grounds in the West Indies region (Whitehead and Moore 1982; Smith et al. 1999; Stevick et al. 2003); however, significant numbers of humpbacks have been found at mid and high latitudes during this time, suggesting that not all individuals undergo a seasonal migration (Clapham et al. 1993; Swingle et al. 1993; Charif et al. 2001). An increasing occurrence of humpbacks, including juveniles, along the U.S. Atlantic coast from Florida north to Virginia suggests that this area may be a supplemental winter feeding ground (Clapham et al. 1993; Swingle et al. 1993; Wiley et al. 1995; Laerm et al. 1997; Barco et al. 2002).

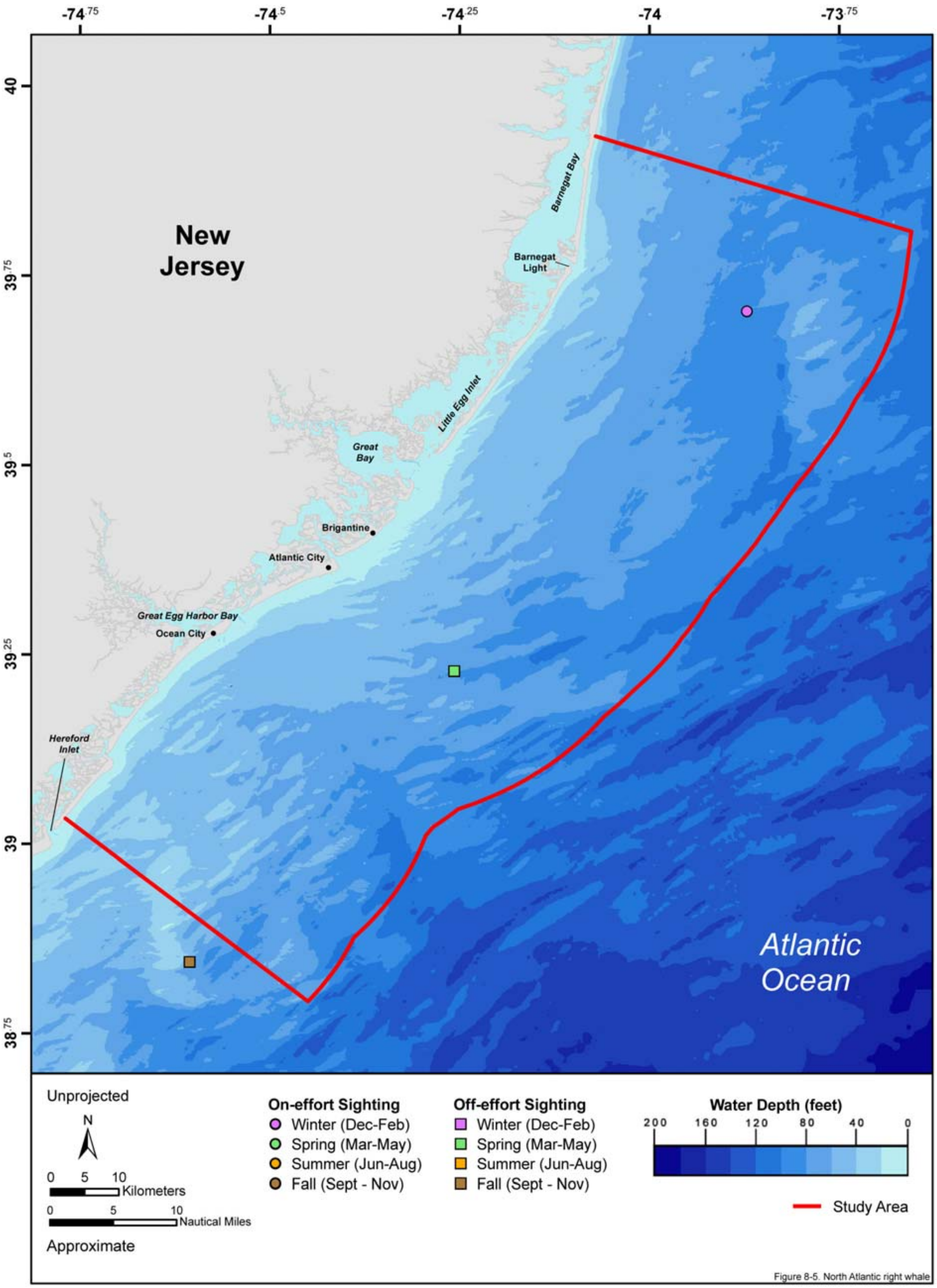

Figure 8-5. On-effort and off-effort sightings of the North Atlantic right whale in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

Humpback whales are known to occur throughout the mid-Atlantic, including New Jersey waters. There are sightings of this species over the continental shelf within the Study Area (particularly during summer) and documented strandings from the coast of New Jersey (Barco et al. 2002). Humpbacks are known to feed in the Study Area; juveniles feed regularly during the summer off the coast of Virginia near the mouth of the Chesapeake Bay just south of the Study Area (Swingle et al. 1993). Humpback whales may occur in the Study Area throughout the year.

During the 2008 surveys, humpback whales were sighted during every season except summer. Most sightings were recorded during fall and winter months. A total of seven sightings were recorded; water depth of the sightings ranged from 15 to 21 m (49 to 69 ft; **Figure 8-6**). Group size ranged from one to two individuals (mean=1.3). In September, a mixed species aggregation of a fin and humpback whale was recorded south of Atlantic City. The humpback whale was observed lunge feeding in the vicinity of the fin whale. No humpback whale calves were observed during the surveys. When possible, photographs were taken of the humpback whales sighted. These photographs will be compared to the College of the Atlantic's North Atlantic Humpback Whale Catalog.

- **Minke Whale (*Balaenoptera acutorostrata*)**

Minke whales are distributed in polar, temperate, and tropical waters (Jefferson et al. 2008), though they are less common in the tropics than in temperate and polar regions. Minke whales are known to occur in shelf waters and in deep offshore waters of the North Atlantic (Slijper et al. 1964; Horwood 1990; Mitchell 1991; Nieukirk et al. 2004). Minke whales are found along the U.S. east coast over the continental shelf (Schmidly 1981; Hamazaki 2002; Calambokidis et al. 2004); they are sighted regularly off New England in the mid-Atlantic (Hamazaki 2002; Waring et al. 2008). Minke whales off the U.S. Atlantic Coast apparently migrate offshore and southward in winter and are known to occur in the western North Atlantic from Bermuda to the West Indies during the winter months (November through March; Mitchell 1991; Mellinger et al. 2000).

Minke whales occur throughout the mid-Atlantic and are documented over New Jersey's continental shelf and in surrounding waters (Schwartz 1962; Mead 1975; Potter 1979; Rowlett 1980; Potter 1984; Winn et al. 1985; DoN 2005). Strandings of this species have been recorded along the coast of New Jersey (Hamazaki 2002).[2] Minke whales are most likely to occur in nearshore waters off New Jersey based on known habitat associations and predictive habitat models (Hamazaki 2002). Minke whales may occur in the Study Area year-round.

Only two sightings of minke whales were observed during the 2008 survey period; both sightings were of a single individual and were recorded in the northernmost portion of the Study Area in February (**Figure 8-7**). Water depth of the sightings ranged from 18 to 24 m (59 to 79 ft).

- **Fin Whale (*Balaenoptera physalus*)**

Fin whales are broadly distributed throughout the world's oceans in continental shelf and offshore waters (Jefferson et al. 2008). The range of fin whales in the North Atlantic extends from the Gulf of Mexico and Caribbean in the west and the Mediterranean Sea in the east, north to Greenland, Iceland, and Norway (Gambell 1985; NMFS 1998). Fin whales are more common north of about 30°N than in the tropics (NMFS 1998). Fin whales are the most commonly sighted large whale in continental shelf waters from the mid-Atlantic coast of the U.S. to eastern Canada (CETAP 1982; Hain et al. 1992; Hamazaki 2002). Fin whales also are detected commonly by Navy deepwater hydrophone arrays in the North Atlantic (Clark 1995).

[2] Dead whale retrieved from Brooklyn Bay. Accessed 19 December 2008. http://www.cbsnews.com/stories/2007/04/19/tech/main2704951.shtml.

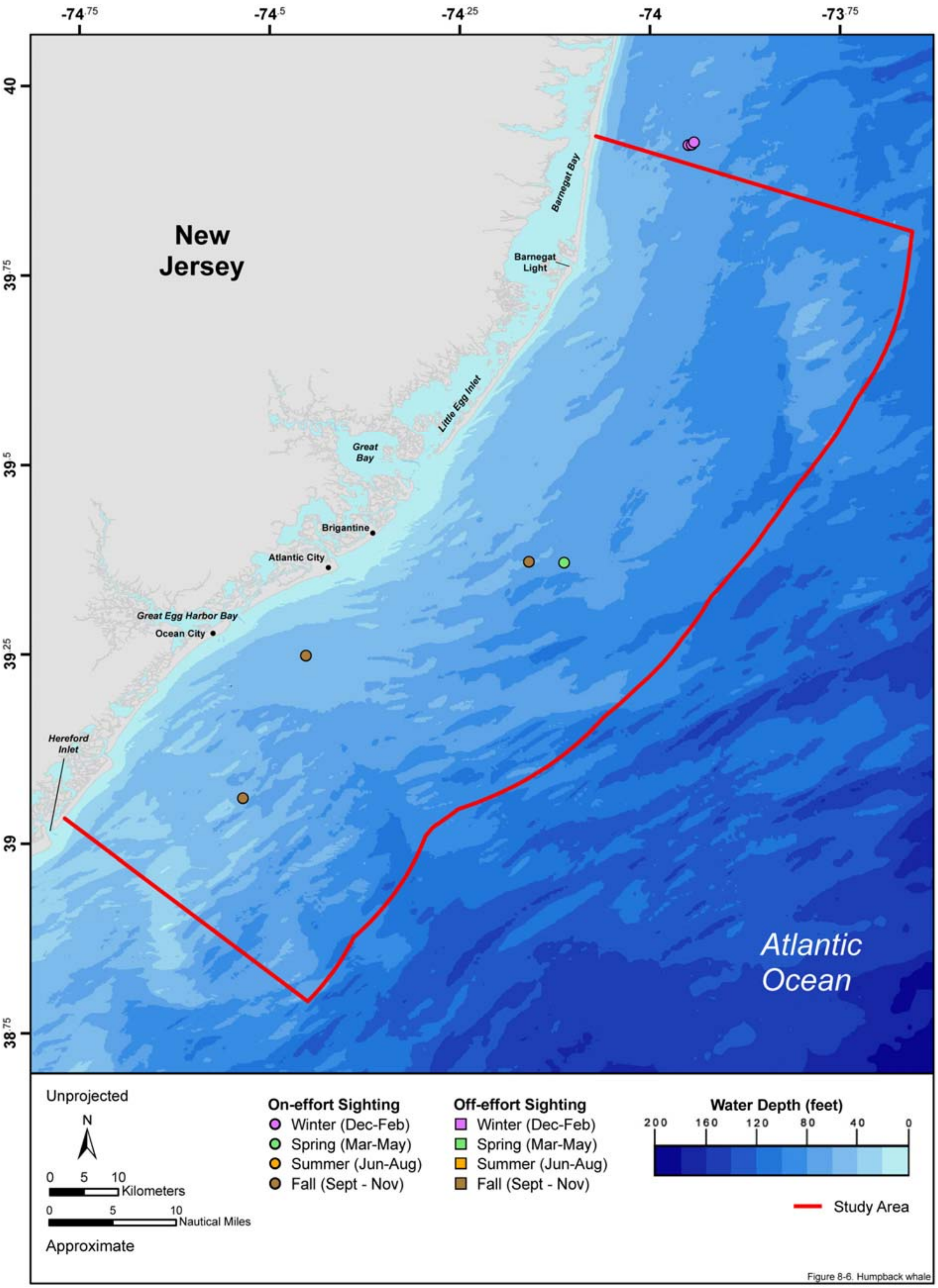

Figure 8-6. On-effort and off-effort sightings of the humpback whale in the New Jersey Study Area from the shipboard and aerial surveys.

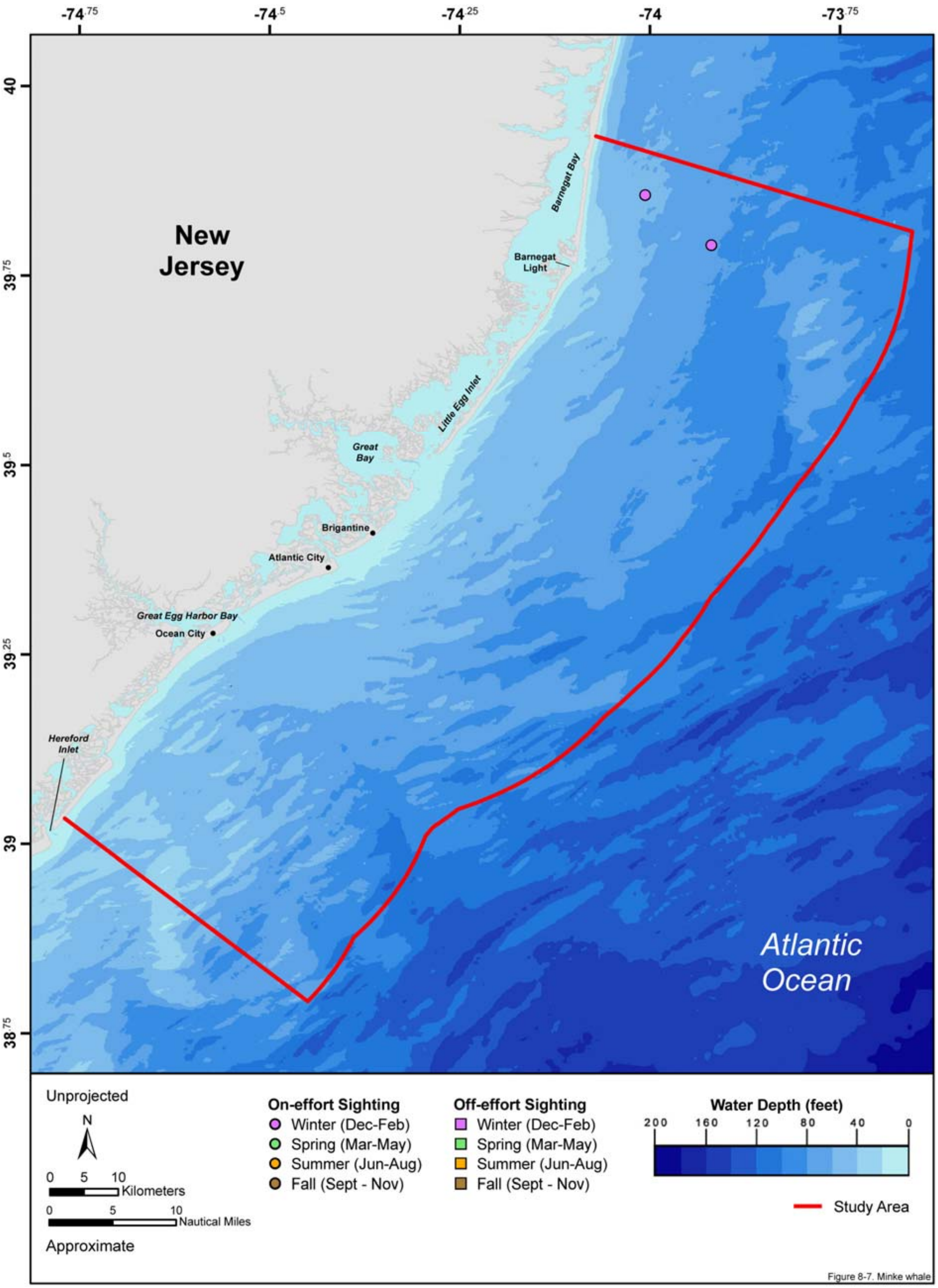

Figure 8-7. On-effort and off-effort sightings of the minke whale in the New Jersey Study Area from the shipboard and aerial surveys.

Fin whales are believed to follow the typical baleen whale migratory pattern, with a population shift north into summer feeding grounds and south for the winter; however, the location and extent of the wintering grounds are poorly known (Aguilar 2002). Acoustic detections by Clark (1995) of fin whales in offshore waters were greatest during winter. This study found a definite southward movement of fin whales in the fall and northward in spring, supporting the idea of seasonal latitudinal movement of fin whales; in the western North Atlantic the endpoints of most of the migration were Newfoundland/Labrador and south of Bermuda into the West Indies. Migration routes are otherwise unknown. Not all fin whales undergo a seasonal migration; they are found on the continental shelf and in higher latitude offshore waters year-round.

Fin whales may occur in the Study Area year-round. This species is commonly sighted in continental shelf waters and is one of the most abundant species of large whale along the U.S. east coast. Fin whales have been sighted and detected acoustically on New Jersey's continental shelf (CETAP 1982; DoN 2005; Turgut and Lefler 2006). Habitat prediction models demonstrate that preferred fin whale habitat in the mid-Atlantic includes the nearshore and shelf waters from south of the Chesapeake Bay north to the Gulf of Maine, including all of the Study Area (Hamazaki 2002). There have been several strandings of fin whales along the New Jersey coast in the last year. In July 2008, a fin whale stranded dead in Long Branch, New Jersey, north of the Study Area[3]; in August, another individual stranded dead at Island Beach State Park at the very northern edge of the Study Area.[4]

During the 2008 surveys, the fin whale was the most frequently sighted baleen whale species and the only marine mammal species sighted throughout the year (**Figure 8-8**). Twenty-six sightings were recorded throughout the Study Area in water depths ranging from 16 to 28 m (52 to 92 ft). Most sightings were recorded during the winter and summer surveys (**Figure 8-8**). Group sizes were usually small ranging from one to four individuals (mean=1.6). As mentioned previously, one mixed-species aggregation of a fin and humpback whale was observed in September. While the humpback whale was lunge feeding, the fin whale surfaced multi-directionally but did not appear to be feeding. One calf was observed with an adult fin whale in August. Attempts were made to photograph all the fin whales sighted during the surveys; these photographs will be compared to the North Atlantic Finback Whale Catalogue managed by Allied Whale for possible matches.

- **Bottlenose Dolphin (*Tursiops truncatus*)**

The overall range of *Tursiops* is worldwide in tropical and temperate waters. *Tursiops* generally do not range poleward of 45°, except around the U.K. and northern Europe (Jefferson et al. 2008). Bottlenose dolphins are found as far north as Nova Scotia in the western North Atlantic. They are distributed continuously southward as far as Venezuela and Brazil (Wells and Scott 1999). Bottlenose dolphins occur seasonally in estuaries and coastal embayments as far north as Delaware Bay (Kenney 1990) and in waters over the continental shelf and upper slope, as far north as Georges Bank (CETAP 1982; Kenney 1990).

In the U.S. Atlantic EEZ, New Jersey is part of the northernmost range of the bottlenose dolphin which occurs along the coast from Long Island, New York, to the Florida Keys (Wang et al. 1994).

This species has been documented in New Jersey from the 19th century (True 1885) and is sighted consistently both along the shore and farther out over the continental shelf and slope (CETAP 1982; Palka 2001; Hamazaki 2002). The bottlenose dolphins that occur off of the coast of New Jersey are migratory, spending the summer and fall months (primarily May through October) off New Jersey and higher latitudes and moving southward during the winter and spring where they overwinter off the coasts of Virginia and North Carolina (Hohn 1997; Read et al. 2003; Toth-Brown et al. in review a); however, not all individuals make this southward migration; in summer 2008, a group of bottlenose dolphins traveled

[3] Endangered whale washes up dead on beach in Long Branch. Accessed 29 December 2008. http://www.mycentraljersey.com/apps/pbcs.dll/article?AID=/20080706/STATE/80706014.

[4] 55-foot fin whale washes ashore at Island Beach State Park. Accessed 29 December 2008. http://www.nj.com/news/index.ssf/2008/08/55foot_fin_whale_washes_ashore.html.

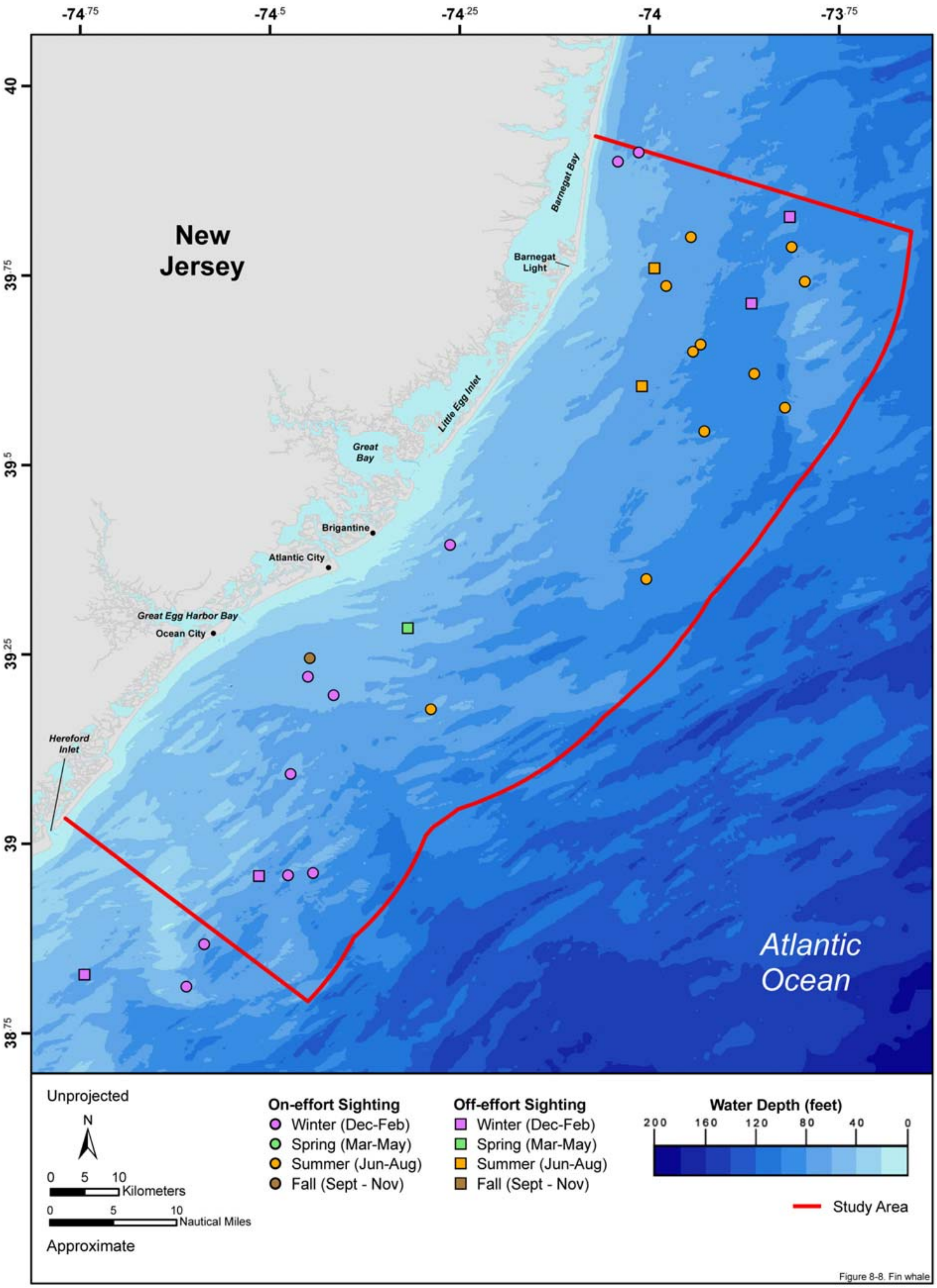

Figure 8-8. On-effort and off-effort sightings of the fin whale in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

into the Shrewsbury and Navesink rivers[5] and remained there into the winter months.[6] Bottlenose dolphins may occur in the Study Area at any time of year.

According to a recent study in nearshore waters off New Jersey, there is a significant break in the habitat usage of bottlenose dolphins, with one group using the waters within 2 km of the shore and the other occupying waters outside of 2 km of shore with very little overlap between the two groups (Toth-Brown et al. in review b). In general, bottlenose dolphins in New Jersey are not found in estuarine habitat, but they are found in Delaware Bay at the very southern end of New Jersey.

During the 2008 surveys, a total of 142 sightings of bottlenose dolphins were recorded throughout the Study Area in waters ranging from <1 to 33 m (<1 to 108 ft) in depth (**Figure 8-9**). This was by far the most sightings of any marine mammal or sea turtle species in the Study Area. The majority of these sightings were recorded during the summer; however, bottlenose dolphins were sighted as early as

March and through the middle of September. Bottlenose dolphins may occur in the nearshore waters of New Jersey through November based on opportunistic observations of bottlenose dolphin near Ocean City, Maryland in mid-November (J. Brandon and T. Ninke personal observation). Group size ranged from one to 108 individuals (mean=15). Calves were frequently observed. Attempts were made to photograph the dorsal fins of all individuals that were in camera range; however, most of the dorsal fins were at least partially covered with the barnacle *Xenobalanus globicipitis* which prevents photo-matching. Photographs that are of acceptable quality and of bottlenose dolphins without the barnacle will be matched to the photographs taken during nearshore surveys of bottlenose dolphins off New Jersey in between 2003 and 2005 (Toth-Brown et al. in review a).

♦ **Common Dolphin (*Delphinus delphis*)**

Delphinus spp. are widely distributed globally in temperate, subtropical, and tropical seas. Common dolphins occur from southern Norway to West Africa in the eastern Atlantic and from Newfoundland to Florida in the western Atlantic (Perrin 2002), although this species more commonly occurs in cold-temperate waters in the western North Atlantic (Waring and Palka 2002).

Selzer and Payne (1988) described the distribution of short-beaked common dolphins along the northeastern U.S. This study found that common dolphins are abundant within a broad band paralleling the continental slope from 35°N to the northeast peak of Georges Bank. There is a strong seasonality to common dolphin distribution in the western North Atlantic, with sightings occurring primarily along the continental shelf break south of 40°N in spring and north of this latitude in fall. During fall, this species is particularly abundant along the northern edge of Georges Bank (CETAP 1982) but less common south of Cape Hatteras (Gaskin 1992).

There have been multiple sightings and strandings of this species along the New Jersey and Long Island, New York coasts (Ulmer 1981; Hamazaki 2002).[7] Sightings of this species tend to occur offshore (>20 NM [37 km]) and in deep waters (Ulmer 1981). Predictive habitat modeling of the waters of the western North Atlantic suggests that common dolphins will occur over the shelf and at the shelf break in the vicinity of the Study Area (Hamazaki 2002). There is a strong seasonal component to common dolphin distribution; this species tends to spend the summer and fall months farther offshore or farther north than during the winter and spring when it is more likely to be found within the Study Area.

[5] Stray dolphins put at risk by onlookers. Accessed 26 June 2008. http://www.northjersey.com/news/aroundnj/21667234.html.

[6] Can dolphins survive winter in NJ rivers? Accessed 30 December 2008. http://news.yahoo.com/s/ap/20081227/ap_on_re_us/wayward_dolphins.

[7] Dolphin found dead in river was not from bottlenose pod. Accessed 15 November 2008. http://www.nj.com/news/ledger/index.ssf?/base/news-14/1226726114210750.xml&coll=1.

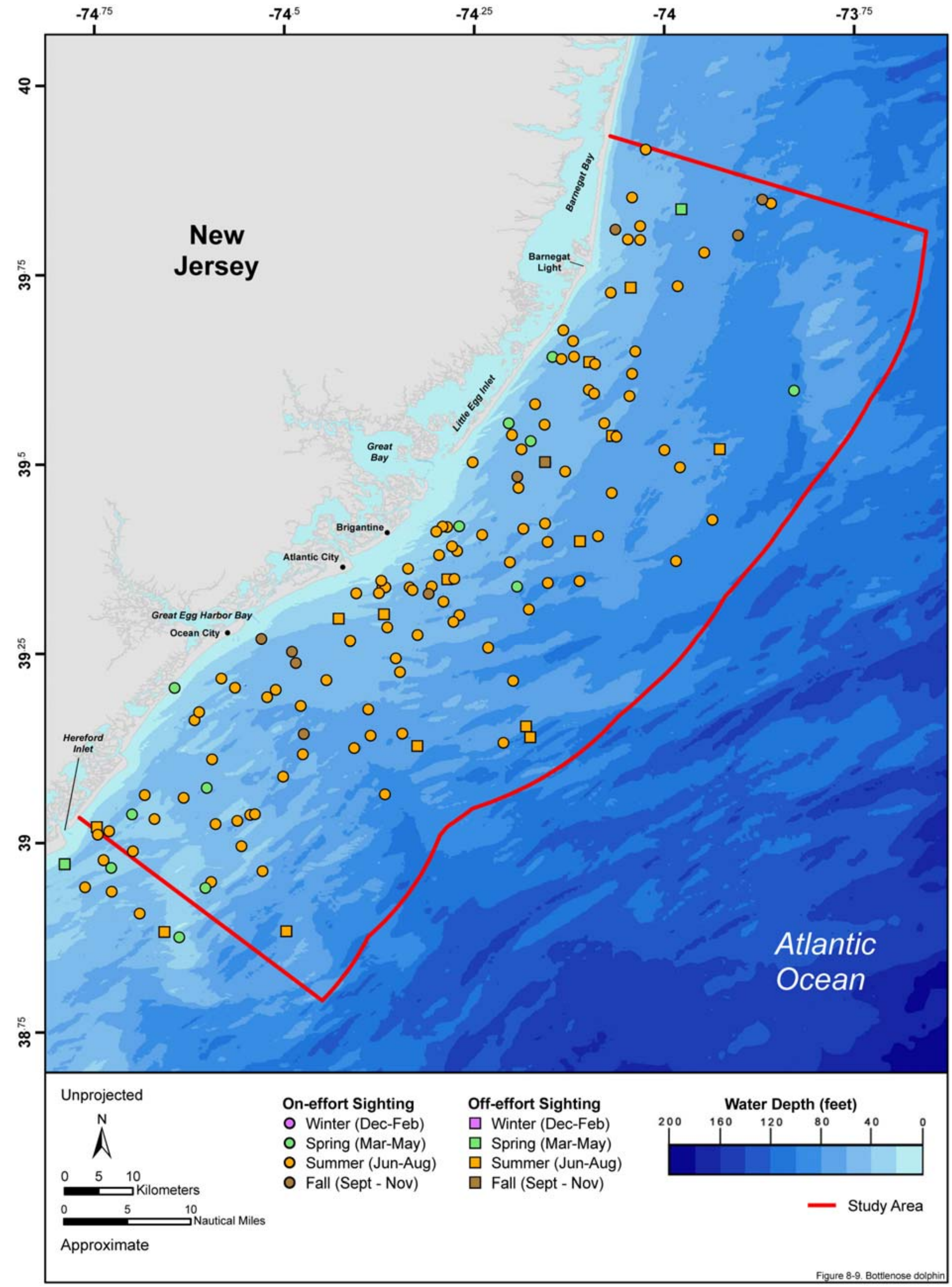

Figure 8-9. On-effort and off-effort sightings of the bottlenose dolphin in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

The twenty-one sightings of common dolphins recorded during the 2008 surveys are consistent with this known seasonal distribution; common dolphins were only observed in the Study Area during the winter and spring surveys (**Figure 8-10**). Sightings were distributed throughout the Study Area; water depth of sightings ranged from 10 to 29 m (33 to 95 ft). Group size ranged from one to 65 individuals (mean=13.6). Calves were frequently observed.

♦ **Harbor Porpoise (*Phocoena phocoena*)**

Harbor porpoises are found in the North Pacific and North Atlantic oceans in sub-polar to cool-temperate waters (Read 1999). In the western North Atlantic, harbor porpoise distribution is concentrated in the Gulf of Maine/Georges Bank region with scattered occurrences south to the mid-Atlantic (CETAP 1982; Northridge 1996). The southern limit of this species' range is probably northern Florida based on available stranding data (Polacheck et al. 1995; Read 1999).

From July through September, harbor porpoises are concentrated in the northern Gulf of Maine and southern Bay of Fundy, generally in waters less than 150 m deep (Palka 1995), with a few sightings in the upper Bay of Fundy and on the northern edge of Georges Bank (Palka 2000). From October through December, harbor porpoises are dispersed in high densities from New Jersey to Maine, with lower densities north and south of this region (NMFS 2001). Harbor porpoises occur mostly on the continental shelf but appear to have an offshore component to their distribution (Read et al. 1996; Westgate et al. 1998), particularly farther south in the mid-Atlantic Bight in the fall and winter (Westgate et al. 1998). During the early winter, sightings occur primarily in the southwestern and northern Gulf of Maine, as well as in the Bay of Fundy (CETAP 1982). From January through March, intermediate densities of harbor porpoises can be found farther south in waters off New Jersey to North Carolina, and lower densities are found in waters off New York to New Brunswick, Canada (NMFS 2001). The New Jersey shore and approaches to New York harbor may represent an important January to March habitat (Westgate et al. 1998). Fisheries bycatch data indicate that harbor porpoises, particularly juveniles, are present in the nearshore waters of the mid-Atlantic during these months (Cox et al. 1998); however, not all harbor porpoises remain in shallow, nearshore waters during winter; harbor porpoise have been bycaught in pelagic fisheries (Read et al. 1996). The presence of bycaught individuals in pelagic fisheries lends credence to the proposed offshore distribution of harbor porpoises during the winter months and explains the observed paucity of sightings in the Bay of Fundy and Gulf of Maine (CETAP 1982).

Harbor porpoises occur in the nearshore waters of New Jersey, including the Study Area, primarily during the late winter and early spring (January to March); however, they may also occur in this region during other times of the year. One satellite-tagged individual was rehabilitated and released near Ocean City, Maryland, in the late spring; the individual remained in the nearshore waters of New Jersey and New York for four weeks before moving north towards Cape Cod in June (Westgate et al. 1998). Fisheries bycatch data acquired between 1999 and 2007 provide insight into the presence of harbor porpoises in New Jersey waters. During this time period, bycatch was recorded only during the months of January through April, with the majority of individuals caught in northern New Jersey waters near Hudson Canyon and in the "mudhole" approximately 13 mi off the New Jersey coast (Palka 2007).[8]

During the 2008 surveys, 23 sightings of harbor porpoises were recorded. Harbor porpoises were sighted throughout the Study Area in water depths ranging from 12 to 26 m (39 to 85 ft; **Figure 8-11**). Harbor porpoises were observed throughout the year except during fall; most sightings were recorded during the spring surveys. Group size ranged from one to six individuals with a mean group size of 1.4 individuals.

[8] Hooked: A magnificent obsession; The Mudhole. Accessed 31 December 2008. http://query.nytimes.com/gst/fullpage.html?res=990CE7D9143DF937A3575BC0A963958260&sec=&spon=.

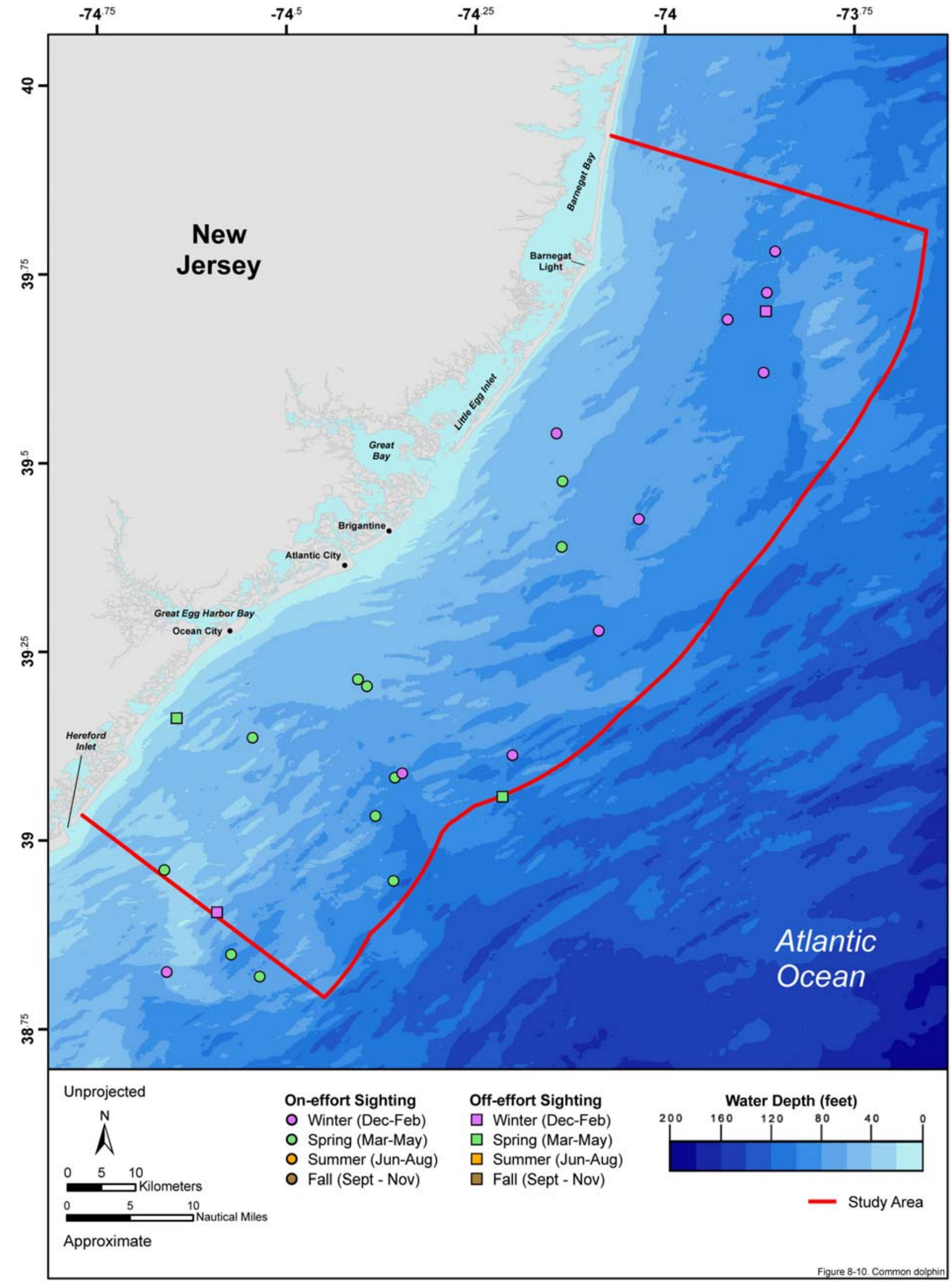

Figure 8-10. On-effort and off-effort sightings of the common dolphin in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

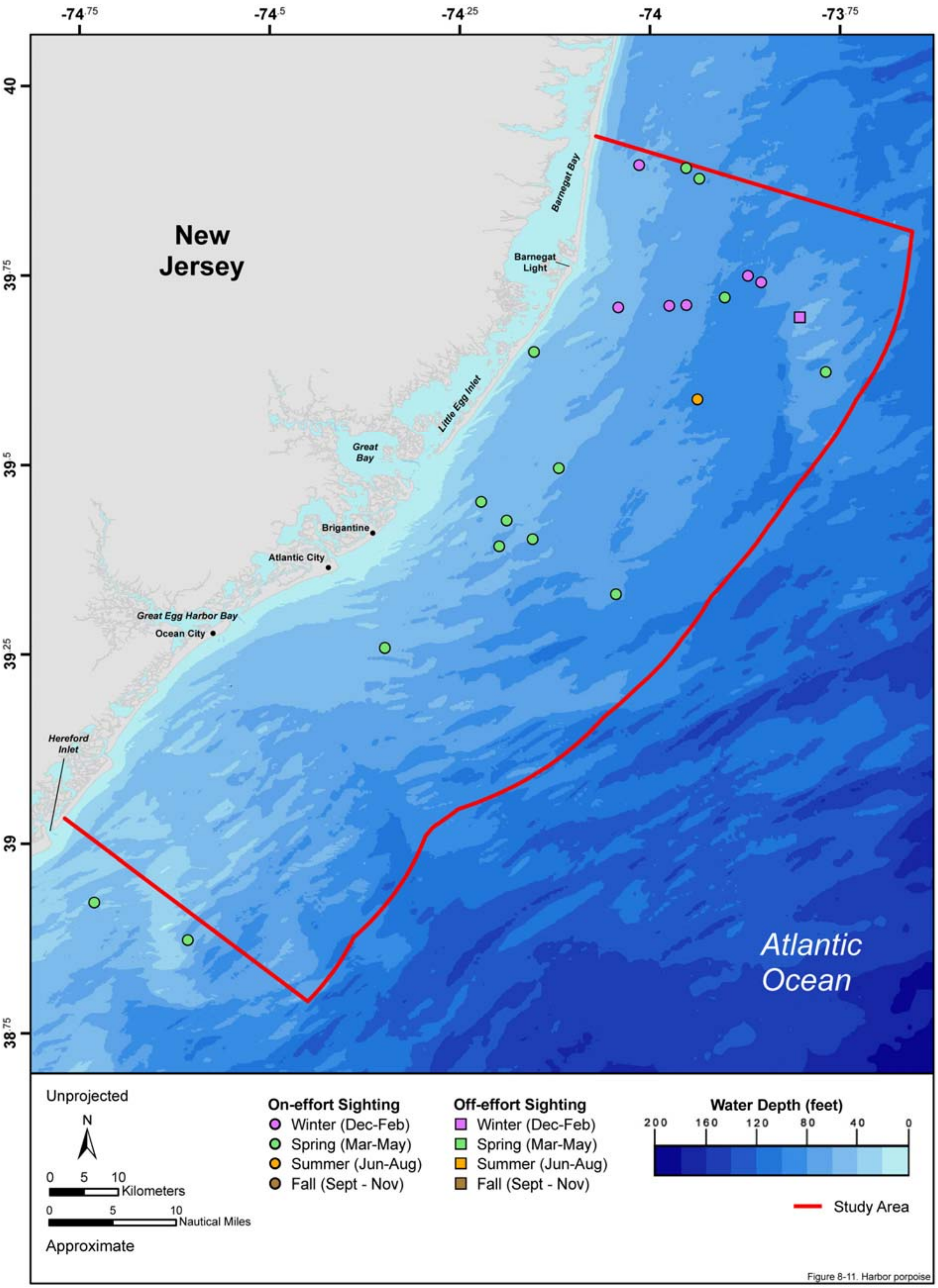

Figure 8-11. On-effort and off-effort sightings of the harbor porpoise in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

♦ **Harbor Seal (*Phoca vitulina*)**

Harbor seals occur in sub-Arctic to temperate coastal waters throughout the North Atlantic and North Pacific basins (Bigg 1981). Harbor seals are year-round residents of eastern Canada (Baird 2001; Boulva 1973) and coastal Maine (Gilbert and Guldager 1998; Katona et al. 1993). Along the U.S. east coast, the greatest concentration of harbor seals is found along the coast of Maine, specifically in Machias and Penobscot bays and off Mt. Desert and Swans Islands (Katona et al. 1993).

