Ocean/Wind Power Ecological Baseline Studies

January 2008 – December 2009

FINAL REPORT

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
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Volume I: Overview, Summary, and Application

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GEO-MARINE GMI
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New Jersey Department of Environmental Protection Baseline Studies

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EXECUTIVE SUMMARY

The State of New Jersey is committed to finding long-term energy solutions and is pursuing alternative energy options. Offshore wind may provide a solution to New Jersey's long-term energy needs. There are limited data and information on the natural resources and their environment occurring in New Jersey's offshore waters, specifically the region being considered for wind turbine development. Geo-Marine, Inc. (GMI) was contracted to conduct a scientific baseline study by the New Jersey Department of Environmental Protection (NJDEP) Office of Science to fill major data gaps for birds, sea turtles, marine mammals, and other natural resources and their environments found in the Study Area.

The objective of this study was to conduct baseline studies in waters off New Jersey's coast to determine the current distribution and usage of this area by ecological resources. The goal was to provide GIS and digital spatial and temporal data on various species utilizing these offshore waters to assist in determining potential areas for offshore wind power development. The scope of work includes the collection of data on the distribution, abundance and migratory patterns of avian, marine mammal, sea turtle and other species in the study area over a 24-month period. These data, as well as existing (historical) data, were compiled and entered into digital format and geographic information system (GIS)-compatible electronic files. Those portions of the study area that are more or less suitable for wind/alternative energy power facilities were determined based on potential ecological impact using predictive modeling, mapping, and environmental assessment methodologies.

Field studies were initiated in January 2008 and continued through December 2009. Data for avian abundance, distribution, and behavior were collected by shipboard surveys (offshore and coastal), aerial surveys, radar surveys (offshore and coastal), Next Generation Radar (NEXRAD) and Thermal Imaging–Vertically Pointing Radar (TI-VPR) studies, and supplemental surveys (shoal surveys and sea watch) were conducted over the 24-month period. Marine mammal and sea turtle data were collected via shipboard surveys, aerial surveys, and passive acoustic monitoring to assess the distribution, abundance, and presence of marine mammal and sea turtle species in the Study Area. Detailed information on the methods, data analyses, and results from these field studies is included in this document. In addition, a thorough review of fish and fisheries resources of the Study Area was conducted, which includes an overview of the ichthyofauna (including fish species designated with essential fish habitat [EFH]) of the Mid-Atlantic Bight (MAB) and the Study Area and the ancillary fishes observed during the shipboard and aerial surveys. A description of the federal- and state-level fishery management is presented for commercial and recreational fisheries, and the results of New Jersey fisheries independent bottom trawl data analyses are discussed.

In addition to the data collected on biotic resources, physical parameters within the Study Area were measured, including wind speeds, water temperature, salinity, depth, chlorophyll, and dissolved organic matter. Extensive literature searches were also conducted on climate, currents and circulation patterns, and other important physiographic components in effort to characterize the Study Area and gain understanding of the relationships between the physical and biological resources.

Avian Summary

Shipboard and Small Boat Surveys

A total of 176,217 birds representing 153 species were recorded, with 84,428 birds of 145 species being recorded during the shipboard offshore surveys and 91,789 birds of 82 species recorded during the small-boat coastal surveys. Federally endangered, threatened, and candidate species were not detected during avian surveys. Fourteen of the 21 federally listed species of concern and 16 of the 20 state-classified endangered, threatened, and special concern species potentially occurring in coastal and offshore waters were observed during the survey.

Avian densities were highest near shore at all seasons, although this finding was much more pronounced in winter than in summer (ratio of abundance on offshore surveys vs. small-boat coastal surveys ranged from 2:5 to 1:5). This was because of the large numbers of coastal-breeding gulls and terns and wintering waterfowl along the New Jersey coast and the relative lack of true pelagic seabirds in the Study Area (although there were large numbers of Wilson's Storm-Petrels (*Oceanites oceanicus*), an austral migrant from the Southern Ocean, present offshore in the summer). Overall, the areas of highest abundance were restricted to inshore waters, with the highest avian abundances recorded east of Hereford Inlet, south and east of Ocean City, and east of Atlantic City. Offshore, the most consistent area of high avian abundance was near a shoal area east of Barnegat Inlet. The summer seasons exhibited the lowest absolute abundance, with the majority (54.4%) of individuals detected being of locally-breeding species, primarily Common Tern (*Sterna hirundo*) and the three breeding gull species (Laughing [*Leucophaeus atricillus*], Herring [*Larus argentatus*], and Great Black-backed [*Larus marinus*]).

An interesting difference among the four seasons was that highest relative abundance was shifted quite noticeably from offshore in summer (56% or 37 of 66 highest-abundance blocks were offshore in the season) to nearshore in winter (3% or 2 of 65 blocks). Spring and fall are transitional seasons and were intermediate in this aspect (spring: 27.7%; fall: 18.5%). This variation was a result in differing habitat preferences between the seasonal avifauna, with the winter avifauna dominated by inshore-foraging species (e.g., scoters) and the summer avifauna dominated by offshore-foraging species (e.g., Common Tern).

Seasonally, species composition varied little between 2008 and 2009. Black Scoter (*Melanitta nigra*) was the most abundant bird in winter for both years, as was Northern Gannet (*Morus bassanus)* in spring and Laughing Gull in summer. In fall, Laughing Gull and Northern Gannet were the two most abundant species in both years. While numbers of many species fluctuated from 2008 to 2009, some of this change can be attributed to differences in survey timing between years. For example, in fall 2008, surveys were spaced rather evenly over the season, while surveys were concentrated at the beginning and end of fall 2009. Thus, species such as Surf Scoter (a mid-season migrant) that migrates through New Jersey in large numbers during mid-fall showed a large decrease in fall abundance from 2008 to 2009.

In addition to examining abundance and distribution, data were also analyzed to determine frequency of occurrence within the potential rotor-swept zone (RSZ) of power-generating wind turbines, defined as 100 to 700 feet (ft; 30.5 to 213.4 meters [m]). Of the >70,000 flying birds recorded, 3,433 (4.8%) occurred in the RSZ, with 33 species recorded in the RSZ at least once. More species occurred in the RSZ in fall (21 species) than any other season, followed by winter (16), spring (15), and summer (five). Scaup (*Aythya* spp.) accounted for 54.5% of all birds in the RSZ for the small-boat coastal surveys, and 31.8% of all birds in the RSZ overall. The only three species to occur in the RSZ in all four seasons were Northern Gannet, Herring Gull, and Great Black-backed Gull. Red-throated Loon (*Gavia stellata)*, Common Loon (*Gavia immer)*, Osprey (*Pandion haliaetus*), and Laughing Gull were recorded in the RSZ in three of the four seasons. Nearly all scaup in the RSZ (1,088 of 1,091) were recorded during a severe cold snap in January 2009, illustrating the potential effects of a major weather event on avian movements. Offshore, Northern Gannet was the species occurring most often in the RSZ (594 individuals), though the percentage of the species detected within the RSZ was small (3.9%)

AVIAN RADAR SURVEYS

Avian radar surveys were conducted at offshore locations over the Study Area in spring 2008, fall 2008, and spring 2009. Data collection was limited in fall 2008 and severely limited in spring 2009. Onshore radar surveys were conducted from three locations during 2008 and 2009.

Vertically scanning radar (VerCat) and horizontally scanning radar (TracScan) data from offshore and onshore were analyzed and data filters were developed to remove detections from rain (especially virga) and sea clutter, because these detections generate false tracks. Track counts were adjusted for dropped tracks that received a new track ID when the target was the same as the original track. The TI-VPR system sampled targets passing through a 20-degree (°) cone directed vertically to determine the proportion of each type of biological target (e.g., birds, bats, insects) detected by VerCat. The TI-VPR data were used to develop a correction factor for insects in the radar count data from the VerCat. Data from offshore barge-based and onshore-based observer validation surveys were analyzed and used to evaluate the results of radar analyses.

The VerCat flux value (adjusted bird tracks/cubic kilometer/hour [abt/km^3/hour]) is the primary metric used to estimate potential bird-turbine collisions. Data related to cumulative diurnal and nocturnal flux were sorted by time period (weeks, daytime and nighttime) into three altitude bands with reference to the potential RSZ: (1) below the RSZ (low altitude band, 1 to 99 ft above mean sea level [AMSL]), (2) within the RSZ (middle altitude band, 100 to 700 ft AMSL), and (3) above the RSZ (high altitude band, 701+ ft AMSL) and by wind category (0-8 miles per hour [mph], 9-16 mph, and above 16 mph).

General overall conclusions and trends regarding bird flux altitude distribution are presented first and then are followed by a detailed summary of flux abundance within each altitude zone.

Offshore Flux

Spring 2008

- Cumulative flux was greater during the day in the middle (RSZ) than in the low altitude band over both nearshore and offshore sampling locations.
- During the night greater cumulative flux values occurred within the RSZ than below the RSZ as the spring season advanced for both nearshore and offshore grids.

During spring 2008, daytime cumulative flux values gradually decreased within the low altitude band (range: approximately 1,200-250 abt/km^3/hour) and gradually increased within the RSZ (range: approximately <50-500 abt/km^3/hour) for nearshore and offshore sites. During the night greater cumulative flux values occurred within the RSZ (range: approximately <50-2,200 abt/km^3/hour) than below the RSZ (range: approximately >200-900 abt/km^3/hour) as the spring season advanced for both nearshore and offshore grids. Cumulative diurnal and nocturnal flux in the high altitude band was <25 abt/km^3/hour throughout the spring season.

Fall 2008

- Radar data are limited in duration and were insufficient to make any conclusions.

Spring 2008

- Radar data collection was limited in duration (two days) and data were insufficient to make any conclusions.

Onshore Flux

Spring 2008 – Fall 2009

- Overall, although some flux occurred within the RSZ during the daytime, most bird movements were below the RSZ in 2008 and 2009. At night, when no migration was occurring, the cumulative flux values were greater below the RSZ than within the RSZ. When migration occurred the flux increased within and above the RSZ.

During spring 2008, the cumulative daytime flux ranged from >50-750 abt/km^3/hour below the RSZ and from >150-300 abt/km^3/hour above the RSZ. In spring during the night, the majority of movement below the RSZ ranged from 100-900 abt/km^3/hour; in contrast the cumulative flux within the RSZ ranged from <25-125 abt/km^3/hour. Cumulative diurnal and nocturnal flux in the high altitude band was <10 abt/km^3/hour throughout the spring season.

In fall 2008, the cumulative daytime flux ranged from >50-550 abt/km^3/hour below the RSZ and from <50-75 abt/km^3/hour within the RSZ. At night during fall 2008, most of the nights had similar cumulative flux values below and within the RSZ (range: 50-275 abt/km^3/hour). Cumulative diurnal and nocturnal flux in the high altitude band was <1 abt/km^3/hour throughout the fall season.

During spring 2009, the cumulative daytime flux ranged from >50-500 abt/km^3/hour below the RSZ and was <50 abt/km^3/hour within the RSZ. At night during spring 2009, the cumulative flux ranges from <25-1,000 abt/km^3/hour and from <25-775 abt/km^3/hour. Cumulative diurnal and nocturnal flux in the high altitude band was <5 abt/km^3/hour throughout the spring season.

In fall 2009, for most sample dates, the cumulative flux was slightly higher (range: <25-450 abt/km^3/hour) below the RSZ than within the RSZ (range: <25-100 abt/km^3/hour). This trend also occurred at night, however, the cumulative flux within the RSZ at night (range: <25-900 abt/km^3/hour was only slightly below that recorded below the RSZ (range: <25-1,200 abt/km^3/hour). Cumulative diurnal and nocturnal flux in the high altitude band was <1 abt/km^3/hour throughout the fall season.