Harbor seals in the northeast U.S. are concentrated in northern New England, but they disperse to other areas during certain times of the year. From late September through late May, harbor seals may be found south of Maine (Barlas 1999; Hoover et al. 1999; Payne and Schneider 1984; Rosenfeld et al. 1988; Schneider and Payne 1983; Schroeder and Kenney 2001; Schroeder 2000; Whitman and Payne 1990). During the winter months many seals move offshore into the Gulf of Maine or south into southern New England; some individuals remain in the nearshore waters of Maine and Canada (Baird 2001). Harbor seals have also been observed over-wintering as far south as New Jersey (Slocum et al. 1999). Payne and Selzer (1989) noted that the majority of harbor seals south of Maine are found at haulout sites on Cape Cod and Nantucket Island, with the largest aggregation occurring at Monomoy Island and adjacent shoals. Extralimital occurrences have been observed as far south as Florida (Caldwell and Caldwell 1969; NMFS unpublished data cited in Waring et al. 2008).

From October through December, and perhaps earlier and later, harbor seal numbers decrease in Canadian waters (Terhune 1985) but increase three- to five-fold south of Maine during this time (Rosenfeld et al. 1988). It is thought that the population undergoes a general southward movement along the Canadian coast and northeastern U.S. during this period (Rosenfeld et al. 1988). Tagging efforts by Gilbert and Wynne (1985) support this hypothesis. Tagged harbor seals in Nova Scotia and Maine were later resighted in Massachusetts. Prior to pupping, this generalized movement pattern reverses as animals move northward to the coasts of Maine and eastern Canada.

Harbor seals are known to occur year-round from the Bay of Fundy to the Maine/New Hampshire border. The majority of harbor seals move into northern Gulf of Maine waters by June although harbor seals may be sighted south of Maine during summer. Large aggregations are rare south of Maine. Harbor seals are known to occur in the Mid-Atlantic (including New Jersey) particularly from late fall to spring (Slocum et al. 2005). Harbor seals are known from sighting and stranding records in the Study Area and vicinity (Slocum and Schoelkopf 2001; Slocum et al. 1999). North of the Study Area, harbor seals are known to haul out in the New York/New Jersey harbor estuary on Sandy Hook as well as several New York state islands (Antonucci et al. n.d.). Harbor seals are a nearshore species and are likely to occur within 20 km (11 NM) of the coast throughout their range; however, they may be found farther offshore at any time of year.

The harbor seal was the only pinniped species seen in the Study Area during the 2008 surveys. Only one sighting of one individual was recorded. This seal was observed in shallow waters (18 m [59 ft] in depth) east of Little Egg Inlet in June (**Figure 8-12**). The two unidentified pinnipeds recorded near Ocean City, New Jersey in April were likely harbor seals but identification could not be confirmed to species.

♦ **Leatherback Turtle (*Dermochelys coriacea*)**

Leatherback turtles show strong seasonal distributions and undergo extensive migrations in the western North Atlantic. The movements of adult leatherbacks appear to be linked to the seasonal availability of their prey and the requirements of their reproductive cycle (Davenport and Balazs 1991; Luschi et al. 2006). Thompson et al. (2001) and James et al. (2006) noted that leatherbacks foraging in the western North Atlantic preferred waters from 16 to 18°C, while Witt et al. (2007) found that SSTs of 10 to 12°C represented the lower thermal limit for accessible habitats for leatherbacks migrating to seasonal foraging habitats in high latitudes. Leatherbacks that frequent the waters of the northeast U.S. are typically subadult or adult individuals greater than 100 cm curved carapace length (CCL).

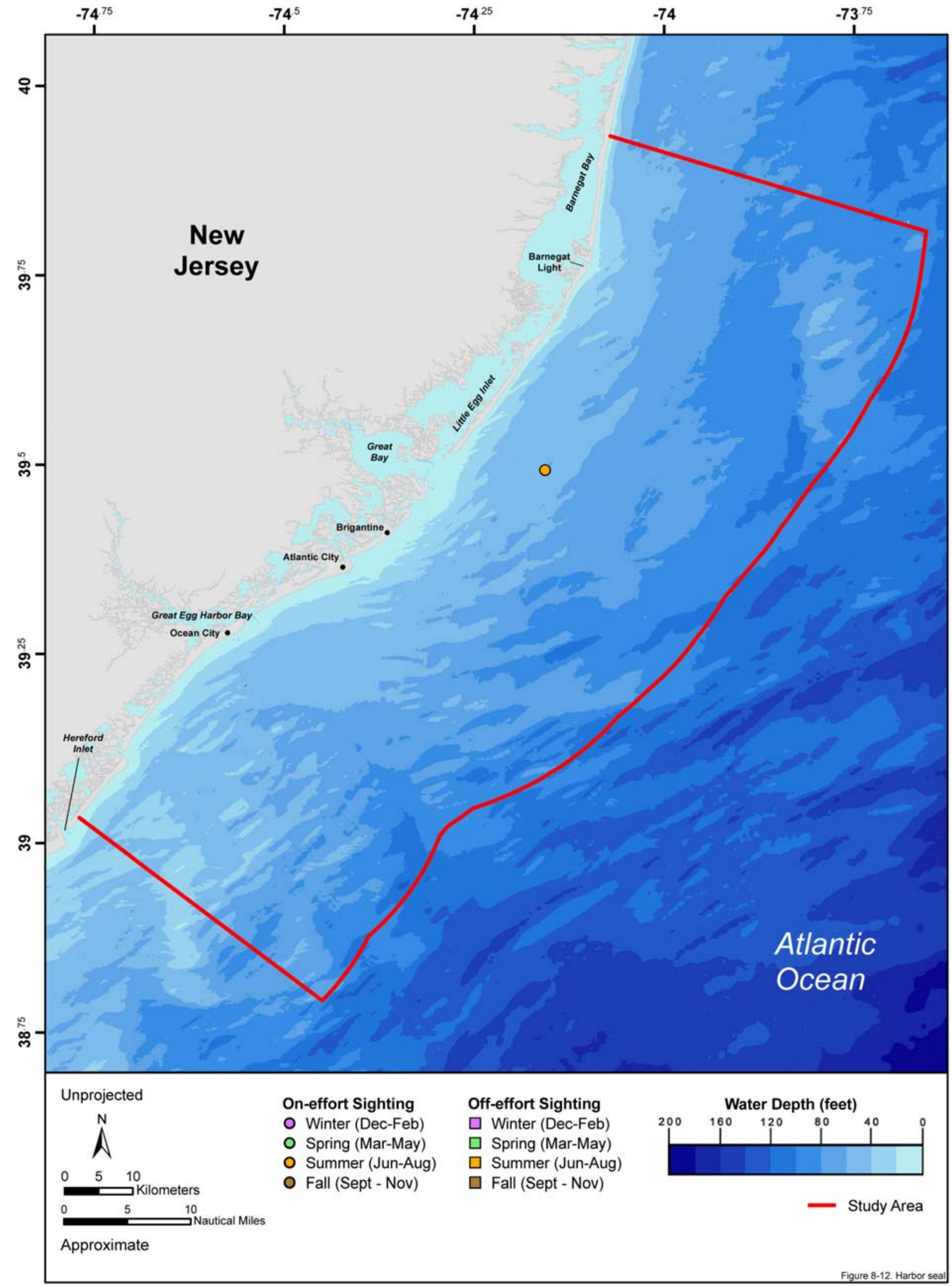

Figure 8-12. On-effort and off-effort sightings of the harbor seal in the New Jersey Study Area from the shipboard and aerial surveys.

A regular, seasonal occurrence of leatherbacks is known to occur along the northeast U.S. Atlantic coast. Survey data indicate that leatherback migrations start with the northward movement of individuals along the southeast 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 northeast Florida; however, by April and May leatherbacks begin to occur in large numbers off the coasts of Georgia and the Carolinas (NMFS 1995; 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; James et al. 2006). Leatherback sightings from New England waters to Canadian waters typically occur between June and October with peak sightings occurring in August (Bleakney 1965; James and Herman 2001); with an estimated 100 to 900 individuals taking up residence during this time (Shoop and Kenney 1992). Leatherbacks frequenting this area have been documented in waters deeper than the 2,000-m isobath but are mostly seen in coastal waters where zooplankton are abundant (Shoop and Kenney 1992; James and Herman 2001; James et al. 2006).

The occurrence of leatherback turtles in the Study Area during the 2008 surveys was consistent with the previously-mentioned seasonal migrations in this region. All ten sightings of leatherback turtles were recorded during the summer and fall; most sightings were observed during the July survey (**Figure 8-13**). The water depth of sightings varied from 18 to 31 m (59 to 102 ft). The group size for each sighting was one individual.

♦ **Loggerhead Turtle (*Caretta caretta*)**

The loggerhead is the most abundant sea turtle occurring in U.S. waters, numbering in the thousands throughout inner continental shelf waters of the Atlantic coast from Cape Cod to southern Florida. Loggerhead distribution along the U.S. Atlantic coast is determined by seasonal water temperatures. Loggerheads prefer water temperatures between 13.3 and 28°C (Mrosovsky 1980), becoming lethargic between 13 and 15°C, and adopting a stunned floating posture in water around 10°C (Schwartz 1978; Mrosovsky 1980).

Off the northeast U.S., loggerheads are commonly sighted from the shore to the shelf break as far north as Long Island Sound although sightings farther north and east are sparse (CETAP 1982; Shoop and Kenney 1992). Loggerhead turtle occurrence north of Cape Hatteras is highly seasonal; loggerheads primarily occur in this region between May and October with a peak in June; however, sightings have been recorded year-round (CETAP 1982; Lutcavage and Musick 1985; Shoop and Kenney 1992). The area of highest summer occurrence likely encompasses waters over the mid-continental shelf from Delaware Bay to Hudson Canyon (Shoop and Kenney 1992). Delaware Bay, Long Island Sound, and Cape Cod Bay are the three most utilized juvenile developmental habitats along the northeast U.S. coast (Burke et al. 1991; Prescott 2000; UDSG 2000). As temperatures drop, loggerheads migrate to overwintering areas south of Cape Hatteras (Epperly et al. 1995; Mitchell et al. 2002); however, strandings and scattered sightings along Cape Cod and Long Island provide evidence that small numbers of loggerheads may remain in the northeast Atlantic during winter. Those individuals are highly susceptible to cold-stunning and hypothermia since winter water temperatures often drop well below the species' thermal tolerance (Burke et al. 1991).

The occurrence of loggerhead turtles in the Study Area was consistent with the known seasonal distribution of this species in the northeast. A total of 10 loggerhead turtle sightings were recorded throughout the Study Area during the summer and fall; most sightings were recorded during the July and September surveys. Water depth of sightings ranged from 17 to 31 m (56 to 102 ft; **Figure 8-14**). The group size for each sighting was one individual.

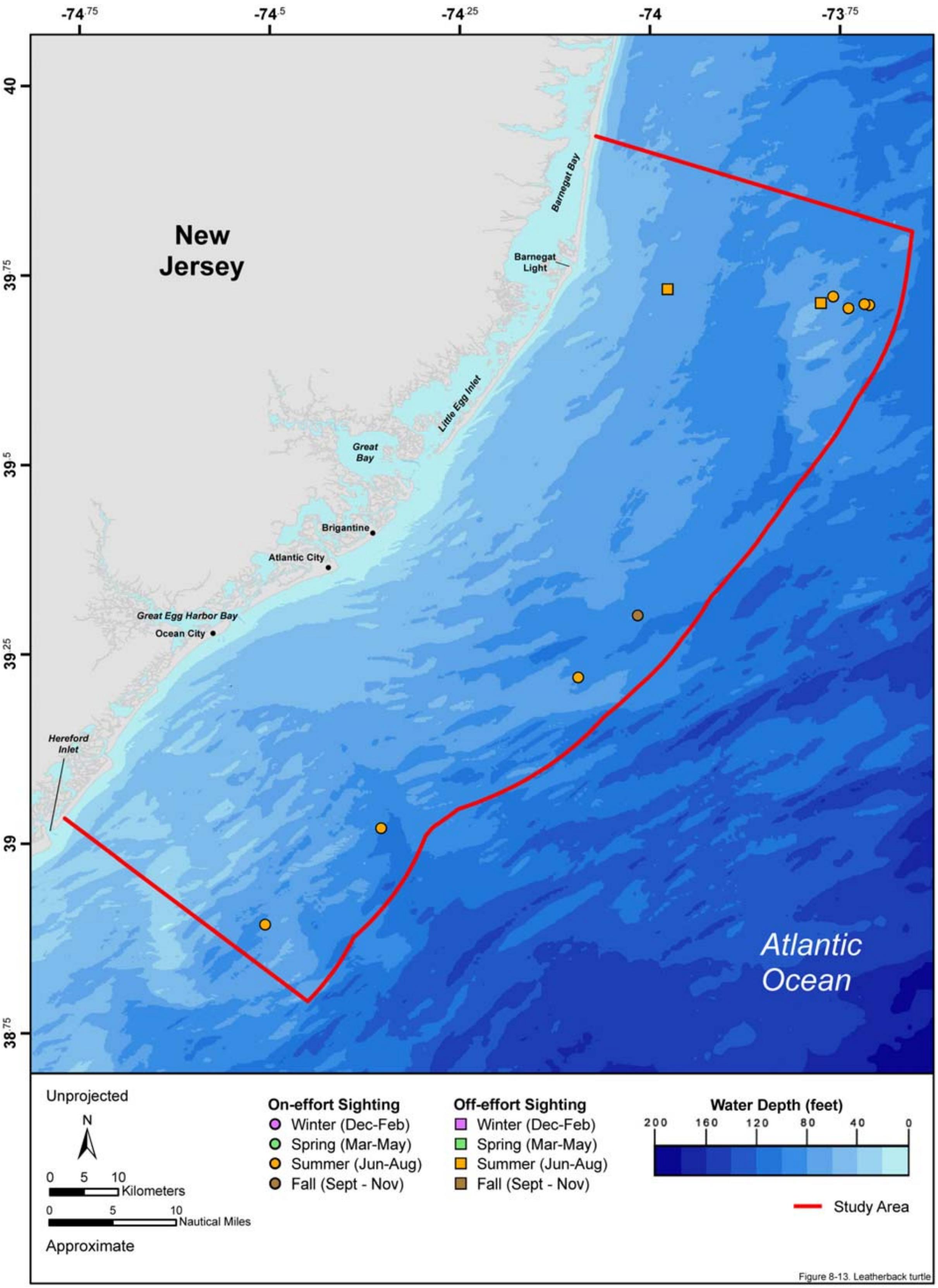

Figure 8-13. On-effort and off-effort sightings of the leatherback turtle in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

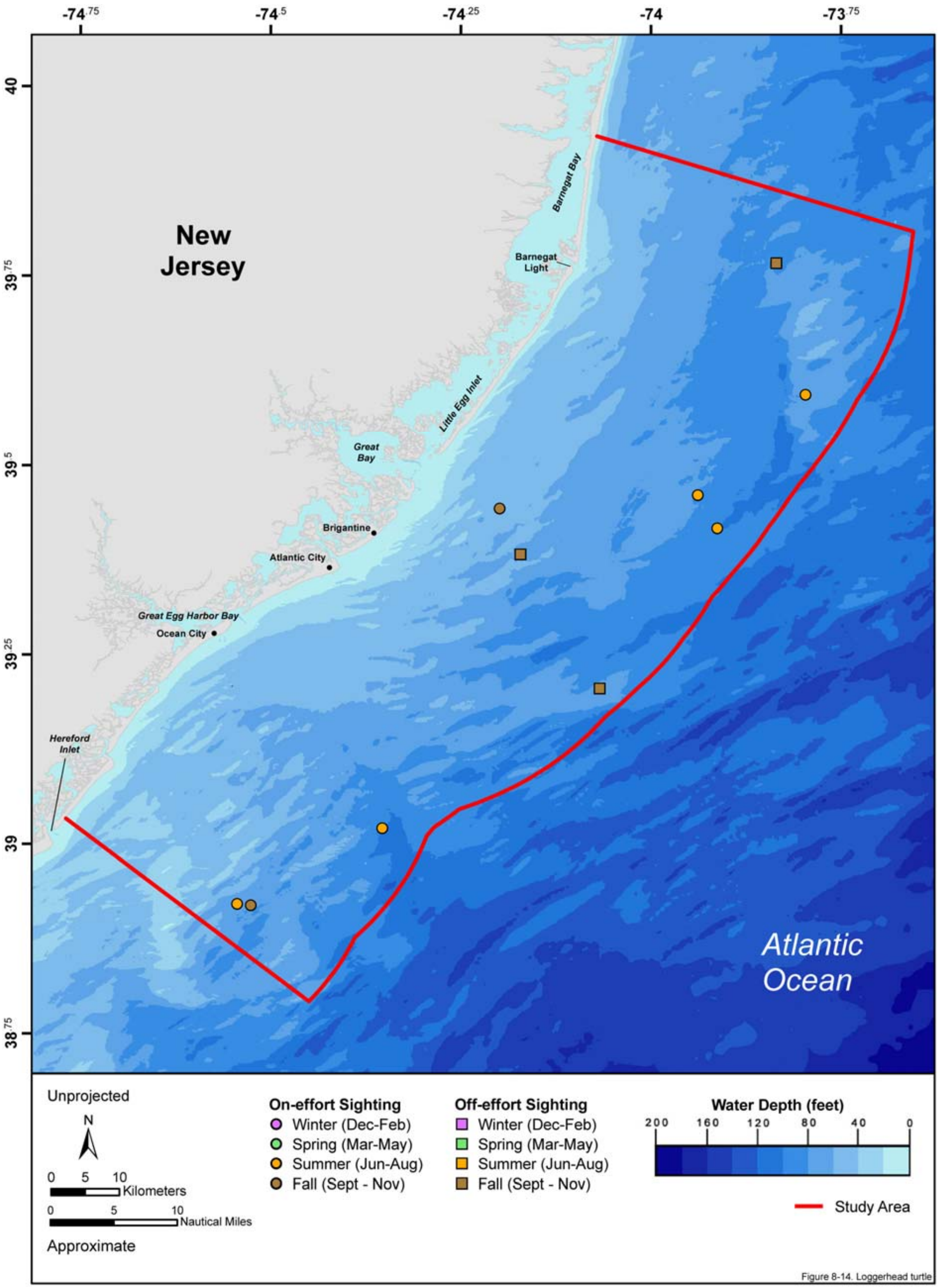

Figure 8-14. On-effort and off-effort sightings of the loggerhead turtle in the New Jersey Study Area and vicinity from the shipboard and aerial surveys.

8.4.1.4 Density Estimates by Species or Group

There were only two species of marine mammals for which there were at least 20 sightings:

1) Bottlenose dolphin (*Tursiops truncatus*)
2) Fin whale (*Balaenoptera physalus*)

Thus, in addition to global density/abundance estimation (conducted by pooling all species together), Program Distance was used to generate individual species density/abundance estimates only for these two species (using post-stratification by species). In addition, to account for other species for which there were an insufficient number of sightings, the species were pooled into the following taxonomic groups:

1) Balaenopterids:
   Fin whale (*Balaenoptera physalus*)
   Minke whale (*Balaenoptera acutorostrata*)
   Humpback whale (*Megaptera novaeangliae*)

2) Delphinids:
   Common dolphin (*Delphinus delphis*)
   Bottlenose dolphin (*Tursiops truncatus*)
   Unidentified small delphinid

Density/abundance estimates for these individual groups were generated using post-stratification by group.

Results of these runs, including density/abundance estimates and associated statistical errors, are summarized in **Tables 8-6** through **8-8**. Detection functions were also plotted versus distance in the form of histograms of the collected data overlaid by a curve describing the fit of the optimal model to the sightings data. These plots are shown in **Figures 8-15** through **8-18**. The modeled detection function (red curve) is plotted assuming g(0)=1 (i.e., 100 percent detection probability for species located at zero perpendicular distance from the observer ship's survey line transect) and shows a general monotonic decrease in detectability (detection probability) with increasing (perpendicular) distance. The histograms (blue boxes) were generated by grouping the sightings-vs.-distance data into distance bins of a given (user-specified) width and plotting the average detection probabilities for each distance bin (rather than for each individual distance). Binning the distances and using relatively wide bins reduces the noise associated with the small-scale variations in detectability with distance (i.e., smooths out the plot). Note that **Figure 8-15** shows >100 percent detection probability at the shortest distance. This phenomenon is due to attractive animal movements toward the observer/ship prior to detection, so that not only are near-100 percent of animals actually within the range of short distances covered by the left-most distance bin being detected, but also some animals not originally within this distance range (but actually at further distances associated with adjacent distance bins) are being detected and (erroneously) included in the left-most distance bin.

8.4.2 Acoustic Monitoring Results

8.4.2.1 Deployment/Recovery Results

Four popups were recovered from the March 2008 deployment and yielded 8,000 hours of data. Popup 039 (PU039) at Station #1 was lost and has not yet been recovered. PU081, PU063, and PU134 (Station #4, #3, and #5, respectively) each presented data from 26 March 2008 to 17 June 2008 (**Table 8-9**). PU086 (Station #2) stopped recording 17 days early and presented data from 26 March 2008 to 30 May 2008 (**Table 8-9**). Potential reasons for PU086's cessation in recording have not been determined.

All four popups were recovered from the June 2008 deployment. Two units were fitted with a 2 kHz sample rate (PU063, PU134) while two had a 32 kHz sample rate (PU081, PU086). PU063 and PU081 (Station #1, #2, respectively) both presented data from 24 June 2008 to 17 September 2008 (**Table 8-9**).

Table 8-6. Estimates of encounter rate (n/L) for each species and taxonomic group (Half-normal key function with cosine series).

Common Name or Group	Scientific Name	Sample Size (n)	Effort (L, km)	n/L (km^{-1})	CV[n/L]	Degrees of Freedom	Lower 95% CL	Upper 95% CL
Species								
Fin whale	*Balaenoptera physalus*	19	4916	0.0038649	37.36	30	0.0018473	0.0080863
Bottlenose dolphin	*Tursiops truncatus*	113	4916	0.022986	20.25	30	0.015265	0.034614
Taxonomic Groups								
Balaenopterids		23	4916	0.0046786	31.45	30	0.0024988	0.0087599
Fin whale	*Balaenoptera physalus*	19						
Minke whale	*Balaenoptera acutorostrata*	1						
Humpback whale	*Megaptera novaeangliae*	3						
Delphinids		129	4916	0.026241	16.85	30	0.018646	0.036930
Common dolphin	*Delphinus delphis*	11						
Bottlenose dolphin	*Tursiops truncatus*	113						
Unidentified small delphinid		5						
Total		**176**						

Table 8-7. Estimates of detection probability f(0) for each species and taxonomic group (Half-normal key function with cosine series).

Common Name or Group	Scientific Name	Sample Size (n)	Degrees of Freedom	CV	f(0) (km^{-1})	Lower 95% CL	Upper 95% CL	ESW (m)	Lower 95% CL	Upper 95% CL
Species										
Fin whale	*Balaenoptera physalus*	19	18	13.88	0.00029843	0.00022326	0.00039892	3350.8	2506.7	4479.1
Bottlenose dolphin	*Tursiops truncatus*	113	109	7.14	0.00046361	0.00040250	0.00053401	2157.0	1872.6	2484.5
Taxonomic Groups										
Balaenopterids		23	22	12.04	0.00031778	0.00024779	0.00040755	3146.8	2453.7	4035.7
Fin whale	*Balaenoptera physalus*	19								
Minke whale	*Balaenoptera acutorostrata*	1								
Humpback whale	*Megaptera novaeangliae*	3								
Delphinids		129	125	6.51	0.00047394	0.00041672	0.00053903	2110.0	1855.2	2399.7
Common dolphin	*Delphinus delphis*	11								
Bottlenose dolphin	*Tursiops truncatus*	113								
Unidentified small delphinid		5								
Total		**176**								

Table 8-8. Estimates of density (D) and abundance (N) for each species and taxonomic group (Half-normal key function with cosine series).

Common Name or Group	Scientific Name	Sample Size (n)	Degrees of Freedom	CV	D (km^{-2})	Lower 95% CL	Upper 95% CL	N	Lower 95% CL	Upper 95% CL
Species										
Fin whale	*Balaenoptera physalus*	19	37.66	39.86	0.00057671	0.00026502	0.0012550	2	1	5
Bottlenose dolphin	*Tursiops truncatus*	113	37.77	21.47	0.0053283	0.0034667	0.0081896	21	14	33
Taxonomic Groups										
Balaenopterids		23	38.32	33.67	0.00074339	0.00038295	0.0014431	3	2	6
Fin whale	*Balaenoptera physalus*	19								
Minke whale	*Balaenoptera acutorostrata*	1								
Humpback whale	*Megaptera novaeangliae*	3								
Delphinids		129	39.41	18.06	0.0062184	0.0043284	0.0089335	25	17	36
Common dolphin	*Delphinus delphis*	11								
Bottlenose dolphin	*Tursiops truncatus*	113								
Unidentified small delphinid		5								
Total		**176**								

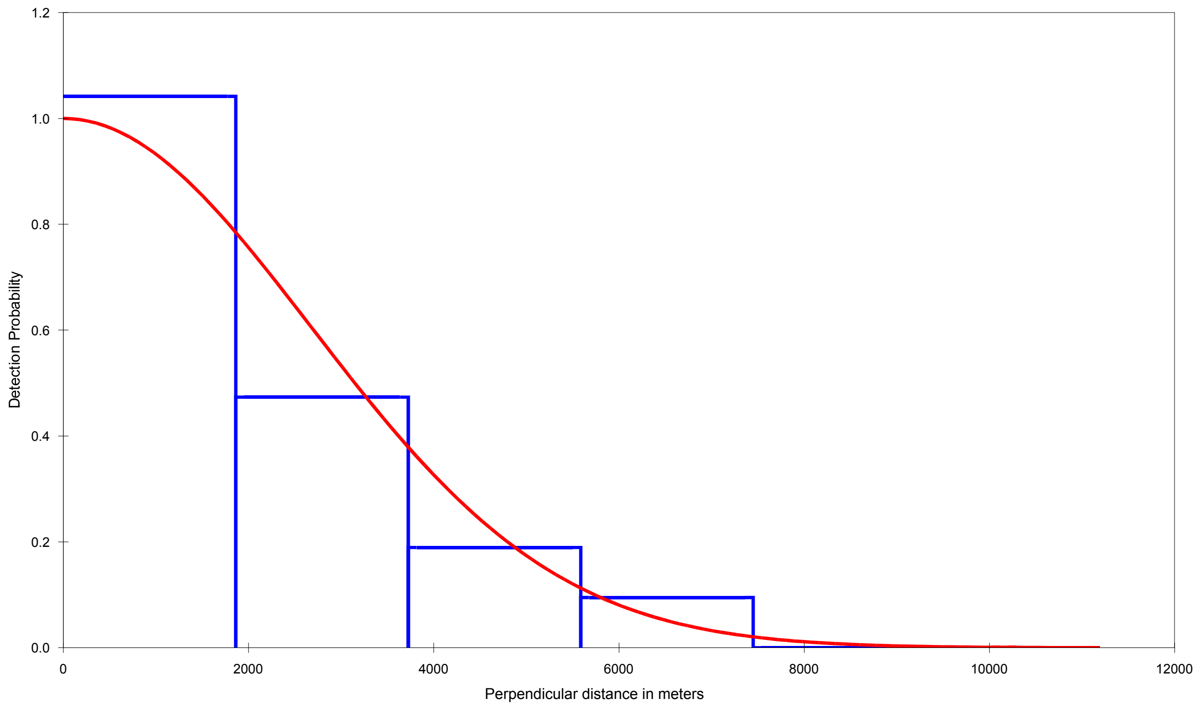

Figure 8-15. Histogram plot of detection function for the fin whale (*Balaenoptera physalus*) (Half-normal key function with cosine series).

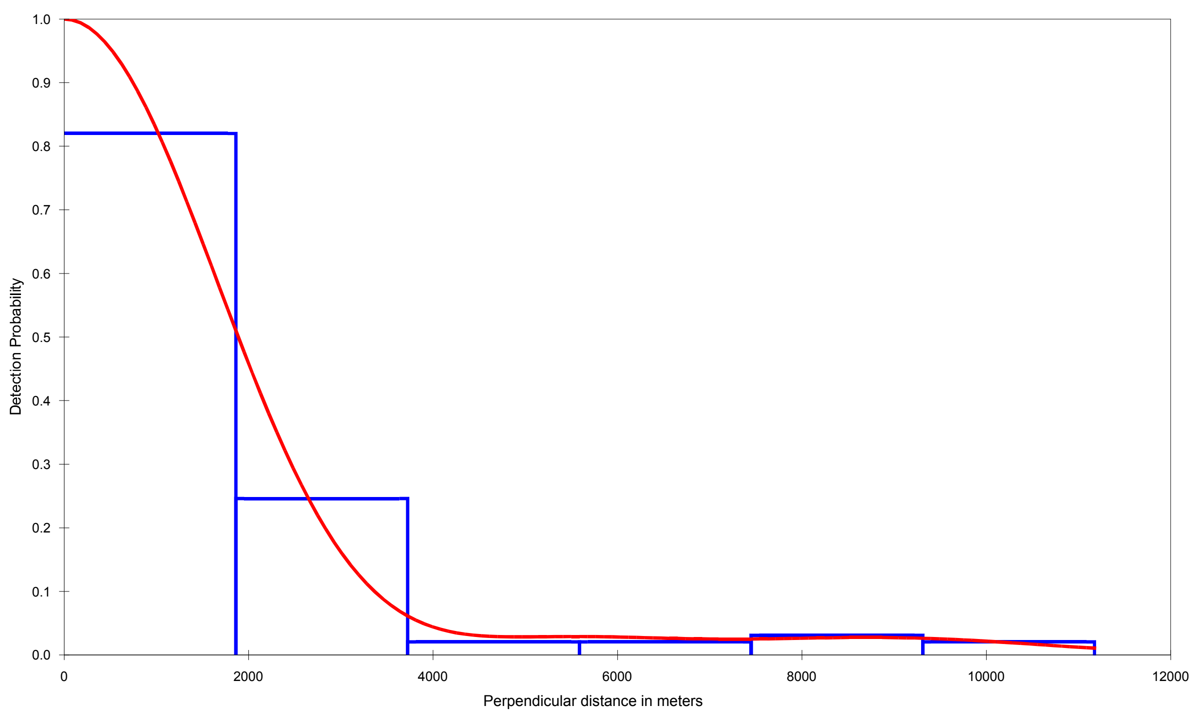

Figure 8-16. Histogram plot of detection function for the bottlenose dolphin (*Tursiops truncatus*) (Half-normal key function with cosine series).

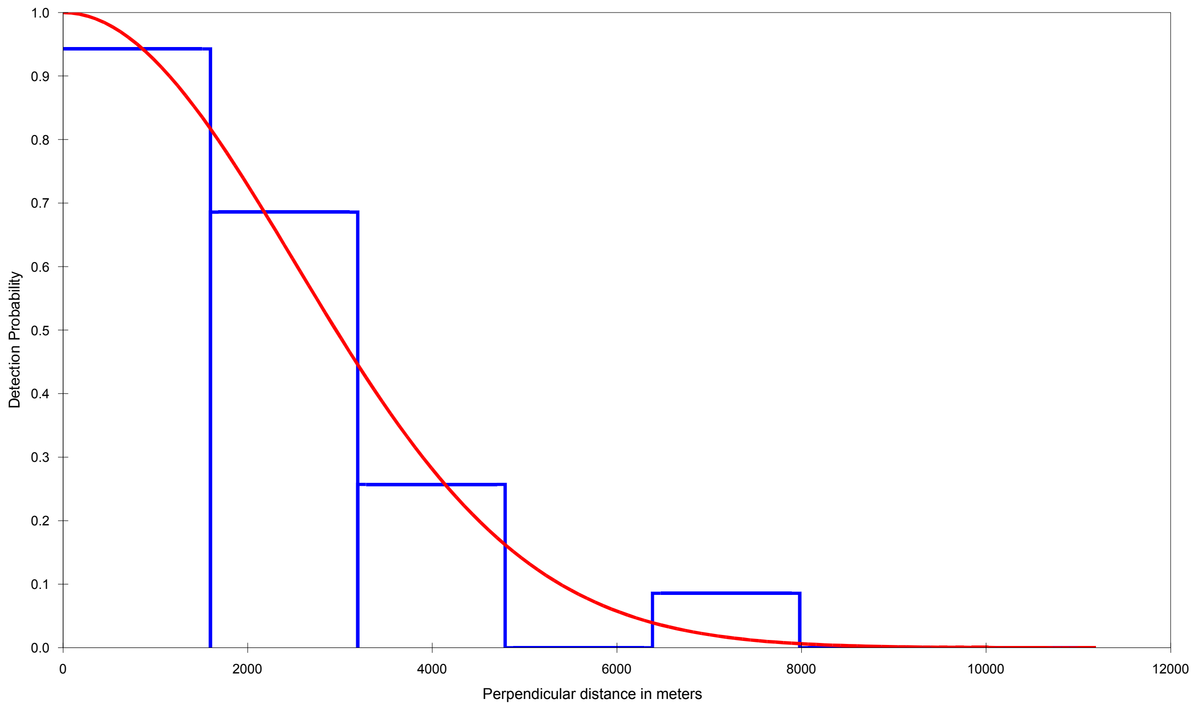

Figure 8-17. Histogram plot of detection function for the pooled species in the group Balaenopterids (Half-normal key function with cosine series).

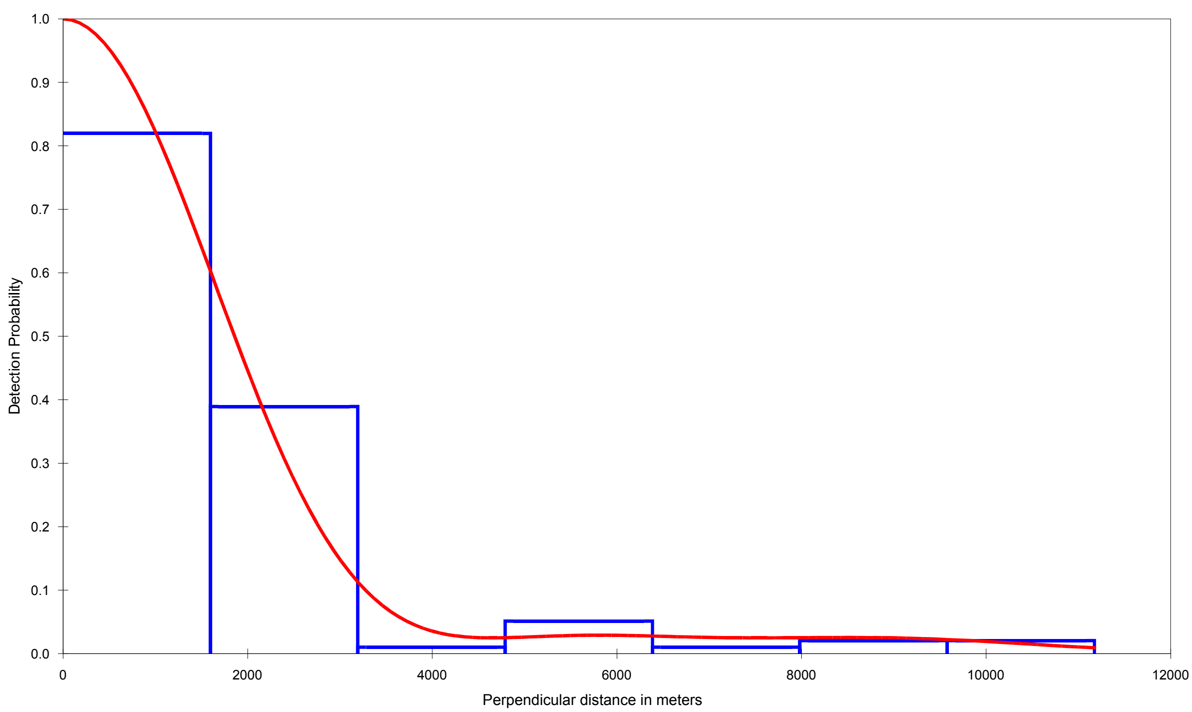

Figure 8-18. Histogram plot of detection function for the pooled species in the group Delphinids (Half-normal key function with cosine series).

PU134 (Station #5) was deployed for one additional day and thus presented data from 24 June 2008 to 18 September 2008 (**Table 8-9**). The burn unit on PU134 did not respond to the acoustic tone, and, thus, a diver recovered PU134. PU086 (Station #4) stopped recording early with data captured from 24 June 2008 to 17 August 2008 (**Table 8-9**). The electronics and hardware for PU086 were returned to BRP for diagnostics and new replacement parts were used for the September 2008 deployment.

Three popups (PU086, PU202, PU203) were recovered from the September 2008 deployment with each unit presenting what seems to be a full amount of data recorded during the two-month deployment period. PU061 and PU081 (Stations #1 and #2, respectively) did not respond to acoustic signals and seem not to be present on site. Data have been extracted from the recovered units but not yet analyzed.

Table 8-9. Summary of deployment data in terms of dates deployed per popup and species identifications (IDs) confirmed per popup during each deployment. Data have been examined with data template detectors for North Atlantic right (Eg) and fin (Bp) whales; the data are being examined for other cetacean species opportunistically.

Deployment	Station #	PopUp ID	Dates deployed	Species ID confirmed (# days detected)
March 2008	1	PU039	Lost	-----
March 2008	2	PU086	03/26/08 – 05/30/08*	Eg (19), Bp (16)
March 2008	3	PU063	03/26/08 – 06/17/08	Eg (21), Bp (5)
March 2008	4	PU081	03/26/08 – 06/17/08	Eg (24), Bp (16)
March 2008	5	PU134	03/26/08 – 06/17/08	Eg (14), Bp (17)
June 2008	1	PU063	06/24/08 – 09/16/08	Eg – not yet analyzed, Bp (18)
June 2008	2	PU081	06/24/08 – 09/5/08**	Not yet analyzed
June 2008	4	PU086	06/24/08 – 08/17/08***	Not yet analyzed
June 2008	5	PU134	06/24/08 – 09/18/08****	Eg (12), Bp (56)
September 2008	1	PU063	Lost	-----
September 2008	2	PU081	Lost	-----
September 2008	3	PU202	10/01/08 – 12/03/08	Data extracted but not yet analyzed
September 2008	4	PU086	10/01/08 – 12/03/08	Data extracted but not yet analyzed
September 2008	5	PU203	10/01/08 – 12/03/08	Data extracted but not yet analyzed

* PU086 stopped recording 17 days early during the March 2008 deployment for unknown reasons.

** PU081 was likely snagged by a trawler and came to the surface on 31 August during the late afternoon. The unit was in air on a boat and then back in the water on 1 September. It was retrieved by a local fisherman and called in on 5 September. It was recovered by GMI on 15 September.

*** PU086 stopped recording 30 days early during the June 2008 deployment for unknown reasons. The PU brain was replaced before September deployment.

**** PU134 did not respond to acoustic burn and was recovered two days later by a diver.

8.4.2.2 Species Detections

Four popups were recovered from the March 2008 deployment and yielded 8,000 hrs of data. The data have been investigated via automatic call detection algorithms for fin whale and North Atlantic right whale calls. Preliminary examination of the data has been conducted for other baleen whale species, but further investigation for possible baleen whales that might be present from March to June 2008 in these data is ongoing. In total from all popups, fin whales were detected on 54 days (overlap in days between popups not considered), while North Atlantic right whales were detected on 78 days (overlap in days between popups not considered). **Table 8-9** and **Figures 8-19** and **8-20** present details on daily presence for fin and right whales detected at each popup station location.

All four popups were recovered from the June 2008 deployment. Data from PU063 and PU134 have been analyzed with custom software algorithms to detect fin whale and North Atlantic right whale calls from 24 June to 17 September 2008. **Table 8-9** and **Figures 8-21** and **8-22** present details on daily presence for fin and North Atlantic right whales detected at each popup station location. Fin whales were recorded almost daily from June to September on Station #5 while only sporadically on the southernmost popup (Station #1). In total from two popups (PU063, PU134), fin whales were detected on 74 days (overlap in days between popups not considered), while North Atlantic right whales were detected on 12 days (overlap in days between popups not considered). Data from PU081 and PU086 are currently being analyzed for both baleen whale calls and toothed whale sounds. The latter requires manual review of the data because call detection algorithms are not available or applicable since toothed whale calls are too variable in structure to allow for consistent computer algorithms to identify standard structural components.

Three of five popups were recovered from the September 2008 deployment. Data from two units with a 2-kHz sample rate (PU202 and PU203) and from one unit with a 32-kHz sample rate (PU086) were recovered. These units represent stations #3, 5, and 4, respectively. Data have been extracted from the hard drives confirming a full recording session of two months for these units; however, data have not yet been analyzed for whale calls.

8.5 CONCLUSIONS

Ten out of the forty-seven possible species to occur in the Study Area were detected visually and/or acoustically during the 2008 surveys. These included five threatened or endangered species: North Atlantic right whale, fin whale, humpback whale, loggerhead turtle, and leatherback turtle. The fin whale was the only species detected during all seasons. Seasonal occurrences known for some species were confirmed for the Study Area. For example, bottlenose dolphin sightings peaked during the summer months, but this species was absent in the winter. Other species that peaked in the summer include the loggerhead and leatherback turtles. In contrast, peak sightings of harbor porpoises and common dolphins were recorded during the winter and spring. Common dolphins appeared to be absent from the Study Area during the summer and fall.

Abundance and density estimates calculated for this report are likely underestimated due to the lack of g(0) estimates for each species and taxonomic group. The sample sizes were also very small; the very minimum number of sightings (n=20) that is required for modeling was used. A larger sample size of 60-80 sightings is recommended for estimating abundance/density with adequate precision. Of the species that were modeled, the bottlenose dolphin was the most abundant in the Study Area; however, due to the small number of sightings, no seasonal estimates could be modeled. More sightings data are needed to model abundance/density of other species and to model seasonal estimates. Estimates of g(0) are needed to minimize bias in the abundance/density estimates, particularly for harbor porpoises which are difficult to detect because of their small size and aversion to vessels.

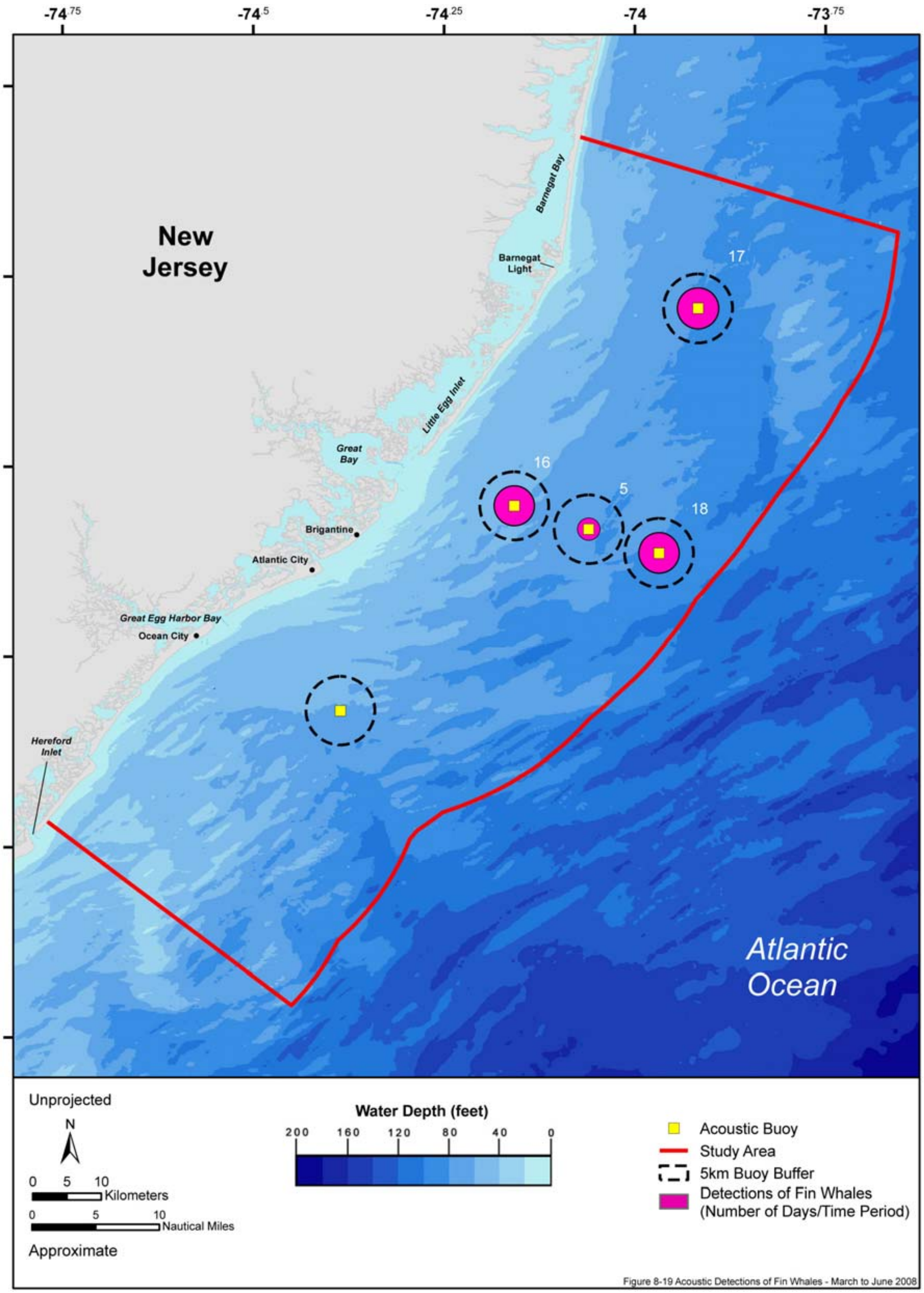

Figure 8-19. Acoustic detections of fin whales in the New Jersey Study Area and vicinity. Fin whales were detected at the array popups on different and overlapping dates during the first deployment from March to June 2008. The thickness of the detection ring around the different buoys gives a relative indication of the number of detection dates per popup.

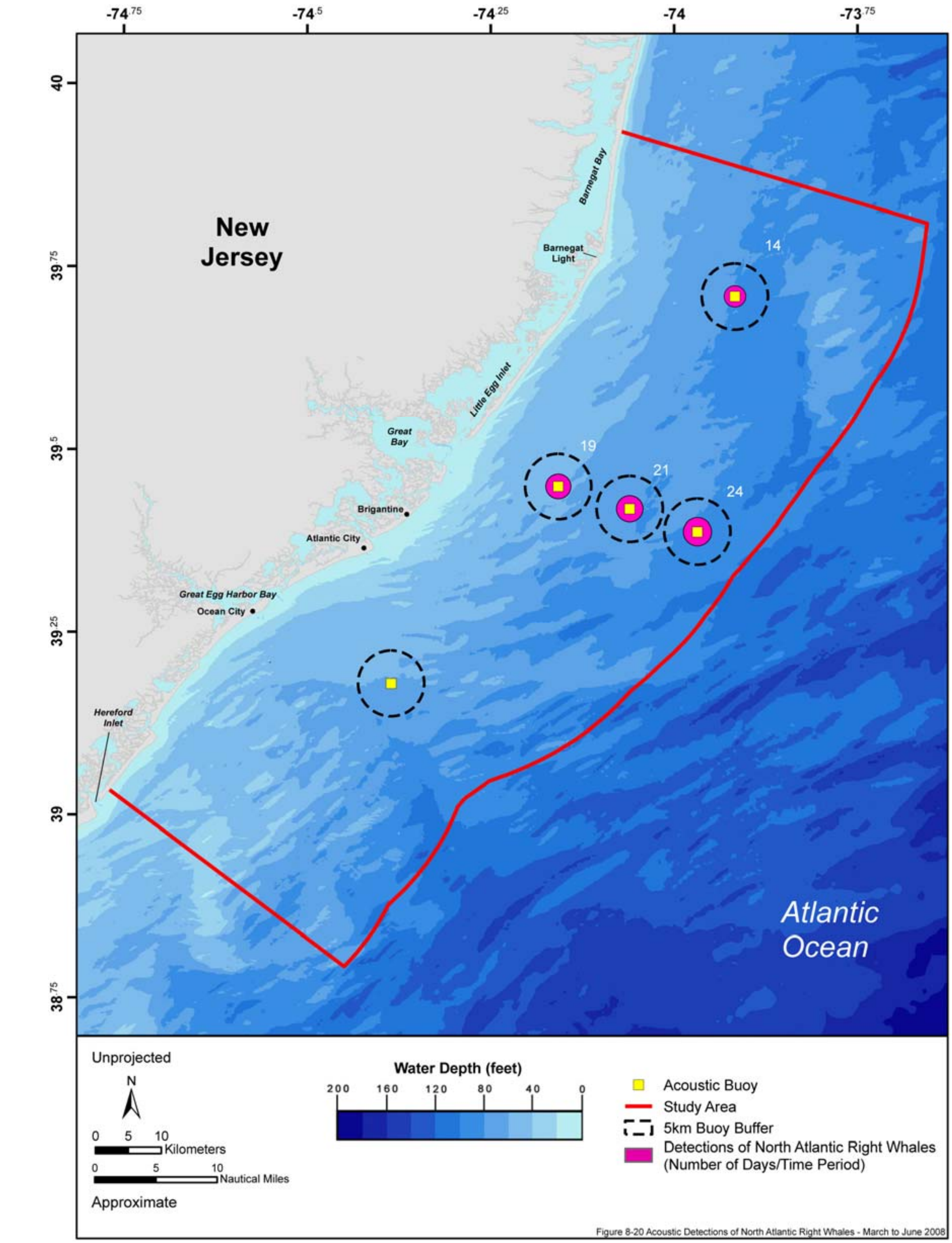

Figure 8-20. Acoustic detections of North Atlantic right whales in the New Jersey Study Area and vicinity. North Atlantic right whales were detected at the array popups on different and overlapping dates during the first deployment from March to June 2008. The thickness of the detection ring around the different buoys gives a relative indication of the number of detection dates per popup.

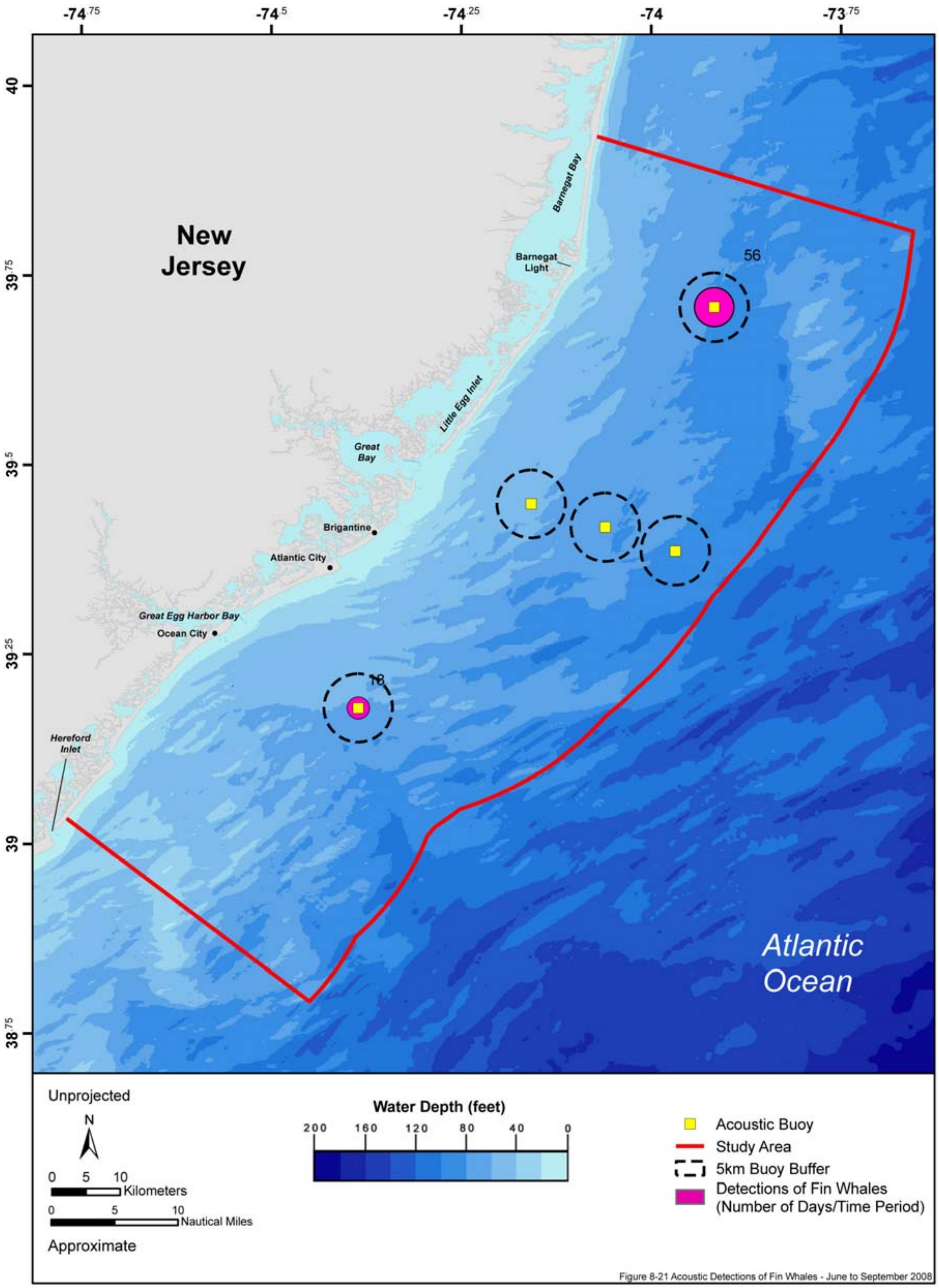

Figure 8-21. Acoustic detections of fin whales in the New Jersey Study Area and vicinity. Fin whales were detected at the array popups on different and overlapping dates during the second deployment from June to September 2008. The thickness of the detection ring around the different buoys gives a relative indication of the number of detection dates per popup.

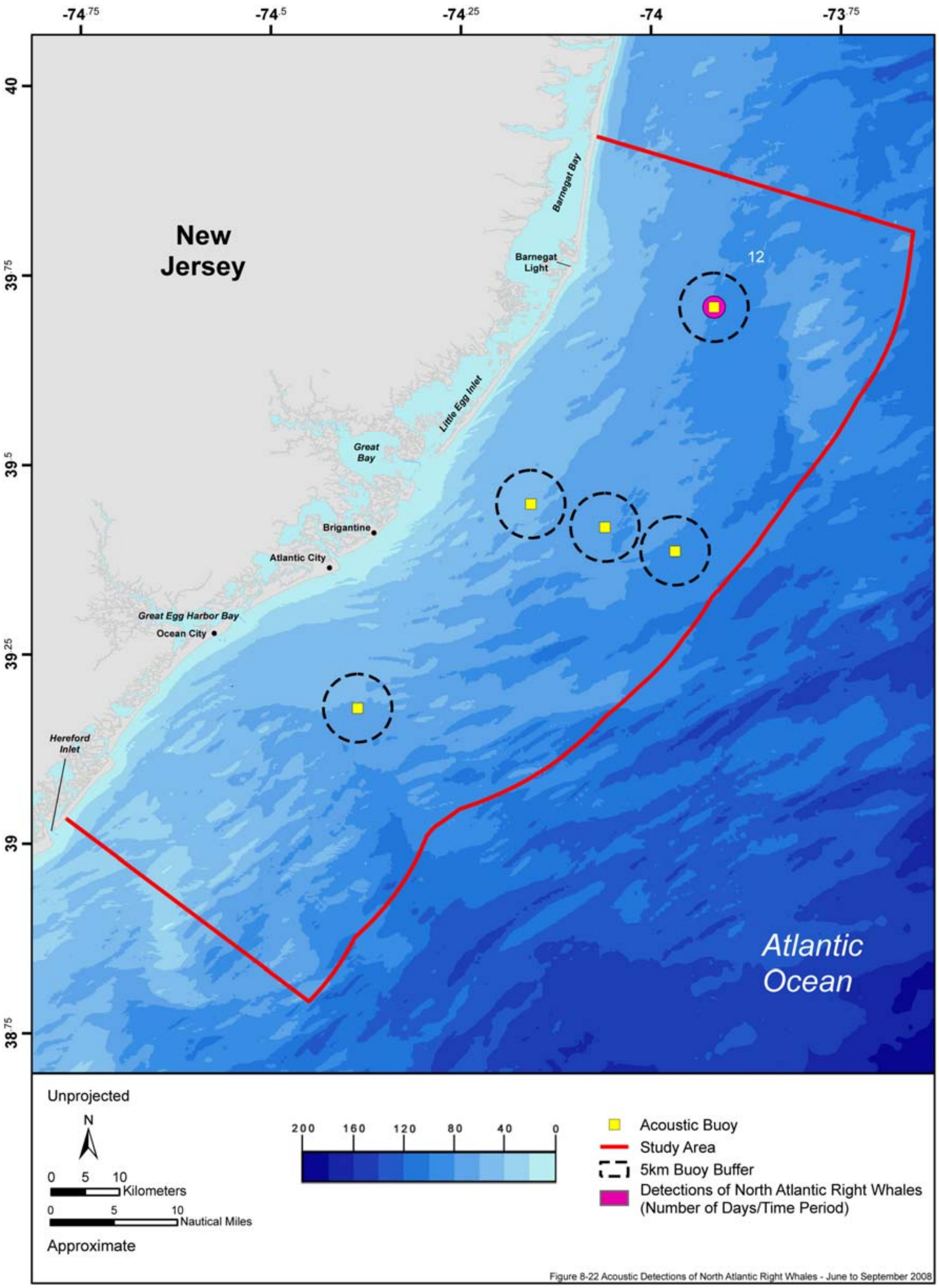

Figure 8-22. Acoustic detections of North Atlantic right whales in the New Jersey Study Area and vicinity. North Atlantic right whales were detected at the array popups on different and overlapping dates during the second deployment from June to September 2008. The thickness of the detection ring around the different buoys gives a relative indication of the number of detection dates per popup.

Better survey effort coverage is also needed for some seasons, particularly the winter months. Bad weather limited survey coverage during the winter surveys. Often only one saw-tooth of tracklines or a partial saw-tooth could be surveyed in acceptable weather conditions. Lower effort during this time likely leads to underestimates of harbor porpoises and common dolphins which are seasonally present during this time of year. The summer surveys had the most consistent good weather conditions so survey effort thoroughly covered the Study Area during these months.

Shipboard and aerial surveys, as well as passive acoustic monitoring, are scheduled to continue through June 2009. The g(0) for each survey technique will be addressed during future surveys, and the g(0) results will be compared with those in the published literature. Additional survey effort through the end of 2009 is recommended; this would provide more data to be able to model abundance/density of other species and to model estimates for each season. Also, it would provide a full two years of data such that abundance/density estimates and distributions of species could be compared between years.

After the completion of survey effort in June 2009, abundance and density estimates for all marine mammal and sea turtle species (both aerial and shipboard data) will be developed through the use of spatial modeling in the program Distance. Density surface models (DSMs) for each species sighted will be generated using GAM with covariates. These covariates will include dynamic (SST, salinity and chlorophyll *a*), as well as static (bottom depth, bottom slope, distance of the sighting from the shore, latitude, and longitude) variables.

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

The method of analyzing estimated abundances per segment surveyed was developed by Hedley et al. (1999). Their original application consisted of dividing each trackline 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 by fitting a GAM (Wood 2006).

All surveys conducted on like platforms (i.e., shipboard or aerial) will be combined, regardless of season or location, to provide the greatest possible number of sightings. By combining surveys, the number of sightings for all species will increase. When possible, individual detection functions will be estimated for all species with 20 or more sightings.

After fitting GAMs to the survey data, the resulting DSM will be applied to a prediction grid superimposed upon the Study Area. In this way, animal density can be predicted for the entire Study Area for each season of interest. The resulting values from the modeling are prediction grid cell-specific densities that will be depicted in the final report.

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9.0 FISH AND FISHERIES

9.1 FISH/INVERTEBRATES

The Study Area is located within the MAB, which is one of the most abundant fishing areas on the east coast of the U.S. The MAB is bound by Massachusetts (Georges Bank) to the north and North Carolina (Cape Hatteras) to the south. In the Study Area, and similar to other temperate communities, seasonal temperature fluctuations are one of the primary factors that influence fish distribution (Sherman et al. 1996). In the MAB, a high proportion of fishes are seasonal, while few (<5 percent) are resident (Sherman et al. 1996). Furthermore, only 15 percent of the approximately 250 fish species found in the waters of the MAB are temperate species. Of the remaining species, approximately 75 percent are classified as subtropical-tropical species (i.e., species with preferences of temperatures above 20°C [68°F]; Briggs 1974; Froese and Pauly 2004).

In addition to the vast number of temperate and subtropical-tropical fish species, the Study Area supports a variety of macroinvertebrates (e.g., ocean quahog and Atlantic surfclam). The distribution of macroinvertebrates is influenced by the availability of benthic habitat (Theroux and Grosslein 1987). Many fish and squid species (i.e., longfin inshore) found within the Study Area demonstrate seasonal migrational patterns, moving offshore during the winter to utilize warmer waters and inshore during the spring and summer to feed and spawn (Casey et al. 1987; Chase 2002; Hatfield and Cadrin 2002). Highly migratory pelagic fishes (i.e., billfishes, tunas, swordfish, and sharks) are found mostly offshore and adjacent to or within the Study Area. These species are influenced by the Gulf Steam Current and with thermal oceanic fronts (Casey et al. 1987; Block et al. 1998).

For juvenile fishes and invertebrates, especially those of commercial importance, estuarine and coastal regions provide critical nursery and settlement habitat. Most of the species found in these inshore regions are abundant in the early spring through summer (Able and Fahay 1998). For example, many larvae of subtropical-tropical species spawned in warmer waters are transported to inshore habitats via the current systems of the Study Area (Begg 1998; Epifauno and Garvine 2001; Hare et al. 2001; Moore et al. 2003). In the Study Area, coastal habitats are quite diverse, consisting of areas of intertidal mudflats, wetlands, and seagrass beds (Roman et al. 2000).

The marine ichthyofauna of New Jersey consists of 336 fish species represented by 116 families which occur from the upper limits of saltwater intrusion in the estuaries (including Delaware Bay) to the 200-m (656.2-ft) contour at the edge of the continental shelf (Able 1992). Along the New Jersey coastline, various inshore (e.g., estuaries, bays, salt marshes, tidal creeks, and coastal beachs), and offshore environments (e.g., sand ridges, continental shelf, canyons, hard bottom, and artificial reefs [e.g., ship wrecks and man-made structures]) are important to fish and fisheries. Four distinct habitats are found within the Study Area: coastal beaches, pelagic zone, demersal/benthic zone, and natural/artificial reef-structures.

The coastal beaches and, in particular, the surf zone is an important habitat for numerous fish species. Studies conducted off northern New Jersy reported 57 species representing 30 families utilize this habitat (Wilber et al. 2003). Ninety percent of the species were dominated by Atlantic and rough silversides (*Menidia menidia* and *Membras martinica*), bluefish (*Pomatomus saltatrix*), bay and striped anchovies (*Anchoa mitchilli* and *Anchoa hepsetus*), and northern kingfish (*Menticirrhus saxatilis*). This ichthyofaunal composition was similar to other comparable locations within (Avalon, New Jersey), north (Long Island Sound and Great South Bay and Fire Isands, New York), and south (Hog Island, Virginia) of the Study Area (Schaefer 1967; Briggs 1975; Hillman et al. 1977; McDermot 1983; Layman 2000; Wilber et al. 2003).

The pelagic zone within the Study Area contains large schools of seasonally abundant herrings (i.e., blueback herring, *Alosa aestivalis,* alewife *Alosa pseudoharengus*, and Atlantic menhaden) along with fast swimming oceanic wanders (e.g., bluefin tuna, swordfish), various elamsobranchs (sharks: sand tiger, dusky, sandbar, skates: clearnose, winter, little, and rays: cownose, *Rhinoptera bonasus*), large predatory fishes (e.g., bluefish, various sciaenids), and several species of cephalopods (i.e., longfin inshore squids; The Louis Berger Group, Inc. 1999). Characterized as a sand or sand-mud plain interrupted by submarine sand ridges separated by mud or clay-bottomed depressions or sloughs, this non-vegetated, sandy benthic habitat is important to various demersal fish and invertebrate species within the Study Area (Steimle and Zetlin 2000). Solitary rather schooling fishes are found within this habitat consisting of species such as sand lances (*Ammodytes* spp.) which are an important food resource for many predatory species, as well as flounders (i.e., summer, winter, windowpane, witch) and hakes (red and silver) which prey upon the benthic infauna and epifauna (The Louis Berger Group, Inc. 1999). Moderate densities of arthropods, annelids, mollusks, and echinoderms dominate these benthic communities off New Jesey (Wigley and Theroux 1981).

Over 71 shoreface sand ridges also occur along the New Jersey coastal areas (McBride and Moslow 1991). These shoreface sand ridges, especially the near-ridge habitats (i.e., Beach Haven Ridge off Little Egg Inlet), have higher species abundances and richness compared to the surrounding inner continental shelf and posses a distinct species assemblages, comprised of important recreational and commercial species (Vasslides and Able 2008). The following fish families (anchovies, flounders, cod, sea robbins, sea basses, drums, and butterfishes) along with the Atlantic surfclam and epibenthic decapod crustaceans (sevenspine bay shrimp [*Crangon septemspinosa*], Atlantic rock crab [*Cancer orroratus*], spider crab [*Libinia emarginata*], and lady crab [*Ovalipes ocellatus*]) are common components of this unique habitat and maybe representative of other New Jersey shoreface sand ridges (Viscido et al. 1997; Ma et al. 2006; Vasslides and Able 2008). The dominat fish species were similar to those species found in inner continental shelf waters off of the northeast (Colvocoresses and Musick 1984; Mahon et al. 1998) and southeast U.S. (Walsh et al. 2006).

Benthic man-made structures, such as artificial reefs, shipwrecks, and other man-made structures (groins, jetties, seawalls, bridges, and piers) are important habitat types for the fish and fisheries found off New Jersey. These man-made structures add complexity and diversity to the non-vegetated, sandy bottom and open ocean environments (Figley 2005). Nine of the 15 artificial reef sites off New Jersey are located within the Study Area in addition to the 3,500 patch reefs that have been added to these sites since 1984. Depending on the depth and average annual and seasonal water temperatures, artificial structures (reefs, 3,000 documented shipwrecks, etc.) can be colonized by various species of invertebrates (e.g., algae, sponges, crustaceans, and mollusks), which then attract reef associated fish searching for food or refuge (The Louis Berger Group, Inc. 1999). This was supported in a study conducted over a five year period off New Jersey which reported that one square meter of reef habitat was colonized by 432,000 marine animals consisting of 145 species with a collective biomass of 58,000 grams (g; 128 lbs; Figley 2003). Artificial reefs within the Study Area support around 150 different fish and other marine life, which are indigenous to New Jersey waters, such as black sea bass, tautog (*Tautoga onitis*), red hake, gray triggerfish (*Balistoides viridescens*), Atlantic cod, pollack (*Pollachius pirens*), American lobster (*Homarus americanus*), and Atlantic rock crab Figley (2005).

Within or near the vicinity of the Study Area, there are various fish species found that are either protected by the State of New Jersey or the federal government (e.g., USFWS and NMFS). These species warrant protection because population levels have declined to levels that could threaten or endanger the species existence throughout all or a significant portion of its range. Although the shortnose sturgeon (*Acipenser brevirostrum*) is the only fish species protected by the federal government under the ESA (classified as endangered) that may be found in the vicinity of the Study Area (i.e., Delaware River), there are no records of shortnose sturgeon within the Study Area. At this time, there are also no known shortnose sturgeon populations in the rivers between the Hudson and Delaware rivers (NMFS 1998). In addition, there are four species of concern and one candidate species found within or in the vicinity of the Study Area. Species of concern are those species about which the NMFS has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA. Candidate species are species that are the subject of either a petition to list or status review, and for which NMFS or USFWS has determined that listing may be or is warranted jurisdiction (NMFS 2008a). Fish species classified as species of concern that may be found within or near the vicinity of the Study Area are the following: alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), dusky shark (*Carcharhinus obscurus*), and sand tiger shark (*Carcharias taurus*). One candidate species that may be found within or near the vicinity of the Study Area is the Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*). The State of New Jersey also protects the shortnose sturgeon (NJDEP 2009a).

Fisheries Resources

Commercial and recreational fisheries are valuable components of the economy for the Study Area. Commercial fishery operations within the Study Area are highly active and are key suppliers of seafood and marine products to both domestic and foreign markets. Recreational fishing in nearshore and offshore waters is also highly popular and well represented (NEFMC 1985). As a result, there is much emphasis on protecting and managing these resources to maintain viability to these resources.

Overfishing has led to a drastic decline in many species, including macroinvertebrates (NMFS 2004a). As a result of these declines, designations of EFH, fishing effort restrictions, and closures have been implemented to manage and conserve these important resources.

The complex bottom topography of the continental shelf and slope adjacent to the Study Area, particularly the abundant presence of banks, shoals, and canyons, provide highly suitable habitat for rich assemblages of fisheries species (e.g., fishes and macroinvertebrates). In addition, the cold-temperate waters, coastal geography, and North Atlantic current system provide nutrient-rich waters that support the fishery populations (NEFMC 1985; Bourne 1987; Wahle 2000). Fishery species seasonally utilize spawning, nursery and feeding grounds within the Study Area's inshore (including bays and estuaries), nearshore, and offshore waters.

The distribution of fishing effort is correlated with the occurrence and distribution of fish and invertebrate target species. Primary factors influencing the spatial distributions of target species include, but are not limited to, salinity, temperature, dissolved oxygen levels, and prey availability. In addition, life history requirements, migrational patterns, and water temperatures affect seasonal fish distributions within the Study Area (Helfman et al. 1999).

9.2 FISHERIES VARIABILITY

Although natural patterns of variability are expected in marine fishery stocks, anthropogenic activities also affect fish distribution and abundance. Human impacts to fisheries include bycatch of non-targeted species, overfishing, habitat alteration/destruction as a result of fishing methods (e.g., dragging nets and dredges on the seafloor), coastal development, and water quality degradation (Saila and Pratt 1973; Malakoff 1997; Williams 1998; Lazaroff 2001). Boesch et al. (2001) and Jackson et al. (2001) stated that nearly all estuarine species (i.e., fishes and macroinvertebrates) have been adversely affected to some degree by human activities, which has altered the viability of many coastal fisheries (e.g., blue crabs [*Callinectes sapidus*], oysters, and striped bass [*Morone saxatilis*]). Shellfish species are especially dependent upon good water quality for survival. Shellfish may be vulnerable to population fluctuations because of pollution. At times, mandatory area closures are required to sustain viable population levels (Waite et al. 1994). Of all the human-induced pressures on fishery populations, overfishing is considered the main factor contributing to current declining catch rates (Waite et al. 1994).

Over the past two centuries and especially within the last 50 yrs, the overall intensity of fishery efforts (both commercial and recreational) has been increasing. The high demand for fishery products and the increase in recreational fishing activities have resulted in intensified fishing pressure on the available resources, causing a decrease in overall fishery landings (Waite et al. 1994; Parker and Dixon 1998). Advanced technology, better and improved access to environmental data, and commercial fishing gears have resulted in improved ease in the location and landing of target species (SeaWeb 2002). While improvements in fishing gear and methods continue, overall catch rates in relation to effort are declining. As fishery landings diminish, species once targeted as commercially desirable have changed to include those species that are less attractive, but still available in harvestable quantities. Smaller fish, as well as those species once discarded as bycatch, are now being targeted for commercial sales (Caddy et al. 1998; Pauly et al. 1998).

9.3 FISHERIES MANAGEMENT

Effective fishery management, with involvement and participation by the fishing community, has become crucial to maintaining viable fishery industries and protecting fishery resources in a harvestable condition. To aid in the conservation of fishery resources, federal laws, executive orders, proclamations, and regulations have been created. One of the mandates of the Sustainable Fisheries Act (SFA) was the creation of a number of fishery management councils (FMCs) to oversee the condition of fishery stocks in the federal waters of the U.S. EEZ. The FMCs use fishery management plans (FMPs) to convey the conservation strategies for specific fishery resources. In addition, the NMFS participates in fishery management efforts by providing fisheries data and analysis as well as managing the highly migratory fishery species (over 80 species of sharks, tunas, and billfishes; NMFS 2004a, NMFS 2004b).

Marine resources (fish and invertebrates) found in the Study Area are managed by the State of New Jersey, four FMCs (NEFMC, MAFMC, South Atlantic Fishery Management Council [SAFMC], and Gulf of Mexico Fishery Management Council [GMFMC]), the ASMFC and the NMFS. In total, NEFMC manages 16 species, the NMFS 10 species, the MAFMC 5 species, and SAFMC 3 species that are found within the Study Area. In addition, seven species are jointly managed by either two FMCs or one FMC and the ASMFC. In general, each FMC is responsible for managed fish found within their respected jurisdictional federal water areas. The MAFMC is responsible for management of fisheries in federal waters which occur predominantly off the mid-Atlantic coast. States with voting representation on the Council include New York, New Jersey, Pennsylvania, Delaware, Maryland, Virginia, and North Carolina, which is represented by the MAFMC and the SAFMC. The ASMFC manages shared marine fishery resources in state waters through the Interstate Fisheries Management Program (IFMP). The ASFMC coordinates the conservation and management of 22 Atlantic coast fish species or species groups, which are found in the Study Area or vicinity (ASFMC 2009). The GMFMC is responsible for management of fisheries in federal waters which occur throughout the Gulf of Mexico. States represented on the Council include Florida, Alabama, Mississippi, Louisiana, and Texas. The Highly Migratory Species (HMS) Division of the NMFS is responsible for managing swordfish, tunas, billfish, and sharks found throughout federal and international waters.

9.3.1 Commercial Fisheries

Commercial fisheries are generally referred to by the species targeted or by the gear type used (**Table 9-1**). The most common gear types used in the Study Area include:

- Trawls—are large nets (bag-shape) that are rectangle or polygon-shaped mouth openings which are pulled behind a fishing vessel to capture fish. Trawls are towed at different water depths (usually bottom and mid-water) depending on target species;
- Dredges—are steel frame supported box or bag-shaped devices used to target benthic animals, such as bivalve mollusks (e.g., scallops and clams). Dredges are dragged behind the fishing vessel along the seafloor;
- Pot and traps—are rectangle, square, or cylindrical devices usually set on the seafloor to target benthic fish and invertebrates (e.g., lobsters, black sea bass, and red deep sea crabs [*Chaceon quinquedens*]). Pots and traps are usually set for an extended period; locations are marked at the surface with a buoy;
- Purse seines—are nets that encircle a school of fish and then is cinched to close and trap target species; Purse seines are used to target menhaden and herring;
- Gillnets—are rectangular panels of net that target species (e.g., mackerel, sharks) at the surface or at the seafloor; and
- Longline—are long lengths of monofilament line fitted with multitudes of hooks that are deployed at the surface or at the bottom for an extended period to target benthic (e.g., cod, haddock [*Melanogrammus aeglefinus*], and sharks) and pelagic species (tuna and swordfish).

Table 9-1. Top commercial fishing gears, landings, and value for the Study Area (State of New Jersey) from 2003 to 2007.

Gear	Landings (mt or 10^3 kg)	Value ($)
Trawls (all types)	103,542.7	$85,927,922
Dredges (all types)	165,388.0	$465,770,895
Pots/Traps (all types)	11,987.3	$41,641,707
Gillnets (all types)	14,614.1	$33,074,635
Hook and line (all types)	16,759.4	$29,266,705
Purse Seine	39,701.5	$7,269,516
Total (All Gears)	372,499.8	$714,050,993

mt = megatons; Source: NMFS (2008b)

The total value of fisheries in New Jersey adjacent to the Study Area during 2003 through 2007 was nearly one billion dollars (an average of 178 million dollars a year [**Table 9-1**]; NMFS 2008b); however, the actual economic value to the region is far greater in terms of the jobs, goods, and services associated with these fisheries.

Of the directed fisheries in the Study Area, the northeast multispecies groundfish fishery (trawl and dredge gear) is the predominant fishery in landings and number of active vessels (**Tables 9-1** and **9-2**) with other fisheries also contributing substantially to the industry. The American lobster, Atlantic sea scallop, and clam fisheries have been important economic and cultural activities in the Study Area for more than a century; however several fisheries (e.g., skates, spiny dogfish sharks, and monkfish) in the region have recently been established due to expanding demand for fish products and the reduction of traditional fishery stocks. Furthermore, fisheries such as the herring fishery have recently expanded beyond their more traditional coastal ranges. Other important fisheries for tuna, sharks, and swordfish are parts of a larger U.S. and worldwide fishery, which has increased in intensity and importance over the past thirty years.

Fishing effort within the Study Area varies throughout the year depending on the target species and weather, but peak landings typically occur from June to September and also January through March (**Figure 9-1**). The following section describes the primary fisheries conducted in the Study Area and includes map figures of the distribution of each of the fisheries.

9.3.1.1 Northeast Multispecies Groundfish Fishery

The Study Area's multispecies groundfish fishery involves the group of benthic finfish (i.e., groundfish), which are often found in mixed assemblages (NEFMC 1985, 1996, 2004b). The groundfish species found in the Study Area include Atlantic cod, ocean pout, red hake, silver hake (whiting), windowpane flounder, winter flounder, witch flounder, and yellowtail flounder.

The Atlantic cod has long been the primary target species in the offshore groundfish fishery that traditionally includes haddock and yellowtail flounder. The primary gear type used in the groundfish fishery to target benthic fish is the bottom trawl (**Figure 9-2**); however, sink gillnets (**Figure 9-3**) and bottom longlines are also used.

Seasonal and year-round closed areas are designated by the NMFS in various locations in the multispecies fishing grounds for stock management purposes. For various reasons, these areas are closed to bottom otter trawls, sink gillnets, and bottom longlines during designated times (**Figures 9-2** through **9-4**). Closed areas for these fisheries often do not exclude other fishing gear, such as scallop dredges, pelagic (drift) gillnets, purse seines, pots and traps, shrimp trawls, mid-water trawls, and others (NEFMC 2004b).

Table 9-2. Major commercial fisheries, active season, and gear used in, or vicinity of, the Study Area (peak months/seasons given in parentheses).

Fishery	Season	Gear
Northeast groundfish	Year-round (seasonal by region)	Bottom trawls, bottom longlines, sink gillnets
Monkfish	Year-round (Winter and Summer)	Bottom trawls, scallop dredges, sink gillnets
Skates	Year-round (Summer)	Bottom trawls, sink gillnets
Spiny dogfish	Year-round (seasonal by region)	Bottom trawls, sink gillnets
Atlantic sea scallop	Year-round (seasonal by region)	Scallop dredges, bottom trawls
Clams	Year-round (Summer)	Hydraulic dredges, scallop dredges, bottom trawls
Atlantic herring	Year-round (seasonal by region)	Purse seines, mid-water trawls
American lobster	Year-round (May through December)	Traps, bottom trawls
Winter trawl	September through April	Bottom trawls, mid-water trawls
Highly migratory species	Year-round (seasonal by region, species, and gear type)	Bottom and pelagic longlines, sink and pelagic gillnets, purse seines, hand gear

Sources: NEFMC (1983, 1985, 1993, 1996, 1998, 1999a, 2002, 2003a, 2003b); Ross (1991); Shepherd and Terceiro (1994); ASMFC (1997); Idoine (1998, 2001); MAFMC (1998a, 1999); NMFS (1999a, 2004a, 2004b); Clark et al. (2000); Weinberg (2000, 2001a).

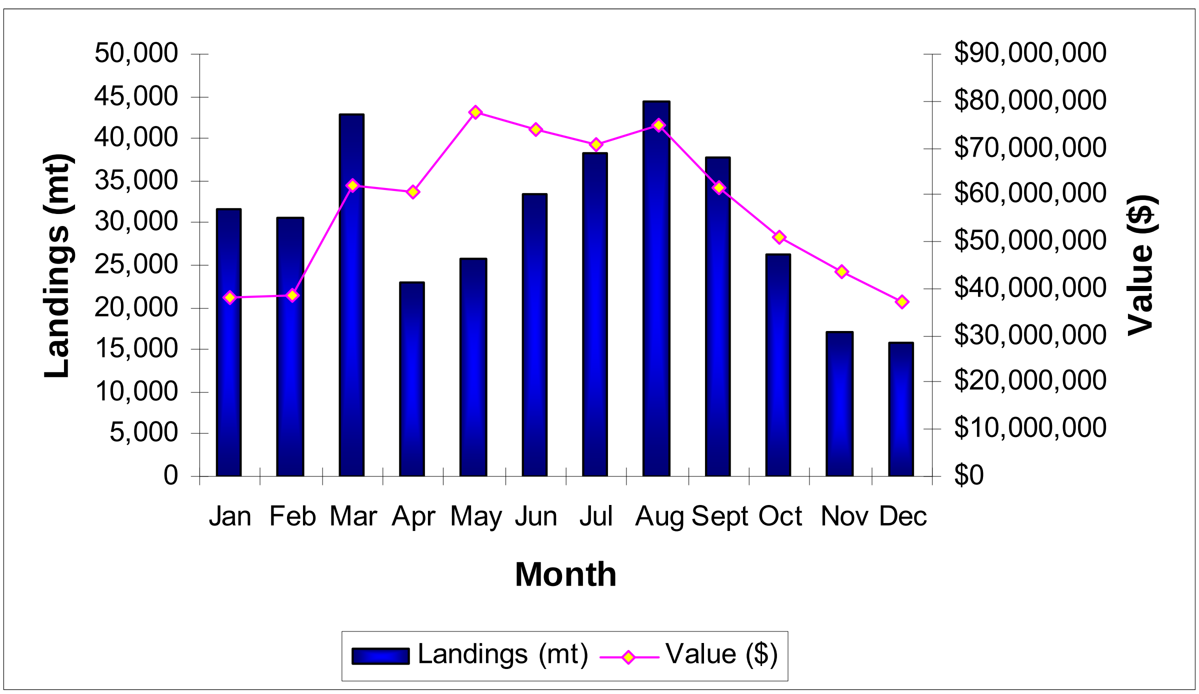

Figure 9-1. Cumulative monthly commercial fishery landings (metric tons) in the waters off New Jersey from 2003 to 2007. Source data: NMFS (2008b).

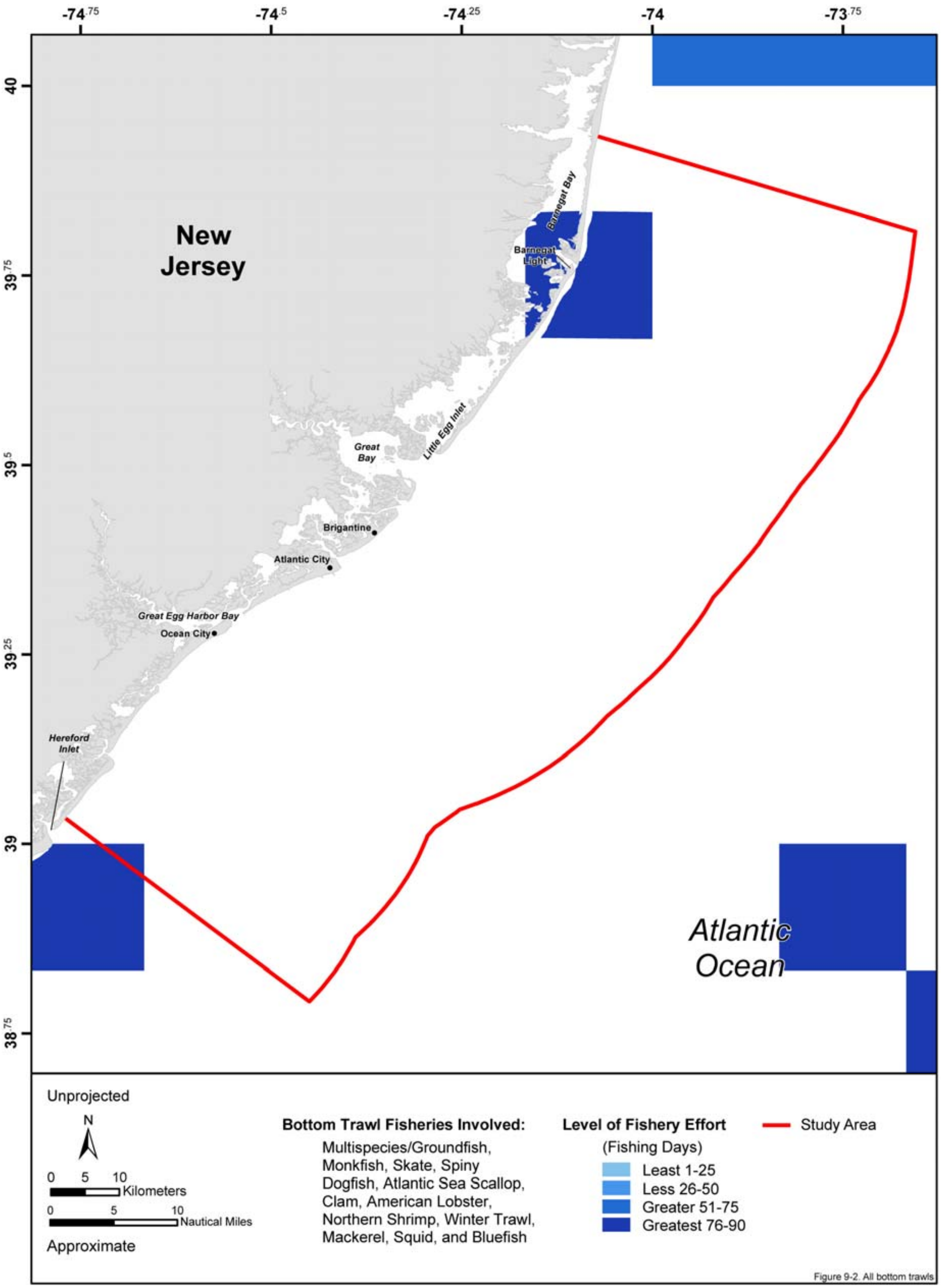

Figure 9-2. Fishing effort distribution of bottom trawling fisheries in the New Jersey Study Area and vicinity from 1995 to 2001. Source data: NMFS (2003b, 2004d). Source information: NEFMC (2003b).