THERMAL IMAGING-VERTICALLY POINTED RADAR

Use of thermal imagery and vertically pointing radar proved to be very valuable in identifying the sources of echoes detected in VerCat. The TI-VPR system could easily detect targets flying through the RSZ. The vertically pointing radar provided accurate altitudes of flight and the thermal imaging video provided enough information on targets to identify them as birds, foraging bats, or insects. Overall, sampling time was limited, especially at onshore sites and offshore sites after spring 2008 because of weather conditions (clouds, rain), and therefore conclusions are limited.

General overall conclusions and trends regarding bird flux altitude distribution are presented first and then are followed by a detailed summary of flux abundance within each altitude zone. Overall, sampling time was limited, especially at onshore sites and offshore sites after spring 2008 because of weather conditions (clouds, rain), and therefore conclusions were limited. Comparisons between the avian radar and TI-VPR data were not made because of the lower number of TI-VPR surveys. Overall, the general conclusions were:

- The majority of birds detected were within the RSZ at the offshore and onshore survey locations during the nighttime sampling periods.
- More foraging bats were detected in fall and more bats were detected offshore than onshore; bats were detected at distances up to 16.1 kilometers (km; 10 miles [mi]) offshore.

During spring 2008, the majority of bird movements occurred within the RSZ. Bird flight direction was primarily from the north-northwest to the north-northeast. Nine foraging bats were detected at distances up to 16.1 km (10 mi) offshore. In contrast to spring 2008, bird movements below and within the RSZ were nearly equal during fall 2008; however, this result may have been affected by the limited survey time during fall. Flight direction was primarily to the southwest and showed little variability. In contrast to spring, more foraging bats were detected even though the sampling effort was limited.

In spring 2009, the mean directions of the movements were towards the northwest-northeast to the north-northeast; one movement was a reverse migration toward the south-southwest. No foraging bats were detected.

Offshore

- During the nights sampled in spring 2008 and 2009, the majority of bird movements (75%) occurred within the RSZ.
- The majority of birds (50-75%) were detected within the RSZ during fall 2009.

Onshore

- Most of the birds (90%) detected were flying within the RSZ
- During spring 2009, all of the detected birds were above the RSZ.
- The majority of birds (50-75%) were detected within the RSZ during fall 2009

Surveys were limited in fall 2008 to one location and/or by weather conditions (clouds, rain). The majority of the birds were moving to the south-southwest. Flight directions were more variable in fall but generally ranged from the southwest to southeast. Six foraging bats were detected.

During limited sampling in spring 2009, all of the detected birds were above the RSZ. Birds were detected moving to the northeast. No foraging bats were detected in spring 2009.

The majority of the birds detected were within the RSZ. Flight directions were more variable in fall but generally ranged from the southwest to southeast. Six foraging bats were detected.

NEXRAD

The overall conclusions of the NEXRAD study were:

- Nearshore bird densities were higher than offshore bird densities in both spring and fall; overall, the density of migration during the fall was on average two to three times greater than the density of migration observed during the spring.
- In the spring, the mean directions from which the movements ranges from 203 to 211° and flights were oriented toward the north-northeast (23° to 32°) 17 to 35° and in fall flights were oriented toward the southeast to south-southwest (197 to 214°).
- Nocturnal migration during the spring and fall shows considerable night-to-night variability. In the spring, migration begins to build in late April, peaks near the middle of May, and then declines towards the end of May. Fall migration builds in early September and peaks in mid-October to early November. After the peak in late October/early November the density of migration declines, and by mid-November very little migratory movement takes place.
- During the five years of spring data, 79 of 365 nights had conditions that would cause birds to fly lower -- sometimes with reduced visibility. Twenty-nine of these nights had migration densities of 25 birds/km^3 or greater.
- During the five years of fall data, 102 of 465 nights had weather conditions that might cause birds to migrate at low altitudes and 24 of these nights had bird movements of 25 birds/km^3 or greater.
- Over the five fall seasons there were 23 more nights than in five spring seasons with weather conditions that could cause birds to fly at low altitudes and sometimes in poor visibility, but generally on these nights there was little or no migration.

Year-to-Year Pattern of Migration

During the spring the sum of nightly peak density (a metric calculated from the summation of the maximum density [birds/km^3] recorded for each evening during a season) differed from year-to-year. As expected, the maximum density of migration measured over the coastal sample areas differed from the maximum density over the offshore sample areas. This can be attributed to the bird's tendency to follow the coast line during their migration. Over the five years of fall data the sum of the nightly peak densities measured over the onshore sample areas ranged from 1,445 (area 3A) in the fall of 2004 to 4,078 (area 1A) in the fall of 2005, with a maximum density of 705 recorded in the fall of 2005 (area 1A). The range of the sum of nightly peak densities over the offshore sample areas ranged from 273 (area 1B) in the fall of 2004 to 658 (area 2B) in the fall of 2005, with a maximum density of 144 recorded in the fall of 2005 (area 2B).

Night-to-Night Pattern of Migration

Nocturnal migration during the spring and fall shows considerable night-to-night variability. Within the three onshore sample areas there were five nights with a mean density of 100 birds/km^3 or greater over the sample areas during the five years of spring migration (21 April, and 01, 04, 07, 11 May), while within the offshore sample areas the maximum was 21 on 21 April [area 1B]). Within the offshore sample areas the mean migration density was considerably less than that measured over the onshore areas (mean peak density of 21 birds/km^3). Though sizable flights can occur anytime from the middle of April through the middle of May, the peak of migration through the area is in early to mid-May. Fall migration builds in early September and peaks in mid-October to early November. After the peak in late October/early November the density of migration declines, and by mid-November very little migratory movement takes place. This pattern can be seen both within the onshore sample areas and within the offshore sample areas. There were 17 nights with a mean density of 100 birds/km^3 or more within the onshore sample areas during the five years of fall migration (31 August, 01, 10, 13, 15, 23, 26, 29 September and 05, 12, 14, 15, 17, 20, 25 October, and 02, 09 November), while within the offshore sample areas there were zero nights with a mean density of 100 birds/km^3 or more. Area 1A measured the highest density for the fall season on 15 October with a mean density of 258 birds/km^3. Similar to the spring, the offshore sample area mean migration densities were considerably less than those measured within the onshore sample area. The maximum mean density only measured 34 birds/km^3 on 12 September within Area 1B.

Direction of Migratory Movements

In the spring, there was some variability in mean direction from year to year but within each year there was relatively strong directionality as indicated by the length of the mean vector [r] (a statistical measure of concentration). All yearly mean directions show low circular variance and are highly significant ($p<0.000$). In the fall, the lengths of the mean vectors from the fall data were comparable to those in spring data. Topographic features such as the shoreline likely influence the directions of seasonal migrations, particularly those occurring at lower altitudes.

AVIAN PREDICTIVE MODELING

One of the primary goals of the study was to develop spatial models for predicting changes in density and spatial distribution of birds and to identify important regions used by birds within the Study Area. The objective was to quantify where birds are most likely to concentrate in relation to geophysical habitat features (e.g. depth, shoals) and predict where birds were likely to occur seasonally. The following questions were addressed: (1) Where and when are birds (species) most likely to concentrate within the Study Area? (2) Are birds more or less concentrated evenly along the coast, or do some species exhibit specific spatial gradients (i.e. latitude/longitude variation)? (3) What is the relationship between bird density/distribution and depth, distance to shoreline, distance to shoals, and slope?

Interpolation (e.g. kernel density), spatial regression, and generalized additive models (GAMs) were used to quantify the relationship between spatial covariates (e.g. bathymetric and distance based metrics) and birds. The spatial models were developed to quantify the effect of each spatial covariate for predicting changes in bird density and distribution. In summary, along with the kernel density maps that identified where and when birds were likely to concentrate, spatial covariates were calculated to develop insight into the geographic distribution and describe the basic attributes of habitat utilized by birds. By incorporating these data in a geographic information system, changes in bird density were determined as a function of depth, slope, distance to shoreline, distance to shoals, and whether there was a spatial gradient in bird density (north/south or east/west) for a variety of species. Collection of kernel density maps was a valuable tool for identifying important locations where and when (by month and season) birds were most likely to concentrate.

Kernel Density Interpolation

Kernel density maps were estimated for all-behavior and sitting densities (number of birds/km^2) in 2008 and 2009, and the combined two-year period 2008-2009. Numerous localized density maxima for all-behavior and sitting birds were located nearshore, midshore, and far-offshore, with the vast majority of these maxima occurring nearshore. A small portion of these density maxima for all-behavior birds are mirrored by the sitting birds, reflecting differences in the numbers of flying and sitting birds. For example, eight and 15 localized sitting density maxima occurred in 2008 and 2009, respectively; and 24 such maxima occurred in the overall cumulative two-year period, most of which occurred nearshore. In 2008, the eight sitting density maxima ranged from 110 to 830 (the latter occurring between Barnegat Light and Seaside Heights and in 2009, the 15 sitting density maxima ranged from 115 to 735 (the latter occurring north of Little Egg Inlet). In the overall cumulative two-year period, the 24 sitting density maxima ranged from 115 to 1,480 (the latter occurring north of Little Egg Inlet). For the all-behavior birds, the highest density maxima were 1,425 in 2008 (midshore southeast of Little Egg Inlet), 1,730 in 2009 (nearshore north of Little Egg Inlet), and 1,805 (on the offshore edge of the nearshore region, between Little Egg Inlet to Brigantine).

Observing these annual and overall cumulative spatial kernel density maps, the following general conclusions can be made:

- Nearshore densities are higher than offshore densities, supporting an offshore gradient of decreasing densities with increasing offshore distance.
- Within the offshore region, midshore densities were generally higher than far-offshore densities.
- All-behavior densities were higher than sitting densities, reflecting the presence of both all-behavior and sitting birds.
- The highest nearshore densities occurred up against the coastline rather than on the offshore edge of the nearshore region.
- Densities of birds were also higher in shoal areas.

Predictive Modeling

In general, depth and distance to shoreline were found to be important predictors of bird density and distribution. For example, using the combined two year dataset, it was determined that bird density and distribution declined in waters greater than 20 m (65.6 ft) in depth and 12.2 km (7.6 mi) from the coastline; however, there was a strong seasonal effect in the location of bird aggregations in relation to depth and distance to shoreline. In fall, when bird density was highest (i.e., migration and seasonal visitors take up residence along the New Jersey coastline) birds were concentrated in waters up to 20 m (65.6 ft) in depth and 12.2 km (7.6 mi) from the coastline. In spring, birds were found concentrated in deeper waters (>20 m [65.6 ft) than in the fall (<20 m), and density was lower. In summer, bird density ranged further offshore (18.3 km [11.4 mi]) and increased significantly in waters greater than 30 m (98.4 ft) in depth. In winter, bird density was concentrated in waters less than 15 m (49.2 ft) in depth and within 12.2 km (7.6 mi) from the coastline. Therefore, there is a moderate shift in concentrations of total bird density from close to shore (fall and winter) to offshore (spring and summer) that is attributed to changes in avian community composition.

Total sitting bird density was modeled to identify where birds are most likely to reside, concentrate, and for some species, feed (i.e. loons, ducks, and gulls sitting on the water may indicate foraging locations). In general, sitting birds were most likely to occur in waters less than 15 m in depth and within 3.8 mi from the coastline. In fact, in fall, spring, and winter, sitting bird density was concentrated in waters within 6.1 km (3.8 mi) from the coastline, whereas in summer the distance increased to 18.3 km (11.4 mi).