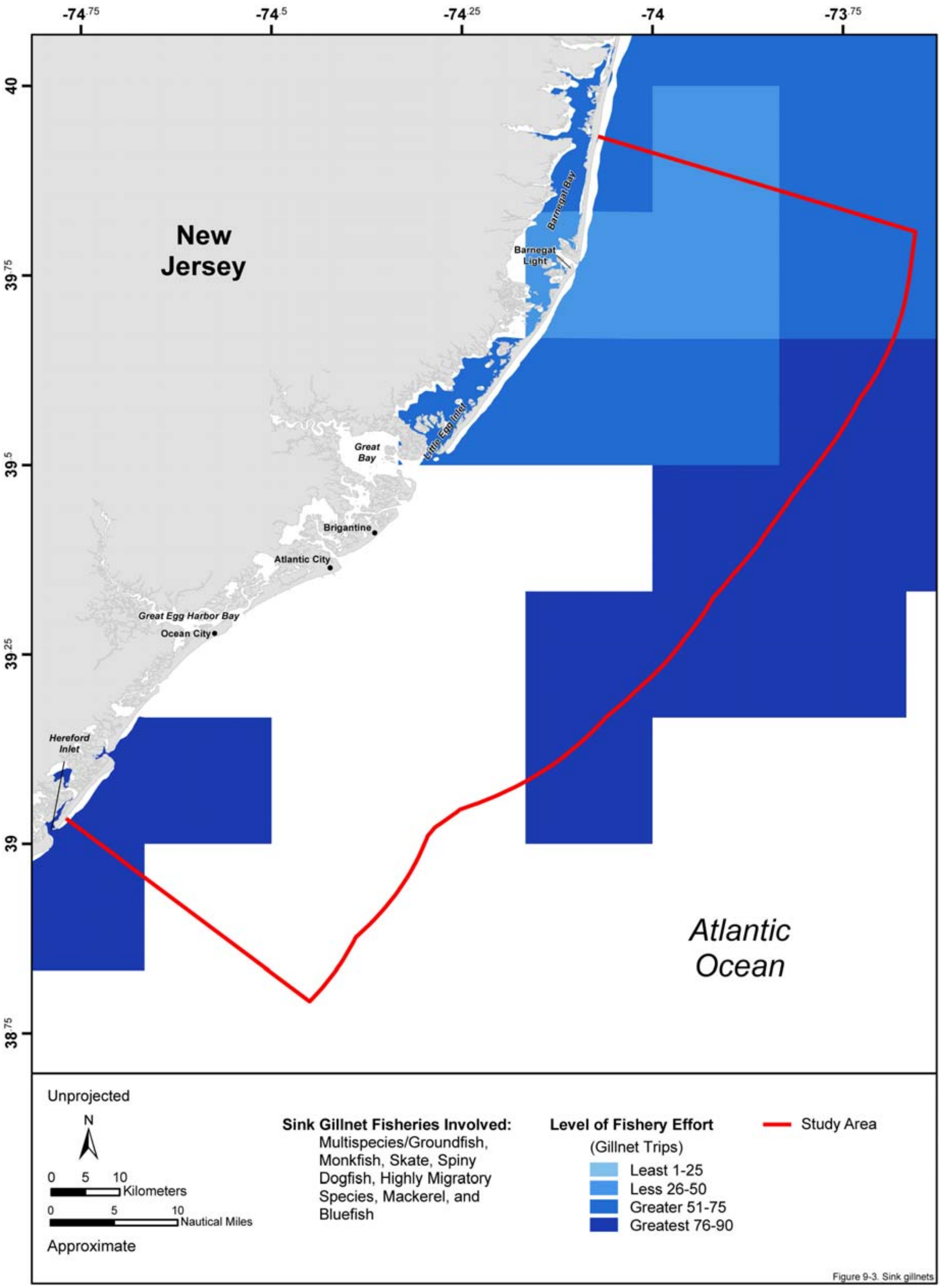

Figure 9-3. Fishing effort distribution of sink gillnet fisheries in the New Jersey Study Area and vicinity from 1995 to 2001. Source data: NMFS (2003b, 2004d). Source information: NEFMC (2003b).

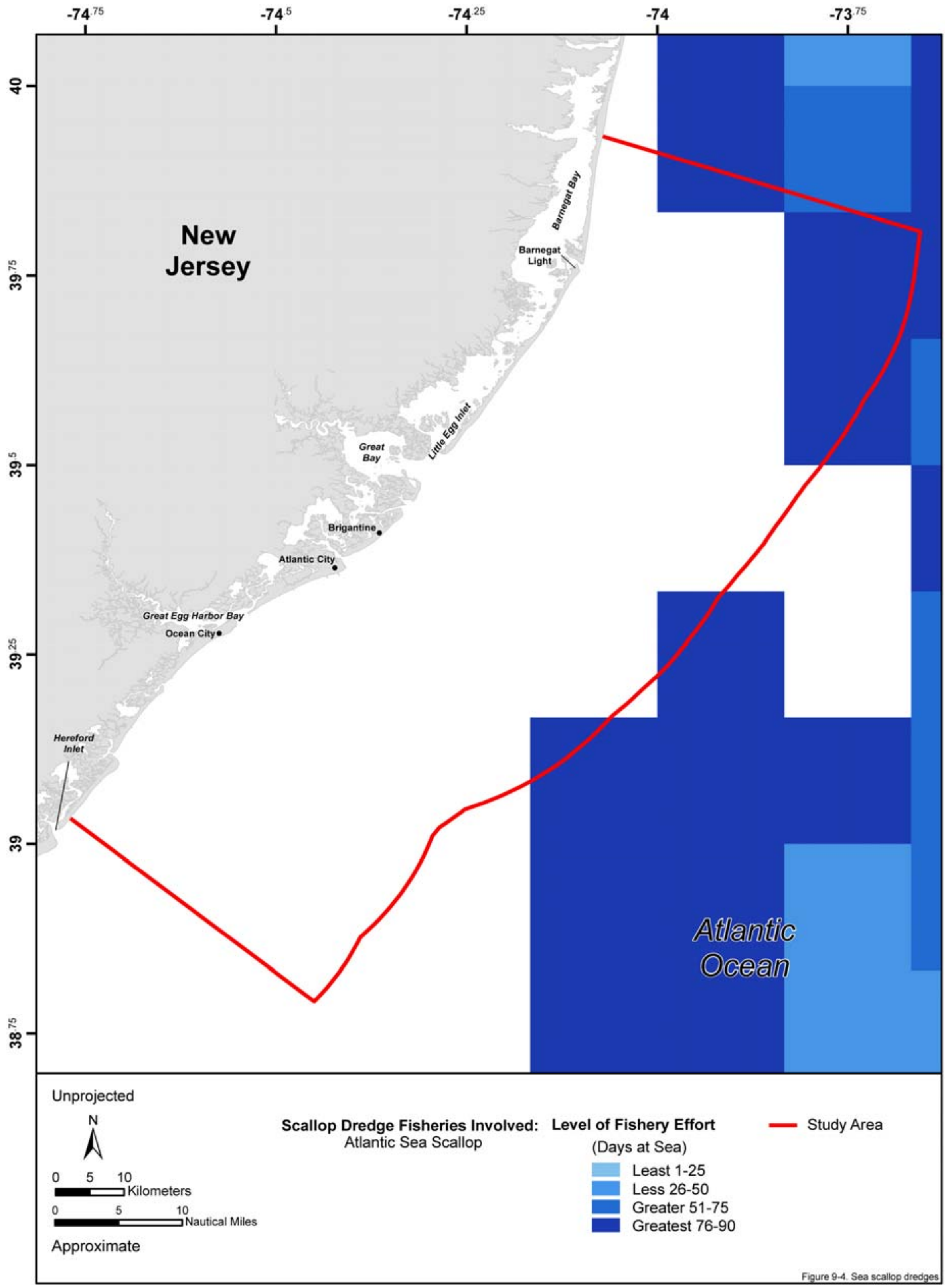

Figure 9-4. Fishing effort distribution of scallop dredge (Atlantic sea scallop) fisheries in the New Jersey Study Area from 1995 to 2001. Source data: NMFS (2003b, 2004d). Source information: NEFMC (2003b).

9.3.1.2 Monkfish Fishery

This fishery has recently developed in the MAB region as a result of high demand from foreign markets and the loss of other primary target fishery stocks, such as cod and haddock. The monkfish fishery is a derivative of the multispecies groundfish and scallop dredge fisheries. In fact, less than a third of the commercial landings result from vessels targeting monkfish directly (NEFMC 1998). The primary gear types used to target monkfish are bottom trawl nets (**Figure 9-2**), sink gillnets (**Figure 9-3**), and dredges (**Figure 9-4**). Commercial landings occur year-round, but New Jersey landings are more seasonal (i.e., beginning in November and extending through February and peaking in summer the months of May and June; NMFS 2004c). The trawl fishery targets monkfish in the canyons and steep edges of the continental shelf break in the northern portion of the MAB.

9.3.1.3 Skate Fishery

Skates are harvested for two distinct fisheries: bait and wing fisheries. The bait fishery primarily supplies lobstermen with skate to use as bait for lobster traps and the “wing” (fin) fishery supplies restaurants for human consumption. Wing meat refers to the large pectoral fin region of the skate and is often sold in fish markets and restaurants as a type of scallop. Similar to other fisheries within the Study Area, commercial landings occur year-round, but peak during the summer months. The directed “wing-meat” fishery is relatively new; developing during the 1990s after the decline in other targeted groundfish species. Landings for the wing meat fishery mainly result from the bycatch of the groundfish, monkfish, and scallop fisheries. Bottom trawls (**Figure 9-2**) are the main gear used to target skates (NEFMC 2003a); however, skates are also targeted with sink gillnet gear (**Figure 9-3**).

9.3.1.4 Spiny Dogfish Fishery

The spiny dogfish fishery is also a relatively new fishery and, similar to the monkfish and skate fisheries, the fishery is primarily based on the bycatch from the multispecies groundfish fisheries using bottom trawls (**Figure 9-2**), sink gillnets (**Figure 9-3**), and bottom longlines (MAFMC 1999). In the MAB region, commercial landings peak in the fall and winter months, while landings from Maine to New York, peak in the spring and summer (ASMFC 2002).

9.3.1.5 Atlantic Sea Scallop Fishery

In the MAB region, scallops have been harvested since the 1800s (NEFMC 1993). Vessels dredging with scallop rakes land the majority of Atlantic sea scallops (**Figure 9-4**), while a smaller percentage of the landings comes from vessels using bottom trawl gear (**Figure 9-2**; NEFMC 2003b). A significant percentage of the landings consist of the vessels the target Atlantic sea scallops in the summer and flounder in the winter. Depending on the size of the vessel that target Atlantic sea scallops, location, and weather conditions, trips range in duration from a single day for small vessels to 22 days for large vessels (NEFMC 1993b).

Fishing activity occurs year-round in the MAB; however, most of the landings occur from April to September. The primary Atlantic sea scallop ports are Cape May, New Jersey and Hampton, Virginia. Vessels from these ports are larger and can make extended trips while targeting scallop grounds in the New York Bight to waters off Virginia. Smaller inshore vessels range in length from 10 to 14 m (32.8 to 46 ft), while the larger vessels can exceed 30.5 m (100 ft) but are generally in the 21 m (69 ft) range (NEFMC 2003b).

9.3.1.6 Clam Fishery

The Atlantic surfclam is the primary commercial species harvested offshore in the Study Area (**Figure 9-5**). It is found in waters as deep as 60 m (197 ft) and is harvested mostly off New Jersey state waters and, to a lesser degree, off New York and Massachusetts (Weinberg 2000). Another important clam species is the ocean quahog. It is found in areas as deep as 256 m (840 ft), most commonly in soft grain sand substrates (Weinberg 2001b). Significant catches are made off New Jersey, Long Island, and coastal southern New England.

Clams are harvested mainly with hydraulic clam dredge gear in the MAB region (**Figure 9-6**). The fishery is active year-round, with most vessels operating during the summer months.

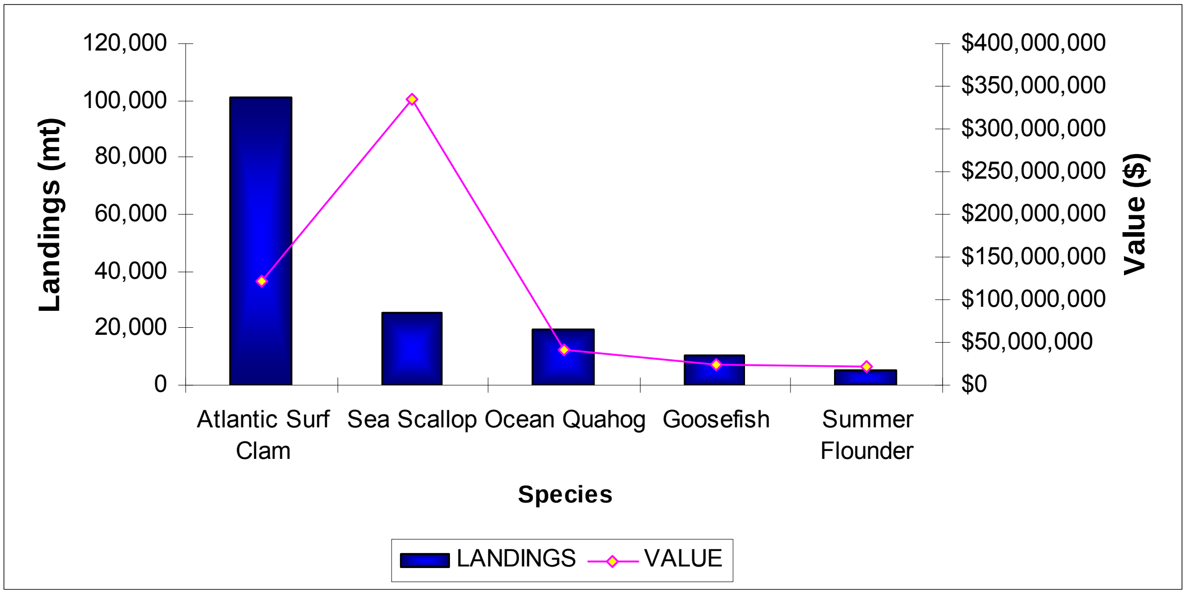

Figure 9-5. Primary commercial species landed in the waters off New Jersey from 2003 to 2007. Source data: NMFS (2008b).

9.3.1.7 Atlantic Herring Fishery

Atlantic herring are used for a variety of purposes, including industrial (fertilizer, lobster bait, fish meal, etc.) and for human consumption (canned, pickled, filleted, oil, etc.). Nearshore fixed gear types (i.e., traps and weirs) originally dominated this fishery; however, most Atlantic herring today are primarily caught with purse seine gear and some are also taken with mid-water trawl gear (ASMFC 1999). Fishing trips are mostly one-day trips, but some vessels with freezers fish for five to seven days. The offshore herring resources in federal waters are considered underexploited, but it is probable that the offshore activity will increase (NEFMC 1999a).

9.3.1.8 American Lobster Fishery

Offshore and inshore fisheries comprise the lobster fishery (ASMFC 1997; Idoine 1998). Traps (lobster pots) are the primary gear used to target American lobster (**Figure 9-7**); however, some lobsters are caught incidentally in bottom trawls. The offshore trap fishing grounds include areas on the continental shelf from Massachusetts to New Jersey and along the continental shelf break from Lydonia Canyon to Norfolk Canyon (NEFMC 1983). The offshore fishery accounts for approximately 20 percent of the total lobster landings, with the remaining 80 percent coming from nearshore areas. Lobster fishing occurs year-round both offshore and inshore, with peak fishing occurring from May to December (NMFS 2004c).

9.3.1.9 Winter Trawl Fishery

The winter trawl fishery is traditionally a southern-based fishery (i.e., North Carolina), but is active from offshore Long Island, New York south to Cape Lookout, North Carolina during September through April (Ross 1991). Fishing occurs in coastal waters at around 90 m (295 ft; Ross and Moye 1989). The trawl fishery is composed of the nearshore flounder, deepwater trawl (**Figure 9-2**), and flynet fisheries.

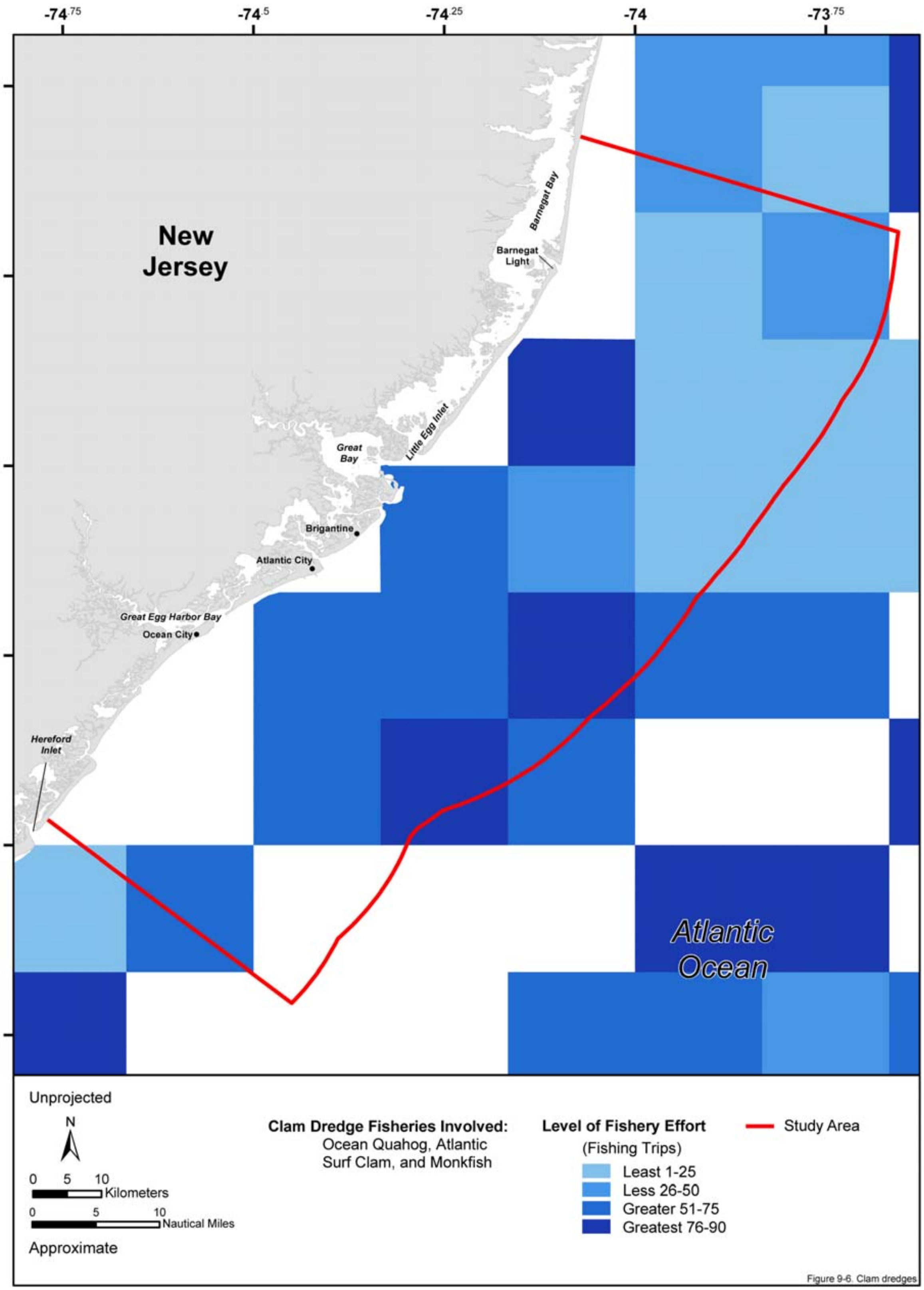

Figure 9-6. Fishing effort distribution of clam dredge fisheries in the New Jersey Study Area and vicinity from 1995 to 2001. Source data: NMFS (2003b, 2004d). Source information: NEFMC (2003b).

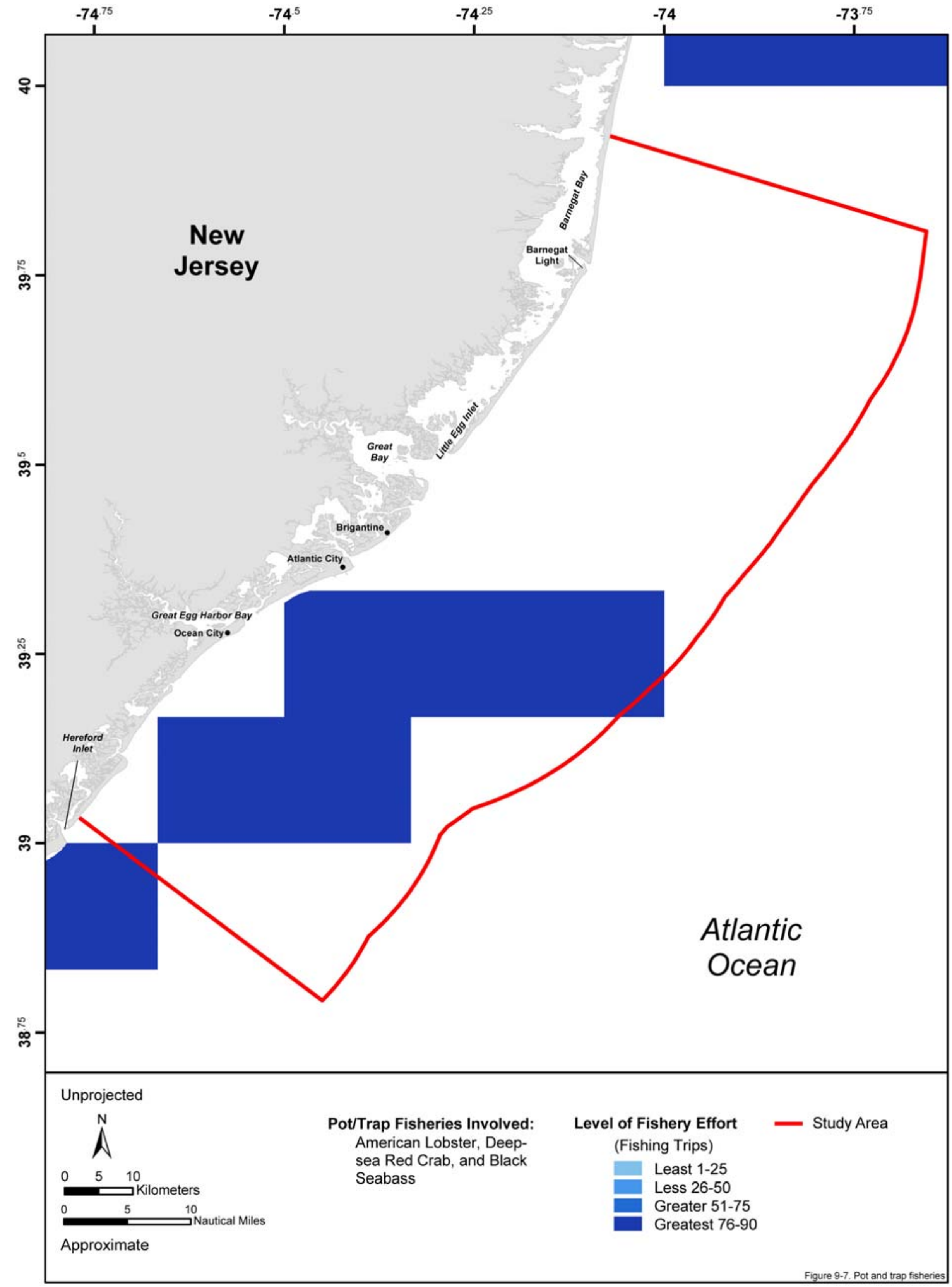

Figure 9-7. Fishing effort distribution of pot and trap fisheries in the New Jersey Study Area and vicinity from 1995 to 2001. Source data: NMFS (2003b). Source information: NEFMC (2003b).

Typically, summer flounder dominate the nearshore and deepwater landings and weakfish (*Cynoscion regalis*), Atlantic croaker (*Micropogonias undulates*), and bluefish dominate the flynet landings. Flynets are mid-water trawl nets that target fish higher up in the water column (Ross and Moye 1989). The deepwater fishery also targets black sea bass along the shelf edge, between January and March, mostly south of Nantucket Shoals (Shepherd and Terceiro 1994).

9.3.1.10 Highly Migratory Species Fisheries

Fisheries for HMS are another valuable commercial fishery that takes place within the vicinity of the Study Area. Target HMS include swordfish, five tuna species, and various species of pelagic sharks (e.g., shortfin mako shark and coastal sharks (e.g., blacktip shark [*Carcharhinus limbatus*]). The gear used to target HMS include pelagic and bottom longlines, purse seines, handgear (handlines and harpoons), and gillnets (i.e., for sharks; NMFS 1999b), but the primary gear is pelagic longline. The tuna fishery remained small until around 1960, when demand increased and advances in fishing gear occurred. Purse seining for tunas in the MAB region occurs from August to October, while handgear fishing occurs from June to October. Swordfish are targeted with pelagic longlines and handgears. Sharks were originally harvested as bycatch in the tuna and swordfish fisheries but now support a directed fishery that peaks in the winter and mid-summer and fluctuates with stock sizes and regulations. Sharks are primarily caught with gillnets (i.e., sink and drift) and longlines (i.e., bottom and pelagic). Longlines set for swordfish are generally set at sunset and retrieved at sunrise, while the opposite is true for longline sets for tuna. This longline fishery for tuna and swordfish is active year-round in the vicinity of the Study Area and occurs mostly (for swordfish) 60 NM offshore.

Currently, 12 of the 19 authorized shark species listed by NMFS that occur in the Study Area may be landed and retained in the commercial shark fishery (**Table 9-3**) and 6 of the 20 prohibited shark species listed by NMFS that occur in the Study Area cannot be possessed or retainted in any form in the commercial shark fishery (**Table 9-4**; Able 1992; NMFS 2009).

9.3.1.11 Closed Areas

Fishery management sometimes consists of closing specific areas to certain species or fishing gears (i.e., Northeastern U.S. Closed Area [39° to 40°N latitude and 68° to 74°W longitude] for pelagic longline fisherman during the month of June each year) (NMFS 2009). The purpose of fishery closures is maintaining and recovering localized fishery populations to harvestable and sustainable levels (NMFS 2004e; **Figures 9-2** to **9-7**). Through the fishery management efforts of the NMFS and MAFMC, certain marine areas are seasonally or permanently closed to specific fishing activities to help protect sensitive fish stocks. Permanent (e.g., year-round) closures remain in place for the specified gear types until the managing authorities modify the regulations. Before being published in the Federal Register, modifications to fishery regulations are subject to the public review process of the National Environmental Policy Act (NEPA). Closed areas change over the years in response to the status of fishery stocks. Seasonal and rolling closures are closed for given parts of the year. Rolling closures persist for a finite duration and are then de-designated and moved to another location to fulfill similar conservation or management goals.

9.3.1.12 Ports

There are three primary ports (Barnegat Light, Atlantic City, and Cape May [south of the Study Area]) that support the fishery fleet operating in the Study Area (**Figure 9-8**). A large number of these vessels are active in the multispecies fishery; however, vessels with other gear types utilize these ports, including pair-trawlers, handliners, trollers, scallop dredgers and trawlers, and Atlantic surf clam dredgers among others. A port's proximity to the fishing grounds, the capability of a port to accommodate various sizes of vessels, and the surrounding community and support services contributes to the nature of a port's character (NEFMC 1996).

Table 9-3. Retainable shark species in the commercial shark fisheries within the Study Area.

Large Coastal Sharks	
Blacktip shark	*Carcharhinus limbatus*
Great hammerhead shark	*Sphyrna mokarran*
Lemon shark	*Negaprion brevirostris*
Scalloped hammerhead shark	*Sphyrna lewini*
Silky shark	*Carcharhinus falciformis*
Smooth hammerhead	*Sphyrna zygaena*
Small Coastal Sharks	
Atlantic sharpnose shark	*Rhizoprionodon terraenovae*
Bonnethead	*Sphyrna tiburo*
Pelagic Sharks	
Blue shark	*Prionace glauca*
Common thresher shark	*Alopias vulpinus*
Porbeagle shark	*Lamna nasus*
Shortfin mako shark	*Isurus oxyrinchus*

Source: NMFS (2009)

Table 9-4. Commercially prohibited shark species within the Study Area.

Common Name	Scientific Name
Atlantic angel shark	*Squatina dumeril*
Basking shark	*Cetorhinus maximus*
Dusky shark	*Carcharhinus obscurus*
Sand tiger shark	*Carcharius Taurus*
Sandbar shark	*Carcharhinus plumbeus*
White shark	*Carcharodon carcharias*

Source: NMFS (2009)

9.3.2 Recreational Fisheries

In general, recreational fishing is growing throughout the U.S., including in the MAB and Study Area. The goods and services associated with recreational fishing have an important economic impact to local, regional, and national communities (Gillis and Millikin 1999a). Advanced fishing technologies and gears have made finding and catching fish easier in recent decades. The annual number of angler trips in New Jersey from 2003 to 2007 ranged from 6.5 million in 2004 to 7.4 million in 2007 (NMFS 2008b). New Jersey's extensive recreational fleet consists of about 100 party and over 300 charter boats, which are docked in ports at all major ocean inlets and bays. Party boats are large vessels, ranging from over 18.2 m (59.7 ft) to over 30.5 m (100 ft) in length, that carry anywhere from 20 to 150 passengers. These vessels sail on a daily schedule for designated species. Charter boats are typically smaller in size, between 7.6 m (25 ft) and 18.3 m (60 ft) in length carrying a maximum of six to eight anglers. These vessels reserve the entire boat for selected group. Both vessels utilizing the following fishing methods: chumming, wreck/bottom fishing, drifting, and jigging. Trolling for fish is restricted to charter boats (Giordano et al. 2008).

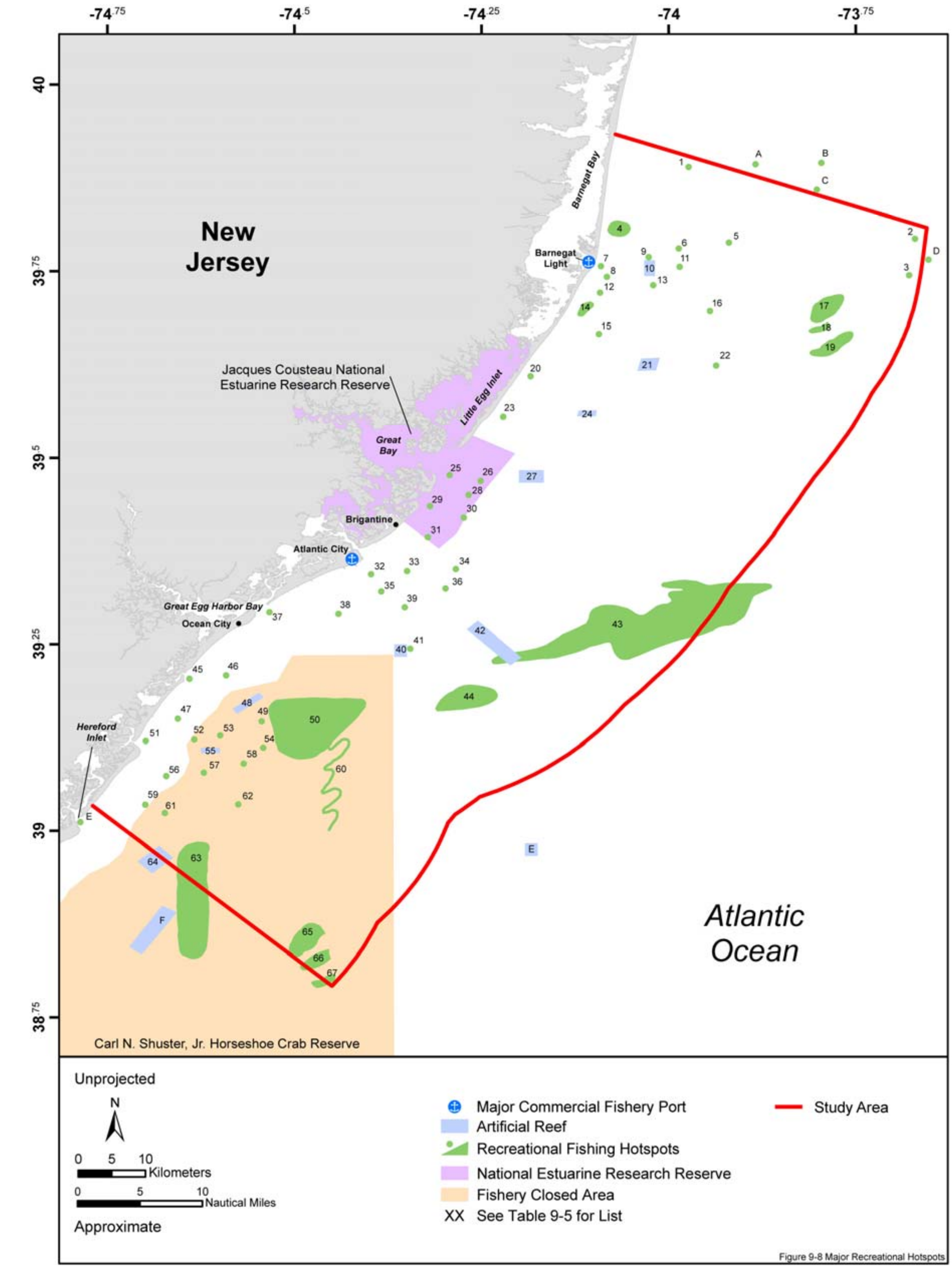

Figure 9-8. Major commercial fishing ports and recreational fishing hotspots found in the New Jersey Study Area and vicinity. Source information: NEFMC (2003b). Map adapted from: Freeman and Walford (1974), Saltwater Directions (2003a, 2003b, 2003c), and NJDEP (2009b).

Historically, evaluating recreational fishing hotspots has been challenging since limited information is available that specifically identifies fishing locations. Recreational fishery information is usually only obtained through state and federal biologists interviewing anglers at the dock or over the telephone. Although a few short term studies have identified local fishing areas (Levesque and Kerstetter 2007), most recreational fishery studies have only focused on evaluating catch. In fact, until recently, there was no mandatory recreational angler reporting requirements for any marine species accept for HMS. Nonetheless, besides recreational anglers that target HMS, there is still are no state or federal regulations that require recreational anglers to submit any detailed information regarding their fishing trips. Even with HMS anglers, fishermen are not required to report to the government any specific information regarding where species were captured or released. At this time, programs to evaluate recreational fishing activities for all other marine fish species are voluntary and interview-response based. Although some interview questions consist of asking anglers about fishing locations, the questions are generally only in reference to shore and are not related to specific fishing locations. Since there are no existing regulations, most recreational anglers prefer to remain anonymous and usually do not assist with submitting any information to researchers regarding fishing locations. Today, recreational fishing hotspot information can be obtained through using historical and updated fishing charts. One such comprehensive chart was completed by Freeman and Walford (1974). For their geographical study of marine recreational fishing, Freeman and Walford (1974) used information they gathered from anglers along the east coast from Maine to Florida to develop a fishing atlas. In gathering information, Freeman and Walford (1974) interviewed hundreds of commercial and recreational fishermen, outdoor writers, and operators of marinas and bait and tackle stores. In addition, they interviewed various state and federal biologists from various environmental agencies. Along with historical information, new updated fishing information can be gathered from various sources including: charts, outdoor fishing magazines, and internet forums.

9.3.2.1 Fishing Areas

Popular fishing sites commonly visited by recreational anglers are usually known as hotspots (**Figure 9-8** and **Table 9-5**). Within and adjacent to the Study Area, fishing hotspots include areas with some type of structural feature,.such as shoals, rocks, and reefs (artificial and natural). Natural and man-made popular fishing sites include piers, docks, rock and concrete jetties, and beach groins. In addition, because hydrographic features also concentrate fish, fishermen often target waters with currents that are rich with nutrients (Walford 1974).

9.3.2.2 Fishing Activity Statistics

Rod-and-reel fishing is the most common method used by recreational anglers (NMFS 2001a). Recreational fishing activity can be classified as inshore or offshore. Inshore recreational fishing involves fishing from boats, beaches, marshes, docks, and piers, while offshore fishing generally involves larger boats including charter and party boats. Most anglers fish from private or rental boats followed by shore and party or charter vessels (**Figure 9-9**). Regardless of the fishing method or location, most anglers fish within 2.6 NM from shore (**Figure 9-10**). As expected, recreational fishermen generally only fish during the warmer summer months, with the peak months being July and August (**Figure 9-11**). Charter boats generally take numerous anglers for a fixed daily rate and party boats or headboats take guests (usually on larger boats) on a per person rate (Abbas 1978). Overall, the charter and headboat businesses provide employment and economic stimulus to the local coastal communities (NMFS 2003a). Charter boats, headboats, and fishing guides are available throughout and adjacent to the Study Area. In general, charter outfitters offer fishing opportunities and professional services to those who do not own their own vessels or fishing equipment. A single group of anglers typically hires a charter boat on a per-trip basis (half or full-day), while headboats are regularly scheduled (morning, afternoon, and evening) and take groups of anglers who pay a flat rate per person. Charter and headboats more commonly fish further offshore than many privately owned vessels, due to the high cost of owning and maintaining a personal vessel.

Table 9-5. Major fishing hotspots found within or adjacent to the New Jersey Study Area.

Fishing Hotspots in the Study Area					
1	Old Freighter	2	Oley's Lump	3	Oley's Lump: southern lump
4	North Pounds	5	Remains of Cornelius Hargraves and Vizcaya wrecks	6	Several sunken barges
7	Barnegat Inlet rough water entrance	8	Sumner wreck	9	Persephone torpedoed wreck
10	Barnegat Light Reef	11	Lump area east	12	Channel behind Loveladies
13	Bow of former tanker Gulftrade	14	Harvey Cedar Lumps	15	Lumps in front of Loveladies
16	San Saba wreck	17	Barnegat Ridge (north)	18	Middle Ridge
19	Barnegat Ridge (south)	20	Brant Beach Lumps	21	Garden State North Reef
22	Great Issac wreck	23	Beach Haven Lumps	24	Garden State South Reef
25	Little Egg Inlet	26	Atomic Lump	27	Little Egg Reef
28	"LE" buoy	29	Brigantine Inlet	30	Shoals ouside Brigantine Inlet
31	Brigantine Shoal	32	Shoaling near Absecon Inlet	33	Long narrow shoal
34	Pig Iron wreck	35	Inshore Ridge	36	Pet wreck
37	Great Egg Harbor Inlet	38	Scattered wreckage	39	Darien wreck
40	Great Egg Reef	41	American Oil wreck	42	Atlantic City Reef
43	Lobster Hole	44	Atlantic City Ridges	45	Corson's Inlet
46	Lumps off Corson' Inlet	47	Shoaling Ridges off Sea Isle City	48	Ocean City Reef
49	Bell wreck	50	Inshore Stone Bed	51	Townsends Inlet
52	The Lump	53	Sea Isle Shoal	54	Wreck
55	Townsends Inlet Reef	56	Wreck	57	Wrecked barge Wayne
58	Avalon Shoal	59	The Fingers	60	Lumps off Stone Harbor
61	Sandy Lump	62	Unknown site	63	Five Fathom Bank
64	Wildwood Reef	65	Northeast Lump	66	Middle Lump
67	East Lump				
Fishing Hotspots adjacent to the Study Area					
A	Old crane barge	B	Tolten torpedoed freighter	C	Totlen Lump
D	Oley's Lump – middle section	E	Deepwater Reef	F	Cape May Reef

Source: Freeman and Walford (1974); Saltwater Directions (2003a, 2003b, 2003c); NJDEP (2009b)

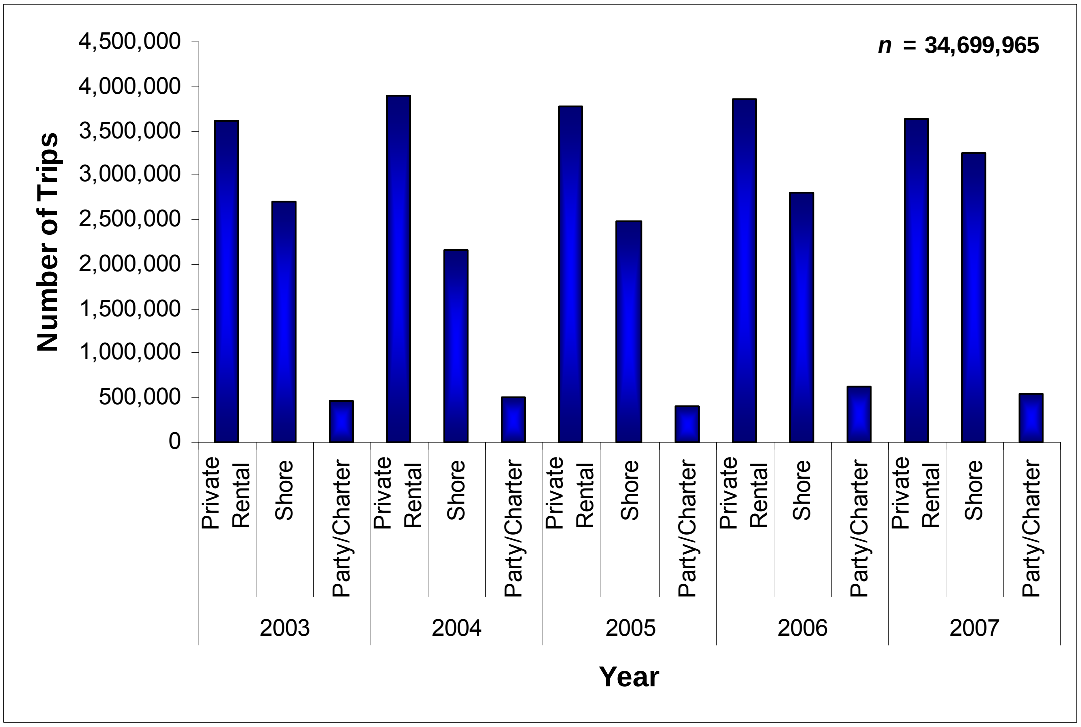

Figure 9-9. The number of recreational fishing trips by the three modes (private/rental, shore, and party/charter boat) in the waters off New Jersey from 2003 to 2007 (NMFS 2008c).

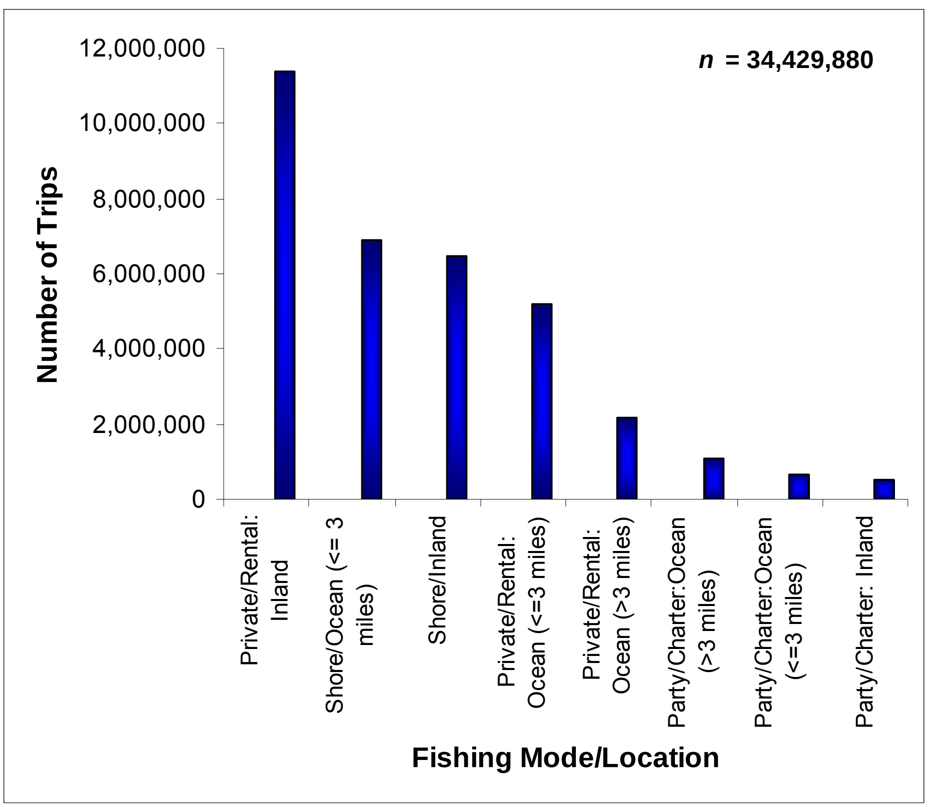

Figure 9-10. The number of recreational fishing trips by the three modes (private/rental, shore, and party/charter boat) in the waters off New Jersey from 2003 to 2007 (NMFS 2008c).

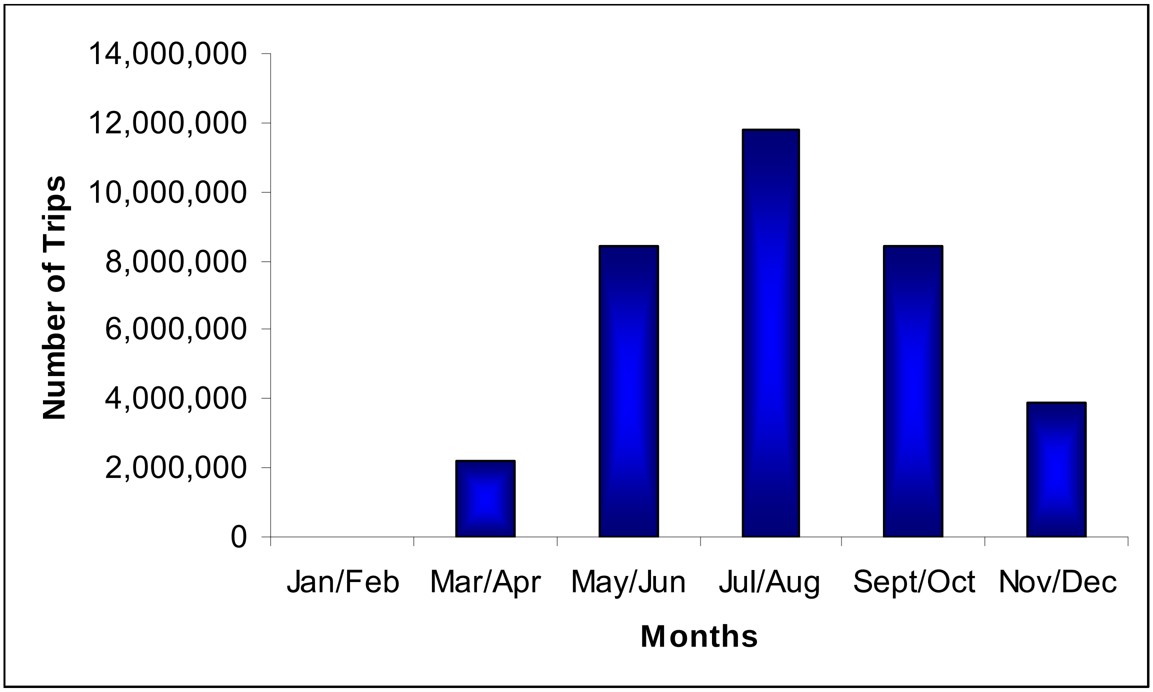

Figure 9-11. The monthly number of New Jersey recreational saltwater fishing trips from 2003 to 2007. Source data: NMFS (2008c).

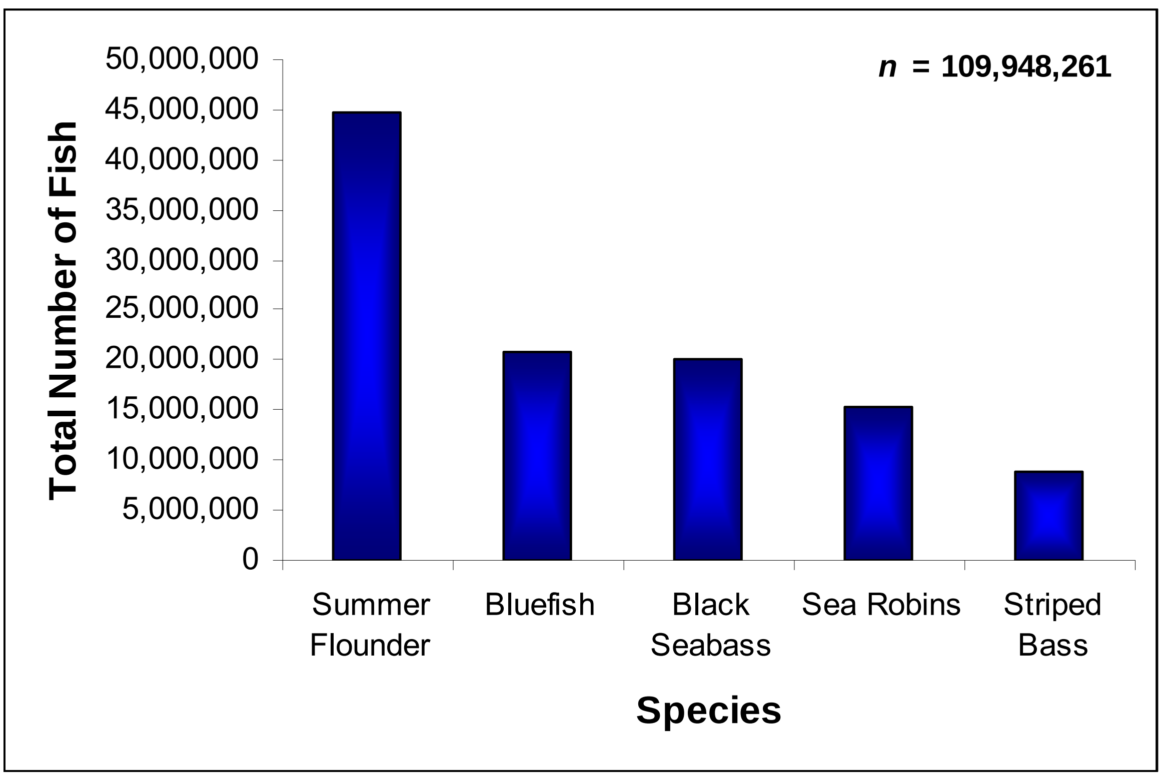

Figure 9-12. Primary recreational fish species caught in the waters off New Jersey from 2003 to 2007 (NMFS 2008c).

9.3.2.3 Fish Species

The primary species taken in the waters of New Jersey include summer flounder, bluefish, black sea bass, sea robins (*Prionotus* spp.), and striped bass (**Figure 9-12**). Summer flounder is by far the most common fish caught in state waters by recreational anglers (Gillis and Millikin 1999a, 1999b). Recreational anglers caught an estimated 44,852,108 summer flounder from 2003 to 2007. Of the total estimated catch, 41 percent were summer flounder. Flounder are caught almost exclusively within 2.6 NM of shore (NEFMC 1996). Besides fish, recreational fishing also includes anglers targeting lobster with traps and dive gear; however, recreational trap fishing is not usually conducted beyond 3 NM from shore (NEFMC 1983).

9.3.2.4 Tournaments

Organized fishing tournaments are popular in and around the Study Area with various recreational fishing tournaments taking place along the coast during the summer months. Tournaments can be economically important to local cities or towns (NMFS 2003a). Organizations and companies usually sponsor each tournament and prizes are given for the most and largest of a given species. Tournament participants target both inshore and offshore species. Each tournament has its own set of rules, which include time limits and geographical boundaries. The most popular and valuable tournaments in the U.S. are the ones specifically for HMS (e.g., billfish and tunas). Anglers choose fishing sites fished according to species targeted, tournament rules, experience, and weather.

Since tournaments vary, the level of participation also varies between individual events, seasons, and years. Although most tournaments are annual events, the list of scheduled tournaments is not static (**Table 9-6**). Existing tournaments may be cancelled due to a lack of participation or support or new tournaments may be organized. The exact dates and weigh-in locations of annual tournaments will vary slightly year to year.

9.4 ESSENTIAL FISH HABITAT DISTRIBUTION AND MANAGED SPECIES

Fish and fisheries found within the Study Area are managed by various FMCs depending on the species and its range. The NEFMC, MAFMC, and the SAFMC manage fisheries found within the Study Area. In addition, the GMFMC co-manages the coastal migratory pelagic species (king mackerel, Spanish mackerel, cobia, cero [*Scomberomorous regalis*], and little tunny [*Euthynnus alletteratus*]) with the SAFMC. In state waters, the ASMFC manages shared marine fishery resources. Through the IFMP, the ASMFC coordinates the conservation and management of 22 Atlantic coast fish species or species groups, which are found in the Study Area or vicinity (ASMFC 2004). Although most Atlantic HMS are usually found outside the Study Area and offshore (e.g., international waters), the NMFS is the only domestic agency that manages these species.

The Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), as amended by the SFA, require that the NMFS, in conjunction with FMCs, identify and protect habitat essential for federal managed fish and invertebrate species. Each FMP should include the identification and description of EFH, description of non-fishing and fishing threats, and suggested measures to conserve and enhance EFH. Fishery Management Councils are also required to identify other important areas called Habitat Areas of Particular Concern (HAPCs). Criteria for HAPC should demonstrate: (a) ecological function, (b) sensitivity to human-induced environmental degradation, (c) development activities stressing habitat type, or (d) rarity of habitat.

Table 9-6. Major New Jersey recreational fishing tournaments occurring in the Study Area and vicinity in 2009.

EVENT DATE	WEIGH-IN LOCATION	EVENT	TARGET SPECIES
1 May 2009- 2 May 2009	Cape May, New Jersey	8th Annual South Jersey/ASA Spring Striper Open	Striped Bass
8 May 2009- 9 May 2009	Sandy Hook, New Jersey	ASA Striper Tournament	Striped Bass
6 Jun 2009 6 Jun 2009	Atlantic City, New Jersey	Greater Atlantic Bluefish Tournament	Bluefish
11 Jun 2009- 14 Jun 2009	Cape May, New Jersey	29th Annual South Jersey Shark Tournament	Mako, Blue, Thresher, and Tiger sharks
13 Jun 2009 13 Jun 2009	Forked River, New Jersey	Forked River Tuna Club Spring Shoot-Out	Tuna
27 Jun 2009 28 Jun 2009	Clark's Landing, New Jersey	Mako Mania	Mako sharks
8 Jul 2009- 12 Jul 2009	Cape May, New Jersey	20th Annual Ocean/Viking Showdown	Marlin, Tuna, Wahoo, Dolphinfish
15 Jul 2009- 18 Jul 2009	Cape May, New Jersey	8th Annual Mid-Atlantic Tuna Tournament	Tuna
24 Jul 2009- 25 Jul 2009	Avalon, New Jersey	Jersey Shore Classic	Tuna, Dolphinfish, Weakfish, Flounder
15 Aug 2009 23 Aug 2009	Forked River, New Jersey	Forked River Tuna Club Annual Tournament	Tuna
16 Aug 2009 21 Aug 2009	Cape May, New Jersey	18th Annual Mid-Atlantic $500,00 Tournament	Tuna, Wahoo, Dolphinfish, Marlin
23 Aug 2009 29 Aug 2009	Atlantic City, New Jersey	Tuna Stakes Invitational	Tuna

Table 9-6 (*continued*). Major New Jersey recreational fishing tournaments occurring in the Study Area and vicinity in 2009.

EVENT DATE	WEIGH-IN LOCATION	EVENT	TARGET SPECIES
4 Oct 2009 4 Oct 2009	Island Beach State Park, New Jersey	Governor's Surf Fishing Tournament	Bluefish, Blackfish, Fluke
17 Oct 2009 22 Oct 2009	Forked River, New Jersey	Forked River Tuna Club Bass and Bluefish Tournament	Striped Bass, Bluefish
6 Nov 2009 7 Nov 2009	Cape May, New Jersey	9^{th} Annual South Jersey Marina's Big Bass Open Tournament	Striped Bass

Source: Atlantic Anglers (2009); Binnacle Custom Tackle (2009); Sportfishermen (2009)

There are 38 fish and invertebrate species in the Study Area that have designated EFH and which are hereinafter referred to as managed species (**Tables 9-7** and **9-8**). These managed species are further grouped as temperate, subtropical-tropical, and HMS. Of the 38 managed species, 23 are temperate, 3 are subtropical-tropical, and 12 are HMS. For each managed species, the management, status, distribution including range, habitat association, life history, forage species, and bolded EFH lifestage designations are provided for the Study Area. In addition, there is an associated map figure that visually depicts the distribution of the designated EFH in the Study Area. It should be noted that although the status of a species may be different at a local scale (i.e., within the Study Area), stock stock refers to the entire population (stock) since state and federal agencies manage species based on the population stock (~usually defined by genetic techniques) and not by localized populations. Management agencies use this approach because many fish species display seasonal movement patterns that cross various state and federal boundary jursidicitons.

In general, EFH within the Study Area may be characterized in the following habitat categories:

- Benthic Habitat: refers to seafloor habitats, which include the continental shelf and slope. These habitats consist of bottom substrate such as rocks, gravel, cobble, pebbles, sand, clay, mud, silt, shell fragments, and hard bottom. Benthic habitats are utilized by a variety species for spawning/nesting, development, dispersal, and feeding (NMFS1999a, 1999b, 2001b; SAFMC 1998).

- Sediment Interface: refers to habitat area between the seafloor and 1 m depth below the water-sediment interface. This habitat usually consisting of soft sediments and therefore is utilized by juvenile and adult invertebrates (e.g., Atlantic surfclam and ocean quahog).

- Aquatic Macrophytes: refers to seagrass beds and macroalgae mats located in estuarine areas, especially in the nearshore bays of New Jersey, which are nursery areas and habitat for juvenile species, such as bluefish and sandbar shark (Collette and Klein-MacPhee 2002).

- Structured Habitats: refers to man-made or natural structures that provide shelter for a variety of species, these habitats provide surface area for settlement, attachment, or colonization. Because of the variety of marine life associated with structures, these habitats often form their own community.

  - Artificial reefs and shipwrecks*:* Artificial habitat primarily used by adults, especially spawning adults (Clark and Livingstone 1982; Steimle and Figley 1996).

  - Biogenic: Includes communities of sponges, mussel beds, hydroids, amphipod tubes, red algae, and bryozoans, which are used primarily by scallop larvae.

- Marine Water Column: refers to the vertical water column, which extends from the surface to the seafloor. Depending on the species, this designated habitat may only refer to part or the entire water column, such as surface or bottom waters. This habitat is important for a wide variety of species and their lifestages.

- Estuarine Water Column: refers to the vertical water column found in estuaries, bays and other inshore coastal waters. This habitat commonly includes the "mixing" (0.5 to 25 practical salinity units [psu]) and "seawater" (>25 psu) salinity zones as defined by the NOAA's Estuarine Living Marine Resources (ELMR) database. The estuarine water column habitat is important to all lifestages of many fishes utilizing these areas (Buckel et al. 1999).

- Habitat Areas of Particular Concern (HAPC): HAPC have been designated in the Study Area and its vicinity for two species (sandbar shark and summer flounder).

  - All lifestages for the sandbar shark: the shallow areas at the mouth of Great Bay, New Jersey; lower and middle Delaware Bay; lower Chesapeake Bay, Maryland; near the Outer Banks, North Carolina, in areas of Pamlico Sound adjacent to Hatteras and Ocracoke Islands to just offshore of these barrier islands. A portion of the HAPC for Great Bay, New Jersey, extends within the boundaries of the Study Area, while HAPC for lower and middle Delaware Bay is south of the Study Area (McCandless et al. 2002; NMFS 2003a).

- Juvenile and adult lifestages for the summer flounder: estuarine and bay areas communities of macoalgae, seagrasses, and freshwater and tidal macrophytes within the designated EFH; these areas are all adjacent to the Study Area.

The FMCs classify EFH for temperate and subtropical/tropical managed species in terms of five basic lifestages: (1) Eggs, (2) Larvae, (3) Juvenile, (4) Adult, and (5) Spawning Adult (MAFMC 1998a; MAFMC and ASFMC 1998a, 1998b; NEFMC 1998, 1999b, 2003a, 2003b). Eggs represents the lifestage that has been spawned and formed, but has yet to hatch; this lifestage is completely dependent on its yolk for nutrition and survival. Larvae are individuals that have hatched and have the ability to obtain or capture food. Juveniles are those individuals that are not sexually mature, but are otherwise morphologically similar to adults. Adults are sexually mature individuals that are not necessarily in spawning condition stage. The last lifestage is spawning adults. This stage is represented by those individuals that are in spawning condition (Moyle and Cech 1988; MAFMC 1998a; MAFMC and ASFMC 1998a, 1998b; NEFMC 1998, 1999b, 2003a, 2003b; SAFMC 1998).

For HMS (e.g., tuna, swordfish, and billfish), the NMFS categorizes lifestages into three categories based on ecological groupings indicative of habitat usage: (1) Spawning Adults, Eggs, and Larvae, (2) Juvenile and Subadult, and (3) Adult (NMFS 1999a, 1999b, 2006). The category of spawning adult, eggs, and larvae is dependent on spawning locations and circulation patterns (controlled by winds and currents) that control the distribution of this lifestage. The juvenile and subadult category is a cumulative group in which all lifestages between age one and maturity have been combined. Adults are characterized as sexually mature fish.

Table 9-7. The fish and invertebrate species with EFH designated in the Study Area. Taxonomy follows Nelson et al. (2004) for fish and Turgeon et al. (1998) for mollusks.

I. Temperate Water/Fish and Invertebrate Species (23)		
Atlantic cod	Goosefish/Monkfish	Spiny dogfish
Atlantic herring	Little skate	Summer flounder
Atlantic mackerel	Longfin inshore squid	Windowpane flounder
Atlantic surfclam	Ocean pout	Winter flounder
Black sea bass	Ocean quahog	Winter skate
Bluefish	Red hake	Witch flounder
Butterfish	Scup	Yellowtail flounder
Clearnose skate	Silver hake/Whiting	
II. Subtropical-Tropical/Southeast Species (3)		
Cobia	King mackerel	Spanish mackerel
III. Highly Migratory Species: Billfishes, Tunas, Swordfish, and Sharks (12)		
Atlantic angel shark	Sand tiger shark	Skipjack tuna
Blue shark	Sandbar shark	Swordfish
Bluefin tuna	Scalloped hammerhead shark	Tiger shark
Dusky shark	Shortfin mako shark	White shark

Table 9-8. Management units (MU) and managed species with essential fish habitat designated in the Study Area by management agency. Taxonomy follows Nelson et al. (2004) for fish and Turgeon et al. (1998) for mollusks.

NEW ENGLAND FISHERY MANAGEMENT COUNCIL

Atlantic Herring MU[1]
Atlantic herring (*Clupea harengus*)

Northeast Multispecies MU
Atlantic cod (*Gadus morhua*)
Ocean pout (*Zoarces americanus)*
Red hake (*Urophycis chuss*)
Silver hake/Whiting (*Merluccius bilinearis*)
Windowpane flounder (*Scophthalmus aquosus*)
Winter flounder (*Pseudopleuronectes americanus*)
Witch flounder (*Glyptocephalus cynoglossus*)
Yellowtail flounder (*Limanda ferruginea*)

Northeast Skate Complex MU
Clearnose skate (*Raja eglanteria*)
Little skate (*Leucoraja erinacea*)
Winter skate (*Leucoraja ocellata*)

Monkfish MU[2]
Goosefish/Monkfish (*Lophius americanus*)

MID-ATLANTIC FISHERY MANAGEMENT COUNCIL

Atlantic Mackerel, Squid, and Butterfish MU
Atlantic mackerel (*Scomber scombrus*)
Butterfish (*Peprilus triacanthus*)
Longfin inshore squid (*Loligo pealeii*)

Bluefish MU3
Bluefish (*Pomatomus saltatrix)*

Spiny Dogfish MU[4]
Spiny dogfish (*Squalus acanthias*)

Summer Flounder, Scup, and Black Sea Bass MU[4]
Black sea bass (*Centropristis striata*)
Scup (*Stenotomus chrysops*)
Summer flounder (*Paralichthys dentatus*)

Surfclam and Ocean Quahog MU
Atlantic surfclam (*Spisula solidissima*)
Ocean quahog (*Arctica islandica*)

SOUTH ATLANTIC FISHERY MANAGEMENT COUNCIL

Coastal Migratory Pelagics MU[5]
Cobia (*Rachycentron canadum)*
King mackerel (*Scomberomorus cavalla)*
Spanish mackerel (*Scomberomorus maculatus)*

NATIONAL MARINE FISHERIES SERVICE
(Highly Migratory Species Management Division)

Tuna MU
Bluefin tuna (*Thunnus thynnus*)
Skipjack tuna (*Katsuwonus pelamis*)

Swordfish MU
Swordfish (*Xiphias gladius*)

Large Coastal Shark MU
Sandbar shark (*Carcharhinus plumbeus*)
Scalloped hammerhead shark (*Sphyrna lewini*)
Tiger shark (*Galeocerdo cuvier)*

Pelagic Shark MU
Blue shark (*Prionace glauca*)
Shortfin mako shark (*Isurus oxyrinchus*)

Prohibited Species MU
Atlantic angel shark (*Squatina dumeril*)
Dusky shark (*Carcharhinus obscurus*)
Sand tiger shark (*Carcharius taurus*)
White shark (*Carcharodon carcharias*)

[1] Jointly managed by the NEFMC and the ASMFC
[2] Jointly managed by the NEFMC (lead) and the MAFMC
[3] Jointly managed by the MAFMC and the ASMFC
[4] Jointly managed by the MAFMC (Lead) and the NEFMC
[5] Jointly managed by the SAFMC (Lead) and the GMFMC

For sharks, the NMFS classifies EFH in terms of three combined lifestages, which are based on the general habitat shifts that accompany each developmental stage. Shark EFH is classified as: (1) Neonate and Early Juvenile (including newborns and pups less than one year old), (2) Late Juvenile and Subadult (age one to adult), and (3) Adult (sexually mature sharks; NMFS 1999b). In 2003, Amendment 1 to the FMP for the Atlantic Tunas, Swordfish, and Sharks, the first two lifestages were modified as follows: Neonate and Early Juvenile was renamed Neonate, which includes primarily neonates and small young-of-the-year sharks, and Late Juveniles and Subadults category was renamed Juveniles, which includes all immature sharks from young juveniles to older or late juveniles (NMFS 2003a; 2006).

9.4.1 Temperate Water Fish and Invertebrate Species

The temperate species found off the coast of New Jersey include principal groundfish species (Atlantic cod, silver hake, and red hake) and other groundfish species (goosefish/monkfish, silver hake, scup, black sea bass, and ocean pout), flounders (summer, yellowtail, witch, winter, and windowpane), principal pelagic species (Atlantic herring/mackerel), other finfish (butterfish, bluefish, spiny dogfish, and skates), and invertebrates (e.g., squids, surfclams, ocean quahogs). Twenty-three temperate fish and invertebrate managed species have designated EFH in the Study Area (**Table 9-7**). Of the total number of managed species found within the Study Area, 11 are managed by the NEFMC, 7 are jointly managed by the MAFMC and ASMFC, and 5 are managed by the MAFMC (**Table 9-8**).

The 38 federally managed species and their designated EFH found within the Study Area are described in the following sections. Specific EFH lifestages found within the Study Area are highlighted in bold.

- **Atlantic Cod (*Gadus morhua*)**

  Management—Atlantic cod EFH is designated under Final Amendment #11 to the Northeast Multispecies FMP (NEFMC 1998). The Atlantic cod is managed as two separate stocks (Georges Bank and Gulf of Maine stocks) in U.S. waters (NEFMC 1998). The Georges Bank stock, whose southern distributional extent ranges into the MAB, is the only stock that occurs within the Study Area (Mayo and O'Brien 2000).

  Status—Both the Georges Bank and Gulf of Maine cod stocks are classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 International Union for Conservation of Nature and Natural Resources (IUCN) Red List classifies Atlantic cod as vulnerable or facing a high risk of extinction (Sobel 1996a).

  Distribution—The range of Atlantic cod extends to both sides of the northern Atlantic Ocean. In the western North Atlantic Ocean, this species is distributed from Greenland to Cape Hatteras, North Carolina (Fahay et al. 1999a).

  Habitat Associations—Cod are a demersal (usually found within 2 m [6.6 ft] of the bottom) temperate species, which are found in waters ranging from 10 to 150 m (32.8 to 492.2 ft) off the northeastern U.S. coast. Cod prefer cobble or gravel shoals and water temperatures between 0°C and 10°C (32°F and 50°F; NEFMC 1998; Klein-MacPhee 2002b). Large cod are commonly found in deeper waters (600 m [1,968.6 ft]; Cohen et al. 1990). Eggs are pelagic and larvae are found near the water surface moving to deeper waters with maturity (Fahay et al. 1999a; Klein-MacPhee 2002a; Lough 2004).

  Life History—In the Study Area, cod are mostly non-migratory, but do undertake minor seasonal movements as water temperatures fluctuate. Cod typically move to the northern parts of their range as water temperatures warm in the summer and early fall (Cohen et al. 1990). Older fish also display vertical movements while searching for food (Klein-MacPhee 2002a). Spawning occurs on Georges Bank, in the Gulf of Maine, and over the inner half of the continental shelf off southern New England at night. Spawning occurs from November to April in waters with temperatures ranging from 0° to 12°C (32.0° to 53.6°F)and depths of less than 50 m (164 ft; Cohen et al. 1990; Fahay et al. 1999a).

Forage Species—Atlantic cod feed primarily on fishes but also consume crustaceans and mollusks. Prey include: herring, sand lance, Atlantic mackerel, rock crab, longfin inshore squid, and northern shortfin squid (*Illex illecebrosus*; Klein-MacPhee 2002a).

EFH Designations—(NEFMC 1998; **Figure F-1**)

- Eggs—Designated EFH includes surface waters around the perimeter of the Gulf of Maine, Georges Bank, the eastern portion of the MAB continental shelf south to Long Island, New York, and within New England estuaries and embayments.

- Larvae—Designated EFH includes pelagic waters of the Gulf of Maine, Georges Bank, the eastern portion of the continental shelf off southern New England, and within southern New England estuaries and embayments.

- Juveniles—Designated EFH includes pelagic waters and bottom habitats with substrate of cobble or gravel in the Gulf of Maine, Georges Bank, MAB south to Long Island, New York, and within New England estuaries and embayments .

- **Adults**—Designated EFH includes bottom habitats with a substrate of rocks, pebbles, or gravel in the Gulf of Maine, Georges Bank, southern New England, MAB south to the Delaware Bay, and within New England estuaries and embayments.

- Spawning Adults—Designated EFH includes bottom habitats with a substrate of smooth sand, rocks, pebbles, or gravel in the Gulf of Maine, Georges Bank, MAB south to the Delaware Bay, and within New England estuaries and embayments.

HAPC Designations—Areas designated as HAPC for this species are located north of the Study Area.

- **Atlantic Herring (*Clupea harengus*)**

Management—Atlantic herring EFH is designated by the NEFMC under the Atlantic Herring FMP (NEFMC 1998).

Status—Clupeids are among the most abundant and commercially important of the world's fishes. The Atlantic herring supports one the oldest and most important fisheries in the northwestern Atlantic (Overholtz 2000a). Atlantic herring are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Atlantic herring inhabits both sides of the North Atlantic Ocean in temperate and boreal waters (below 5°C [41°F]; Munroe 2002). In the western North Atlantic Ocean, this species ranges from Labrador, Canada to Cape Hatteras, North Carolina (Overholtz 2000a).

Habitat Associations—Atlantic herring are a pelagic schooling species found at various depths depending on lifestage, season, and location. Eggs are demersal, adhesive, and deposited on a variety of benthic habitats including boulders, rocks, gravel, shell fragments, and on macrophytes typically in water depths ranging from 20 to 80 m (65.6 to 262.5 ft). Larvae are pelagic and either remain at or near spawning sites for an extended periods (~months) or are dispersed by local currents (Reid et al. 1999). Larvae prefer waters with temperatures ranging from 6 to 16°C (42.8° to 60.8°F), salinities of 32 psu, and depths of 50 to 90 m (164 to 295 ft; Reid et al. 1999). Juveniles have a preference for water temperatures below 10°C (50°F), a salinity range of 26 to 32 psu and depths of 15 to 135 m (49 to 443 ft). Adults typically are found in waters with temperatures below 10°C (50°F), depths of 20 to 130 m (65.6 to 426.5 ft), and salinities above 28 psu (NEFMC 1998; Stevenson and Scott 2005).

Life History—Atlantic herring spawn in well-mixed waters with tidal currents ranging from 2.8 to 5.6 kph (1.7 to 3.5 mph), temperatures below 15°C (59°F), depths of 20 to 90 m (66 to 295 ft), and a salinity range of 32 to 33 psu. Atlantic herring spawn over a variety of substrates including rocks, shells, pebbles, gravel, and clay (Reid et al. 1999; Munroe 2002). Spawning occurs from July to November in relatively shallow waters. Known spawning locations are southwestern Nova Scotia, Georges Bank/Nantucket Shoals, and the Gulf of Maine (Reid et al. 1999). Adult and juvenile herring undergo complex and extensive north-south and inshore-offshore migrations to spawn, feed, or overwinter. In addition, herring undertake diel vertical migrations in response to light intensity (Reid et al. 1999; Munroe 2002).

Forage Species—Atlantic herring are opportunistic filter feeders, preying primarily on zooplankton (copepods and euphasiids) with larger fish also preying on shrimp. This species feeds in the upper layers of the water with peak feeding activity occurring at dusk and dawn (Munroe 2002).

EFH Designations—(NEFMC 1998; **Figure F-2**)

- Eggs—Designated EFH includes bottom habitats with substrates of gravel, sand, cobble, and shell as well as aquatic macrophytes in the Gulf of Maine, Georges Bank, and New England estuaries and embayments.

- **Larvae**—Designated EFH includes pelagic waters and bottom habitats within in the Gulf of Maine, Georges Bank, MAB south to New Jersey (~40°N), and New England and mid-Atlantic estuaries and embayments.

- **Juveniles**—Designated EFH includes pelagic waters and bottom habitats in the Gulf of Maine, Georges Bank, MAB south to Cape Hatteras, North Carolina, and New England and mid-Atlantic estuaries and embayments including Barnegat Bay adjacent to the Study Area.

- **Adults**—Designated EFH includes the pelagic waters and bottom habitats from the Gulf of Maine, Georges Bank, MAB south to Cape Hatteras, North Carolina, and New England and mid-Atlantic estuaries and embayments including Barnegat Bay adjacent to the Study Area.

- **Spawning Adults**—Designated EFH includes bottom habitats with substrate consisting of gravel, sand, cobble, and shell fragments as well as aquatic macrophytes located in the Gulf of Maine, Georges Bank, MAB south to Cape Hatteras, North Carolina, and New England estuaries and embayments.

HAPC Designations—There are no HAPC identified for this species.

♦ **Atlantic Mackerel *(Scomber scombrus)***

Management—The MAFMC designates EFH for the Atlantic mackerel through Amendment 8 to the Atlantic Mackerel, Squid, and Butterfish FMP (MAFMC 1998a).

Status—Atlantic mackerel are not classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Atlantic mackerel inhabits the North Atlantic Ocean, including the Baltic, Black, and Mediterranean seas. In the western North Atlantic Ocean, their distribution ranges from Black Island, Labrador, Canada to Cape Lookout, North Carolina (Collette 2002).

Habitat Associations—Atlantic mackerel are fast-swimming, pelagic schooling fish primarily found in the open sea but rarely occur beyond the continental shelf. Eggs are pelagic and have been collected from shore to a depth of 15 m (49.2 ft) in water temperatures between 5°C and 23°C (41.0°F and 73.4°F). Larvae are found at depths between 10 m and 130 m (49.0 ft and 426.5 ft) in water temperatures between 6°C and 22°C (42.8°F and 71.6°F). Atlantic mackerel juveniles are generally found from shore to a depth of 320 m (1,049.9 ft) and in water temperatures between 4°C and 22°C (39.2°F and 71.6°F). Adults inhabit waters from shore to 381 m (1,250 ft) and have a temperature preference range 4° to 16°C (39.2°F to 60.8°F) (Studholme et al. 1999). This species primarily inhabits open waters and does not depend directly on the coastline or bottom waters during any of its lifestages (Collette 2002). Adults overwinter in deeper waters between 70 m and 200 m (229.7 ft and 656.2 ft; Collette 2002).

Life History—Atlantic mackerel are serial spawners (spawning in bursts or pulses more than once in a spawning season) and utilize inshore areas to spawn (Collette 2002). Spawning occurs from April to July, peaking in mid-April off Chesapeake Bay and in May off New Jersey and Long Island, when water temperatures begin to warm and are between 9°C and 14°C (48.2°F and 57.2°F; Studholme et al. 1999; Collette 2002). In the southern Gulf of St. Lawrence, spawning occurs from the end of May to mid-August (Overholtz 2000b; Collette 2002).

Forage Species—Atlantic mackerel are opportunistic feeders that prey upon small fauna such as copepods, amphipods, mysid shrimp, decapod larvae, pelagic mollusks, euphausiids, and larvae of various other marine species. Larger mackerel are also capable of eating squid and fishes (silver hake, sand lance, herring, hake, and sculpin; Collette 2002).

EFH Designations—(MAFMC 1998b; **Figure F-3**)

- Eggs—Designated EFH are the pelagic waters found over the continental shelf in areas that comprise the highest 75 percent of the catch where Atlantic mackerel eggs were collected during the Marine Resources Monitoring, Assessment, and Prediction (MARMAP) ichthyoplankton surveys from the Gulf of Maine to Cape Hatteras, North Carolina. EFH is also designated within New England and mid-Atlantic estuaries and embayments.

- Larvae—Designated EFH are the pelagic waters found over the continental shelf in areas that comprise the highest 75 percent of the catch where Atlantic mackerel larvae were collected in the MARMAP ichthyoplankton surveys from the Gulf of Maine to Cape Hatteras, North Carolina. EFH is also designated within New England and mid-Atlantic estuaries and embayments.

- **Juveniles**—Designated EFH are the pelagic waters found over the continental shelf in areas that comprise the highest 75 percent of the catch where juvenile Atlantic mackerel were collected in the NEFSC trawl surveys, from the Gulf of Maine through Cape Hatteras, North Carolina. EFH is also designated within New England and mid-Atlantic estuaries and embayments."

- **Adults**—Designated EFH are the pelagic waters found over the continental shelf; in areas that comprise the highest 75 percent of the catch where adult Atlantic mackerel were collected in NEFSC trawl surveys, from the Gulf of Maine to Cape Hatteras, North Carolina. EFH is also designated within New England and mid-Atlantic estuaries and embayments.

HAPC Designations—There are no HAPC identified for this species.

♦ **Atlantic Surfclam (*Spisula solidissima*)**

Management—Atlantic surfclam EFH is designated by the MAFMC under Amendment 12 to the Atlantic Surfclam and Ocean Quahog FMP of the MAFMC (1998b).

Status—Atlantic surfclam are not classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Atlantic surfclam is distributed in the northwestern North Atlantic Ocean continental shelf waters from the southern Gulf of St. Lawrence, Canada to Cape Hatteras, North Carolina (Cargnelli et al. 1999a). Concentrations of this species are found on Georges Bank, south of Cape

Cod, Massachusetts, off Long Island, New York, and southern New Jersey, and off the Delmarva Peninsula (Delaware Bay to Chesapeake Bay; Cargnelli et al. 1999a).

Habitat Associations—Eggs and larvae are dispersed by currents and settlement corresponds with the relaxation of upwelling events (Cargnelli et al. 1999a). Juvenile and adult lifestages are benthic and are found in sandy substrates at depths from 8 to 66 m (26.0 to 216.5ft; Cargnelli et al. 1999a).

Life History—Atlantic surfclams spawn in summer and early fall usually in waters with temperatures warmer than 15°C (59°F; Cargnelli et al. 1999a). In Virginia, spawning occurs from May to the end in July (Cargnelli et al. 1999a). Atlantic surfclams are sedentary and do not migrate or exhibit seasonal movements (Ropes et al. 1982).

Forage Species—Atlantic surfclams are opportunistic filter feeders that feed upon plankton as small as 4 µm (39.4 microinches [µ in]) in diameter (Cargnelli et al. 1999a).

EFH Designations—(MAFMC 1998a; **Figure F-4**)

- **Juveniles and Adults**—Designated EFH are substrates (to a depth of 1 m [3.3 ft] below the water-sediment interface) that encompass the highest 90 percent of catch during the NEFSC surflclam dredge surveys, from the eastern edge of Georges Bank and Gulf of Maine through Cape Hatteras, North Carolina.

HAPC Designations—There are no HAPC identified for this species.

- **Black Sea Bass (*Centropristis striata*)**

Management—Atlantic black sea bass are managed as two separate stocks divided north and south of Cape Hatteras, North Carolina. The northern stock has EFH designated by the MAFMC under Amendment 12 to the Summer Flounder, Scup, and Black Sea Bass FMP (MAFMC and ASMFC 1998a). The southern black sea bass stock, which occurs between Cape Hatteras, North Carolina and Cape Kennedy, Florida, is managed by the SAFMC and does not have EFH designated in the Study Area (SAFMC 1998).

Status—The northern black sea bass stock is not classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Black sea bass are found from southern Nova Scotia and Bay of Fundy, Canada to Cape Canaveral, Florida, and in the Gulf of Mexico (Steimle et al. 1999a; Klein-MacPhee 2002b).

Habitat Associations—Black sea bass are usually found in deeper waters (up to 165 m [541 ft]) associated with structured habitats such as artificial reefs and shipwrecks on the continental shelf (Musick and Mercer 1977; Steimle et al. 1999a; Klein-MacPhee 2002b). Black sea bass also associate with multispecies fish assemblage that include scup and summer flounder (Steimle et al. 1999a; Klein-MacPhee 2002b). Adults and juveniles are common in estuaries with salinities greater than 12 psu (Klein-MacPhee 2002b). When inshore, black sea bass prefer hard bottom habitats around wrecks, while offshore they prefer ledges, banks, rocks, and coral habitats (Klein-MacPhee 2002b). Eggs are buoyant and found on the continental shelf from May to October, while larvae move to estuarine habitat, between New York and Virginia, to metamorphosize into juveniles. Larvae are initially benthic, but then become demersal and utilize structured inshore habitats such as sponge beds (MAMFC and ASFMC 1998a). Juveniles and adults usually prefer waters warmer than 6°C (MAMFC and ASFMC 1998a; Drohan et al. 2007).

Life History—Black sea bass from the northern stock seasonally migrate from inshore to offshore, typically traveling in small schools depending on water temperatures (Klein-MacPhee 2002b). As coastal waters cool below 14°C (57.2°F) in the fall, black sea bass migrate south and offshore to overwintering areas in deeper waters between central New Jersey and North Carolina (Musick and

Mercer 1977). In the spring, as bottom waters warm above 7°C (44.6°F), black sea bass then migrate inshore into coastal shallow areas and bays in the MAB. The southern stock of black sea bass is not known to make an extensive migration but may move away from shallow coastal areas during cold winters, especially in the Carolinas (Steimle et al. 1999a; Klein-MacPhee 2002b). The northern stock spawns on the continental shelf from May through October, peaking in June at depths from 18 to 45 m (59 to 148 ft), while the southern stock spawns in April and May (Musick and Mercer 1977; Klein-MacPhee 2002b).

Forage Species—Black sea bass prey upon crustaceans (lobster and crabs), mollusks (clams), worms, and fishes (anchovy, herring, seahorse, pipefish, cusk-eel, scup, sand lance, and windowpane flounder; Klein-MacPhee 2002b). Feeding activities increase after periods of spawning (Steimle et al. 1999a).

EFH Designations—(MAMFC and ASFMC 1998a; **Figure F-5**)

- Eggs—Designated EFH includes mid-Atlantic estuaries.
- **Larvae**—Designated EFH includes the pelagic waters found over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 90 percent of the area where black sea bass larvae were collected in MARMAP surveys (Gulf of Maine to Cape Hatteras, North Carolina). EFH is also designated within New England and mid-Atlantic estuaries."
- **Juveniles**—Designated EFH includes the demersal waters over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 90 percent of the area where black sea bass juveniles were collected by the NEFSC surveys (Gulf of Maine to Cape Hatteras, North Carolina). EFH is also designated within New England and mid-Atlantic estuaries including, Barnegat Bay and the New Jersey Inland Bays adjacent to the Study Area.
- **Adults**—Designated EFH includes the demersal waters over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 90 percent of all the area where black sea bass adults were collected by NEFSC surveys (Gulf of Maine to Cape Hatteras, North Carolina). EFH is also designated within New England and mid-Atlantic estuaries including Barnegat Bay and the New Jersey Inland Bays adjacent to the Study Area.

HAPC Designations—There are no HAPC identified for this species.

- **Bluefish (*Pomatomus saltatrix*)**

Management—East coast Bluefish are managed as a single stock, with EFH designated under Amendment 1 to the Bluefish FMP developed by the MAFMC and the ASMFC (MAFMC and ASMFC 1998b).