The seasonal changes in density and distribution of total birds were dynamic and related to changes in bird community composition. For example, in the fall and winter there were dense concentrations of diving ducks that were absent in the summer when the bird community was primarily composed of terns, gulls and petrels. This difference in community composition was likely responsible for the varying degree of bird density clustered inshore and offshore. The models detected this and quantified habitat use by total birds as a function of depth and distance to shoreline. These dynamics were investigated further to quantify the effect of covariates for predicting changes in species distribution. Scoter density and distribution exhibited a peak in waters 10 m (32.8 ft) in depth and were concentrated within 6.1 km (3.8 mi) from the coast and increased offshore to approximately 30.6 km (19 mi) from the coast. Northern Gannets, which were present in each season, were generally concentrated in waters greater than 10 m (32.8 ft) in depth that was within 25.3 km (9.5 mi) from the coastline. Laughing Gulls and Common Terns, which were seasonal summertime breeders in New Jersey, displayed interesting distribution patterns. Laughing Gulls were generally concentrated within 7.6 km (4.7 mi) from the coast and decreased in waters greater than 15 m in depth. On the other hand, Common Terns ranged further offshore and their density declined around 18.3 km (11.4 mi) from the coast, and thereby occupied a wider range of coastal habitat than Laughing Gulls. The density and distribution of Cory Shearwaters, which were also summertime visitors, showed an increase in density offshore in waters greater than 30 m (98.4 ft) in depth to approximately 27.3 km (17 mi) from the coastline.

Overall, bird density and spatial distribution exhibited a striking onshore to offshore gradient that was highly variable among seasons and linked to changes in community composition. The results pinpoints where repeated maximum densities are likely to occur in relation to a variety of species. This information was integral to the understanding of the spatial ecology of marine birds along the New Jersey coastline and should be used to examine potential changes in habitat due to environmental changes from human activity (e.g., offshore wind development, water quality degradation, etc.).

Marine Mammal and Sea Turtle Summary

Marine mammal and sea turtle data were collected via shipboard and aerial surveys and passive acoustic monitoring over a 24-month period to assess the distribution, abundance, and presence of marine mammal and sea turtle species in the Study Area. Ten of the 47 possible species to occur in the Study Area were detected visually and/or acoustically during the baseline study period. Detected species include the following five federally threatened or endangered species: North Atlantic right whale (*Eubalaena glacialis*), fin whale (*Balaenoptera physalus*), humpback whale (*Megaptera novaeangliae*), leatherback turtle (*Dermochelys coriacea*), and loggerhead turtle (*Caretta caretta*). The minke whale (*Balaenoptera acutorostrata*), bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*), harbor porpoise (*Phocoena phocoena*), and harbor seal (*Phoca vitulina*) were also detected.

Some clear seasonal patterns in distribution were evident from our study. Although all of the 10 species detected during this study could occur in the Study Area at any time, only the North Atlantic right whale, fin whale, humpback whale, and bottlenose dolphin were detected during all seasons. The occurrence of dolphins and porpoises, as well as turtles, is largely seasonal. Bottlenose dolphins, loggerheads, and leatherbacks mostly occur in the Study Area in the summer, while short-beaked common dolphins and harbor porpoises are common in the Study Area during the winter and spring. The fall season appears to be a transitional period for seasonal cetacean species. Few sightings of bottlenose dolphins and short-beaked common dolphins were recorded during the fall despite the large amount of survey effort. It is likely that most bottlenose dolphins move south of the Study Area, and most short-beaked common dolphins and harbor porpoises are farther north during this time of year.

Of particular ecologic importance are the sightings/acoustic detections of endangered large whale species, the North Atlantic right whale, fin whale, and humpback whale. Each of these species was detected during all seasons, including those seasons during which North Atlantic right and humpback whales are known to occupy feeding grounds north of the Study Area or breeding/calving grounds farther south of the Study Area. Cow-calf pairs of each of these species were also observed in the Study Area. Two North Atlantic right whales exhibited possible feeding behavior, and one humpback whale was observed lunge feeding off the coast of Atlantic City. Based on these limited occurrences and behavioral observations, the nearshore waters off New Jersey may provide feeding and nursery habitat for these endangered species. Peak densities were predicted throughout the Study Area for these species and, although the overall abundance estimates of the whale species were relatively low, the Study Area is only a very small portion of the known ranges of these species. These species may use the waters of the Study Area for short periods of time as they migrate or follow prey movements or they may remain in the Study Area for extended periods of time. High concentrations of these species were not documented in the Study Area at any time during the study period; however, the presence of these endangered large whale species in New Jersey waters indicates that these animals are utilizing the area as habitat. The detections of these species in the Study Area, particularly during times of the year when they are thought to be in other areas, demonstrate the potential importance of the Study Area. The occurrence of these endangered species provides critical information on the distribution of the species in this region.

The density and abundance of the dolphin and porpoise species were relatively high for the Study Area. The highest abundances of marine mammals in the Study Area were estimated for the bottlenose dolphin during spring and summer. These bottlenose dolphins are thought to belong to the coastal northern migratory stock which occupies a small range between Long Island, New York and southern North Carolina. The high abundances of bottlenose dolphins in the Study Area coincide with the known movement of this stock into the northern portion of their range. High abundances of short-beaked common dolphins in the Study Area coincided with their known movement patterns south of 40º North (N) in the winter/spring. High abundances of harbor porpoises also occurred during the winter when the New Jersey waters and the waters of the New York Bight provide an important habitat for this species.

Fish and Fisheries Summary

A variety of economic and ecologically important fish and invertebrates are found within the Study Area. The New Jersey coast of the Atlantic northeastern United States (U.S.) supports extremely valuable commercial and recreational fisheries in state and federal waters. The marine ichthyofauna (336 fish species represented by 116 families) inhabit various inshore (e.g., estuaries and coastal beaches [surf zone]), offshore (e.g., pelagic [water column], demersal [sand-mud plain and shoreface ridges], and artificial reef [ship wrecks and man-made structures]) environments within the Study Area.

The economic impact of commercial and recreational fisheries in New Jersey is approximately $4.5 billion annually. These marine fishery resources (fish and invertebrates) that are found in the Study Area are managed through an elaborate process that includes the State of New Jersey, three Fishery Management Councils (FMCs: New England Fishery Management Council [NEFMC], Mid-Atlantic Fishery Management Council [MAFMC], and South Atlantic Fishery Management Council [SAFMC]), the Atlantic States Marine Fisheries Commission (ASMFC), and the National Marine Fisheries Service (NMFS).

From 2003 to 2007, the total value of commercial fisheries landed in New Jersey was nearly one billion dollars with the actual value being measured in terms of the jobs, goods, and services associated with these fisheries. Commercial fisheries in New Jersey ranked eighth in the U.S. in value and tenth in landings in 2007. The top five commercial species were Atlantic surfclam (*Spisula solidissima*), Atlantic sea scallop (*Placopecten magellinanicus*), ocean quahog (*Arctica islandica*), goosefish/monkfish (*Lophius americanus*), and summer flounder (*Paralichthys dentatus*). Within the Study Area, the clam dredge, targeting Atlantic surfclam and ocean quahog, is the primary commercial fishing gear utilized in terms of value and landings. The primary landed commercial species in tonnage is the Atlantic surfclam, whereas the Atlantic sea scallop is the most economically valuable species within the Study Area.

Recreational fishing is another important social and economic activity within the Study Area. There are about 75 fishing clubs and around 30,000 active members according to the New Jersey Anglers Association (NJAA). From 2003 through 2007, the annual number of angler trips ranged from 6.5 to 7.4 million. The primary species landed during this period was summer flounder, accounting for 40.8% of the total landings, with bluefish (*Pomatomus saltarix*) and black sea bass (*Centropritis striata*) representing 18.6%. There are a total of 143 fishing hotspots with 57% of these areas located in the southern half of the Study Area. The locations of these fishing hotspots are often dictated by structural features, such as shoals, ridges, lumps, banks, ship wrecks, and artificial reefs. These structural features provide prime fishing sites for anglers targeting Atlantic striped bass (*Morone saxatilis*) and bluefish around shoals; bluefish and summer flounder near ridges; and black sea bass and tautog (*Tautog onitis*) around shipwrecks/reefs. In addition, the New Jersey Artificial Reef Program, one of the largest on the east coast, consists of over 1,000 reefs and 100 vessels dispersed among 15 ocean sites, nine of which are located within the Study Area. Organized fishing tournaments are also popular public events that take place from May through October annually in nearshore as well as in offshore areas of the Study Area.

The Study Area provides important habitats to many juvenile fish and invertebrates of economic and ecological importance. Trends in these juvenile fish and invertebrate populations were analyzed by utilizing the ocean trawl data (New Jersey Ocean Stock Assessment [OSA] Program) collected in defined areas from 2003 to 2008. This independent monitoring program provided information on the spatial and temporal variability of the fish community within and adjacent to the Study Area. Data were compiled and sorted into two separate groups according to landings (i.e., top 10 species numerically collected) and economic value (i.e., top 5 species [US$]). It was demonstrated that the coastal fishery landings within the Study Area that the juvenile butterfish (*Peprilus triacanthus*), scup (*Stenotomus chrysops*), squid (*Loligo* spp.), and Atlantic herring (*Clupea harengus*) were numerically abundant and the squid was most economically valuable. In terms of relative juvenile fish/invertebrate abundance, summer and fall were the most important seasons with the winter and spring period being the least important. Summer was dominated numerically by butterfish, spring and fall by Atlantic herring and scup, and winter by Atlantic herring. The squid dominated both the summer and fall periods. The areas exhibiting the numerically dominant species also contained the largest number of fishing hotspot locations within the Study Area.

Within the Study Area, various fish and invertebrates are listed as essential fish habitat (EFH) and ASMFC managed species or are afforded protection under state and/or federal regulations such as the Endangered Species Act (ESA). Forty managed species have EFH designation by three FMCs and NMFS. These managed species are grouped as temperate water (23), subtropical-tropical/southeast (3), and highly migratory billfishes, sharks, and tunas (14). Two of these species have habitat areas of particular concern (HAPC) designation: summer flounder (adjacent estuarine systems) and sandbar shark (*Carcharhinus plumbeus*: mouth of Great Bay, New Jersey). The ASMFC manages 20 Atlantic coastal fishes/invertebrates, four shad/river herring (*Alosa* spp.) species, and 20 coastal shark species within the Study Area. The State of New Jersey and the federal government provide protection for the shortnose sturgeon (*Acipenser brevirostrum*) that is found primarily south of the Study Area (Delaware Bay). Currently, the NMFS has prepared a determination on whether listing the species or multiple distinct population segments (DPSs) of the Atlantic sturgeon (*Acipenser oxyrinchus oxyrhinus*) as threatened or endangered is warranted. Atlantic sturgeons commonly aggregate in shallow nearshore areas along the New Jersey coast.

The projected changes occurring in the Northeast (NE) U.S .Continental Shelf Large Marine Ecosystem (LME) as a result of climate-induced forcing operating through related physical changes (e.g., sea level, ocean temperature) could cause major poleward shifts in marine fish diversity and abundance. These shifts could inadvertently affect the productivity of economically important fish and shellfish causing increased uncertainty for the commercial and recreational fishing industry and be instrumental in the re-designing of fishery management systems.

Additional details on the methods and results of all surveys and studies conducted are found in this report as follows:

- **Volume I**—Overview, Summary, and Application;
- **Volume II**—Avian Studies;
- **Volume III**—Marine Mammal and Sea Turtle Studies;
- **Volume IV**—Fish and Fisheries Studies.

Application of Data

Environmental Sensitivity Index

To reach the end goal of identifying the environmental resources of the Study Area and assessing locations for offshore development that may have the least impact on those resources, an environmental sensitivity index (ESI) was developed. The index was created to visually summarize the overlapping resources of the Study Area and depict areas that may be more or less suitable for development. The index includes data collected during field studies, through review of published literature, and from resource agencies such as NJDEP, National Oceanic and Atmospheric Administration (NOAA), NMFS, and Minerals Management Service (MMS). The resources considered for the index include: artificial reefs, marine protected areas (MPAs), shoals, HAPCs, EFH, known obstructions, known shipwrecks, unexploded ordnance (UXO), shipping lanes, utility cables, commercial fishing grounds, recreational fishing grounds, and modeled avian, marine mammal, and sea turtle density data. Areas that score low on the index are likely more favorable environmentally for development; however, those areas that show high overlap of environmental resources should not be dismissed as areas of development; rather these regions may require additional research or mitigation efforts to reduce potential impacts to an area. Only areas described as “Prohibited Development Areas” (obstructions, shipping lanes, traffic separation zones, pipelines, cables, etc.) should be avoided. The index is to be used only as a guide. The collection of additional data may be required by state and/or federal agencies for offshore development at specific sites. In general, the ESI is a useful tool for preliminary planning for both developers and stakeholders. It provides a quick overview of the potentially sensitive resources off the New Jersey coast, and the areas where these resources are most abundant; however, this index should be used only as a guide to help determine which locations within the Study Area may be suitable for offshore development, as well as those areas that may need to be avoided due to ecological importance. While the ESI should not be used in lieu of site specific resource studies, it provides a good synthesis of baseline data for initial planning purposes and future impact assessments.

IMPACTS ANALYSIS

The construction and operation of an offshore wind farm has potential to produce short- and long-term impacts on the biological resources such as birds, bats, marine mammals, sea turtles, fish, and a wide array of other demersal or pelagic biota (e.g., crustaceans, plankton, coral and algae). The potential impact-producing activities of the operations and maintenance phase of the wind farm include vessel traffic and visual presence and lighting from the vessels used for the periodic or emergency maintenance. An additional impact is potential direct mortality to birds/bats from the turbine blades. The visual presence, noise and vibrations, and habitat modification from the turbines and their foundations or scour protection are also potential impacts of the operation phase. Electromagnetic fields produced by the cables transmitting the generated power could also have impacts on the seafloor and surrounding areas. Most of these impacts would be long-term given the anticipated 20 to 25 year life span of an offshore wind farm.

Preconstruction and decommissioning activities may have similar potential impacts. The potential impact-producing activities of the construction phase include vessel presence and light, vessel collision, noise from the construction vessels and the installation equipment (pile drivers), physical disturbance and displacement, the suspension of sediments and any contaminants within those sediments, and substratum changes or loss. Most of these are short-term impacts that would decrease or stop once construction is complete. Potential long-term impacts would result from vessel collisions with marine mammals or sea turtles that result in injury or death, in addition to any changes in seafloor height and sediment dynamics.

The compilation of this baseline data can also assist with the development of environmental documentation such as biological and environmental assessments and Environmental Impact Statements that will be required for development of offshore renewable energy sites. The potential impacts associated with offshore wind development presented in this report provide a good starting point for understanding the dynamic relationships of the physical and biological resources within the Study Area and how disturbance (i.e., wind farm construction) may positively or negatively affect those resources. Ultimately, more data of fine spatial and temporal scales are needed to fully understand long-term impacts from offshore wind development, as the development of offshore wind energy sites is relatively new; however, the spatial and temporal data gathered throughout this baseline study provides a broader understanding of the specific resources of the Study Area, which in turn allows for proactive approaches to offshore development to minimize potential impacts and monitor critical resources.

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LIST OF ACRONYMS AND ABBREVIATIONS

°	Degree(s)
°C	Degree(s) Celsius
°F	Degree(s) Fahrenheit
‘	Minute(s)
“	Second(s)
µg/L	Microgram(s) per Liter
µm	Micron(s)
µW	Microwatt(s)
AAQS	Ambient Air Quality Standards
ABR	Auditory Brain Stem
abt	Adjusted Bird Tracks
ACCSP	Atlantic Coastal Cooperative Statistics Program
ADCP	Acoustic Doppler Current Profiler
AEAU	Alternative Energy and Alternate Use
AMSL	Above Mean Sea Level
AMTR	Adjusted Migration Traffic Rate
AOU	American Ornithologists’ Union
AQCR	Air Quality Control Regions
AREC	Atlantic Renewable Energy Corporation
ASMFC	Atlantic States Marine Fisheries Commission
AWS	AWS Scientific, Inc.
BACI	Before-After/Control-Impact
BB	Brigantine Beach
BLUE	Best Linear Unbiased Estimate
BRP	Blue Ribbon Panel
BSS	Beaufort Sea State
CAA	Clean Air Act
CDOM	Colored Dissolved Organic Matter
CDS	Conventional Distance Sampling
CEQ	Council on Environmental Quality
CFR	Code of Federal Regulations
chl *a*	Chlorophyll *a*
CI-SIC	Corson’s Inlet-Sea Isle City
cm	Centimeter(s)
cm^2	Square Centimeter
cm/s	Centimeter(s) per Second
CODAR	Coastal Ocean Dynamics Applications Radar/Coastal Radar
CTD	Conductivity-Temperature-Depth
CWA	Clean Water Act
CZMA	Coastal Zone Management Act
dB	Decibel(s)
dB re 1 µPa-m	Decibels at the Reference Level of 1 Micropascal at 1 Meter
DPS	Distinct Population Segment
DSM	Density Surface Model
E	Electric
EA	Environmental Assessment
EBS	Ecological Baseline Studies
ECMA	East Coast Magnetic Anomaly
EEZ	Exclusive Economic Zone
EFH	Essential Fish Habitat
EIS	Environmental Impact Statement
EMF	Electromagnetic Field
ENSO	El Niño-Southern Oscillation
EO	Executive Order

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

EPA	Environmental Protection Agency
ESA	Endangered Species Act
ESI	Environmental Sensitivity Index
ESP	Electrical Service Platform
EST	Eastern Standard Time
EWEA	European Wind Energy Association
FAA	Federal Aviation Administration
FAD	Fish Aggregating Device
FMC	Fishery Management Council
FMP	Fishery Management Plan
FONNSI	Finding of No New Significant Impacts
ft	Foot(Feet)
ft/s	Foot(Feet) per Second
ft^3	Cubic Foot(Feet)
ft^3/s	Cubic Foot(Feet) per Second
FWPCA	Federal Water Pollution Control Act
g	Gram(s)
G&G	Geotechnical and Geophysical
gal	Gallon(s)
GAM	Generalized Additive Model
GIS	Geographic Information System
GMI	Geo-Marine, Inc.
GPS	Global Positioning System
HAPC	Habitat Area of Particular Concern
HDD	Horizontal Directional Drilling
HMS	Highly Migratory Species
hr	Hour
HSWA	Hazardous and Solid Waste Amendments
Hz	Hertz
IBSP	Island Beach State Park
IDWI	Inverse Distance Weighted Interpolation
IFMP	Interstate Fisheries Management Program
in.	Inch(es)
in./s	Inch(es) per Second
JMA	Japan Meteorological Agency
ka	Thousand Year(s) Ago
kg	Kilogram(s)
kg/m^3	Kilogram(s) per Cubic Meter
kHz	Kilohertz
km	Kilometer(s)
km^2	Square Kilometer(s)
km^3	Kilometer(s)
kPa	Kilopascal(s)
kph	Kilometer(s) per Hour
kt	Knot
kV	Kilovolt(s)
L	Liter(s)
lat	Latitude
lb	Pound
lb/ft^3	Pound per Cubic Foot
lon	Longitude
m	Meter(s)
m/s	Meter(s) Per Second

LIST OF ACRONYMS AND ABBREVIATIONS (*continued*)

m^3	Cubic Meter(s)
m^3/s	Cubic Meter(s) per Second
Ma	Million Year(s) Ago
MAB	Mid-Atlantic Bight
MAFMC	Mid-Atlantic Fisheries Management Council
mbar	Millibar(s)
MBTA	Migratory Bird Treaty Act
MET	Meteorological
mg/L	Milligram(s) per Liter
mi	Mile(s)
mi^2	Square Mile(s)
min	Minute(s)
$mL/m^2/s$	Milliliter(s) per Square Meter per Second
MLLW	Mean Lower-low Water
mm	Millimeter(s)
MMPA	Marine Mammal Protection Act
MMS	Minerals Management Service
MODIS	Moderate Resolution Imaging Spectroradiometer
MOU	Memorandum of Understanding
MPA	Marine Protected Area
MPRSA	Marine Protection, Research, and Sanctuaries
mph	Mile(s) per Hour
MRIP	Marine Recreational Information Program
MSFCMA	Magnuson-Stevens Fishery Conservation and Management Act
MTL	Mean Tide Level
MW	Megawatt(s)
N	North
NAAQS	National Ambient Air Quality Standards
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NCDC	National Climatic Data Center
NEFMC	New England Fisheries Management Council
NEFSC	Northeast Fisheries Science Center
NEPA	National Environmental Policy Act
NEXRAD	Next Generation Radar
NJDEP	New Jersey Department of Environmental Protection
nm	Nanometer(s)
NM	Nautical Mile(s)
NM^2	Square Nautical Mile(s)
NMFS	National Marine Fisheries Service
NMSA	National Marine Sanctuaries Act
No.	Number
NOAA	National Oceanic and Atmospheric Administration
NODC	National Oceanographic Data Center
NOMADS	National Operational Model Archive & Distribution System
NPDES	National Pollutant Discharge Elimination System
NPS	National Park Service
NRC	National Research Council
OBIS-SEAMAP	Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations
OCL	Ocean Climate Laboratory
OCRM	Office of Ocean and Coastal Resource Management (NOAA)
OCS	Outer Continental Shelf

LIST OF ACRONYMS AND ABBREVIATIONS
(*continued*)

OSA	Ocean Stock Assessment
oz	Ounce(s)
PAM	Passive Acoustic Monitoring
PAR	Photosynthetically Available Radiation
psu	Practical Salinity Unit(s)
PTS	Permanent Threshold Shift
R/V	Research Vessel
Radar	Radio Detection and Ranging
RCRA	Resource Conservation and Recovery Act
RSSI	Return Signal Strength
RSZ	Rotor-Swept Zone
s	Second(s)
S	South
SAFMC	South Atlantic Fishery Management Council
SEL	Sound Exposure Level
SFA	Sustainable Fisheries Act
SIC	Sea Isle City
SMS	Surface Mapping System
SOI	Southern Oscillation Index
SPL	Sound Pressure Level
SPUE	Sightings per Unit Effort
SSS	Sea Surface Salinity
SST	Sea Surface Temperature
Sv	Sverdrup(s)
T&E	Threatened and Endangered
TI-VPR	Thermal Imaging-Vertically Point Radar
TSS	Traffic Separation Scheme
TTS	Temporary Threshold Shift
TV	Television
U.K.	United Kingdom
U.S.	United States
U.S.C.	United States Code
UID	Unidentified
USACE	United States Army Corps of Engineers
USCG	United States Coast Guard
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UTC	Coordinated Universal Time
UXO	Unexploded Ordinance
W	West
WOD09	World Ocean Database 2009
yd^3	Cubic Yard(s)

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)	1.151
Meter (m)	Foot (ft)	3.281
	Inch (in.)	39.37
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)	0.0006214
	Foot per second (ft/s)	3.281
Centimeter per second (cm/s)	Inches per second (in./s)	0.3937
Kilometers per hour (kph)	Mile per hour (mph)	0.6214
	Knot (nautical mile/hour)	0.5400
Knot (nautical mile/hour)	Mile per hour (mph)	1.151
AREA		
Square kilometer (km^2)	Square mile (mi^2)	0.3861
	Square nautical mile (NM^2)	0.2916
Square nautical mile (NM^2)	Square mile (mi^2)	1.324
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
Liter (L)	Gallon (gal)	0.2642
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
Gram (g)	Ounce (oz)	0.035274
DENSITY		
Kilograms per cubic meter (kg/m^3)	Pounds per cubic foot (lb/ft^3)	0.06243
CONCENTRATION		
Microgram per liter (µg/L)	Ounces per gallon (oz/gal)	1.336×10^{-7}
TEMPERATURE		
Degree Celsius (°C)	Degree Fahrenheit (°F)	1.8*(°C + 32)

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1.0 INTRODUCTION

On December 23, 2004, New Jersey Governor Richard Codey signed Executive Order (EO) Number (No.) 12. This order established a Blue Ribbon Panel (BRP) on the 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 BRP submitted a Final Report to Governor Jon Corzine in April 2006, providing policy recommendations regarding the appropriateness of developing offshore wind turbine facilities. The BRP 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. They recommended that the State of New Jersey initiate a limited test project "…to obtain practical knowledge of benefits and impacts resulting from offshore wind turbine facilities." The BRP 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…" (BRP 2006).