Status—Bluefish are not classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Bluefish are a schooling species found in most oceans of the world, except the eastern Pacific Ocean. This species lives in the waters over the continental shelf but may be found in brackish estuaries and nearshore waters (Klein-MacPhee 2002c). In the western Atlantic, bluefish range from Nova Scotia and Bermuda to Argentina, but is considered rare between southern Florida and northern South America (Fahay et al. 1999b).

Habitat Associations—Bluefish are a warm-water pelagic species that rarely are found in temperatures below 14°C (57.2°F). The species is found inshore in bays, beaches, and coastal habitats as well as offshore (Klein-MacPhee 2002c). Bluefish eggs and larvae are pelagic and are typically found in waters with temperatures above 18°C (64.4°F) and salinities greater than 30 psu between April and August (MAFMC and ASMFC 1998b). Similar to other offshore spawning species, larvae are transported from spawning grounds to nursery habitats via the Gulf Stream Current (Hare and Cowen 1996). Juveniles utilize estuarine habitat in the MAB from May to October (MAFMC and ASMFC 1998b). Adult bluefish utilize offshore and estuarine habitats with water temperatures above 16°C (60.8°F; Fahay et al. 1999b). Adults typically are found in estuaries in the MAB from April to October (MAFMC and ASMFC 1998b; Shepherd and Packer 2006).

Life History—Adult bluefish are known to seasonally migrate both north-south and inshore-offshore. Bluefish move north during the spring through summer and southward and offshore during the fall and winter, when their highest abundance is found off New York and coastal southern New England (Klein and MacPhee 2002c). Bluefish overwinter in the South Atlantic Bight (SAB), between Florida and the Gulf Stream. Fluctuations in light levels and water temperature are the primary triggers for migrational movements, but offshore and inshore migrations occur because of prey availability (Klein-MacPhee 2002c). There are two discrete spawning events for western Atlantic bluefish: 1) a spring spawning event occurs near the edge of the continental shelf in the SAB during March through May and 2) a summer spawning event occurs over the mid-continental shelf in the MAB between June and August in waters with temperatures between 18°C and 25°C (64.4°F and 77°F) and salinities from 25 to 31 psu (Fahay et al. 1999b; Klein-MacPhee 2002c).

Forage Species—Bluefish are piscivorous feeding on a variety of species including Atlantic menhaden, herring, alewife, anchovy, eel, sculpin, killifish, silverside, croaker, scup, goby, sand lance, butterfish, and mackerel. This species also feeds on invertebrates (shrimp, squid, crabs, and worms; Klein-MacPhee 2002c).

EFH Designations—(MAFMC and ASMFC 1998b; **Figure F-6**)

- **Eggs**—Designated EFH are the pelagic waters located within the mid-shelf depths of the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 90 percent of the area where bluefish eggs were collected by MARMAP surveys (Montauk Point, New York, south to Cape Hatteras, North Carolina). Designated EFH also includes the pelagic waters between Cape Hatteras, North Carolina, and Key West, Florida.

- **Larvae**—Designated EFH are the pelagic waters (most commonly above 15 m [49.2 ft]) over the continental shelf (from the coast out to the limits of the EEZ) that encompass the highest 90 percent of the area where bluefish larvae were collected by MARMAP surveys (Montauk Point, New York, south to Cape Hatteras, North Carolina). Designated EFH also includes the “Slope Sea” (between the continental shelf and north wall of the Gulf Stream) and Gulf Stream Current between latitudes 29° and 40°N to the limits of the U.S. EEZ. Additional EFH includes the waters south of Cape Hatteras, North Carolina, to Key West, Florida.

- **Juveniles**—Designated EFH are the pelagic waters found over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 90 percent of the area where bluefish juveniles were collected by NEFSC trawl surveys (from Nantucket Island, Massachusetts, south to Cape Hatteras, North Carolina). Designated EFH also includes the “Slope Sea” (the oceanic area located between the continental shelf and north wall of the Gulf Stream) and the Gulf Stream Current between latitudes 29° and 40°N to the U.S. Additional designated EFH includes the waters south of Cape Hatteras, North Carolina, to Key West, Florida as well as all north Atlantic, mid-Atlantic, and southeast Atlantic estuaries.

- **Adults**—Designated EFH are the pelagic waters found over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 90 percent of all the area where bluefish adults were collected by the NEFSC trawl surveys (from Cape Cod Bay, Massachusetts, south to Cape Hatteras, North Carolina). Additional designated EFH includes the waters from Cape Hatteras, North Carolina to Key West, Florida as well as all north Atlantic, mid-Atlantic, and southeast Atlantic estuaries.

HAPC Designations—There are no HAPC identified for this species.

- **Butterfish (*Peprilus triacanthus*)**

Management—Butterfish have EFH designated under Amendment 8 to the Atlantic Mackerel, Squid, and Butterfish FMP by the MAFMC (MAFMC 1998b).

Status—Butterfish are classified as overfished; however, overfishing is not occurring (NMFS 2008d).

Distribution—In the western North Atlantic Ocean, butterfish range from the Gulf of St. Lawrence and the southern coast of Newfoundland, Canada to deeper waters off Florida. The species is common between Nova Scotia, Canada, and Cape Hatteras, North Carolina (Colton 1972; Klein-MacPhee 2002d).

Habitat Associations—All lifestages of the butterfish are common from the outer continental shelf to the lower, high salinity portions of bays and estuaries. Butterfish eggs are buoyant and pelagic and found between June and August (Waring and Murawski 1982; Klein-MacPhee 2002d). Eggs are generally found in surface waters with temperatures ranging from 6° to 26°C (42.8° to 78.8°F), salinities of 25 to 33 psu, and depths of 10 to 1,250 m (33 to 4,101 ft; most common in water of <200 m [656 ft]; Cross et al. 1999). As larval butterfish develop, they become more nektonic (i.e., able to actively swim) than planktonic (i.e., passively floating) (Cross et al. 1999). Larval butterfish often associated with large jellyfish and *Sargassum* and other flotsam (Waring and Murawski 1982; Cross et al. 1999; Klein-MacPhee 2002d). Larvae are found from April to December at temperatures between 4.4°C and 27.9°C (40°F and 82°F), salinities of 6.4 to 37.4 psu, and depths of 10 to 1,750 m (33,0 to 5,741.2 ft); most found in water <120 m [394 ft]) (Waring and Murawski 1982; Cross et al. 1999). As juveniles, butterfish depart shelters and begin schooling (Klein-MacPhee 2002d). They are found in a variety of areas, habitats, and conditions over sandy and muddy substrates, temperatures from 4.4° to 29.7°C (40.0° to 85.5°F), salinities from 3 to 37.4 psu, and depths from 10 to 330 m (33 to 1,083 ft; most often found in <120 m [394 ft]; Cross et al. 1999). Adult schools are found throughout the water column from surface waters to deep waters (420 m [1,378 ft]). They are found in a variety of benthic bottoms including sand, sand-silt, and mud substrates (Cross et al. 1999). They are eurythermal and euryhaline, tolerating temperatures from 4.4° to 29.7°C (40.0° to 85.5°F) and salinities from 3.8 to 33 psu (Cross et al. 1999; Klein-MacPhee 2002d).

Life History—Butterfish are broadcast spawners (Klein-MacPhee 2002d). Spawning occurs in nearshore waters of the MAB and SAB annually from late January to July (Rotunno and Cowen 1997). Butterfish are sensitive to temperature; spawning does not occur in waters less than 15°C (59°F; Colton 1972). Butterfish north of Cape Hatteras, North Carolina, undergo seasonal migrations when water temperature change with the season. In general, butterfish move northward and inshore in the summer and southward and offshore during the winter (Klein-MacPhee 2002d).

Forage Species—Butterfish feed on a variety of invertebrates but primarily on tunicates, sea squirts, salps, and sea angels (Klein-MacPhee 2002d).

EFH Designations—(MAFMC 1998b; **Figure F-7**)

- Eggs—Designated EFH are the pelagic waters found over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 75 percent of the area where butterfish eggs were collected by the MARMAP surveys (from the Gulf of Maine through Cape Hatteras, North Carolina). EFH is also designated within New England and mid-Atlantic estuaries.

- **Larvae**—Designated EFH are the pelagic waters found over the continental shelf (from the coast out to the limits of the EEZ) in areas that encompass the highest 75 percent of the area where butterfish larvae were collected by the NEFSC trawl surveys (from the Gulf of Maine through Cape Hatteras, North Carolina). EFH is also designated within New England and mid-Atlantic estuaries.

- **Juveniles**—Designated EFH are the pelagic waters found over the continental shelf (from the coast out to the limits of EEZ) in areas that encompass the highest 75 percent of the area where butterfish juveniles were collected by NEFSC trawl surveys (shelf from the Gulf of Maine through Cape Hatteras, North Carolina). EFH is also designated in New England and mid-Atlantic estuaries including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- Adults—Designated EFH are the pelagic waters found over the continental shelf (from the coast out to limits of EEZ) in areas that encompass the highest 75 percent of the area where butterfish adults were collected by the NEFSC trawl surveys (from the Gulf of Maine through Cape Hatteras, North Carolina). EFH is also designated within New England and mid-Atlantic.

HAPC Designations—There are no HAPC identified for this species.

♦ **Clearnose Skate (*Raja eglanteria*)**

Management—Clearnose skates have EFH designated under the NEFMC Final FMP for the NE Skate Complex (NEFMC 2003a).

Status—Clearnose skate are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Clearnose skate are found along the eastern U.S. coast from the Nova Scotia Shelf to northeastern Florida; including the northern Gulf of Mexico (northwestern Florida to Texas) (McEachran and Musick 1975). In the western North Atlantic Ocean, clearnose skate are mostly found south of Cape Hatteras, North Carolina, but can also be found north of Cape Hatteras, North Carolina, during warmer months (McEachran and Musick 1975).

Habitat Associations—Clearnose skate are a benthic species that prefers mud and sand substrates along the continental shelf, but can also be found on rocky or gravel bottoms (Packer et al. 2003a). The species is found from shallow inshore waters out to depths of 330 m (1,049.9 ft); however, is most abundant at depths less than 111 m (364 ft; McEachran and Musick 1975; McEachran 2002). Juveniles and adults inhabit waters with temperatures ranging from 9° to 30°C (48.2° to 86.0°F; Packer et al. 2003a).

Life History—Limited information is available regarding the species' spawning habitat; however, in Delaware Bay, incubation time for the egg capsules (known as "mermaid's purses") had been reported to approximately three months, with spawning occurring in the spring (McEachran 2002; Packer et al. 2003a). As water temperatures begin to cool, individuals north of Cape Hatteras, North Carolina, move offshore and southward, while those south of Cape Hatteras do not usually move to deeper waters during the winter since water temperatures do not significantly fluctuation (McEachran and Musick 1975).

Forage Species—Clearnose skates feed on a variety of invertebrate (shrimp, amphipods, mollusks, and squid) and fish species (anchovy, croaker, spot, tonguefish, weakfish, and butterfish), with crabs being the primary component of their diet (McEachran 2002; Packer et al. 2003a).

EFH Designations—(NEFMC 2003a; **Figure F-8**)

- Eggs—There is no information available on the offshore habitat association or distributions of the egg stage for this species. The following embayments and estuaries are designated as EFH for this lifestage: Hudson River/Raritan Bay and Chesapeake Bay north and south of the Study Area.

- Larvae—No larval stage exists for this species. Upon hatching, they are fully developed juveniles.

- **Juveniles**—Designated EFH includes bottom habitats with substrates consisting of soft bottom along the continental shelf and rock or gravel bottom from the Gulf of Maine south along the continental shelf to Cape Hatteras, North Carolina. The following embayments and estuaries are designated as EFH: Hudson River/Raritan Bay and Chesapeake Bay north and south of the Study Area.

- **Adults**—Designated EFH includes bottom habitats with a substrate of soft bottom along the continental shelf and rock or gravel bottom from the Gulf of Maine south along the continental shelf to Cape Hatteras, North Carolina. Various mid-Atlantic embayments and estuaries are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area

- Spawning Adults—Designated EFH are the following estuaries and embayments: the Hudson River and Raritan Bay north of the Study Area.

HAPC Designations—There are no HAPC identified for this species.

- **Goosefish/Monkfish (*Lophius americanus*)**

Management—Goosefish currently have EFH designated under Amendment #1 to the Monkfish FMP and are separated into two stocks for management purposes (NEFMC 1998). The northern stock inhabits the Gulf of Maine and the northern Georges Bank. The southern stock ranges from southern Georges Bank to Cape Hatteras, North Carolina (Almeida et al. 1995; Richards 2000).

Status—Neither goosefish stock are classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Goosefish range from the Gulf of St. Lawrence and Newfoundland, Canada to the east coast of Florida; however, they are uncommon south of Cape Hatteras, North Carolina (Wood 1982; Caruso 2002).

Habitat Associations—Goosefish release their eggs in long mucous veils that float at the surface exposing them to currents, wind, and waves (Wood 1982; Steimle et al. 1999b; Caruso 2002). Eggs are found inshore and offshore on the continental shelf from March to September in waters with temperatures ranging from 4° to 18°C (39.2° to 64.4°F; Wood 1982; Steimle et al. 1999b). Larval goosefish are pelagic and found across the continental shelf at water temperatures ranging from 10° to 16°C (50.0° to 60.8°F) and depths of 30 to 90 m (98.5 to 295.0 ft; Steimle et al. 1999b). After transition from larval to juvenile, goosefish become benthic. Juveniles are found in bottom habitats at temperatures of 3° to 19°C (37.4° to 66.2°F), salinities of 32.6 to 33.9 psu, and at depths of 25 to 182 m (82 to 597 ft; Steimle et al. 1999b). Adult goosefish prefer hard sand, gravel and broken shell, pebble, and soft mud substrates at depths from just below the tide line to 840 m (2,756 ft), although large adults rarely occur below 400 m (1,312 ft; Almeida et al. 1995; Caruso 2002). They also prefer temperatures ranging from 0° to 24°C (32.0° to 75.2°F) and salinities of 30 to 36 psu (Almeida et al. 1995; Steimle et al. 1999b).

Life History—Goosefish spawn between spring and early fall, depending on latitude (Wood 1982). Spawning occurs from March to May off North Carolina, between May and June in the Gulf of Maine, and as late as September off Maine and in Canadian waters (Steimle et al. 1999b; Caruso 2002). Spawning occurs across the continental shelf throughout its range (Caruso 2002). Goosefish migrate inshore and offshore seasonally depending on the water temperatures. Larger goosefish (>20 cm [7.87 in]) in the Gulf of Maine move offshore in the winter and spring to avoid cold coastal conditions, and return inshore as the coastal waters warm in the summer and fall (Steimle et al. 1999b). Conversely, smaller goosefish (<20 cm [7.87 in]) in the Gulf of Maine and along the MAB remain inshore during the winter and spring and then move offshore during the summer and fall, presumably to avoid overly warm summer conditions (Wood 1982; Almeida et al. 1995; Steimle et al. 1999b).

Forage Species—Goosefish feed on benthic prey, such as bony fishes (silver hake, red hake, American plaice [*Hippoglossaides platessoides*], little skate, red hake, sand lance, and herring species), cephalopods (squid), and elasmobranches. They have also been recorded to feed on various seabird species. This species uses its angling apparatus (modified first dorsal spine) to lure small fishes (Caruso 2002).

EFH Designations—(NEFMC 1998; **Figure F-9**)

- **Eggs**—Designated EFH consists of surface waters from the Gulf of Maine, Georges Bank, and MAB south to Cape Hatteras, North Carolina.

- **Larvae**—Designated EFH consists of the pelagic waters from the Gulf of Maine, Georges Bank, and MAB south to Cape Hatteras, North Carolina.

- **Juveniles**—Designated EFH consists of bottom habitats that are a sand-shell mix, algae-covered rocks, hard sand, pebbly gravel, or mud from the outer continental shelf of the MAB south to Cape Hatteras, North Carolina, and all bottom areas of the Gulf of Maine.

- Adults—Designated EFH consists of bottom habitats that are a sand-shell mix, algae-covered rocks, hard sand, pebbly gravel, or mud from the outer continental shelf of the MAB south to Cape Hatteras, North Carolina. It also consists of the outer perimeter of Georges Bank and all benthic areas of the Gulf of Maine.

- Spawning Adults—Designated EFH consists of the bottom habitats that are a sand-shell mix, algae-covered rocks, hard sand, pebbly gravel, or mud from the outer continental shelf of the MAB, the outer perimeter of Georges Bank, and all benthic areas of Gulf of Maine.

HAPC Designations—There are no HAPC identified for this species.

- **Little Skate (*Leucoraja erinacea*)**

Management—Little skate EFH is designated under the NEFMC Final FMP for the NE Skate Complex (NEFMC 2003a).

Status—Little skates are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—The little skate ranges from Nova Scotia to Cape Hatteras, North Carolina with its center of abundance occurring on Georges Bank and in coastal waters south to the mouth of Chesapeake Bay (McEachran 2002; Packer et al. 2003b).

Habitat Associations—Little skate juveniles and adults typically utilize sand, gravel, or mud substrates (McEachran and Musick 1975; Packer et al. 2003b). They have been associated with microhabitat features including biogenic depressions and flat sand during the day with their abunances increasing in the spring and fall (Packer et al. 2003b). Little skate are found at deep depths (384 m [1,260 ft]), but are most common at depths less than 111 m [364 ft], especially in the northern section of the MAB (McEachran and Musick 1975). Little skate eggs are found in waters with temperatures warmer than 7°C (44.6°F) and depths less than 27 m (88.6 ft), while juveniles prefer temperatures between 4°C and 15°C (39.2°F and 59.0°F) and depths from shore to 137 m (449 ft) deep (NEFMC 2003a).

Life History—Egg cases, known as a “mermaid’s purse,” are found partially to fully developed year-round, but are most abundant from late October to January and from June to July (McEachran 2002; Packer et al. 2003b). Little skates do not undertake extensive seasonal migrations, but instead move inshore and offshore, along with north-south movements along the southern end of its range, in response to seasonal temperature changes (McEachran and Musick 1975). Little skate typically moves to deep waters in December and January and migrates to shallow waters in April and May (McEachran 2002).

Forage Species—Little skate prey upon benthic invertebrates (shrimp, crabs, and worms) and fishes (herring, alewife, tomcod [*Microgadus tomcod*], silver hake, sculpin, silverside, Atlantic wolffish [*Anarhichas lupus*], sand lance, cunner [*Tautogolabrus adspersus*], winter flounder, and yellowtail flounder; McEachran 2002; Packer et al. 2003b).

EFH Designations—(NEFMC 2003a; **Figure F-10**)

- **Eggs**—Designated EFH consists of bottom habitats with a sandy substrate from Georges Bank and MAB south to Cape Hatteras, North Carolina. Southern New England and mid-Atlantic embayments and estuaries are designated EFH.
- Larvae—No larval stage exists for this species. Upon hatching, they are fully developed juveniles.
- **Juveniles**—Designated EFH consists of bottom habitats with a sand or gravel substrate from Georges Bank through the MAB to Cape Hatteras, North Carolina that encompass the highest 90 percent where this species was collected during NMFS trawl surveys. Southern New England and mid-Atlantic embayments and estuaries are designated EFH
- **Adults**—Designated EFH conisist of bottom habitats with a sand, gravel, or mud substrate. It ranges from Georges Bank through the MAB to Cape Hatteras, North Carolina that encompass the highest 90 percent where this species was collected during NMFS trawl surveys. Southern New England and mid-Atlantic embayments and estuaries are designated EFH including Barnegat Bay and New Jersey Inland Bays adjacent ot he Study Area.
- Spawning Adults—Designated EFH includes the following southern New England and mid-Atlantic embayments and estuaries: Buzzards Bay, Narragansett Bay, Long Island Sound, and Hudson River/Raritan Bay north of the Study Area.

HAPC Designations—There are no HAPC identified for this species.

- **Longfin Inshore Squid (*Loligo pealei*)**

Management—The population of longfin inshore squid from southern Georges Bank to Cape Hatteras, North Carolina have EFH designated by MAFMC under Amendment 8 to the Atlantic Mackerel, Squid, and Butterfish FMP (MAFMC 1998b).

Status—Longfin inshore squid are neither classified as overfished, nor subject to overfishing (NMFS 2008d).

Distribution—This pelagic, schooling species is found across the continental shelf and slope from Newfoundland, Canada to the Gulf of Venezuela, South America. It is abundant from Georges Bank to Cape Hatteras, North Carolina (Lange 1982; Cargnelli et al. 1999b).

Habitat Associations— Longfin inshore squid are found on mud or sand/mud substrate in waters with temperatures warmer than 8°C (46.4°F; Lange and Sissenwine 1980; Cargnelli et al. 1999b; Jacobson 2005). Demersal egg masses are commonly found attached to rocks and small boulders on sandy-muddy bottom and on aquatic vegetation in waters with temperatures colder than 8°C (46.4°F; Cargnelli et al. 1999b). Larvae are pelagic and are found near the surface at temperatures between 10°C and 26°C (50.0°F and 78.8°F; Vecchione 1981). Juveniles are usually found in the upper 10 m (33 ft) of the water column over water 50 to 100 m (164 to 328 ft) deep and prefer water temperatures ranging from 10° to 26°C (50.0° to 78.8°F; Cargnelli et al. 1999b). Adults are found in waters over the continental shelf and upper continental slope to depths of 400 m (1,312 ft; Cargnelli et al. 1999b). This species displays a diel migration pattern. It is typically demersal during the day and utilizes the water column at night (Vecchione 1981).

Life History—Longfin inshore squid seasonally migrate inshore and offshore as temperatures change; squid move offshore during late fall to overwinter along the edge of the continental shelf and moving inshore during the spring and early summer to spawn (Lange 1982; MAFMC 1998b). During winter and early spring when inshore waters are coldest, longfin inshore squid are most common along the outer edge of the continental shelf where waters are 9° to 13°C (48.2° to 55.4°F). The inshore movement to the shelf region begins when water temperatures start warming (Cargnelli et al. 1999b; MAFMC 1998b). Longfin inshore squid spawn from April to November (Cargnelli et al. 1999b) with peak spawning in May. Most eggs hatch during the summer around July (Lange and Sissenwine 1980).

Forage Species—This species feeds on crustaceans (crabs, worms, and shrimp) and small fishes (silver hake, sand lance, anchovy, weakfish, silversides, mackerel, herring, and Atlantic menhaden). Longfin inshore squid have also been recorded engaged in cannibalism. While inshore, they prey primarily on fish, and when offshore, they feed upon fishes, squid, and crustaceans (Cargnelli et al. 1999b).

EFH Designations—(MAFMC 1998b; **Figure F-11**)

- **Juveniles** (±8 cm [3.1 in])—Designated EFH are the pelagic waters found over the continental shelf in areas that comprise the highest 75 percent of the catch where juvenile longfin inshore squid were collected by the NEFSC trawl surveys (from the Gulf of Maine to Cape Hatteras, North Carolina).

- **Adults** (>8 cm [3.1 in])—Designated EFH are the pelagic waters found over the continental shelf in areas that comprise the highest 75 percent of the catch where recruited adult longfin inshore squid were collected by the NEFSC trawl surveys (from the Gulf of Maine to Cape Hatteras, North Carolina).

HAPC Designations—There are no HAPC identified for this species.

- **Ocean Pout (*Zoarces americanus*)**

Management—EFH for the ocean pout is designated by the NEFMC under Final Amendment #11 to the NE Multispecies FMP (NEFMC 1998). Two separate stocks have been suggested based on stock identification studies. The first stock is found within the region of the Bay of Fundy and the northern Gulf of Maine, while the second stock ranges from Cape Cod Bay, Massachusetts south to Delaware (Wigley 2000).

Status—Ocean pout are classified as overfished; however, overfishing is not occurring (NMFS 2008d).

Distribution—Ocean pout commonly are found from Labrador and the southern Grand Banks, Canada to Maryland (Dunaway 2001), but can also be found in the deeper, cooler waters south of Cape Hatteras, North Carolina (Steimle et al. 1999c).

Habitat Associations—Ocean pout lay demersal eggs in gelatinous clumps in sheltered areas where they are guarded and protected by either one or both sexes (Steimle 1999c; Wigley 2000). Once the eggs hatch, larvae remain near the sheltered area throughout the duration of the transition stage. As juveniles ocean pout disperse along the shallow, coastal waters. They are typically found in association with rocks and attached algae (Klein-MacPhee and Collette 2002). Adults are commonly found in deep, cooler waters (3° to 14°C [37.4° to 57.2°F]) of the continental shelf and the upper continental slope (Clark and Livingstone 1982; Steimle et al. 1999c).

Life History—Ocean pout spawning occurs in late summer through early winter. Peak spawning occurs in September and October and earlier (August through October) in the southern part of their range. Ocean pout spawn on hard bottom, sheltered areas (Klein-MacPhee and Collette 2002), including rock crevices, artificial reefs, and shipwrecks, at depths of less than 50 m (164 ft) and temperatures of 10°C (50°F) or colder (Clark and Livingstone 1982; Steimle et al. 1999c). Although ocean pout move seasonally within a region, this species is considered non-migratory (Klein-MacPhee and Collette 2002) and seasonal inshore/offshore movements are not extensive (Wigley 2000).

Forage Species—Ocean pout prey primarily on mollusks, crustaceans (crabs), echinoderms (sand dollars, brittle stars, and sea urchins), and other invertebrates, and less commonly, on fishes and fish eggs. This species feeds primarily near the bottom and during the daytime (Klein-MacPhee and Collette 2002).

EFH Designations—(NEFMC 1998; **Figure F-12**)

- **Eggs, Larvae, and Adults**—Designated EFH are primarily hard bottom habitats, on the continental shelf from the Gulf of Maine, Georges Bank, and MAB south to Delaware Bay. Southern New England estuaries and embayments are designated as EFH.
- **Juveniles**—Designated EFH are bottom habitats consisting of smooth bottom near rocks or algae from the Gulf of Maine, Georges Bank, and MAB south to Delaware Bay. Southern New England estuaries and embayments are designated as EFH,
- **Spawning Adults**—Designated EFH are bottom habitats wit ha hard bottom substrate including artificial reefs and shipwrecks from the Gulf of Maine, Georges Banks, and MAB south to Delaware Bay. Southern New England estuaries and embayments are designated as EFH.

HAPC Designations—There are no HAPC identified for this species.

♦ **Ocean Quahog (*Arctica islandica*)**

Management—Ocean quahog EFH is designated under Amendment 12 to the Atlantic Surfclam and Ocean Quahog FMP of the MAFMC (1998a).

Status—Ocean quahog is neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—The ocean quahog is found in temperate and boreal waters occurring on both sides of the north Atlantic (Serchuk et al. 1982). In the northwestern Atlantic Ocean, ocean quahog are found on the continental shelf from Newfoundland, Canada to Cape Hatteras, North Carolina (Mann 1982; Weinberg 2001b).

Habitat Associations—Ocean quahog egg and larval stages are planktonic and are subject to dispersal by currents (Cargnelli et al. 1999c). Following metamorphosis, juveniles settle to the bottom, displaying a preference for sand substrates in offshore waters, but also inhabit mud intertidal environments (Cargnelli et al. 1999c). Ocean quahog are generally found in waters with salinities ranging from 32 to 34 psu at depths between 45 m and 75 m (148 ft and 246 ft). Adults typically congregate in dense beds, just below the sediment surface. Ocean quahog prefer silty or fine to medium grade sand substrates as habitat (Serchuk et al. 1982; Cargnelli et al. 1999c).

Life History—Ocean quahog spawning is protracted. Spawning begins in the spring and ends in the fall. Ocean quahog display multiple spawning events which occur at the individual and population level (Mann 1982; Cargnelli et al. 1999c). The spawning season begins in late spring or early summer when water temperatures reach 13.5°C (56.3°F). Peak ocean quahog spawning occurs from August to early October (Serchuk et al. 1982). Adult quahogs do not exhibit seasonal movements (Serchuk et al. 1982).

Forage Species—Ocean quahogs are filter feeders that primarily consume phytoplankton (Cargnelli et al. 1999c).

EFH Designations—(MAFMC 1998a; **Figure F-13**)

- **Juveniles and Adults**—Designated EFH consist of the bottom substrates (to a depth of 1 m [3.3 ft] below the water-sediment interface in areas) that encompass the top 90 percent of the NEFSC surfclam and ocean quahog dredge surveys (from the eastern edge of Georges Bank and the Gulf of Maine) throughout the Atlantic U.S. EEZ.

HAPC Designations—There are no HAPC identified for this species.

- **Red Hake (*Urophycis chuss*)**

Management—Red hake EFH is designated by the NEFMC under Final Amendment #11 to the Northeast Multispecies FMP (NEFMC 1998). The red hake is divided into two separate stocks (northern and southern separated by the central axis of Georges Bank) in U.S. waters (NEFMC 1999b).

Status—Red hake (southern Georges Bank/Mid-Atlantic) are not classified as overfished; however, it is undefined and unknown whether overfishing is occurring (NMFS 2008d).

Distribution—Red hake are found in the coastal waters off southern Newfoundland, Canada to North Carolina, with peak abundance occurring along Georges Bank, in the Gulf of Maine off Cape Cod, and in the northern MAB off Long Island, New York. In addition, all lifestages of red hake are also found in estuaries from southern Maine to Chesapeake Bay (Steimle et al. 1999d).

Habitat Associations—Red hake eggs are pelagic and buoyant and are most common off Georges Bank, Canada, and southern New England coast during May and June (Klein-MacPhee 2002e). Larvae are found from May to December on Georges Bank and southern New England, but are most numerous during September and October (Klein-MacPhee 2002e). In the MAB, larvae are found in waters with temperatures ranging from 8° to 23°C (46.4° to 73.4°F) and at depths between 10 m and 200 m (32.8 ft and 656.0 ft; Steimle et al. 1999d). Both eggs and larvae drift with the prevailing currents (Clark and Livingston 1982). Upon recruitment from the plankton to the benthos, juvenile red hake are commonly found in close association with benthic debris (e.g., shells, sponges, rocks), which serve as shelters at depths of 40 to 50 m (131 to 164 ft; Klein-MacPhee 2002e). Juvenile red hake prefer water temperatures between 4.2°C and 7.5°C (39.6°F and 45.5°F) and salinities of 31 to 32.8 psu. Adults prefer water temperatures ranging from 5° to 12°C (41.0° to 53.6°F) and salinities of 33 or 34 psu. Red hake prefer soft sediments and wide ranging depths between 35 m and 980 m (115.0 ft and 3,215.4 ft; Steimle et al. 1999d; Klein-MacPhee 2002e).

Life History—Red hake spawning grounds include: the southwest portion of Georges Bank, the continental shelf off southern New England, and eastern Long Island, New York. Spawning adults are commonly found in coastal bays between Narragansett Bay and Massachusetts Bay, but are uncommon to the north or the south of this range (Steimle et al. 1999d). Spawning occurs from April through November at water temperatures around 5° and 10°C (41° and 50°F Steimle et al. 1999d). Red hake undergo extensive seasonal migrations; they are found in coastal waters, typically less than 100 m (328 ft), during the warmer months and migrate further offshore (>100 m [328 ft]) during the colder months (Steimle et al. 1999d).

Forage Species—Red hake feed primarily on crustaceans (crab and shrimp) and other invertebrates (bivalves, squid, and worms) and secondarily on fishes (haddock, silver hake, sand lance, sea robin, and mackerel; Klein-MacPhee 2002h).

EFH Designations—(NEFMC 1998b; **Figure F-14**)

- **Eggs**—Designated EFH are the surface waters from the Gulf of Maine, Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, North Carolina.

- **Larvae**—Designated EFH are the surface waters from the Gulf of Maine, Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, North Carolina. New England and northern mid-Atlantic estuaries and embayments are designated as EFH.

- **Juveniles**—Designated EFH are bottom habitats with substrates consisting of shell fragments, including areas with an abundance of live scallops from the Gulf of Maine, Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, North Carolina. New England and mid-Atlantic estuaries and embayments are designated as EFH.

- Adults—Designated EFH are bottom habitats in depressions with substrates consisting of sand and mud from the Gulf of Maine, Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, North Carolina. New England and mid-Atlantic estuaries and embayments are designated as EFH.

- Spawning Adults—Designated EFH are the bottom habitats in depressions with a substrates consisting of sand and mud from the Gulf of Maine, the southern edge of Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, New England and northern mid-Atlantic estuaries and embayments are designated as EFH.

HAPC Designations—There are no HAPC identified for this species.

- **Scup (*Stenotomus chrysops*)**

Management—The scup fishery has EFH designated jointly by the MAFMC and the ASMFC under Amendment 12 to the Summer Flounder, Scup, and Black Sea Bass FMP (MAFMC and ASMFC 1998a).

Status—Scup are classified as overfished and overfishing is occurring (NMFS 2008d).

Distribution—Scup are a continental shelf species found in the western North Atlantic Ocean that occurs primarily from Cape Cod, Massachusetts to Cape Hatteras, North Carolina (Morse 1982). Scup have been reported as far north as the Bay of Fundy and Sable Island Bank, Nova Scotia (Steimle et al. 1999e; Klein-MacPhee 2002f) and as far south as Florida (Manooch 1988).

Habitat Associations—During May through August, scup pelagic eggs are found in coastal waters of southern New England, including bays and sounds (Morse 1982; Steimle et al. 1999e). Larval scup are also pelagic and are found from May to September in coastal waters at temperatures ranging from 14° to 22°C (57.2° to 71.6°F). Both eggs and larvae are typically found in waters of less than 50 m (164 ft) in depth (Steimle et al. 1999e). During the transition of larvae into juveniles, the scup abandons the pelagic stage in favor of bottom habitats (Morse 1982). Juvenile scup prefer intertidal and subtidal habitats. During summer and fall, these areas include sand bottoms, mud bottoms, mussel beds, and eelgrass beds, while during winter and spring, juvenile scup are found on the continental shelf over habitats ranging from flat, open, sandy-silty bottoms to the heads of submarine canyons. Adult scup are commonly associated euryhaline waters with soft, sandy bottoms on or near structures including rock ledges, mussel beds, artificial reefs, and wrecks. Both juveniles and adults prefer waters with temperatures ranging between 5°C and 27°C (41.0°F and 80.6°F; Steimle et al. 1999e).

Life History—In the MAB, scup spawn once a year during the daytime and typically close to shore from May to August, with peaks occurring in June and July (Morse 1982; Steimle et al. 1999e; Klein-MacPhee 2002f). Migration times and overwintering localities vary from year to year depending on water temperatures. Scup migrate out of the inshore waters to the warmer, deeper waters of the outer continental shelf ranging in depth from 70 to 180 m (230 to 591 ft) south of Hudson Canyon off New

Jersey and along the coast from south of Long Island, New York to North Carolina (Tercerio 2001; Klein-MacPhee 2002f). Scup return to the inshore waters once the water temperatures begin to rise again in the spring (Steimle et al. 1999e). During the summer, scup are most common in most large estuaries and coastal areas (Klein-MacPhee 2002f).

Forage Species—Scup feed on benthic invertebrates (mollusks, crab, shrimp, squid, crustaceans, and worms) and fishes but rarely feed any higher in the water column (Klein-MacPhee 2002f).

EFH Designations—(MAFMC and ASMFC 1998a; **Figure F-15**)

- Eggs and Larvae—Designated EFH includes southern New England and mid-Atlantic estuaries and embayments.

- **Juveniles**—Designated EFH are the bottom waters from the coast out to the limits of the U.S. EEZ in areas that encompass the highest 90 percent of where juvenile scup were collected by the NEFSC trawl surveys (Gulf of Maine to Cape Hatteras, North Carolina). Southern New England and mid-Atlantic estuaries and embayments are designated EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Adults**—Designated EFH are the bottom waters from the coast out to the limits of the U.S. EEZ in areas that encompass the highest 90 percent of where juvenile scup were collected by the NEFSC trawl surveys (Gulf of Maine to Cape Hatteras, North Carolina). Southern New England and mid-Atlantic estuaries and embayments are designated EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

HAPC Designations—There are no HAPC identified for this species.

- **Silver Hake/Whiting (*Merluccius bilinearis*)**

Management—Two main stocks are recognized in U.S. coastal waters: a northern stock within waters of the Gulf of Maine and the northern portion of Georges Bank and a southern stock inhabiting the southern portion of Georges Bank to the MAB (Helser 1996; Brodziak 2001). Both stocks have EFH designated by the NEFMC under Final Amendment #11 to the Northeast Multispecies FMP (NEFMC 1998).

Status—Silver hake are neither overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Silver hake are found in the northwestern Atlantic from the southern edge of the Grand Banks off Newfoundland, Canada, and the Gulf of St. Lawrence south to Cape Fear, North Carolina, along the continental shelf (Klein-MacPhee 2002g). They are most commonly found in the waters of the Gulf of Maine, the Scotian Shelf, Georges Bank, off Long Island, New York, and the southern edge of the Grand Banks (Morse et al. 1999).

Habitat Associations—Silver hake eggs are pelagic and drift with the prevailing currents. Eggs are typically observed at temperatures between 5°C and 21°C (41.0°F and 69.8°F) and over bottom depths of 10 to 1,250 m (33.0 to 4,101.2 ft) over the continental shelf but are most abundant at depths of 50 to 150 m (164 to 492 ft; Lock and Packer 2004). The pelagic larval stage inhabits waters over the continental shelf between temperatures of 5°C and 16°C (41.0°F and 60.8°F) and at depths of 10 to 1,250 m (33.0 to 4,101.2 ft), although they are most common in depths of 50 to 130 m (164.0 to 426.5 ft; Lock and Packer 2004). During the transition between larvae and juveniles, silver hake drop out of the plankton and settle into the benthic habitat (Steves and Cowen 2000; Lock and Packer 2004). While juvenile silver hake are found over a wide range of temperatures and depths on the continental shelf (Lock and Packer 2004), they display a preference for bottom temperatures between 8°C and 10°C (46.4°F and 50.0°F) and depths of 60 to 100 m (197 to -328 ft; Steves and Cowen 2000). Adults have been observed in waters ranging from 3° to 18°C (37.4° to 64.4°F) in temperature, although they are most common between 7°C to 17°C (44.6°F and 62.6°F). Silver hake are nocturnal hunters, and during the day they are believed to rest on the bottom, on sand or pebbly bottom or on mud, but seldom over rocks. During the night, silver hake can be found throughout the water column in pursuit of prey with no limits to their vertical movements (Klein-MacPhee 2002g; Lock and Packer 2004).

Life History—During feeding and spawning, silver hake are often found in dense schools. Spawning extends throughout the year and peaks between May and August (Brodziak 2001; Klein-MacPhee 2002g). Primary spawning activity occurs along the southeastern and southern slopes of Georges Bank, around Nantucket Shoals, and south of Martha's Vineyard to Cape Hatteras, North Carolina (Klein-MacPhee 2002g). Silver hake migrate in response to seasonal changes in water temperatures. During the spring, silver hake migrate into shallow water where spawning takes place throughout late spring and early summer. When autumn arrives, the fish move back into the deeper waters of the Gulf of Maine and the outer continental shelf and slope waters (Brodziak 2001).

Forage Species—Silver hake prey upon crustaceans, fishes (anchovy, herring, lanternfish, mackerel, sand lance, and butterfish), and squid (Klein-MacPhee 2002g).

EFH Designations—(NEFMC 1998; **Figure F-16**)

- **Eggs and Larvae**—Designated EFH are the surface waters from the Gulf of Maine, Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, North Carolina. Southern New England estuaries and embayments are designated as EFH.

- **Juveniles, Adults, and Spawning Adults**—Designated EFH are the bottom habitats off all substrates from the Gulf of Maine, on Georges Bank, and the continental shelf of the MAB south to Cape Hatteras, North Carolina. Southern New England estuaries and embayments are designated as EFH.

HAPC Designations—There are no HAPC identified for this species.

- **Spiny Dogfish (*Squalus acanthias*)**

Management—Spiny dogfish have EFH designated under the joint management of the MAFMC and the NEFMC through the Spiny Dogfish FMP (MAFMC and NEFMC 1999).

Status—Spiny dogfish are neither classified as overfished, nor is overfishing occurring (NMFS 2008d). According to the 2008 IUCN Red List, spiny dogfish is classified as vulnerable (Fordham et al. 2006).

Distribution—In the western North Atlantic Ocean, the spiny dogfish ranges from Greenland to southern Florida and Cuba, but is most abundant between Newfoundland, Canada, and Georgia (Nammack et al. 1985).

Habitat Associations—Spiny dogfish are ovoviviparous and eggs develop internally (Burgess 2002). The offspring, known as pups, are born live as fully developed juveniles following a gestation period of two years (Cohen 1982). Both juvenile and adult spiny dogfish are epibenthic, but move throughout the water column. They inhabit nearshore shallow waters out to depths of 900 m (2,952.9 ft) along the inshore and offshore continental shelf (Burgess 2002; Stehlik 2007).

Life History—Spiny dogfish spawn in the winter in offshore waters (Cohen 1982; Burgess 2002). Parturition occurs between November and January in offshore wintering grounds but can occur as late as May in areas of colder temperatures (Nammack et al. 1985; McMillan and Morse 1999; Burgess 2002). Spiny dogfish migrate north in the spring and summer, typically north of Cape Cod, Massachusetts and return south again in the fall and winter, usually off of the North Carolina coast (McMillan and Morse 1999). Seasonal inshore-offshore migrations are also common for this species and are related to water temperature. Spiny dogfish overwinter in deeper offshore waters and move into the nearshore shallow waters during the summer (McMillan and Morse 1999; Burgess 2002).

Forage Species—Spiny dogfish are very aggressive piscivores that feed primarily on fishes, such as mackerel, herring, Atlantic menhaden, sand lance, capelin (*Mallotus villosus*), wolffish, flatfish species, Atlantic cod, and haddock. They also consume mollusks, crustaceans, and other invertebrates (Burgess 2002).

EFH Designations—(MAFMC and NEFMC 1999; **Figure F-17**)

- **Juveniles**—Designated EFH are the waters off the continental shelf in areas that encompass the highest 90 percent of the area where juvenile dogfish were collected by the NEFSC trawl surveys (Gulf of Maine through Cape Hatteras, North Carolina). New England estuaries and embayments are designated as EFH. Additional EFH is designated in waters with depths to 390 m (1,280 ft) south of Cape Hatteras, North Carolina, to Cape Canaveral, Florida.

- **Adults**—Designated EFH are the waters over the continental shelf in areas that encompass the highest 90 percent of the area where adult dogfish were collected by the NEFSC trawl surveys (Gulf of Maine through Cape Hatteras, North Carolina). New England estuaries and embayments are designated as EFH. Additional EFH is designated in waters with depths to 450 m (1,476 ft) south of Cape Hatteras, North Carolina, to Cape Canaveral, Florida.

HAPC Designations—There are no HAPC identified for this species.

- **Summer Flounder (*Paralichthys dentatus*)**

Management—The summer flounder stock has EFH jointly designated by the MAFMC and the ASMFC under Amendment 12 to the Summer Flounder, Scup, and Black Sea Bass FMP (MAFMC and ASMFC 1998a).