1.1 PROJECT GOALS

The BRP noted 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 within New Jersey's outer continental shelf (OCS). Recommendation four of the BRP'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" (BRP 2006).

Recommendation six 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" (BRP 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 selected to provide those studies. To meet the project goal, baseline data were collected on birds, sea turtles, and marine mammals over an 18-month period and later expanded to a 24-month period to fill major data gaps identified for each group. The solicitation identified and stated the major data gaps as follows:

- 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) when 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 dataset for the Study Area (which extends out to 37 kilometers [km, 20 nautical miles (NM)] offshore), but standardized abundance data and information on movement pathways are lacking.

- Sea Turtles: Available data indicates that most sea 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 dataset 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 LOCATION

The state of New Jersey is located on the northeast coast of the United States (U.S.) between 41 degrees (°) 21 minutes (') North (N) and 38°55'N (Vermeule 1898). The length of the state (267 km [166 miles (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 NJDEP Study Area (Study Area) borders a barrier island chain along part of the New Jersey shoreline. The Study Area encompasses approximately 4,665 square kilometers (km^2; 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°55' 56 seconds ["] 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 37 km (20 NM) perpendicular to the shoreline (i.e., 126 x 37 km [68 x 20 NM] in size) and flanked by the Hudson and Delaware rivers (**Figure 1-1**). 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). **Figure 1-1** displays the Study Area with the Minerals Management Service (MMS) lease blocks superimposed as a reference.

1.3 PROJECT OBJECTIVES

The overall goal of the study was 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 were 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?

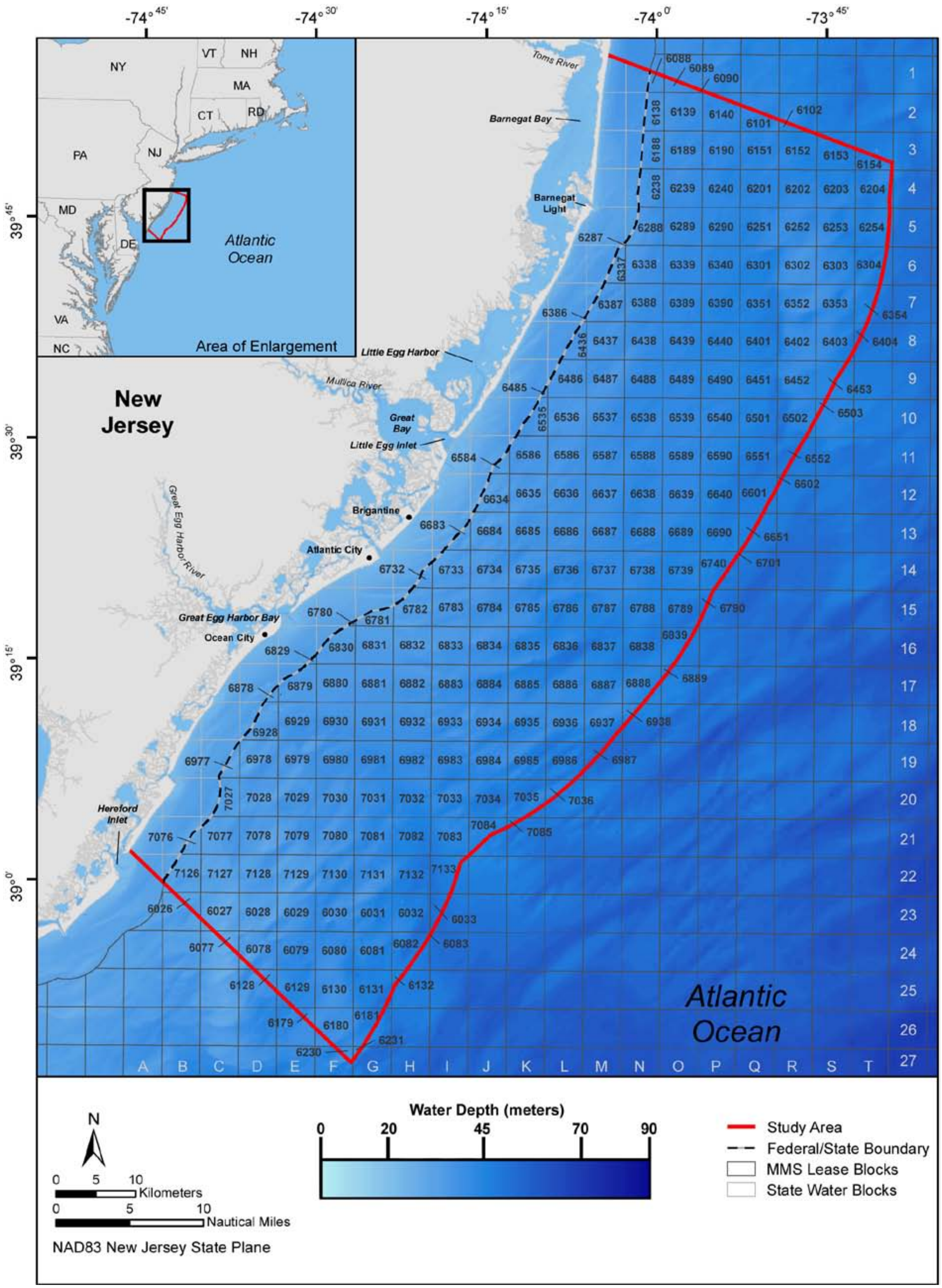

Figure 1-1. Location of the Study Area (0 to 20 NM [0 to 23 mi] offshore).

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 were required to provide the data necessary to answer the project objectives. Other study components necessary to answer the project objectives included 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). The following sections discuss some of the requirements in the Solicitation.

1.3.1 Avian Baseline Study

Most wind power impact data in the U.S. have been collected in terrestrial systems; however, impact studies in marine systems have been conducted in Europe. As recommended by the BRP, this baseline study was 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 required 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 was used to complete an impact analysis on effects of wind power development activities on avian species in the Study Area. A brief description of each technique is discussed below; detailed information on each method and the results of the study are included in **Volume II**.

GMI, in conjunction with NJDEP, defined the spatial and temporal variables of interest. These included but are not limited to: water depth, shoals, location (e.g., distance from shore), and season. GMI performed work such that the critical spring or fall migration periods are sampled twice. Data collected over the entire duration of the study was used to calibrate and populate 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 anything that could aid in determining the distribution of avian species during breeding, wintering, and migration such as time of day, season, and weather. The predictive model and data collection/design includes assessment of the model's power and accuracy and is detailed in **Volume II**.

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

Avian aerial transect surveys were initially scheduled to be conducted once monthly during the 24-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 were also noted. Survey methods generally followed U.S. Fish Wildlife Service (USFWS) methods (e.g., Fischer et al. 2002; Camphuysen et al. 2004). Aerial surveys were discontinued after the first month in favor of increased radar surveys.

Shipboard line transect surveys were conducted offshore during daylight hours at defined intervals each month (except July 2009) during the 24-month study period. The surveys followed randomly-generated tracklines in a double saw-tooth pattern to provide comparable spatial and temporal coverage of the entire Study Area. Two experienced avian biologists used binoculars to enumerate, estimate flight altitude, identify bird species within an established range, and record other observations (e.g., behavior, morphology). Survey methods generally follow Camphuysen et al. (2004) and Ballance (2007).

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 design differed from that of the shipboard offshore surveys in that a randomly-generated "single saw-tooth" sample design was implemented to survey the area. The starting location for each survey was 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. Field survey methods were identical to the methods described for shipboard offshore surveys.

The third avian survey technique involved the use of onshore and offshore 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 was 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 maximized 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 were added to the digital database. Aerial, boat, and radar data were used to determine the spatial and temporal distribution of avian species off the New Jersey coast.

1.3.2 Marine Mammal and Sea Turtle Baseline Study

1.3.2.1 Marine Mammals

There are numerous studies on the potential impacts of offshore windfarms on marine mammals (e.g., Hoffmann et al. 2000; Tougaard et al. 2003; Teilmann et al. 2006; Tougaard et al. 2006; Nedwell et al. 2007; Diederichs et al. 2008; Gilles et al. 2009). These include, among others, discussions of noise impacts, habitat and behavior disturbance, and potential mitigation strategies. The majority of information comes from Europe and the United Kingdom (U.K.) where wind farms have been installed and operational for over seven years (e.g., DONG Energy 2006). As recommended by the BRP (2006), the design of this baseline study was based on methods used in some of these European studies of offshore wind power as well as on standard protocols for marine mammal surveys used in the U.S. and throughout the world. The objective of this study was to determine the spatial distribution and to estimate the abundance/density of marine mammals in the Study Area. The study was conducted over a 24-month period between January 2008 and December 2009. Three sampling techniques were used to determine the abundance, distribution, and behavior of marine mammals in the Study Area. These techniques included aerial line transect surveys, shipboard line transect surveys, and passive acoustic monitoring (PAM). The survey design, data recording methods, and safety guidelines were prepared in consultation with the NJDEP, NMFS Northeast Fisheries Science Center (NEFSC) personnel, and other marine mammal experts identified by NJDEP. The NJDEP obtained the necessary National Oceanic and Atmospheric Administration (NOAA) permits to conduct the shipboard and aerial surveys in waters offshore of New Jersey. A brief description of each technique is discussed below; detailed information on each method and the results of the study are included in **Volume III**.

Aerial line transect surveys for marine mammals were conducted in the Study Area once or twice monthly; the survey days were randomly selected and/or were based on the availability of the aircraft and the observers. The survey aircraft consisted of a twin-engine, high-winged Cessna Skymaster 337 with bubble windows (flown February through May 2008) and a Cessna Skymaster without bubble windows (flown January through June 2009). The aircraft flew along randomly-generated tracklines (transect lines) at an altitude of approximately 229 meters (m; 750 feet [ft]) and a speed of 204 kilometers/hour (kph; 110 knots [kts]). The tracklines were designed in a double saw-tooth pattern to provide comparable spatial and temporal coverage of the entire Study Area. Additional strip transects were flown along the coastline (at low tide) when possible to assess the presence/absence of pinnipeds in the Study Area. Two experienced marine mammal observers recorded all observations of marine mammals (including species, abundance, and behavior). A GPS unit recorded latitude and longitude at 10-s intervals for correlation with field observations. When feasible, digital photographs of marine mammals were taken for photo-identification purposes. Weather conditions were also recorded during all surveys. Surveys were flown only under appropriate conditions (e.g., visibility, sea state) as defined in consultation with federal and NJDEP representatives.

Shipboard line transect surveys were conducted once a month; survey days were mainly based on the research vessel (R/V) *Hugh R. Sharp*'s schedule. The surveys followed randomly-generated tracklines in a double saw-tooth pattern to provide comparable spatial and temporal coverage of the entire Study Area. The marine mammal observation team on duty consisted of three experienced observers who recorded observations from the flying bridge. Two of these observers used big-eye binoculars to scan for marine mammals while the third observer scanned via naked eye or 7x hand-held binoculars and acted as the data recorder. A total of six observers rotated through these positions. The observers recorded the same observational and environmental data as mentioned above and only surveyed during appropriate weather conditions.

PAM was used to determine the presence of marine mammal species in the Study Area. Five marine autonomous recording units (i.e., “popups”) from the Bioacoustics Research Program, Cornell Laboratory of Ornithology were placed in a cross configuration in the Study Area. There were roughly 72.42 km (45 mi) between the southern and northern popup stations and about 24.14 km (15.00 mi) between the eastern and western popup stations. Popups were placed consistently within 6.10 m (20.00 ft) of the GPS coordinates identified for station deployment. Depths for deployed popups ranged from 17.68 to 27.43 m (58.00 to 90.00 ft). Three of the popups had a 2-kilohertz (kHz) sample rate and a continuous duty cycle for recording while the other two popups had a 32-kHz sample rate with a 5-minute (min) on/25 min off duty cycle. The acoustics data were recorded on the popups. Each popup was retrieved so that the data could be uploaded and analyzed.

1.3.2.2 Sea Turtles

Sea turtle detections were recorded during the aerial and shipboard line transect surveys for marine mammals. The sampling periods and recording methods are the same as described above.

1.3.3 Fish and Shellfish Baseline Studies

Existing federal and state aquatic baseline data, as well as other data sources, were identified, collected, and placed into the digital database. Sources consulted include the NMFS (e.g., NEFSC), the Atlantic States Marine Fisheries Commission (ASMFC), the Mid-Atlantic Fisheries Management Council (MAFMC), NJDEP, and the New England Fisheries Management Council (NEFMC; e.g., fisheries management plans and Essential Fish Habitat [EFH] assessments), as well as local researchers (e.g., value of sand shoals by Rutgers University). For shellfish, the maps prepared consisted of GIS maps showing the latest densities and distribution of two important commercial species (i.e., surf clam and quahog). GMI used maps of fishing grounds from Long et al. (1982) along with the most recent data available for the Study Area: Freeman and Walford (1974), Saltwater Directions (2003c; 2003b; 2003a), and NJDEP (2008a). These maps were digitized and converted by GMI into GIS format (e.g., GIS layers) so that a cumulative picture of offshore distribution was developed. These data were used to map the spatial and temporal distributions of major marine fish and shellfish species in the Study Area. Detailed information on this literature review is included in **Volume IV**.

1.3.4 Other Natural Resources

Side-scan surveys and 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 were collected. Federal and state data, as well as other available data sources were compiled and added to the digital database and used to map the location and distribution of these resources. Detailed information on the side-scan survey method and the results of the study are included in **Appendix A**.

1.3.5 Environmental Assessment of Impacts

The EBS data collected and analyzed was 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. Detailed information on this assessment is included in this volume.

The collection, compilation, presentation, and evaluation of data provided addressed 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 classes of environmental impacts were 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) were used to prepare the environmental assessment (EA).

GMI compiled data and characterized 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. GMI's assessment included a literature review of potential and known impacts, including data and information from planned and operating offshore wind facilities (e.g., those in Europe). GMI reviewed and referenced the Programmatic Environmental Impact Statement (EIS) for the OCS Alternative Energy and Alternate Use (AEAU) program and associated regulations issued by the MMS for this task (MMS 2007). GMI also reviewed the Cape Wind Energy Project Final EIS (MMS 2009c) and the Louis Berger Group (1999) environmental report concerning the use of offshore sand resources.

1.4 REPORT ORGANIZATION

This report consists of four independent volumes each with a table of contents, literature references, and appendices:

Volume I—provides background information on this project, an explanation of its purpose and need, a description of the methodology used in the assessment, an overview of the existing environment (including the benthic mapping surveys), regulatory compliance, potential impacts, environmental sensitivity index, and conclusions;

Volume II—describes avian surveys and predictive modeling;

Volume III—covers marine mammal and sea turtle surveys;

Volume IV—describes fish and fisheries.

2.0 EXISTING ENVIRONMENT

2.1 CLIMATE

The sum of the meteorological phenomena which characterize the average condition of an area's atmosphere can be described as the climate. The factors that define the climate of an area include the spatial and temporal characteristics associated with temperature, humidity, rainfall, winds, and pressure of the atmosphere (Smock 1888). New Jersey's location lies approximately at the 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 and daily weather that is highly variable and influenced by wet, dry, hot, and cold airstreams (Hammer 2006; SNJ 2007). The climate of the Study Area is characteristic of a coastal climate with continental and oceanic influences. Due to New Jersey's location proximal to the Atlantic Ocean, with its high heat capacity, the coastal region is less prone to rapid temperature changes and extremes. During the standard seasonal definitions of fall and early winter, sea surface temperature (SST) is higher than the terrestrial temperatures resulting in mediated coastal temperatures (Ludlum 1983; Hammer 2006). In fall and early winter, the coastal climate of the Study Area experiences warmer temperatures than interior regions of the state because the ocean is warmer than the continental region. In spring, the coastal climate of the Study Area will experience cooler temperatures than the interior regions of the state due to local ocean breezes (see **Section 2.1.3** for a discussion of the winds of the Study Area; Ludlum 1983; Hammer 2006).

Several studies have been conducted to investigate significant contemporaneous associations of SSTs and the climate. It has been speculated that historic atmospheric and oceanic data can be used to forecast (for periods of months or longer) surface air temperature or precipitation (Harnack et al. 2005) and that a lag between a change in SST and a resultant change in climate exists (Hartley and Robinson 1999). Creilson et al. (2001) suggested that the climate of the Study Area may be influenced by the tropical SST anomalies associated with the El Niño-Southern Oscillation (ENSO; a large-scale climatic fluctuation of the tropical Pacific Ocean). Creilson et al. (2001) found that between the years of 1896 and 1995, a higher North Atlantic Oscillation (NAO; a large-scale fluctuation in atmospheric pressure between the subtropical high pressure system located near the Azores in the Atlantic Ocean and the sub-polar low pressure system near Iceland) index corresponded with warmer SSTs in the Northeast region during winter (see **Section 2.1.6** for a more in depth discussion of the NAO). A positive winter NAO is associated with a zonal jet stream centered over the 40°N latitude, thereby reducing the flow of Arctic air into the Northeast and offshore waters. Similarly, a negative winter Southern Oscillation Index (SOI), as associated with an El Niño event, will produce a comparable zonal atmospheric circulation causing pronounced temperature and precipitation anomalies (Creilson et al. 2001).

The climate of the Study Area can be heavily influenced by the barometric characteristics associated with the passage of low pressures, high pressures, or storm centers. In the winter, low barometric pressures (cyclonic) are accompanied by precipitation and an increase in temperature; whereas, in the summer, the low pressures bring lower temperatures and precipitation. Conversely, high barometric pressures (anti-cyclonic) are characterized by the reverse conditions; in the winter, high pressures bring lower temperatures and in summer, high pressures bring elevated temperatures (Smock 1888).

The humidity of the atmosphere of the Study Area is subject to continual change and is modified as a function of several processes including the direction of the prevailing winds and the temperature. In general, the humidity is greater near the coastal and the southern part of the state than in the inland areas and northern regions of the state. The average humidity is greatest from June to September with August having the highest percentage; spring and winter have relatively less humidity (Smock 1888).

Sea Surface Temperature Defined Seasons

Seasons were defined for the Study Area by calculating the median changes of SST over a three year period. Calculations were based on three years (01 January 2007 to 31 December 2009) of SST data derived from the National Aeronautics and Space Administration (NASA), Moderate Resolution Imaging Spectroradiometer (MODIS), Level 3 data that was collected on board the Aqua Earth Observing System satellite. This data was post processed by the Rutgers Coastal Ocean Observation Lab and was originally supplied by the NASA Goddard Earth Sciences Data and Information Services Center (NASA 2010). 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 while the sign of a value in fall is negative). The resulting seasons that are used in the modeling and discussions of oceanography of this report are defined as winter (18 December through 09 April), spring (10 April through 21 June), summer (22 June through 27 September), and fall (28 September through 17 December). 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 Air Temperature

The Study Area is characterized by mild seasons and storms which bring precipitation (rain and snow) to the region; the mild seasons are influenced by sea winds that reduce both the range and mean temperature while providing humidity. Offshore of the Study Area, the influence of the Gulf Stream appears to provide a moderating influence on the Study Area. The proximity of the Gulf Stream tends to raise the average temperature of the Study Area during winter by approximately 8 to 10 degrees Fahrenheit (°F; 4 to 6 degrees Celsius [°C]) in relation to inland New Jersey; in summer, the average temperature of the Study Area is decreased due to a cold current running southward between the coast and Gulf Stream. This decrease in average temperature during summer, however, is tempered by warm inland air being carried seaward by the prevalent westerly winds. Winds from the southeast quarter of the state tend to have a warming affect as a result of the Gulf Stream; winds from the south tend to have a cooling affect due to the influence of the colder shore current. Southern New Jersey (Cape May) tends to have 2° to 3°C (4° to 5°F) warmer temperatures in winter and less extreme temperatures than northern New Jersey (Barnegat and Atlantic City; Smock 1888); however, in southern New Jersey, it is not unusual for the combination of humid conditions and high temperatures to bring extreme summer heat conditions (SNJ 2007). Along the coast of New Jersey, the average number of freeze days per year is 217, a much smaller number than that for inland New Jersey (342 days; Hammer 2006). **Figure 2-1** shows a long term record of mean annual air temperatures for New Jersey from 1895 through 2009. Over the entire record, mean annual air temperature has increased from 11.0°C (51.8°F) between 1895 and 1970 to 11.5°C (52.7°F) between 1971 and 2000 to 12.1°C (53.8°F) between 2001 and 2009.[1]

Air temperature data were collected from the Office of the New Jersey State Climatologist, Rutgers University.[2,3] These data were averaged for annual, seasonal, and monthly means for the vicinity adjacent to the Study Area, the southern and coastal areas of New Jersey, between 1895 through 2010. **Figure 2-2** provides a graphical depiction of these mean air temperatures.

The annual mean air temperature was 11.78°C (53.20°F). The mean seasonal temperature ranged from 3.64°C (38.56°F) in winter to 21.58°C (70.85°F) in summer with the lowest average temperatures in January (0.28°C [32.50°F]) and highest averages in July (23.61°C [74.50°F]). The greatest mean monthly temperature change occurred from October to November (a decrease of 5.75°C [10.35°F]) while the smallest change occurred from January to February (an increase of 0.25°C [0.45°F]). The largest mean rise in temperature occurred from April to May (an increase of 5.6°C [10.1°F]) and the largest mean temperature decline occurred from October to November (a decrease of 5.75°C [10.35°F]).

Figure 2-3 provides the mean seasonal air temperature for the Study Area. The figure was developed based on air temperature data from the NOAA National Operational Model Archive & Distribution System (NOMADS) service. Air temperature data were downloaded for the year of 2008 from rolling archives of 1-hr interval data (MARCOOS 2008). Data were interpolated between 500 and 600 lat-lon points evenly spaced throughout the shown map extent. Air temperatures were averaged over seasons: winter (18 December through 09 April), spring (10 April through 21 June), summer (22 June through 27 September), and fall (28 September through 17 December).