Status—Summer flounder are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Summer flounder range from Nova Scotia, Canada to Florida, but their occurrence north of Cape Cod, Massachusetts, and south of Cape Hatteras, North Carolina, is rare (Byrne and Arzarovitz 1982; Klein-MacPhee 2002h).

Habitat Associations—Summer flounder eggs are pelagic and occur over the continental shelf in waters with temperatures ranging from 9° to 23°C (48.2° to 73.4°F), although the majority of eggs have been observed between 12°C to 19°C (53.6°F to 66.2°F). Eggs are most common in the MAB between Long Island, New York, and Cape Hatteras, North Carolina, within 46 km (24.8 NM) of shore (Byrne and Arzarovitz 1982). The larvae are also pelagic and found primarily over the continental shelf. Larvae thrive in waters with temperatures between 0°C and 23°C (32.0°F and 73.4°F) but appear with the most frequency in waters between 9°C and 18°C (48.2°F and 64.4°F; Byrne and Arzarovitz 1982). Following the metamorphosis into juveniles, the summer flounder seek out inshore demersal habitats (Byrne and Arzarovitz 1982). They display a preference for portions of estuaries containing sandy substrates or where there is a transition from fine sand to silt and clay, and water temperatures ranging between 3°C and 27°C (37.4°F and 80.6°F; Packer et al. 1999c). Adults share the same temperature preferences as the juveniles, but upon reaching maturity, move out of the estuaries and onto the continental shelf (Byrne and Arzarovitz 1982; Packer et al. 1999c).

Life History—Summer flounder have two distinct annual spawning periods. The first is also the most intense and occurs over the southern New England and Mid-Atlantic regions during autumn and winter. The second spawning period occurs in the southern part of the Mid-Atlantic region in the spring (Berrin and Sibunka 1999). Female summer flounder continually produce egg batches throughout the spawning period (Klein-MacPhee 2002h). Summer flounder begin moving into the inshore waters of southern New England in April continue through July or August. Those fish that move inshore from the Chesapeake Bay north move offshore again in the fall. This offshore migration begins in September and by October or November, most of the summer flounder have left the northern part of their range (Klein-MacPhee 2002h).

Forage Species—Summer flounder's diet consists of bony fish (sand lance, anchovy, herring, silver hake, and flatfish species) and squid (Klein-MacPhee 2002h). Summer flounder feed on benthos as well as throughout the water column to the surface (Klein-MacPhee 2002h).

EFH Designations—(MAFMC and ASFMC 1998a; **Figure F-18**)

- **Eggs**—Designated EFH are the pelagic waters found over the continental shelf in the highest 90 percent of the area where summer flounder eggs were collected during the MARMAP survey (Gulf of Maine to Cape Hatteras, North Carolina). Additional designated EFH is south of Cape Hatteras, North Carolina, to Cape Canaveral, Florida in waters over the continental shelf (from the coast to the limits of the EEZ) to depths of 110 m (361 ft).

- **Larvae**—Designated EFH are the pelagic waters found over the continental shelf in the highest 90 percent of the area where summer flounder larvae were collected during the MARMAP survey (Gulf of Maine to Cape Hatteras, North Carolina). Southern New England, mid-Atlantic, and southeast Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area. Additional designated EFH is nearshore waters (to 44 NM from shore) of the continental shelf (from the coast to the limits of EEZ) south of Cape Hatteras, North Carolina, to Cape Canaveral, Florida.

- **Juveniles**—Designated EFH are the demersal waters over the continental shelf in the highest 90 percent of the area where juvenile summer flounder were collected by the NEFSC trawl survey (Gulf of Maine to Cape Hatteras, North Carolina). Southern New England, mid-Atlantic, and southeast Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area. Additional designated EFH is waters over the continental shelf (from the coast to the limits of the EEZ) to depths of 152 m (498.7 ft) south of Cape Hatteras, North Carolina, to Cape Canaveral, Florida.

- **Adults**—Designated EFH are the demersal waters over the continental shelf in the highest 90 percent of the area where adult summer flounder were collected by the NEFSC trawl survey (Gulf of Maine to Cape Hatteras, North Carolina). Southern New England, mid-Atlantic, and southeast Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area. Additional designated EFH for this lifestage is waters over the continental shelf (from the coast to the limits of the EEZ) to depths of 152 m (498.7 ft) from Cape Hatteras, North Carolina, to Cape Canaveral, Florida.

HAPC Designations—For juvenile and adult lifestages, HAPC is considered to include all native species of macroalgae, seagrasses, and freshwater and tidal macrophytes, whether found as small aggregations or in beds, located within the adult and juvenile summer flounder EFH. Areas designated as HAPC for this species are adjacent to the Study Area (MAFMC and ASFMC 1998a).

♦ **Windowpane Flounder (*Scophthalmus aquosus*)**

Management—Windowpane flounder currently have EFH designated by the NEFMC through the Final Amendment #11 to the NE Multispecies FMP (NEFMC 1998). This species is managed as two stocks: a northern stock, located in the Gulf of Maine and Georges Bank region, and a southern stock, located in the MAB region (NEFMC 1998; 2004b).

Status—Windowpane flounder (southern stock) are classified as overfished; however, overfishing is not occurring (NMFS 2008d).

Distribution—Windowpane flounder range throughout the western North Atlantic Ocean from the Gulf of St. Lawrence to Florida, but primarily is found between Georges Bank and the Chesapeake Bay (Morse and Able 1995).

Habitat Associations—Windowpane flounder eggs are primarily found throughout the high salinity areas of estuaries and the inner continental shelf in waters between 5°C to 20°C (41°F and 68°F) in temperature and less than 70 m (230 ft) in depth (Chang et al. 1999). Larval windowpane flounder start off as pelagic but settle to the bottom at approximately 10 mm (0.4 in). They are found primarily in estuaries and on the nearshore continental shelf in waters with temperatures ranging from 3° to 19°C (37.4° to 66.2°F) and at depths of less than 70 m (230 ft; Morse and Able 1995; Chang et al. 1999). Juveniles and adults are found in estuaries and throughout much of the continental shelf between depths of 5 m and 207 m (16.4 ft and 679.0 ft; most common in waters <50 m [164 ft]) and temperatures of 0° to 27°C (50.0° to 80.6°F; Morse and Able 1995; Chang et al. 1999; Klein–MacPhee 2002i). Adults are euryhaline and can tolerate salinity ranges of 5.5 to 36.0 psu (Chang et al. 1999; Klein–MacPhee 2002i). Adult windowpane flounder prefer sandy substrates off southern New England and in the MAB but are also frequently observed on mud grounds in the Gulf of Maine (Chang et al. 1999).

Life History—Spawning occurs in the inner shelf waters between New Jersey and Cape Hatteras, North Carolina, in February or March. By April, spawning has expanded into the deeper waters and on to Georges Bank. The peak spawning period is between May and October (Klein–MacPhee 2002i) and spawning is completed by January (Morse and Able 1995). Spawning typically occurs in waters with temperatures of 6° to 17°C (42.8° to 62.6°F; Klein–MacPhee 2002i). Windowpane flounder display limited seasonal movement (Morse and Able 1995). Based on trawl surveys, they are concentrated in shoal waters during the summer and early fall and migrate offshore for the winter and early spring as water temperatures decline (Dery and Livingstone 1982).

Forage Species—The main prey of the windowpane flounder's diet are opossum shrimp, sand shrimp, bony fishes (anchovy, snake eel, silver hake, tomcod, cusk, killifish, silverside, pipefish, blackbelly rosefish [*Helicolenus dactylopterus*], sculpin, Atlantic striped bass, sand lance, and flatfish species) and fish larvae (Klein–MacPhee 2002i). They have also been reported to feed on various other invertebrates, including squids, mollusks, worms, isopods, krill, and salps (Klein–MacPhee 2002i).

EFH Designations—(NEFMC 1998; **Figure F-19**)

- **Eggs**—Designated EFH are the surface waters around the perimeter of the Gulf of Maine, Georges Bank, and the MAB south to Cape Hatteras, North Carolina. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Larvae**—Designated EFH are the pelagic waters around the perimeter of the Gulf of Maine, Georges Bank, and the MAB south to Cape Hatteras, North Carolina. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Juveniles**—Designated EFH are the bottom habitats consisting of mud or fine-grained sand around the perimeter of the Gulf of Maine, Georges Bank, and the MAB south to Cape Hatteras, North Carolina. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Adults and Spawning Adults**—Designated EFH are the bottom habitats consisting of substrate of mud or fine-grained sand around the perimeter of the Gulf of Maine, Georges Bank, and the MAB south to the Virginia-North Carolina border. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

HAPC Designations—There are no HAPC identified for this species.

♦ **Winter Flounder (*Pseudopleuronectes americanus*)**

Management—Winter flounder EFH is designated by the NEFMC under the Final Amendment #11 to the NE Multispecies FMP (NEFMC 1998).

Status—Winter flounder are classified as overfished and overfishing is occurring (NMFS 2008d).

Distribution—Winter flounder are distributed in the northwestern Atlantic from as far north as Labrador south to Georgia (McCracken 1963) with highest population densities are found between the Gulf of St. Lawrence and the Chesapeake Bay (Klein-MacPhee 2002h).

Habitat Associations—Winter flounder eggs are demersal and stick together in clusters. They are laid in estuaries, coves, and inlets in less than 5 m (16.4 ft) of water, at temperatures of 10°C (50°F) or less and salinities of 10 to 30 psu. Eggs occur on a variety of substrates including sand, muddy sand, mud, and gravel (Pereira et al. 1999). Larval winter flounder are negatively buoyant and sink when not swimming (Klein-MacPhee 2002h). They occur inshore, with the exception of Georges Bank and Nantucket Shoals, in waters ranging from 2.0° to 19.5°C (35.6° to 67.1°F) in temperature, salinities of 6 to 26 psu, and depths of 2 to 70 m (6.6 to 230.0 ft) depending on location (Pereira et al. 1999). Newly settled juvenile winter flounders are found in temperature ranges of 4° to 15°C (39.2° to 59.0°F) and are the most densely congregated over muddy substrates or fine-grained substrates. Older juveniles are found to a lesser extent in a variety of habitats, including mud-shell litter, marsh creeks, macroalgae, and eelgrass (Pereira et al. 1999; Klein-MacPhee 2002h). Adult winter flounder prefer water temperatures of 2.0° to 19.5°C (35.6° to 66.2°F) and salinities of 15 psu or greater (McCracken 1963; Pereira et al. 1999). They are found in a variety of habitats ranging from muddy sand, sand, clay, pebbles, and gravel inshore to hard bottom on the offshore banks (Klein-MacPhee 2002h).

Life History—Winter flounder are batch spawners, which spawn on sandy bottoms in shallow waters, estuaries, and coastal ponds (Pereira et al. 1999; Klein-MacPhee 2002h). Spawning occurs between January and May off southern New England and during November to April in the southern part of their range, from Delaware south (Klein-MacPhee 2002h). Winter flounder migrate out of the bays and the shore zone during the summer months south of Cape Cod, Massachusetts. North of Cape Cod, this movement pattern is not uniform in all areas. This migration has been correlated with an increase in temperature in excess of 15°C (59°F) in the inshore waters (McCracken 1963). In early fall, winter flounder reappear within the bays and estuaries once temperatures return to the preferred range (McCracken 1963).

Forage Species—Winter flounder are opportunistic feeding primarily on benthic invertebrates (shrimp, mollusks, and worms) during the daytime. They have also been recorded to eat sand lances and fish eggs (Pereira et al. 1999; Klein-MacPhee 2002h).

EFH Designations—(NEFMC 1998; **Figure F-20**)

- **Eggs**—Designated EFH are the bottom habitats consisting of sand, muddy sand, mud, and gravel on Georges Bank, inshore areas of the Gulf of Maine, and the MAB south to the Delaware Bay. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Larvae**—Designated EFH are the pelagic and bottom waters of Georges Bank, the inshore areas of the Gulf of Maine, and the MAB south to the Delaware Bay. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Juveniles**—Designated EFH consists of bottom habitats with mud or fine-grained sand located on Georges Bank, the inshore areas of the Gulf of Maine, and the MAB south to the Delaware Bay. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Adults**—Designated EFH are the bottom habitats including estuaries with substrates consisting of mud, sand, and gravel on Georges Bank, inshore areas of the Gulf of Maine, and the MAB south to the Delaware Bay. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area.

- **Spawning Adults**—Designated EFH are the bottom habitats including estuaries with substrates consisting of sand, muddy sand, mud, and gravel on Georges Bank, inshore areas of the Gulf of Maine, and the MAB south to the Delaware Bay. New England and mid-Atlantic estuaries and embayments are designated as EFH including Barnegat Bay and New Jersey Inland Bays adjacent to the Study Area

HAPC Designations—There are no HAPC identified for this species.

♦ **Winter Skate (*Leucoraja ocellata*)**

Management—Winter skate has EFH designated by the NEFMC through the Final FMP for the NE Skate Complex (NEFMC 2003a).

Status—Winter skate are classified as overfished; however, overfishing is not occurring (NMFS 2008d).

Distribution—Winter skates are found from southern Newfoundland and the southern Gulf of St. Lawrence to Cape Hatteras, North Carolina (McEachran and Musick 1975; McEachran 2002; Packer et al. 2003g).

Habitat Associations—Winter skates lay their eggs in capsules on the bottom (McEachran 2002; Packer et al. 2003c). Upon hatching, the skates are already fully developed juveniles (NEFMC 2003a). During the spring, the juvenile winter skates are most common in waters with temperatures of 4° to 5°C (39.2° to 41.0°F), salinities of 32 to 33 psu, and depths of 11 to 70 m (26 to 230 ft). In the fall, juveniles are typically observed in waters with temperatures of 7° to 16°C (44.6° to 60.8°F; peaks between 13°C and 15°C [55.4°F and 59.0°F]), salinities between 32 psu and 33 psu, and depths ranging from 21 to 80 m (69 to 262 ft; Packer et al. 2003c). In spring, adult winter skates are most abundant in waters ranging from 4 to 6°C (39.2° to 42.8°F) in temperature, salinities of 33 psu, and depths of 31 to 60 m (102 to 197 ft), while during the fall, adults are most commonly distributed in waters with temperatures ranging from 11° to 15°C (51.8° to 59.0°F), salinities of 32 psu, and depths of 31 to 50 m (102 to 164 ft; Packer et al. 2003c). Winter skates are most frequently found in habitats containing sandy to gravelly bottoms (McEachran 2002).

Life History—Female winter skates carrying fully formed egg capsules are present throughout the year but are most common during the summer and fall (McEachran 2002). Winter skates undergo seasonal movements in the southern portion of its range (McEachran and Musick 1975). Only during the winter months are winter skates abundant south of Delaware. In addition, they are more abundant during the winter than the rest of the year in inshore waters near Woods Hole, Massachusetts and in Massachusetts Bay (McEachran 2002).

Forage Species—Winter skate prey primarily on benthic invertebrates, including squid, worms, crabs, krill, shrimp, bivalves, amphipods, echinoderms, and fishes (skates, eels, herring, alewife, Atlantic menhaden, silver hake, red hake, tomcod, cod, smelt, sculpins, redfish [*Sebastes* spp.], sand lance, cunner, butterfish, mackerel, summer flounder, and yellowtail flounder) (McEachran 2002).

EFH Designations—(NEFMC 2003a; **Figure F-21**)

- Eggs—Designated EFH includes southern New England and mid-Atlantic estuaries and embayments.

- Larvae—No larval stage exists for this species. Upon hatching, they are fully developed juveniles.

- **Juveniles**—Designated EFH are the bottom habitats consisting of sand and gravel or mud in Cape Cod Bay, on Georges Bank, and through the MAB to North Carolina. Southern New England and mid-Atlantic estuaries and embayments are designated EFH.

- **Adults**—Designated EFH are the bottom habitats consisting of sand and gravel or mud in Cape Cod Bay, on Georges Bank, and through the MAB to North Carolina. Southern New England and mid-Atlantic estuaries and embayments are designated EFH including Barnegat Bay and New Jersey inland bays adjacent to the Study Area.

- Spawning Adults— Designated EFH includes southern New England and mid-Atlantic estuaries and embayments.

HAPC Designations—There are no HAPC identified for this species.

♦ **Witch Flounder (*Glyptocephalus cynoglossus*)**

Management—Witch flounder EFH is designated by the NEFMC through the Final Amendment #11 to the NE Multispecies FMP (NEFMC 1998).

Status—Witch flounder are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution— Witch flounder occur on both sides of the Atlantic Ocean. In U.S. waters, this species occurs on or adjacent to Georges Bank and along the continental shelf edge and upper slope south to Cape Hatteras, North Carolina (Cargnelli et al. 1999d).

Habitat Associations—Witch flounder area benthic species exhibiting a preference for deep water (Cargnelli et al. 1999d). Juveniles and adults are found at depths of 20 to 1,565 m (65.6 ft to 5,134.8 ft), although the highest concentrations occur between 90 m and 300 m (295 ft and 984 ft; Klein-MacPhee 2002h). Juvenile witch flounder tend to inhabit deeper waters than their adult counterparts (Cargnelli et al. 1999d). Both juveniles and adults prefer temperatures of 0° to 15°C (32° to 59°F; Klein-MacPhee 2002h) and salinities of 31 to 36 psu (Cargnelli et al. 1999d). Substrate preferences for the species include mud, silt, clay, and muddy sand (Cargnelli et al. 1999d).

Life History—Spawning occurs from March to November and generally begins earlier in the southern portion of the range. The peak spawning period takes place between May and August (Brander and Hurley 1992). During spawning, witch flounder form dense aggregations that are concentrated around areas of cold water, typically in the range of 0° to 10°C (32° to 50°F; Cargnelli et al. 1999d).

Forage Species—Witch flounder feed primarily on polychaete worms but also consume echinoderms, squid, mollusks, amphipods, and isopods (Klein-MacPhee 2002h).

EFH Designations—(NEFMC 1998; **Figure F-22**)

- **Eggs**—Designated EFH are surface waters of the Gulf of Maine, Georges Bank, and the MAB south to Cape Hatteras, North Carolina.

- **Larvae**—Designated EFH are surface waters to 250 m (820 ft) from the Gulf of Maine, Georges Bank, and the MAB south to Cape Hatteras, North Carolina.

- Juveniles—Designated EFH are fine-grained substrates in the Gulf of Maine and along the shelf break region from Georges Bank south to Cape Hatteras, North Carolina.

- Adults and Spawning Adults—Designated EFH are fine-grained substrates in the Gulf of Maine and along the shelf break region from Georges Bank south to the Chesapeake Bay.

HAPC Designations—There are no HAPC identified for this species.

- **Yellowtail Flounder (*Limanda ferruginea*)**

Management—Yellowtail flounder are managed by the NEFMC as five separate stocks (Nova Scotia, Georges Bank, southern New England, Cape Cod, Massachusetts, and the MAB) and have EFH designated under the Final Amendment #11 to the NE Multispecies FMP (NEFMC 1998).

Status—Yellowtail Flounder are classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies yellowtail flounder as vulnerable, or facing a risk of extinction in the wild (Sobel 1996b).

Distribution—Yellowtail flounder are found between the south coast of Labrador and the Chesapeake Bay and occur with greatest frequency between southern New England and Georges Bank, on the Grand Bank, and around Sable Island off the Nova Scotia coast (Lux and Livingstone 1982).

Habitat Associations—Yellowtail flounder eggs are buoyant and remain suspended near the surface until hatching (Lux and Livingstone 1982; Johnson et al. 1999). They are found in waters with temperatures of 2° to 15°C (35.6° to 59.0°F) and depths of 10 to 750 m (33 to 2,461 ft; most common from 30 to 90 m [98 to 295 ft]) between February and September (Johnson et al. 1999). Eggs are found on the continental shelf off New Jersey and Long Island, New York, on Browns Bank, on Georges Bank, northwest of Cape Cod, Massachusetts, and in some years as far south as the Chesapeake Bay (Lux and Livingstone 1982; Johnson et al. 1999). Larval yellowtail flounder are pelagic and found during April through August in 5° to 17°C (41.0° to 62.6°F)water temperatures and between 10 m and 1,250 m (33.0 ft and 4,101.3 ft); most abundant between 10 m and 90 m [33 ft and 295 ft]; Lux and Livingstone 1982; Johnson et al. 1999). Juvenile yellowtail flounder prefer benthic habitats and are most commonly found in water temperatures of 2° to 17°C (35.6° to 62.6°F) and between 5 m and 125 m (16.4 ft and 410.0 ft) in depth (Johnson et al. 1999b). Adult yellowtail flounder prefer sand and gravel substrates in waters ranging from 2° to 15°C (35.6° to 59.0°F) in temperature and depths of 10 to 100 m (33 to 328 ft; Johnson et al. 1999; Klein-MacPhee 2002h).

Life History—Yellowtail flounder are batch spawners, spawning once a year primarily between March and July, with a peak around mid-May (Lux and Livingstone 1982; Klein-MacPhee 2002h). Little migration occurs between the five relatively distinct stocks of yellowtail flounder and each stock remains primarily within its fishing grounds (Johnson et al. 1999); however, there is evidence to suggest that some yellowtail flounder move considerable distances (Klein-MacPhee 2002h).

Forage Species—Amphipods, particularly *Erichthonius rubricornis*, are the primary component of the yellowtail flounder's diet. They also consume other invertebrates and small fishes (Klein-MacPhee 2002h).

EFH Designations—(NEFMC 1998; **Figure F-23**)

- **Eggs**—Designated EFH are the surface waters of Georges Bank, Massachusetts Bay, Cape Cod Bay, and the MAB south to Delaware Bay. New England estuaries and embayments are designated EFH.

- **Larvae**—Designated EFH are the surface waters of Georges Bank, Massachusetts Bay, Cape Cod Bay, and the MAB south to Chesapeake Bay. New England estuaries and embayments are designated EFH.

- **Juveniles and Adults**—Designated EFH are the bottom habitats consisting of sand or a combination of sand and mud on Georges Bank, the Gulf of Maine, and the MAB south to Delaware Bay. New England estuaries and embayments are designated EFH.

- **Spawning Adults**—Designated EFH are the bottom habitats consisting of sand or a combination of sand and mud on Georges Bank, the Gulf of Maine, and the MAB south to Delaware Bay. Some New England estuaries and embayments are designated EFH.

HAPC Designations—There are no HAPC identified for this species.

9.4.2 Subtropical-Tropical/Southeast Fish Species

The collective distribution of subtropical/tropical species encompasses a portion of the marine and estuarine waters along the Atlantic coast from Cape Cod, Massachusetts through the Florida Straits; however, most species occupy only limited portions of this overall region. EFH designation for the subtropical/tropical managed species extends from the MAB through Florida under the management of the SAFMC (1998). Species that are managed by the SAFMC and for which EFH has been designated include the coastal migratory pelagic species complex. The GMFMC co-manages members of the coastal migratory pelagic species complex with the SAFMC but current EFH designations apply only to those habitats within the jurisdictional boundaries of either the SAFMC or GMFMC. Thus, EFH designations for this complex along the Atlantic coast are exclusively from the SAFMC.

Of the subtropical/tropical species and species-groups managed by the SAFMC, all three species of the coastal migratory pelagic complex have EFH designated and occur on the continental shelf in the Study Area: cobia, king mackerel, and Spanish mackerel. The EFH designations for these three species are based on the distribution of the resource (Hoff, T., MAFMC, pers. comm., 14 May 2004; Pugliese, R., SAFMC, pers. comm., 17 May 2004) and are described below.

♦ **Cobia (*Rachycentron canadum*)**

Management—Cobia off the southeast coast of the U.S. are managed jointly by the SAFMC and GMFMC; however, EFH in the Study Area is only designated by the SAFMC through the Final Habitat Plan for the South Atlantic Region (SAFMC 1998).

Status—Cobia are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Cobia are distributed world-wide throughout tropical, subtropical, and warm-temperate waters, with the exception of the eastern Pacific (Williams 2001). In the western Atlantic, cobia range from Massachusetts and Bermuda to Argentina but are most common along the U.S. coast south of Virginia and in the northern Gulf of Mexico (Franks et al. 1999; FMRI 2003).

Habitat Associations—Cobia eggs and larvae are pelagic and found at the surface within the upper meter of water (Ditty and Shaw 1992). Eggs occur between May and August and larvae are found from May to September across the continental shelf from the Gulf Stream to inshore inlets and bays (GMFMC and SAFMC 1985; Ditty and Shaw 1992; Franks et al. 1999). Eggs are found in surface water exceeding 20°C (68°F) in temperature and between 19 psu and 35 psu in salinity (Ditty and Shaw 1992). Developing larvae occupy waters with temperatures of 24.2° to 32.0°C (75.6° to 89.6°F), salinities between 18.9 psu and 37.7 psu, and depths of less than 100 m (328 ft; Ditty and Shaw 1992). Juvenile and adult cobia are found in coastal bays and inlets and across the continental shelf. Juveniles occur at temperatures between 16.8°C and 25.2°C (62.2°F and 77.4°F) and at salinities of 30.0 to 36.4 psu. Adults prefer temperatures of 19.6° to 28.0°C (67.3° to 82.4°F), salinities ranging from 24.6 to 36.4 psu, and waters ranging in depth from nearshore shallows out to 70 m (230 ft;

GMFMC 1998). They are closely associated with any type of structure including artificial reefs, pilings, platforms, anchored boats, *Sargassum*, and flotsam (Bester 1999a; Williams 2001).

Life History—Spawning occurs in the daylight hours between April and September in estuarine or shelf waters (Ditty and Shaw 1992; CBP 2004). Cobia are batch spawners and form large aggregations during spawning (Bester 1999a; Williams 2001). Cobia undergo seasonal migrations. Following the spawning season, cobia migrate south to warmer offshore waters of the Florida Keys during the autumn and winter (CBP 2004). In the spring, they begin their migration north to the poly/mesohaline waters of coastal Virginia and the Carolinas for the summer and to spawn (Williams 2001).

Forage Species—Cobia mostly feed on demersal organisms, particularly crustaceans. Shrimp (i.e., mantis and penaeid), eels, and squid are consumed with the highest frequency. Several fish species have also been observed in the stomachs of cobia, including Spanish mackerel (GMFMC and SAFMC 1985). Cobia also are commonly seen in schools following sharks, turtles, and large rays as they feed, to scavenge food from the other animals (Williams 2001; CBP 2004).

EFH Designations—(SAFMC 1998; **Figure F-24**)

- Larvae—The Gulf Stream is designated as EFH for this lifestage because it provides a mechanism for dispersal.

- **All Lifestages**—In the MAB and the SAB, designated EFH includes sandy shoals of capes and offshore bars, high profile rock bottoms, and barrier island (ocean side) waters from the surf zone to the shelf break but only from the edge of the Gulf Stream shoreward. In addition, high salinity bays, estuaries, seagrass habitat, and coastal inlets are also considered as EFH.

HAPC Designations—Areas designated as HAPC for this species are located south of the Study Area.

♦ **King Mackerel (*Scomberomorous cavalla*)**

Management—King Mackerel are managed by the GMFMC and SAFMC. In the Study Area, King mackerel EFH is designated by the SAFMC under the Final Habitat Plan for the South Atlantic Region (SAFMC 1998).

Status—King mackerel are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—King mackerel are commonly found along the continental shelf in the warmer waters of the western North Atlantic Ocean from North Carolina to Brazil, but occasionally reported as far north as Massachusetts (Gold et al. 2002; Collette 2002). This species is not usually found further offshore than the shelf break (GAMFMC and SAFMC 1985).

Habitat Associations—King mackerel eggs are pelagic and occur in waters over depths of 35 to 180 m (115 to 591 ft) during the spring and summer (GMFMC 1998). Larvae occur over the middle and outer continental shelf off the eastern coast of the U.S. from May to November in waters ranging from 22° to 28°C (71.6° to 82.4°F) in temperature, salinities between 30 psu and 37 psu, and over bottom depths of 35 to 180 m (115 to 591 ft; GMFMC and SAFMC 1985; Godcharles and Murphy 1986; GMFMC 1998). Juvenile and adult king mackerel can be found ranging from inshore waters to the shelf break, but are commonly found at depths of less than 80 m (262 ft). They prefer areas of temperatures greater than 20°C (68°F) and salinities between 32 psu and 36 psu. As adults, king mackerel rarely enter estuaries but feed upon estuarine dependent species (GMFMC 1998).

Life History—King mackerel are highly fecund serial spawners (Gledhill and Lyczkowski-Schultz 2000). They have a protracted spawning season that runs from May to October (Godcharles and

Murphy 1986). King mackerel exhibit seasonal movements; during the summer, they migrate north and occur in the waters off Virginia and the Carolinas through fall. As the waters become cooler in the winter, they migrate south again to Florida (Godcharles and Murphy 1986; Schaefer and Fable 1994).

Forage Species—King mackerel feed on a variety of fish species including sardines, thread herrings, Atlantic menhaden, scad, jacks, snappers, mackerels, and grunts. Invertebrate species such as shrimp and squid also make up a large portion of their diet (GMFMC and SAFMC 1985; Collette 2002).

EFH Designations—(SAFMC 1998; **Figure F-24**)

- Larvae—The Gulf Stream is designated as EFH for this lifestage because it provides a mechanism for dispersal.
- **All Lifestages**—In the MAB and the SAB, designated EFH includes sandy shoals of capes and offshore bars, high profile rock bottoms and barrier island ocean side waters from surf zone to the shelf break but only in the region from the wall of the Gulf Stream shoreward. Additionally, all coastal inlets are designated as EFH.

HAPC Designations—Areas designated as HAPC for this species are located south of the Study Area

♦ **Spanish Mackerel (*Scomberomorous maculatus*)**

Management—Spanish mackerel are managed jointly by the SAFMC and the GMFMC. In the Study Area, Spanish mackerel EFH is only designated by the SAFMC under the Final Habitat Plan for the South Atlantic Region (SAFMC 1998).

Status—Spanish mackerel are neither classified as overfished, nor is overfishing occurring (NMFS 2008d).

Distribution—Spanish mackerel are abundant from Chesapeake Bay south to the Gulf of Mexico; however, they occasionally occur as far north as the southern coast of New England (Collette 2002).

Habitat Associations—Spanish mackerel eggs are pelagic and usually occur over depths of less than 50 m (164 ft) along the inner continental shelf during the spring and summer (Godcharles and Murphy 1986; GMFMC 1998). Larvae occur in coastal waters with temperatures ranging from 20° to 32°C (68.0° to 89.6°F), salinities between 28 psu to 37 psu, and over depths of 9 to 84 m (29.5 to 276.0 ft; most abundant in waters <50 m [164 ft]) (Godcharles and Murphy 1986; GMFMC 1998). They occur between May and September off the southeast U.S. coast (GMFMC and SAFMC 1985). Juvenile Spanish mackerel utilize a variety of habitats from low salinity estuaries to high salinity nearshore waters as nursery grounds (Godcharles and Murphy 1986). They prefer water temperatures greater than 25°C (77°F) and tolerate a wide range of salinities, typically greater than 10 psu (GMFMC 1998). Adults are surface feeders that form large schools of similar sized fish and often frequent nearshore coastal waters. They also frequently enter tidal estuaries, bays, and lagoons (GMFMC and SAFMC 1985). They are found in waters exceeding 20°C (68°F) and at depths of less than 75 m (246 ft; GMFMC 1998).

Life History—Spanish mackerel have a protracted spawning season, which runs from April to September (GMFMC and SAFMC 1985; Godcharles and Murphy 1986). The onset of spawning progresses from south to north and occurs over the inner continental shelf in waters 12 to 34 m (39.0 to 111.5 ft) deep. Spawning starts in April off the Carolinas, in mid-June in the Chesapeake Bay, and from late August to September off the coasts of New Jersey and New York (Godcharles and Murphy 1986; Collette 2002). Spanish mackerel make seasonal migrations along the Atlantic coast. They are found off Florida during the winter and migrate north as the waters warm. They occur off the Carolinas in April, off Virginia by May, and as far north as Narragansett Bay by July, in some years.

They remain in the cooler northern waters until September before beginning their migration south again (GMFMC and SAFMC 1985).

Forage Species—Spanish mackerel feed primarily on small fishes, including round herring (*Etrumeus teres*), Atlantic menhaden, alewives, anchovies, pilchards, and mullets. This species also preys upon shrimp, crabs, and squid (GMFMC and SAFMC 1985; Collette 2002).

EFH Designations—(SAFMC 1998; **Figure F-24**)

- Larvae—The Gulf Stream is designated as EFH for this lifestage as it provides a mechanism for dispersal.

- **All Lifestages**—In the MAB and the SAB, designated EFH includes sandy shoals of capes and offshore bars, high profile rock bottom, and barrier island (ocean side) waters from the surf zone to the shelf break but only from the Gulf Stream wall shoreward. Additionally, all coastal inlets are designated as EFH.

HAPC Designations—Areas designated as HAPC for this species are located south of the Study Area.

9.4.3 Highly Migratory Species

Billfish, swordfish, members of the mackerel family (tuna), and many shark species are highly migratory fishes that are distributed over wide areas of the open ocean as well as over the neritic waters of the continental shelf and coastal waters. These species are capable of both horizontal and vertical movements; they move great horizontal distances as well as vertically in the water column. Seasonal migrations may involve north to south or inshore to offshore movements.

Identifying the habitat for highly migratory fish is complicated, as these fishes generally occur in the open ocean but may also frequent nearshore waters. HMS are not correlated with the areas or features that typify most fish habitat (bottom substrate or submerged vegetation) but rather are associated with physiographic and hydrographic features such as ocean fronts, current boundaries, the continental shelf margin, or sea mounts. The distributions of the various lifestages of these highly mobile species are also constrained by temperature, salinity, and oxygen concentrations (NMFS 1999a, 1999b, 2003a, 2006a). The majority of the resulting habitat parameters are dynamic, changing both spatially and temporally, and make habitat characterization for highly migratory fish species nearly impossible except in a broad context. The NMFS manages and designates EFH for all HMS. The 12 managed HMS occurring within the Study Area are described in the following sections.

- **Atlantic Angel Shark (*Squatina dumeril*)**

Management—Atlantic angel shark is managed under the Prohibited Species Management Unit (MU) through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—The NMFS (1999b; 2006a) prohibits possession of this species as a precautionary measure since so little is known about its reproductive biology or life history.

Distribution—Atlantic angel sharks inhabit temperate and subtropical waters in the northwestern Atlantic from Massachusetts to Florida, the Gulf of Mexico, and the Caribbean Sea (Castro 1983). It is common in the MAB south to Maryland.

Habitat Associations—This demersal shark species buries itself in the sand or mud in shallow waters of the northern part of its range, while in the southern part of its range, it inhabits deeper waters (up to 1,390 m [4,560.6 ft) off the continental shelf (Castro 1983; Compagno 1984a).

Life History—This shark appears seasonally in shallow water, moving inshore in the spring and summer. Its winter grounds are not known as it disappears from shallow waters, presumably retreating to deeper water for the duration of winter (Castro 1983). It gives birth to live young in the spring or early summer (Castro 1983).

Forage Species—Atlantic shark is a demersal feeder, which often feeds on fishes, crustaceans, and bivalves (Compagno 1984a).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-25**)

- **Neonate** (<31 cm [12.2 in] Total Length [TL])—Designated EFH occurs along the shallow coastal waters of southern New Jersey, Delaware, and Maryland, including the mouth of Delaware Bay (39°N to 38°N) seaward to the 25-m (82-ft) isobath.
- **Juveniles** (32 to 113 cm [12.6 to 44.5 in] TL)—Identical to neonate EFH.
- **Adults** (>113 cm [44.5 in] TL)—Identical to neonate EFH.

HAPC Designations—There are no HAPC identified for this species.

- **Blue Shark (*Prionace glauca*)**

Management—Blue shark is managed under the Pelagic Shark MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Currently, it is unknown whether blue shark are overfished or if overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List designates blue shark as lower risk/near threatened or likely to qualify for a threatened future in the near future (Stevens 2000a).

Distribution—Blue sharks have a world-wide distribution and is considered the widest ranging shark species (Compagno 1984a). Even though its range extends into the tropics, it is commonly found in deeper, more temperate waters (Ferrari and Ferrari 2002). In the northwestern Atlantic, this shark is found from Newfoundland, Canada south to Argentina, South America (Compagno 1984a). There are no records of this shark in the Gulf of Mexico (Castro 1983).

Habitat Associations—Blue sharks can inhabit waters with depths up to 350 m (1,148 ft) and although this species is oceanic, it can be found close to shore at night or in areas where the continental shelf is narrow (Castro 1983; Compagno 1984a; Cooper 2003). This shark is often found in large aggregations close to the surface in temperate waters. It prefers relatively cool water, from 7° to 16°C (44.6° to 60.8°F) but can tolerate water as warm as 21°C (69.8°F); NMFS 1999b, 2006a; Cooper 2003).

Life History—Little is known about the reproductive locations of this species in the Atlantic, but mating is believed to occur in May and June (Branstetter 2002a). Blue shark nurseries are believed to occur in the open oceanic waters of higher latitudes of their range (NMFS 1999b, 2006a). The exact migration routes of this species are also poorly understood, but a population of blue sharks from the northwest Atlantic was reported to migrate to northeastern South America (Castro 1983).

Forage Species—Blue sharks feed on small fishes (herring, sardine, skate, lancetfish, cod, bluefish, scup, butterfish, mackerel, and yellowtail flounder) and invertebrates (squid, cuttlefish, and octopus), as well as scavenge on dead marine mammals (Cooper 1999). In the mid-Atlantic, squid are the primary component of the blue shark's diet (Branstetter 2002a).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-26**)

- Neonate (≤60 cm [23.6 in] TL)—Designated EFH is north of 40°N, from Manasquan Inlet, New Jersey, to Buzzards Bay, Massachusetts, in waters from the 25-m (82-ft) isobath to the U.S. EEZ boundary.

- **Juveniles** (61 to 183 cm [24 to 72 in] TL)—Designated EFH is from offshore Cape Hatteras, North Carolina (35°N), in waters from the 25-m (82-ft) isobath to the U.S. EEZ boundary

- **Adults** (≥184 cm [72.4 in] TL)—Designated EFH is from offshore Cape Hatteras, North Carolina (35°N), in waters from the 25-m (82-ft) isobath to the U.S. EEZ boundary and extending around Cape Cod, Massachusetts, including the southern part of the Gulf of Maine.

HAPC Designations—There are no HAPC identified for this species.

- **Bluefin Tuna (*Thunnus thynnus*)**

Management—Bluefin tuna is managed under the Tuna MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Bluefin tuna are classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies bluefin tuna (northern stock) as data deficient to properly assess the population (Safina 1996a); however, the southern stock (*T. maccoyii*) is classified as critically endangered or facing an extremely high risk of extinction in the wild (Punt 1996).

Distribution—Bluefin tuna have a world-wide distribution in tropical and temperate waters, from Argentina and South Africa north to Labrador and northern Scandinavia in the Atlantic Ocean, including the Gulf of Mexico and the Caribbean Sea (Schultz 2004). In the western North Atlantic Ocean, bluefin tuna range from 0°N to 45°N, but have been reported as far north as 55°N (Collette and Nauen 1983; NMFS 1999b, 2006a).

Habitat Associations—This species can tolerate a considerable range of temperatures and has been observed to depths greater than 1,000 m (3,281 ft; Block et al. 2001). Although bluefin tuna are epipelagic and oceanic, they often occur over continental shelf waters and in embayments during the summer months (Collette 2002). Juveniles typically inhabit regions off the continental shelf, from North Carolina to Rhode Island, in waters with depths less than 40 m (131 ft) and temperatures greater than 20°C (68°F) in the summer (June and July; Schuck 1982; Brill et al. 2002). Juveniles, along the continental shelf, utilize the entire water column including the benthic habitat but spend the majority of their time near the surface (Brill et al. 2002). Fertilized eggs are buoyant (Collette 2002). Larvae are believed to associate with Gulf Stream along the continental shelf in regions of upwelling (NMFS 1999b, 2006a).

Life History—The western North Atlantic bluefin tuna spawns from mid-April to mid-June in the Gulf of Mexico, the Florida Straits, western edge of the Bahamas Banks, and along the eastern portion of the Florida current at temperatures of 24.9° to 29.5°C (76.8° to 85.1°F; Gusey 1981; Collette and Nauen 1983; NMFS 1999b). The Gulf of Mexico spawning site is considered the primary spawning area of the northwest Atlantic (Mather et al. 1995; Block et al. 2001). The adult bluefin tuna moves seasonally from offshore spawning grounds in the Gulf of Mexico through the Straits of Florida to inshore seasonal feeding grounds in the northern part of their range in the western north Atlantic in the early spring and summer the New England continental shelf (Jeffreys Ledge, Stellwagen Bank, Cape Cod Bay, Great South Channel, and south of Martha's Vineyard) (Gusey 1981; Schuck 1982; Block et al. 2001; Chase 2002). Data on the southerly three-way movements of adults from these feeding areas to wintering areas and back to breeding areas (Gulf of Mexico/Florida Straits) are limited. It has been postulated that juveniles have a shorter two-way movement from feeding to wintering areas (Mather et al. 1995; Chase 2002).

Forage Species—Bluefin tuna prey upon squid, pelagic crustaceans, and school fishes (anchovies, sauries, and hakes; Schuck 1982; NMFS 1999b, 2006a).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-27**)

- Spawning Adults, Eggs, and Larvae—Designated EFH is pelagic and near coastal surface waters from North Carolina/South Carolina border south to Cape Canaveral, Florida (from 13 NM offshore to 200 m [656 ft]) and all waters off the coast of Cape Canaveral, Florida south around the peninsular Florida to the U.S./Mexico border (Gulf of Mexico) ranging from 13 NM offshore to U.S. EEZ boundary.

- **Juveniles and Subadults** (<145 cm [57 in] TL)—Designated EFH are all the inshore and pelagic surface waters warmer than 12°C (53.6°F) from the Gulf of Maine to Cape Cod Bay (from Cape Ann [~42.75°N] east to 69.75°W, including water of the Great South Channel west of 69.75°W) and Nantucket Shoals (70.5°W) south to Cape Hatteras, North Carolina (~35.5°N). Additional designated EFH is the Florida Straits.

- **Adults** (>145 cm [57 in] TL)—Designated EFH are the pelagic waters of the Gulf of Maine and Great South Channel to south of Georges Bank (39°N) from the 50-m (164-ft) isobath to the EEZ boundary; and south of 39°N to offshore Cape Lookout, North Carolina (34.5°N), from the 50-m (164-ft) isobath to the 2,000-m (6,652-ft) isobath. Additional designated EFH is from Daytona Beach, Florida, to Key West, Florida; and into the Gulf of Mexico.

HAPC Designations—There are no HAPC identified for this species.

♦ **Dusky Shark (*Carcharhinus obscurus*)**

Management—Dusky shark is managed under the Prohibited Species MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Currently, dusky shark is classified as overfished and overfishing is occurring (NMFS 2008d). Dusky sharks are listed as a prohibited species to assist with rebuilding the population status. Under the ESA classification system, dusky shark are currently identified as a species of concern (formerly a candidate species) by NMFS (2004f, 2006b). The 2008 IUCN Red List classifies dusky shark (northwest Atlantic and Gulf of Mexico subpopulation) as vulnerable or facing a high risk of extinction in the wild in the medium-term future (Musick and Fowler 2000).