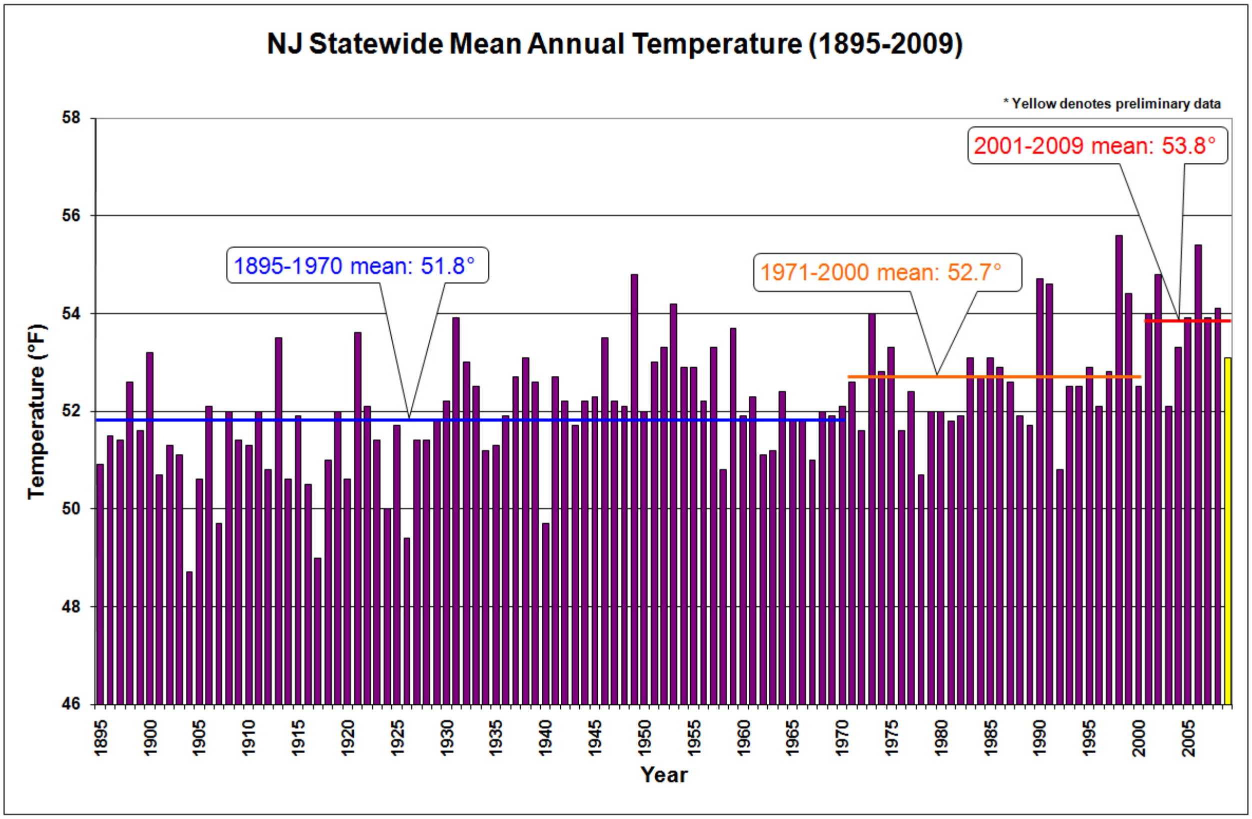

Figure 2-1. The mean annual air temperatures for the State of New Jersey between 1895 and 2009.[1]

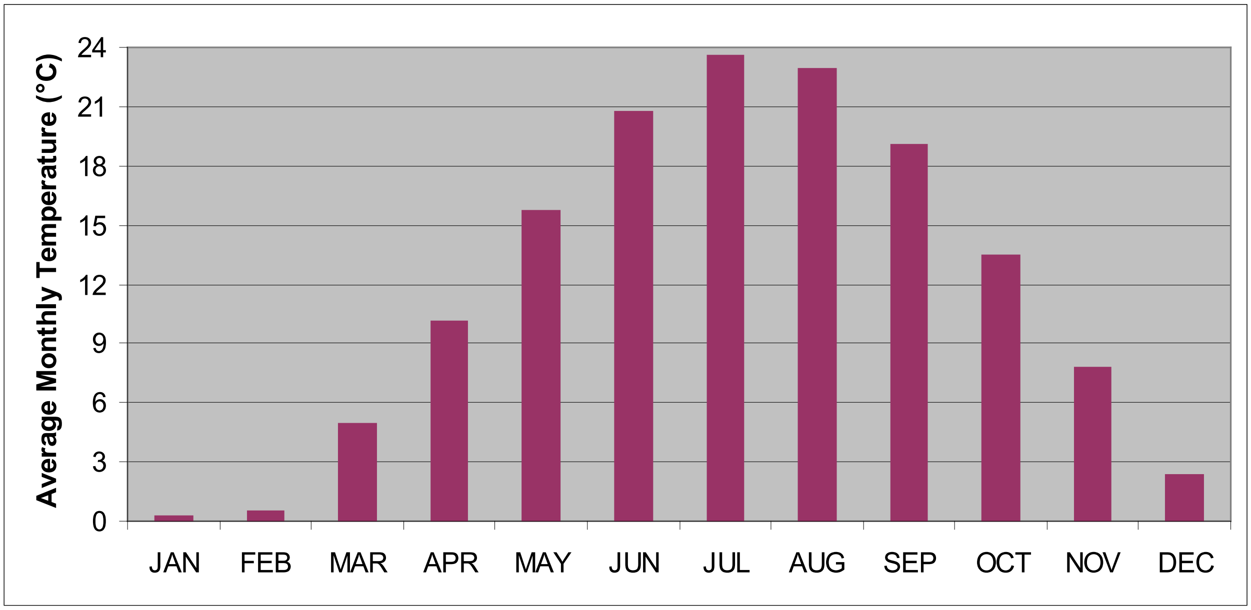

Figure 2-2. The mean monthly temperatures derived from climate tables for the combined southern and coastal area of New Jersey, adjacent to the Study area for the years 1895 to 2010.[2,3]

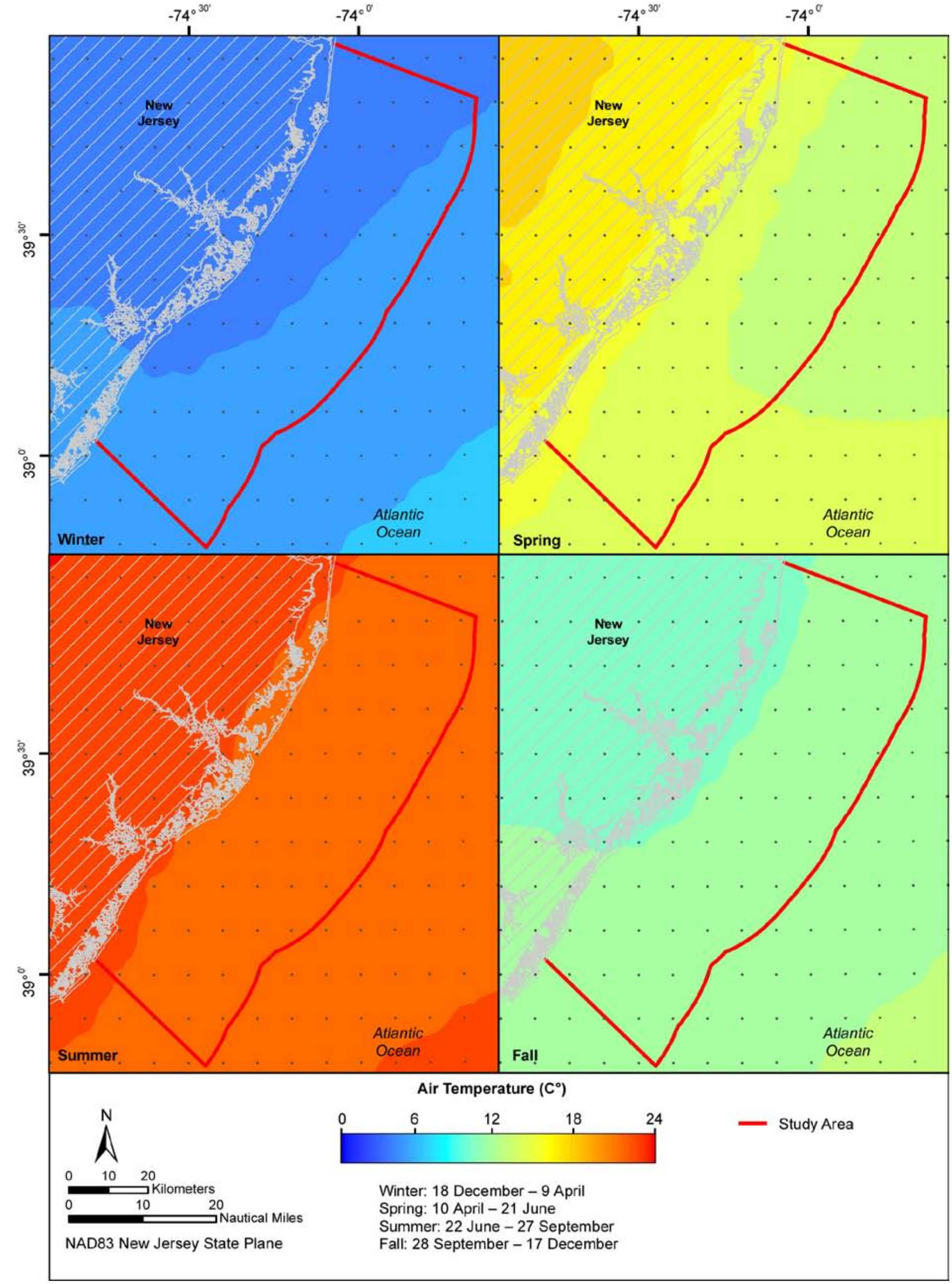

Figure 2-3. Mean seasonal air temperature (°C) in the Study Area during 2008. Source information: MARCOOS (2008).

2.1.2 Precipitation

Precipitation is necessary for sustaining ecosystem health and the spatial and temporal characteristics of precipitation can be affected by climate change. In particular, too little precipitation is manifested by drought while too much precipitation can result in widespread flooding (Ludlum 1983). The average total precipitation (rain or snow) for an area is a function of many different variables, including an area's position on the earth's surface, prevailing winds, influence of storms, topography, in addition to other factors. For New Jersey, a large portion of the annual precipitation comes with the passage of storms. In colder months (approximately December through March), precipitation largely falls as snow; however, for the Study Area and coastal areas of New Jersey, precipitation more commonly occurs in the form of rain. In the warmer months, thunderstorms (short term storms) and cyclonic storms (relatively longer term storms) provide a large portion of the annual rainfall, especially during the months of July, August, and September. In general for the State of New Jersey, more precipitation falls in the southern regions than northern regions of the state; that trend is especially apparent in the summer months (Smock 1888). **Figure 2-4** shows a long term record of mean annual precipitation for New Jersey from 1895 through 2009. Although highly variable, mean annual precipitation has increased from 111.40 centimeters (cm; 43.86 inches [in.]) between 1895 and 1970 to 119.9 cm (47.2 in.) between 1971 and 2000 to 124.18 cm (48.89 in.) between 2001 and 2009.[4]