Distribution—Dusky sharks are wide-ranging. They are distributed in warm-temperate and tropical continental waters throughout the world and can be found in the western North Atlantic Ocean from southern Massachusetts and the Georges Bank southward to the northern Caribbean Sea and Gulf of Mexico to Nicaragua and southern Brazil (Compagno 1984a; Castro 1993).

Habitat Associations—Dusky sharks are coastal pelagics found from the surf zone to offshore waters. They are found from surface waters to depths of 400 m (1,312 ft; Compagno 1984a; Branstetter 2002a). Major nursery areas have been identified in coastal waters from Massachusetts to South Carolina coast (Castro 1993; McCandles et al. 2002).

Life History—In the western North Atlantic Ocean, dusky shark mating occurs in the spring and birth to live young is from late winter to summer (Compagno 1984a). In Bulls Bay, North Carolina, dusky sharks typically give birth from April to May, while in the Chesapeake Bay it occurs in June and July (NMFS 2003a). Females mate in alternate years as a result of their long gestation period (9 to 16 months) (Compagno 1984a). The dusky shark undertakes long seasonal, temperature-related migrations. On both coasts of the U.S., this species migrates northward in summer as the waters warm and retreats southward in fall as water temperatures decline (Compagno 1984a; NMFS 2003a).

Forage Species—Dusky sharks feed on bony fish (eels, menhaden, herring, anchovies, hakes, goosefish, black sea bass, scups, croakers, bluefish, sand lance, mackerels, tunas, and flatfish), other sharks, crustaceans, and squid (Branstetter 2002a).

EFH Designations—(NMFS 1999b, 2003a; 2006a; **Figure F-28**)

- **Neonate** (<110 cm [43.3 in] TL)—Designated EFH are the shallow coastal waters, inlets, and estuaries to the 70-m (230-ft) isobath from the eastern end of Long Island, New York (72°W), south to New Jersey, inlets and estuaries to the 25-m (82-ft) isobath in from Delaware Bay and off Delaware, and coastal waters to the 200-m (656-ft) isobath off Maryland south to North Carolina. Additional EFH has been designated from Cape Lookout, North Carolina, to West Palm Beach, Florida in shallow waters, inlets, and estuaries and offshore areas to the 90-m (295-ft) isobath.

- **Juveniles** (111 to 299 cm [43.7 to 117.7 in] TL)—Designated EFH are the coastal and pelagic water between the 25-m and 200-m (82-ft and 656-ft) isobaths from the coast of southern New England (70°W) and shallow coastal waters, inlets, and estuaries to the 200-m (656-ft) isobath from Assateague Island at the Virginia/Maryland border (38°N) to Jacksonville, Florida (30°N) and shallow coastal waters, inlets, and estuaries to the 500-m (1,640-ft) isobath and continuing south to Dry Tortugas, Florida.

- Adults (≥300 cm [118.1 in] TL)—Designated EFH are pelagic waters offshore from Virginia/North Carolina border (36.50°N) south to Cape Romain, South Carolina out to the 25-m (82-ft) isobath; from Cape Romain, South Carolina south to the Georgia/Florida border (30.8°N), EFH consists of water between the 25-m and 200-m (82-ft and 656-ft) isobaths, and coastal waters out to the 200-m (656-ft) isobath from the Georgia/Florida border to Cape Canaveral, Florida (28.5°N).

HAPC Designations—There are no HAPC identified for this species.

- **Sand Tiger Shark (*Carcharias taurus*)**

Management—Sand tiger shark is managed under the Prohibited Species MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Under the FMP, the sand tiger shark receives full protection from harvest on the Atlantic coast. Under the ESA classification system, the Atlantic and Gulf of Mexico populations of the sand tiger shark are currently identified as a species of concern (formerly a candidate species) by NMFS (NMFS 2004f; NMFS 2006b). The 2008 IUCN Red List classifies sand tiger shark as vulnerable or facing a high risk of extinction in the wild in the medium-term future (Pollard and Smith 2000).

Distribution—Sand tiger sharks are known to have broad inshore distribution in tropical and warm-temperate waters throughout the world but are nonexistent in the eastern Pacific Ocean (Castro 1983; Branstetter 2002b). In the western Atlantic, the sand tiger shark occurs from the Gulf of Maine to Florida, the northern Gulf of Mexico, the Bahamas, and Bermuda and southward to Argentina (Castro 1983; Compagno 1984b). In warmer months, this species is common from Cape Cod to the Delaware Bay (Castro 1983).

Habitat Associations—Sand tiger sharks are demersal sharks primarily found in shallow bays and around coral or rocky reefs (depths <20 m [65.6 ft]) but also are found to depths to 191 m (627 ft) over the continental shelf (Compagno 1984b; NMFS 1999b; Bransetetter 2002b). Neonate and juvenile sand tiger sharks utilize estuarine waters as nurseries from Massachusetts to South Carolina including Sandy Hook, New Jersey and Delaware Bay, north and south of the Study Area (McCandless et al. 2002; NMFS 2006a).

Life History—Sand tiger sharks mate in the winter and spring, with parturition beginning during the winter from late October to the end of November (NMFS 1999b; Branstetter 2002b). In Florida, sand tiger sharks are born from November to February (Castro 1983). The neonates then migrate northward to summer nurseries. Sand tiger sharks are migratory in the northern portion of its range moving northward and inshore during the summer and south to deeper waters in the fall and winter (Castro 1983; Compagno 1984b).

Forage Species—Sand tiger sharks feed primarily on fishes (skates, goosefish, sea robin, scup, spot, bluefish, and butterfish), specifically summer flounder, as well as invertebrates (lobster, crab, and squid) (Branstetter 2002b).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-29**)

- **<u>Neonate</u>** (<117 cm [46.1 in] TL)—Designated EFH are the shallow coastal waters to the 25-m (82-ft) isobath from Barnegat Inlet, New Jersey to Cape Canaveral, Florida.

- <u>Juveniles</u> (118 to 236 cm [46.5 to 92.9 in] TL)—Currently, available information is insufficient for the identification of EFH for this lifestage.

- **<u>Adults</u>** (>237 cm [93.3 in] TL)—Designated EFH are the shallow coastal waters to the 25-m (82-ft) isobath from Barnegat Inlet, New Jersey to Cape Lookout, North Carolina and from St. Augustine, Florida to Cape Canaveral, Florida.

HAPC Designations—There are no HAPC identified for this species.

- **Sandbar Shark (*Carcharhinus plumbeus*)**

Management—Sandbar shark is managed under the Large Coastal Shark MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Sandbar shark are classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies the northwest Atlantic stock as a lower risk/near threatened (Musick and Fowler 2000).

Distribution—Sandbar sharks are cosmopolitan in distribution, found in shallow coastal waters from Cape Cod, Massachusetts, southward to Brazil, including the Gulf of Mexico and Caribbean Sea but are most common from South Carolina to Florida and in the eastern Gulf of Mexico (Castro 1983; Branstetter 2002a).

Habitat Associations—This bottom-dwelling species is found in temperate to tropical waters over the continental shelf and in deep water adjacent to the shelf break. Sandbar sharks are found in water depths ranging from the intertidal zone to 280 m (919 ft) during migration, but are common in 20- to 53-m (65.6- to 174.0-ft) depths (Compagno 1984a; Knickle 2003a). Sandbar sharks avoid surf zones, coral reefs, or rough benthic substrates, preferring smooth substrates (Castro 1983; Compagno 1984a). It is common in inshore areas with mud or sand sub rates such as estuaries, river mouths, and harbors but does not enter freshwater (Compagno 1984a).

Life History—Sandbar shark is reported to make extensive seasonal migration, where it moves to the northern part of its range in the summer and the southern part during the winter (Castro 1983). Seasonal temperature changes are the primary trigger for the migration; however, oceanographic features also influence this behavior (Compagno 1984a). Male sandbar sharks typically migrate earlier in the year and to deeper waters than females (Knickle 2003a). In the northwest Atlantic, mating occurs from May to June with young being born from March to August after a gestation period of approximately one year (Castro 1983; NMFS 1999b; Knickle 2003a). This species segregates by sex with large females dominating shallow, nursery areas from Great Bay, New Jersey to Cape Canaveral, Florida, as well as the Gulf of Mexico (Castro 1983; Castro 1993; McCandless et al. 2002). The Chesapeake Bay, Delaware Bay, and waters off North Carolina are regarded as one of the primary nursery grounds in the mid-Atlantic (Bransetter 2002a).

Forage Species—Sandbar sharks feed on benthic prey, such as fishes (eels, skates, rays, and dogfish) and invertebrates (squid, octopus, bivalves, shrimp, and crabs). They feed all day, but are most active at night (Knickle 2003a).

EFH Designations—(NMFS 1999b, 2003a, 2006a; **Figure F-30**)

- **Neonate** (≤71 cm [28 in] TL)—Designated EFH are the shallow coastal areas out to the 25-m (82-ft) isobath from Montauk, Long Island, New York (72°W), south to Cape Canaveral, Florida (80.5°W), except from the Virginia/Maryland border (37.8°N) south to Pamlico Sound, North Carolina, where the seaward extent of the EFH is 17 NM (31.5 km) from shore. Seasonally (summer), nursery areas within the shallow coastal waters from Great Bay, New Jersey to Cape Canaveral, Florida, especially Delaware and Chesapeake Bays, are designated as EFH. Additional designated EFH is from south of Cape Canaveral extending through the Florida Keys to the west coast of Florida.

- **Juveniles** (72 to 147 cm [28.3 to 57.8 in] TL)—Designated EFH are the coastal and pelagic waters offshore from Cape Poge Bay and the south shore of Cape Cod, Massachusetts to Long Island, New York (north of 40°N and west of 70°W); shallow coastal areas out to the 25-m (82-ft) isobath from Barnegat Inlet, New Jersey (40°N) to Cape Canaveral, Florida (27.5°N); and in the MAB (39° to 36°N) during the winter, the benthic areas underlying the shelf break between the 90-m and 200-m (295-ft and 656-ft) isobaths. In addition, EFH excludes areas from 39.2°N off the coast of New Jersey south to 35.2°N off Cape Hatteras, North Carolina (finger-like projection roughly following the 200-m [656-ft] isobath). Additional designated EFH includes the Florida Keys and the west coast of Florida.

- **Adults** (≥148 cm [58.3 in] TL)—Designated EFH is from Nantucket, Massachusetts, south to Miami, Florida, in the shallow coastal areas from the shore seaward to 50 m (164 ft). Designated EFH excludes the areas from 39.2°N off the coast of New Jersey south to 35.2°N off Cape Hatteras, North Carolina (finger-like projection roughly following the 200-m [656-ft] isobath). Additional designated EFH includes the peninsular of Florida, Florida panhandle, and Florida Keys.

HAPC Designations—HAPC are designated in the shallow areas at the mouth of Great Bay, New Jersey; lower and middle Delaware Bay; lower Chesapeake Bay; and in areas of Pamlico Sound adjacent to Hatteras and Ocracoke Islands (North Carolina) and offshore of these barrier islands, since they represent important nursery and pupping grounds (NMFS 1999b, 2003a, 2006a). A portion of the Great Bay, New Jersey, HAPC extends within the boundaries of the Study Area, while the middle and lower Delaware Bay HAPC is found south of the Study Area.

♦ **Scalloped Hammerhead (*Sphyrna lewini*)**

Management—Scalloped hammerhead shark is managed under the Large Coastal Shark MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—*S*calloped hammerhead shark is classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies scalloped hammerhead as lower risk/near threatened (Kotas 2000).

Distribution—Scalloped hammerheads are found in warm-temperate to tropical waters worldwide over the continental shelf and slope (Castro 1983; Compagno 1984a). In the western Atlantic, the scalloped hammerheads range extends from New Jersey to Brazil, as well as the Gulf of Mexico and the Caribbean Sea (Bester 1999b).

Habitat Associations—Scallop hammerheads are found from the surface to depths of 275 m (902 ft). It is found close to shore, in bays and estuaries, and prefers water temperatures of at least 22°C (71.6°F; Castro 1983; Compagno 1984a). Typically, scalloped hammerhead sharks spend the day close to shore and move to deeper waters at night to feed (Bester 1999b).

Life History—Scalloped hammerheads give birth once a year in the summer starting around June, in shallow coastal nurseries found from Virginia to the Gulf of Mexico (Castro 1993; McCandless et al.

2002). This species forms large schools when it migrates seasonally north to south along the eastern U.S coast (NMFS 1999b, 2006a).

Forage Species—Scalloped hammerhead sharks consume a wide variety fishes, as well as invertebrates, and have been reported feeding only at night (Compagno 1984a).

EFH Designations—(NMFS 1999b, 2006; **Figure F-31**)

- Neonate (≤62 cm [24.4 in] TL)—Designated EFH are the shallow coastal waters, from the shoreline to 22 NM offshore, is from South Carolina to Florida (west of 79.5°W and north of 30°N). Additional EFH is the Gulf of Mexico.
- **Juveniles** (63 to 283 cm [24.8-111.4 in] TL)—Designated EFH are the shallow coastal waters, from shoreline to the 200-m (656-ft) isobath, extending from 39°N southward to the vicinity of the Dry Tortugas and the Florida Keys (82°W). Additional EFH is the Gulf of Mexico.
- Adults (>228 cm [89.7 in] TL)—Designated EFH for this lifestage is from the Virginia/North Carolina border south to Florida at depths varying between the 25-m (82-ft) isobath to the 200-m (656-ft) isobath. Additional EFH is the Florida Straights and the Dry Totugas.

HAPC Designations—There are no HAPC identified for this species.

- **Shortfin Mako Shark (*Isurus oxyrinchus*)**

Management—Shortfin mako shark is managed under the Pelagic Shark MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Currently, is it unknown whether shortfin mako shark is overfished or overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies shortfin mako as lower risk/near threatened (Stevens 2000b).

Distribution—Shortfin mako shark has a world-wide distribution. In the western North Atlantic Ocean, it ranges from the Grand Banks, Newfoundland, and Gulf of Maine southward to the tropics, including the Gulf of Mexico (Schultz 2004). It is common offshore from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina (Castro 1983).

Habitat Associations—Shortfin mako shark is found in warm-temperate to tropical waters around the world, but is rarely found in water temperatures lower than 16°C (60.8°F; Compagno 1984b). Shortfin mako shark is an epipelagic species found from the surface to depths of 152 m (498.7 ft), but has been recorded as deep as 740 m (2,427.9 ft; Compagno 1984b; Passarelli et al. 2003).

Life History—Tagging data suggests that within the northern extent of its range, this species is follows the movement of warm-water masses towards the poles in the summer (Compagno 1984b; Kohler et al. 1998). Similar to other sharks, reproduction does not occur annually. Shortfin mako shark has a 2- or 3-yr reproductive cycle, a gestation period of approximately 18 months, and a late winter to mid-spring parturition (Mollet et al. 2000). Locations of nursery areas have not been identified, but are hypothesized to be located within deep tropical waters (NMFS 1999b, 2006a).

Forage Species—Shortfin mako sharks prey upon a variety of pelagic fishes including: swordfish, tuna, mackerel, bluefish and squid (Passarelli et al. 2003; Branstetter 2002c). In the western North Atlantic, bluefish are the primary prey species (Passarelli et al. 2003; Wood et al.2009).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-32**)

- **Neonate** (≤85 cm [33.5 in] TL)—Designated EFH is between the 50-m and 2,000-m (164-ft and 6,562-ft) isobaths from southeast of Georges Bank (~42°N and 66°W) to Cape Lookout, North

Carolina (~35°N), and from the 25-m and 50-m (82-ft and 164-ft) isobaths offshore from the Chesapeake Bay to a line running west of Long Island, New York, to just southwest of Georges Bank (~67°W and 41°N).

- **Juveniles** (108 to 262 cm [42.5 to 103 in] TL)—Designated EFH is the area from the 25-m and 2,000-m (82-ft and 6,562-ft) isobaths from offshore Onslow Bay, North Carolina, north to Cape Cod, Massachusetts, and extending west between 38°N and 41.5°N to the U.S. EEZ boundary.

- **Adults** (≥263 cm [103.5 in] TL)—Designated EFH is the area between the 25-m and 2,000-m (82-ft and 6,562-ft) isobaths from offshore Cape Lookout, North Carolina, north to Long Island, New York, and extending west between 38.5°N and 41°N to the U.S. EEZ boundary.

HAPC Designations—There are no HAPC identified for this species.

- **Skipjack Tuna (*Katsuwonus pelamis*)**

Management—Skipjack tuna is managed under the Tuna MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Currently it is unknown whether skipjack tuna are overfished and overfishing is occurring (NMFS 2008d).

Distribution—Skipjack tuna is circumglobal in tropical and warm-temperate waters, generally limited by the 15°C (59°F) isotherm. In the northwest Atlantic, the skipjack typically ranges from Cape Cod, Massachusetts, south to Brazil (NMFS 1999b; Schultz 2004).

Habitat Associations—Skipjack tuna are an epipelagic, oceanic species that moves at the surface during the day and descends to depths of 260 m (853 ft) at night (Collette and Nauen 1983). Aggregations of skipjack tuna are associated with convergence zones and other hydrographic fronts. Adult skipjack tuna prefer waters with a temperature range of 14.7° to 30.0°C (58.5° to 86.0°F; Collette 2002). Skipjack tuna exhibit a strong tendency to school in surface waters with birds, whales, sharks, and other tuna species, as well as drifting objects (Collette and Nauen 1983).

Life History—Near the equator the skipjack tuna spawn year-round, while at northern latitudes spawning is restricted to warmer months, from spring to early fall (NMFS 1999b; Gardieff 2004a). Larvae have been collected off the east coast of Florida from October to December and in the Gulf of Mexico and Florida Straits from June to October (NMFS 1999b).

Forage Species—Skipjack tuna are opportunistic feeders that prey upon fish (herring, anchovies, and sardines), cephalopods, and crustaceans with peak feeding occurring at dawn or dusk (visual feeders; Gardieff 2004a; NMFS 1999b). Additionally, *Sargassum* and species associated with *Sargassum* have been recorded in their stomachs (NMFS 1999b, 2006a). Cannibalism is also considered common (Gardieff 2004a).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-33**)

- Spawning Adults, Eggs, and Larvae—Designated EFH is offshore water (from the 200-m [656-ft] isobath out to EEZ) from the Peninsular Florida into the Gulf of Mexico.

- Juveniles and Subadults (<45 cm [17.7 in] fork length [FL])—Designated EFH is pelagic surface waters (from the 25-m [82-ft] isobath to the 200-m [656-ft] isobath) from the Florida Straights to Key Largo, Florida.

- **Adults** (>45 cm [17.7 in] FL)—Designated EFH are the pelagic surface waters with a temperature range of 20° to 31°C (68.0° to 87.8°F) from the 25-m [82-ft] isobath to the 200-m [656-ft] isobath in the MAB off the coast of Martha's Vineyard, Massachusetts (71°W), south and west to offshore of Oregon Inlet, North Carolina (35.5°N).

HAPC Designations—There are no HAPC identified for this species.

♦ **Swordfish (*Xiphias gladius*)**

Management—Swordfish are managed under the Swordfish MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—The western north Atlantic swordfish stock is not classified as overfished and overfishing is not occurring (NMFS 2008d). The 2008 IUCN classifies the north Atlantic swordfish stock as endangered (Safina 1996b).

Distribution—Swordfish inhabit the tropical, temperate, and sometimes cold water regions of all the world's oceans and seas (Nakamura 1985). In the northwest Atlantic, they occur from Cape Breton Island, Nova Scotia, to Jamaica, Cuba, and Bermuda (50°N to 40-45°S). It is also common in the Gulf of St. Lawrence and on the Grand Banks. Its presence in the waters of the western Atlantic is generally restricted to the warmer seasons (Gusey 1981).

Habitat Associations—Swordfish eggs are pelagic, buoyant, and present in offshore waters throughout the year but occur most commonly between April and November (Palko et al. 1981; Govoni et al. 2003; Gardieff 2004b). Distribution of larval swordfish is related to surface water temperatures with larvae occuring in the surface waters of all tropical seas with temperatures that range between 24°C and 29°C (75.2°F and 84.2°F; Palko et al. 1981; Govoni et al. 2003). The greatest densities of larvae in the northwest Atlantic Ocean occur between the Straits of Florida and Cape Hatteras, North Carolina (Palko et al. 1981). Adults are oceanic mid-water fish that primarily occupy depths of 200 to 600 m (656 to 1,969 ft), although they can be found throughout the water column ranging from the surface to depths of 650 m (2,132.7 ft; Nakamura 1985). They also display a preference for water temperatures bewteen 18°C and 22°C (64.4°F and 71.6°F), but can tolerate a range from 5° to 27°C (41.0° to 80.6°F; Gardieff 2004b).

Life History—Swordfish spawn year-round in the western North Atlantic, with variations in occurrence depending on area and season (Palko et al. 1981; Arocha 1997; Govoni et al. 2003). Peak spawning takes place between April and September (Palko et al. 1981; Nakamura 1985). It is believed that spawning for swordfish inhabiting the northwest Atlantic occurs near the Yucatan Channel and the Straits of Florida and also south of the Sargasso Sea (Gusey 1981; Arocha 1997). Water temperatures in spawning grounds typically exceed 20° to 22°C (68.0° to 71.6°F) and spawning occurs at salinities of 33.8 to 37.4 psu and depths up to 75 m (246 ft; Nakamura 1985; Gardieff 2004b). As the waters warm in the summer months in the northwest Atlantic Ocean, swordfish migrate north and east along the edge of the continental shelf. They return south and west in autumn. There is also evidence suggesting that other groups of swordfish may migrate toward the continental shelf from deeper waters in the summer and return in the fall (Gusey 1981).

Forage Species—Swordfish are opportunistic predators that prey primarily upon pelagic fishes (small tunas, dolphinfishes, flying fishes) but also feed on squid (*Ommastrophes*, *Loigo*, and *Illex* spp.) and demersal fishes (hakes, redfish, lanternfishes, pomfrets). They use their sword to slash and obtain larger prey, while consuming smaller prey whole (Nakamura 1985; Gardieff 2004b).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-34**)

➢ Spawning Adults, Eggs, and Larvae—Designated EFH is offshore (from the 200-m [656-ft] isobath to the EEZ) from Cape Hatteras, North Carolina through the Gulf of Mexico. And the Caribbean Sea.

- **Juveniles and Subadults** (<180 cm [70.9 in] lower jaw fork length [LJFL])—Designated EFH are the pelagic waters warmer than 18°C (64.4°F) from the surface to a depth of 500 m (1,640 ft) from offshore Manasquan Inlet, New Jersey (40°N), east to 73°N and south to off Georgia (31.5°N) between the 25-m and 2,000-m (82-ft and 6,562-ft) isobaths. Additional designated EFH is from Cape Canaveral, Florida, into the Gulf of Mexico.

- Adults (>180 cm [70.9 in] LJFL)—Designated EFH are the pelagic waters warmer than 13°C (55.4°F) from the surface to 500 m (1,640 ft) deep extending from the southeast of Cape Cod, Massachusetts, to Biscayne Bay, Florida, (25.5°N), from the 100-m (328-ft) isobath to the 2,000-m (6,562-ft) isobath or the EEZ boundary (whichever is closer to land). Additional designated EFH is the Gulf of Mexico.

HAPC Designations—There are no HAPC identified for this species.

- **Tiger Shark (*Galeocerdo cuvier*)**

Management—Tiger shark is managed under the Large Coastal Shark MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Currently, tiger sharks are classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies tiger shark as lower risk/near threatened (Simpfendorfer 2000).

Distribution—Tiger sharks are found throughout the temperate and tropical coastal waters of the world, with the exception of the Mediterranean Sea (Natanson et al. 1999; Knickle 2003b). In the northwest Atlantic, they are year-round residents in the coastal waters of Florida but make seasonal migrations range from Cuba to as far north as Nova Scotia (Natanson et al. 1999).

Habitat Associations—Tiger sharks are present over a wide variety of marine habitats but display a preference for cloudy or turbid coastal waters (Compagno 1984a; Knickle 2003b; Ferrari and Ferrari 2002). They are found across the continental shelf, as well as in estuaries, harbors, and inlets, from surface waters to depths of up to 350 m (1,148 ft; Compagno 1984a; Knickle 2003b). They prefer waters with temperatures exceeding 18˚C (64.4°F; Branstetter 2002a). Tiger sharks are nocturnal, hunting in shallow waters of bays, estuaries, and lagoons, then returning to deeper waters during daylight hours (Compagno 1984a; Tricas et al. 1997; Ferrari and Ferrari 2002).

Life History—Tiger sharks are ovoviviparous. In the northern hemisphere, mating takes place between March and May and pupping is reported to occur from April to June of the following year (Compagno 1984a; Knickle 2003b). This species partakes in extensive seasonal migrations throughout the north Atlantic, traveling distances of 2,300 km (1,241.1 NM) to as far as Cuba and Africa (Natanson et al. 1999; Ferrari and Ferrari 2002).

Forage Species—Tiger sharks feed on a wider variety of prey than most other shark species, including other sharks, skates, fishes (goosefish and bluefish), squid, horseshoe crab (*Limulus polyphemus*), crab, conch, birds, marine mammals, and sea turtles (Branstetter 2002a).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-35**)

- **Neonate** (≤90 cm [35.4 in] TL)—Designated EFH are the shallow coastal areas out to the 200-m (656-ft) isobath, from offshore Montauk, Long Island, New York, south to Cape Canaveral, Florida. Additional designated EFH is the Gulf of Mexico.

- **Juveniles** (91 to 296 cm [35.8 to 116.5 in] TL)—Designated EFH are the shallow coastal areas, the 25-m (82-ft) isobath to the 100-m (328-ft) isobath, from offshore Montauk, Long Island, New York, to north of the mouth of the Chesapeake Bay. Additional designated EFH is from the mouth of Chesapeake Bay extending into the Gulf of Mexico, also including the waters off the south and southwest coasts of Puerto Rico.

- Adults (≥297 cm [116.9 in] TL)—Designated EFH is offshore from Chesapeake Bay to Ft. Lauderdale, Florida extending into the Gulf of Mexico, also including the waters off the south and southwest coasts of Puerto Rico.

HAPC Designations—There are no HAPC identified for this species.

- **White Shark (*Carcharodon carcharias*)**

Management—White shark is managed under the Prohibited Species MU through the Final Consolidated Atlantic HMS FMP (NMFS 2006a).

Status—Currently, white shark is classified as overfished and overfishing is occurring (NMFS 2008d). The 2008 IUCN Red List classifies white shark as vulnerable or facing a high risk of extinction in the wild on (Fergusson et al. 2000).

Distribution—White sharks are found worldwide in temperate, subtropical, and tropical waters. In the northwest Atlantic, it occurs from Newfoundland to Florida, the northern Gulf of Mexico, the Bahamas, and Cuba as well as from Brazil to Argentina (Castro 1983; Compagno 1984b). The white shark is rare south of Cape Hatteras, North Carolina, and in the Gulf of Mexico except during the winter (Castro 1983).

Habitat Associations—White sharks are an epipelagic shark, but can be found utilizing depths over 250 m (820 ft). They are found from the surfzone to offshore, including oceanic islands (Castro 1983; Compagno 1984b; Martins and Knickle 2003). This shark is commonly found in areas of small coastal archipelagos inhabited by pinnipeds (main prey items), offshore reefs, banks, and shoals, as well as rocky headlands where deeper water is closer to shore (Martins and Knickle 2003). Larger individuals are more common in subtropical and tropical waters than smaller white sharks (less than 3 m [9.8 ft] in length), which typically are confined to temperate waters (Compagno 1984b).

Life History—Little is known of the white shark's reproductive behavior and habitat association, but records indicate that live young are born in temperate shelf waters during the spring to late summer (Martins and Knickle 2003). The white shark inhabits waters over the continental shelf in the summer and migrates to warmer waters during the winter months (Castro 1983).

Forage Species—White sharks prey on marine mammals (including, seals, sea lions, elephant seals, dolphins) and fishes (including other sharks and rays). In addition, marine reptiles are sporadically ingested (i.e., sea turtles; Compagno 1984b).

EFH Designations—(NMFS 1999b, 2006a; **Figure F-36**)

- Neonate (≤166 cm [65.4 in] TL)—Currently, available information is insufficient for the identification of the EFH for this lifestage.

- **Juveniles** (167 to 479 cm [65.7 to 188.6 in] TL)—Designated EFH are the pelagic waters from the 25-m (82-ft) isobath to the 100-m (328-ft) isobath, offshore of northern New Jersey and Long Island, New York, bounded to the east at 71.5°W and to the south at 39.5°N. Additional EFH has been designated for this lifestage for the waters off Cape Canaveral, Florida between the 25-m and 100-m (82-ft and 328-ft) isobaths.

- Adults (≥480 cm [189 in] TL)—Currently, available information is insufficient for the identification of the EFH for this lifestage.

HAPC Designations—There are no HAPC identified for this species.

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10.0 POTENTIAL IMPACTS

The following is a preliminary and general description concerning potential impacts of wind farm projects. Additional detail on impacts as they relate to the study area will be described in the Draft Final Report.

10.1 GENERAL IMPACTS

10.1.1 Construction/Decommissioning

Construction and decommissioning of wind farms result in similar impacts such as disturbing the sediments on the seafloor, noise and vibration and the potential for collisions between marine life and vessels used for construction or demolition. The discussion below discusses these potential impacts in the process of installing the turbines (and their foundations) and installing the transmission lines needed to get the electricity generated at the turbine to facilities onshore. Only when there may be impacts specific to decommissioning (e.g., using explosives to remove turbine platforms) are different than those of installation will decommissioning be mentioned.

10.1.1.1 Disturbance of Bed/Habitat

The installation of the turbine foundations and transmission lines would result in disturbance the seafloor and the benthic habitat there. The impacts from these activities include suspension of bottom sediments and the associated increase in water turbidity; burial of the existing surface sediments and the disruption of benthic habitat; and changes in seafloor topography and the concurrent effects on waves, currents, and normal sediment transport in the area of the wind farm.

10.1.1.1.1 Installation of Turbines

Turbine installation results in seafloor disturbance due to the methods used to install the foundations. In some cases, steel piles roughly 4 m (13 ft) in diameter are driven 22 to 24 m (72 to 78 ft) into the seafloor sediments and the tower and turbines sit on the pile. Another method involves using gravity to stabilize large steel or concrete structures on the seafloor. These structures typically measure 15 by 15 m (49 by 49 ft) at the base (MMS 2007). Either of these methods would stir up bottom sediments when installed, which in turn would increase the turbidity of the water in the vicinity. Turbidity reduces the amount of light able to penetrate the water column affecting the biota living in either the water column or the sediments. Following the disturbance of the seafloor, the suspended sediments settle back to the seafloor surface. Currents in the water likely carry the sediments away from their original location and deposit them on top of other benthic habitat.

The degree of impact caused by seafloor disturbance during turbine installation depends on the amount of sediments suspended, the time that it takes the sediments to settle back to the seafloor, the degree in which currents disperse the sediments away from their original location and the nature of the of the biota living in the benthic habitat. The farther the sediments are dispersed by currents, the less turbid the water becomes and the thinner the layer of sediments settling out. Benthic biota are usually able to overcome burial by moving up the sediment column or the area is recolonized with biota from the surrounding undisturbed area. Finer-grained sediments are going to take longer to settle back to the seafloor, but also are going to disperse farther. The stronger the current, the farther the sediments will travel; however, the amount of fine sediments settling at any particular location would be less. Once the installation activity is completed, the effect on the benthic biota would be minimal.

Installation of fixed structures on the seafloor in an area with a sandy bed may lead to the scour of the seafloor around the structures (Hiscock 2002). This problem is most frequently seen with gravity caisson-type foundations. Scour protection (typically large boulders or concrete surrounding the foundation) and spacing the turbines farther apart help mitigate the scour impacts (Ecoserve 2000, Hiscock 2002).

10.1.1.1.2 Installation of Transmission Lines

Cable installation can also result in seafloor disturbances. In order to use the electricity produced by the turbines, cables are laid to transmit the electricity to facilities onshore. These cables are typically buried below the seafloor in order to reduce the potential for damage from vessels, such as fishing trawlers, transiting between the turbine platforms and the shoreline (Ecoserve 2000).Cables can be installed using high powered water jets or mechanical plows, either of which displaces bottom sediments to create a trough in which the cable is placed. Usually, the sediments displaced for the cable slough back into the trough, thereby burying the cable; however, the action would still result in temporary turbidity increases.

10.1.1.2 Noise and Vibration

10.1.1.2.1 Installation of Turbines

The installation of offshore wind farms involves several activities with the potential to produce significant noise and vibrations. These activities include ship and barge noise, pile driving, general construction noise, and helicopter and crew boat operations. Ship and barge noise would be similar to those of general ship traffic; therefore, it would have a minimal effect on marine life or human populations. Pile driving has the greatest potential for impact and is the primary concern with respect to construction noise from offshore projects. Pile driving produces intense sound pulses in water at a rate of 30 to 60 beats per minute over a period of 1 to 2 hrs for each pile (MMS 2007).

Noise generated during construction could disturb the normal behaviors of marine mammals such as feeding and communication, disrupt echolocation capabilities, and mask sounds produced by predators. These behavioral effects may be incurred at ranges of many miles; whereas hearing impairment could occur at close range. The normal habits of sea turtles could also be disrupted by offshore construction noises. Fish can be susceptible to high-intensity noises with effects ranging from avoidance to mortality. Physical impacts on fish depend on the species of fish and type of sound perception system in a particular species. Marine and coastal birds could also be displaced from normal feeding grounds during construction, if the wind farm is being constructed in offshore foraging areas. This displacement could have an adverse impact on onshore nesting sites or rookeries by making the parents travel longer and stay away from the nest longer to get food to feed the young (MMS 2007). Many of these impacts could be reduced or eliminated by careful planning of the wind farm site relative to the habitats of marine mammals, sea turtles, fisheries and marine and coastal birds.

Additional construction noises include the use of hand tools and machinery such as air compressors, and helicopters or crew boats used to ferry workers or materials to offshore work sites. These noises could cause short-term individual behavior and communication disturbances; however, population-level effects are not likely.

Demolition activities would produce similar noise impacts as construction except that pile driving would not be performed. In some cases, explosives may be used to remove the pilings, which would produce similar levels of noise as pile driving although for a shorter duration (one blast rather that repetitive hammering).

10.1.1.2.2 Installation of Transmission Lines

Sea turtles and shore birds would be the most likely biota to be affected by noises from the installation of transmission lines, because of the need to install the cable across the beach area. Sea turtles lay eggs on the beach and then the hatchlings travel back across the beach to the water. Noise on the beach is known to cause sea turtles to avoid nesting in the vicinity and create confusion for the hatchlings (MMS 2007); however, no sea turtle nesting is documented for the New Jersey coast. Similarly, shore birds that nest on beaches could be driven from the area due to the noise from construction and some may stay away permanently. If the cable landing must occur on a beach known for sea turtle or bird nesting, construction should be scheduled to avoid the nesting season.

10.1.1.3 Vessel Collision

10.1.1.3.1 Installation of Turbines

During construction numerous vessels are used to transport people and equipment to the construction site. Vessel traffic may affect adversely marine mammals and sea turtles by direct collision. Whale strikes have been recorded at vessel speeds of 2 to 51 kts (2 to 59 mph), with most lethal or severe injuries occurring when the vessels are moving at more than 14 kts (16 mph). Collisions can occur with any size vessel; however, impacts with larger vessels (more than 80 m [262 ft] in length) are generally more lethal or result in severe injuries. In most of the documented whale strikes the whales were either not seen beforehand or were spotted too late to avoid collision (MMS 2007).

The potential for collisions between sea turtles and construction vessels would depend on the species, life state, the location and speed of the vessel, and visibility. While adult turtles are generally visible at the water surface during daylight and clear visibility, they may be difficult to spot from a moving vessel when they are resting below the surface or during nighttime and periods of inclement weather. Sea turtle hatchlings are transported passively on currents or mats of *Sargassum* and are difficult to spot from a moving vessel. They have limited ability to avoid oncoming vessels; therefore, they are more susceptible to vessel collisions.

The effect of vessel collisions on marine mammals and sea turtles during construction of the turbine platforms would be short-term do to the limited duration of construction.

10.1.1.3.2 Installation of Transmission Lines

Impacts from vessel collisions during installation of transmission lines would be similar to those from installation of turbines. The one difference is that the cable laying vessel generally travels at a much slower speed than vessels carrying equipment and personnel to and from the construction area. Marine mammals and sea turtles are more likely to be spotted from slower moving vessels and avoidance measures taken.

10.1.2 Normal Operations

10.1.2.1 Collisions

The potential impacts on marine mammals and sea turtles from vessel collision during normal operations are similar to those during construction.

The collision of birds with wind turbines is one of the most recognized ecological impacts surrounding the use of wind energy. Studies have shown that wind energy facilities (both terrestrial and offshore) around the United States average a death rate of between one and two birds per turbine per year (Reeves and Beck 2003). Proper siting of facilities and proper management after construction are the most critical steps in minimizing avian death due to collisions with turbines (Janss 2000). Bird collisions tend to increase during low visibility events such as fog. Birds are likely attracted to the navigation lights in these situations and are subsequently struck by turbine blades (Hiscock 2002). A much more comprehensive review of the relevant literature and discussion of collision of birds with wind turbines offshore will appear in the Final Report.

10.1.2.2 Noise/Vibration Avoidance

The noise and vibration produced during the operational phase can also have disruptive effects on the marine environment (Gerdes 2005). The noise caused by turbines, is unfortunately unavoidable, but has been minimized through advances in turbine design (Reeves 2003). During the operation of an offshore wind farm, noise is created by not only the turbine blades, but also by the transformer (Gerdes 2005).

Underwater noise studies from existing wind farms have come to the following conclusions:

1) Underwater sound from wind turbines is mainly generated by vibrations in the tower;
2) The large contact area of a tower with the water provides an effective path for sound transmission to the water;
3) Tower vibrations transmitted to the seafloor have negligible impact on underwater sound levels (MMS 2007).

The impacts from operational noise on marine mammals could include behavioral changes in foraging, socializing, and movement. Affected animals may exhibit auditory masking, which in turn could affect foraging and predator avoidance. Unlike construction impacts, operation noise may affect more species over a longer period of time. This could lead to the abandonment of feeding or mating grounds or disruption of migratory routes, which in turn could lead to long-term population-level effects (MMS 2007).

Noise generation could result in long-term avoidance of the area by adult and juvenile sea turtles. Hatchlings may drift into the area unintentionally and be exposed to long term noise levels. Sea turtle noise sensitivity or noise-induced stress have not been largely studied; therefore, the long-term affect of turbine noise on sea turtles is unknown (MMS 2007).

Noise and vibrations associated with wind turbines could also disturb or displace fish within the surrounding areas or could mask the sounds used by fish for communicating and detecting prey. The level of effect is influenced by the species of fish. Some fish may avoid the noise up to 1 to 5 km (0.6 to 3 mi) from the turbine, while others may only be affected up to 4 m (13 ft; MMS 2007).

Bird studies have shown that birds are usually aware of the turbines and alter their fight patterns to avoid the turbines. In some cases, birds flew at higher altitudes to avoid the offshore wind farm (Janss 2000). Other studies showed modified flight routes, which can add significant mileage to the migration event (Exo 2003). This modification in behavior, especially for migratory birds, could have substantial effects, as migration can already be a stressful time for birds. The addition of higher altitudes or longer flight paths could have a detrimental impact on the individuals.

10.1.2.3 Electromagnetic Fields of Transmission Lines

Transmission of electricity from offshore wind farms requires extensive lengths of cables laid along the seafloor back to land for integration into the grid. Transmission of electricity through these cables can lead to the generation of electrical and magnetic fields. Most marine organisms can sense electric fields, including fish; however, it is unknown how anthropogenic EMFs may affect these organisms, as current knowledge is limited (Petersen 2006). EMFs may inhibit the navigation of marine mammals, sharks, and rays, and may also affect the feeding behaviors of sharks and rays (Hiscock 2002).

In the past, monopolar cables were used, which created very strong EMFs. These EMFs were thought to have had deleterious effects on marine organisms and on the shipping industry. Two other technologies are now used, which use alternating or direct current cables. The EMF of these cables has been shown to be very small, if one is generated at all; therefore, it does not seem likely that these cables would have significant effects on the marine environment (Gerdes 2005). Overall, while the presence of a foreign EMF may or may not have an impact on species in the vicinity of the transmission lines associated with an offshore wind farm, current data is too inconclusive to make a decision with any certainty (Petersen 2006).

10.1.2.4 Fishery Modifications

The presence of an offshore wind farm can limit recreational and commercial fishing and boating, not only because of the spacing and presence of the wind turbines and their associated foundations, but also due to the potential presence of underwater obstructions such as transmission lines (Ecoserve 2000). To ensure the safety of fishermen and their equipment, most fishing activities (trawling, ground nets, etc) would need to be restricted in an area larger than the actual footprint of the offshore wind farm to reduce the number of accidents and gear losses due to the presence of the underwater hazards (Fayram 2007, Ecoserve 2000).

The ecological impact associated with the installation and operation of the turbine foundations that has the potential to have the greatest impact on the marine ecosystem is the creation of benthic habitat. The presence of an offshore wind farm and the additional habitat substrate associated with the facility could have a significant effect on the species composition and structure in the vicinity of the structures (Petersen 2006). Several studies have shown that the introduced surfaces (the turbine foundations) can begin to function as nursery grounds for species, allowing for greater survival of the juveniles (Gerdes 2005).

As discovered in previous offshore wind turbine construction projects, preparation of the seabed can destroy suitable habitats and reduce habitat complexity; however, once turbines and their foundations are installed and colonized, three-dimensional habitat, which serves to protect young fish and other organisms from predation, is created (Ecoserve 2000). Anthropogenic structures placed into the marine environment are known to increase the biodiversity, productivity, and nutrient cycling of the area (Hiscock 2002). Several studies have shown that offshore wind turbines (whether floating or constructed in the sea bed) serve as fish aggregating devices (FADs). Catch rates of some species can be 10 to 100 times greater in the vicinity of offshore wind farms. Typically the fish associated with such a system are juveniles (Fayram 2007). This suggests the need to restrict fishing in the wind farm area.

10.1.2.5 Alteration of Ocean Currents

Potential impacts of a wind farm on ocean currents and waves include a reduction in current energy produced by structural drag, a decrease in wave height in the vicinity of the support structures caused by wave interception, and a decrease in wave height downwind of the facility caused by a decrease in wind energy. A typical foundation can range from 4.5 to 15 m (15 to 50 ft). When the spacing of these structures is considered (typically 300 to 500 m [984 to 1640 ft] apart), it is unlikely that their presence will have a significant impact on ocean currents or tidal flows (Ecoserve 2000). These impacts would be small and limited to the immediate vicinity of the facility (MMS 2007).

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