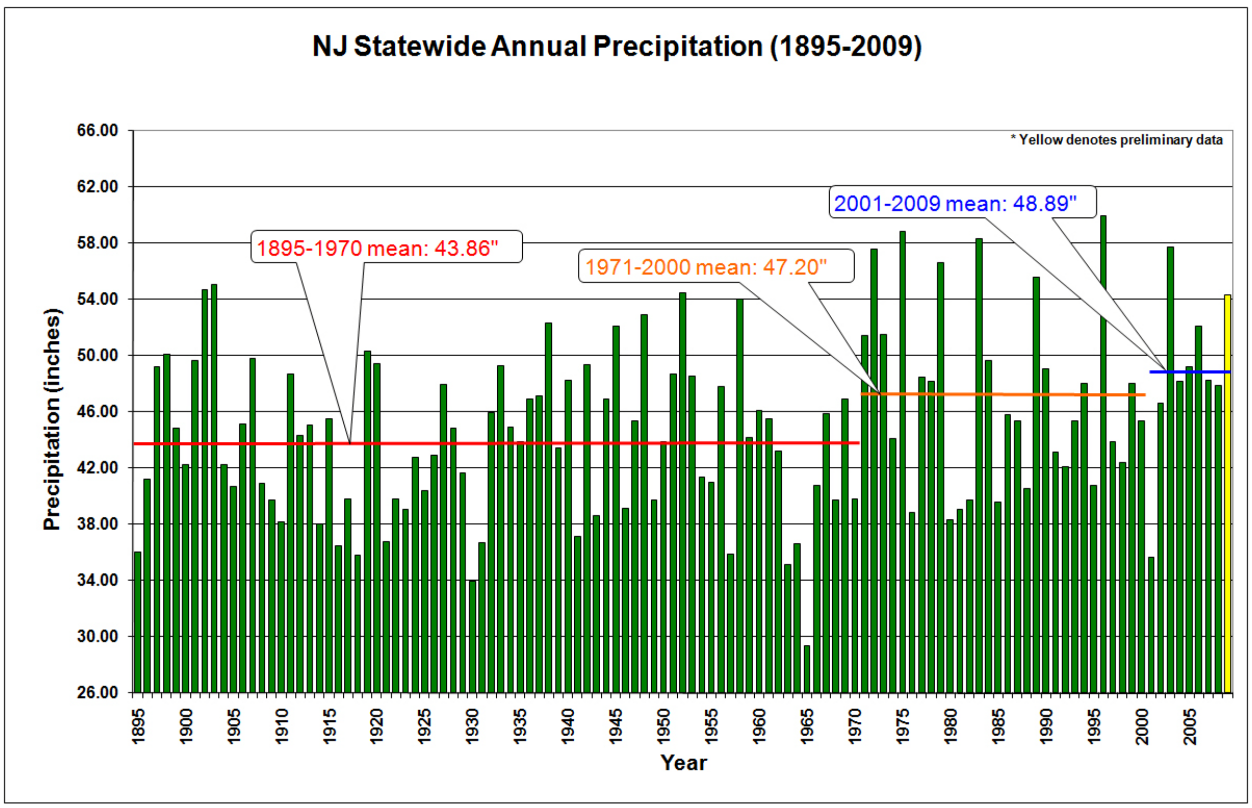

Figure 2-4. The mean annual precipitation for the State of New Jersey between 1895 and 2009.[4]

Figure 2-5 provides the mean seasonal precipitation for the Study Area. The figure was developed based on precipitation data from the NOAA NOMADS service. Precipitation data were downloaded for the year of 2006 from rolling archives of 6-hr interval data (MARCOOS 2006). Data were interpolated between 500 and 600 lat-lon points evenly spaced throughout the shown map extent. Precipitation data were averaged over seasons: winter (18 December through 09 April), spring (10 April through 21 June), summer (22 June through 27 September), and fall (28 September through 17 December).

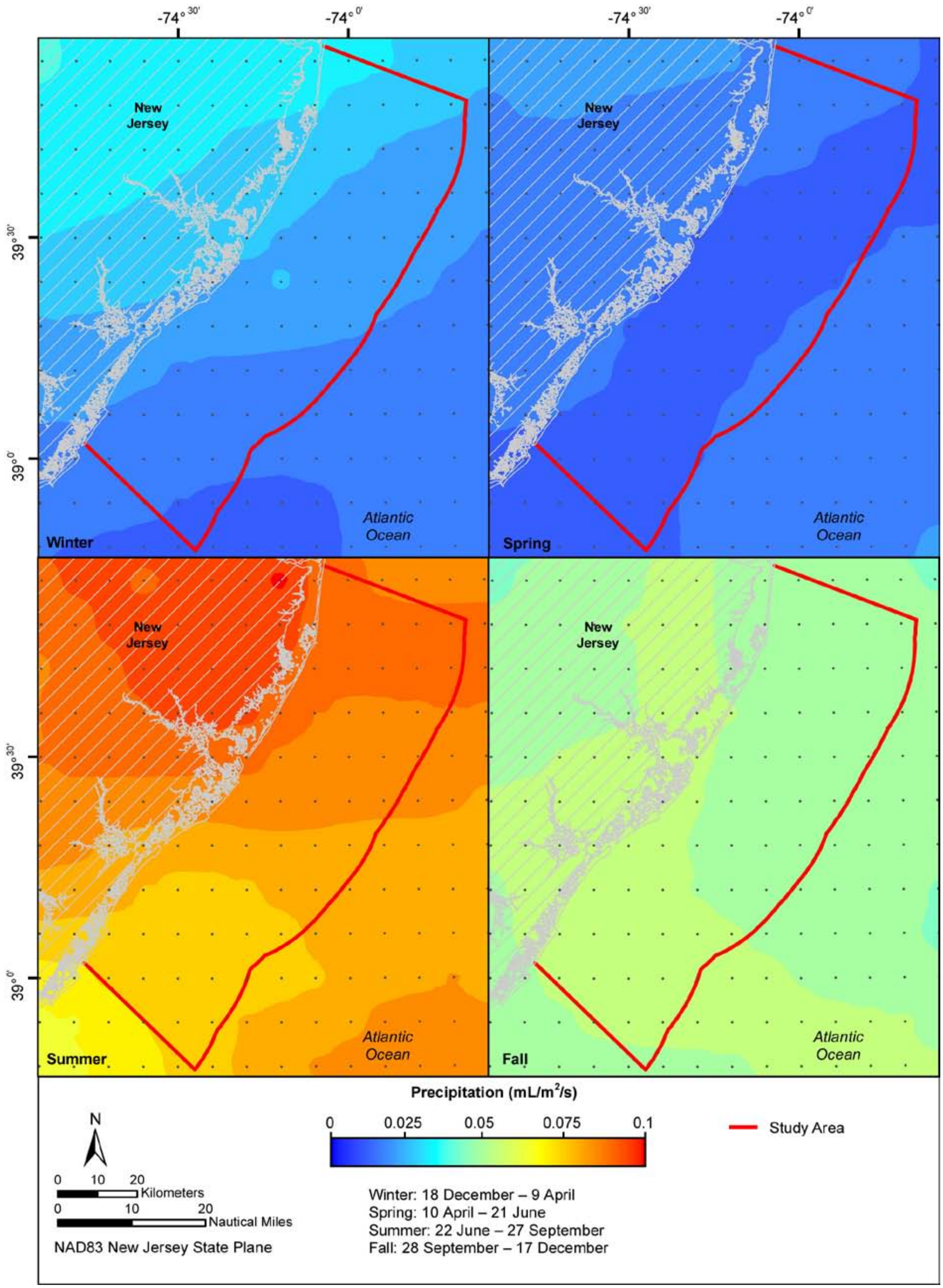

Figure 2-5. Mean seasonal precipitation (milliliters per square meter per second [mL/m^2/s]) in the Study Area during 2006. Source information: MARCOOS (2006).

Several scientists have studied the correlations between SSTs and climate variability on the east coast of the U.S. For the years between 1896 and 1995, Creison et al. (2001) suggested contemporaneous and lagged correlations between the SSTs and precipitation of the Study Area for all seasons. Both Hartley and Robinson (1999) and Creilson et al. (2001) found that a positive NAO index, in conjunction with active ENSO, resulted in warmer than normal winter SSTs, which in turn caused greater winter and spring precipitation for the Study Area. In addition, it was suggested that with the arrival of spring, increases in SSTs may result in stronger storms and increased precipitation along the northeast coastal U.S. (Creilson et al. 2001). Hartley and Robinson (1999) found that increased winter snow along the northeastern U.S. coast may be influenced by lower than average SSTs during the preceding fall.

Precipitation data were collected from the Office of the New Jersey State Climatologist, Rutgers University.[5,6] These data were averaged for annual, seasonal, and monthly means for the vicinity adjacent to the Study Area, the southern and coastal areas of New Jersey, between 1895 through 2010. **Figure 2-6** provides a graphical depiction of the mean monthly precipitation.

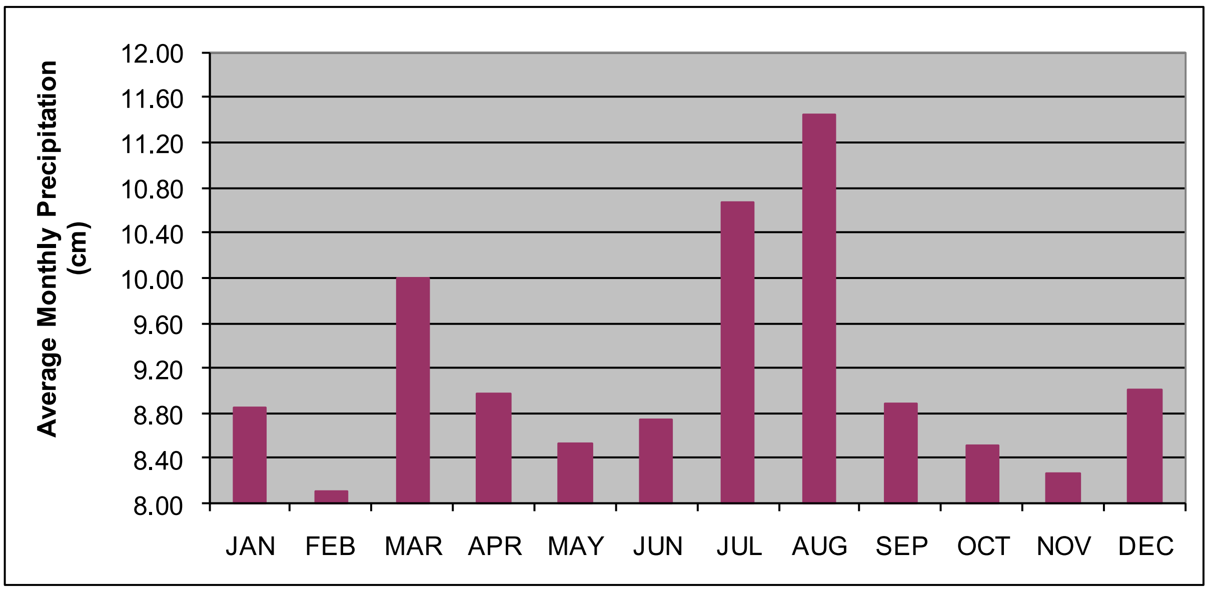

Figure 2-6. The mean monthly precipitation derived from the climate tables for the combined southern and coastal area of New Jersey, adjacent to the Study Area for the years 1895 to 2010.[5,6]

The mean annual precipitation (between the years of 1895 and 2010) for the combined southern and coastal regions of New Jersey is 109.91 cm (43.27 in.). The mean seasonal precipitation ranged from 26.26 cm (10.34 in.) in spring to 44.96 cm (17.70 in.) in winter with the lowest average precipitation in February (8.10 cm [3.19 in.]) and highest averages in August (11.46 cm [4.51 in.]). The greatest mean monthly precipitation change occurred from August to September (a decrease of 2.57 cm [1.01 in.]) while the smallest change occurred from December to January (a decrease of 0.15 cm [0.06 in.]). The largest mean rise in precipitation occurred from June to July (an increase of 1.93 cm [0.76 in.]) and the largest mean precipitation decline occurred from August to September (a decrease of 2.57 cm [1.01 in.]).[5,6]

Snowfall data were collected from the NOAA National Climatic Data Center (NCDC), for the monthly station climate summaries (Atlantic City) between 1971 and 2000 (NOAA 2004).[7] These data were averaged for annual, seasonal, and monthly means for the Atlantic City, New Jersey station (**Figure 2-7**).

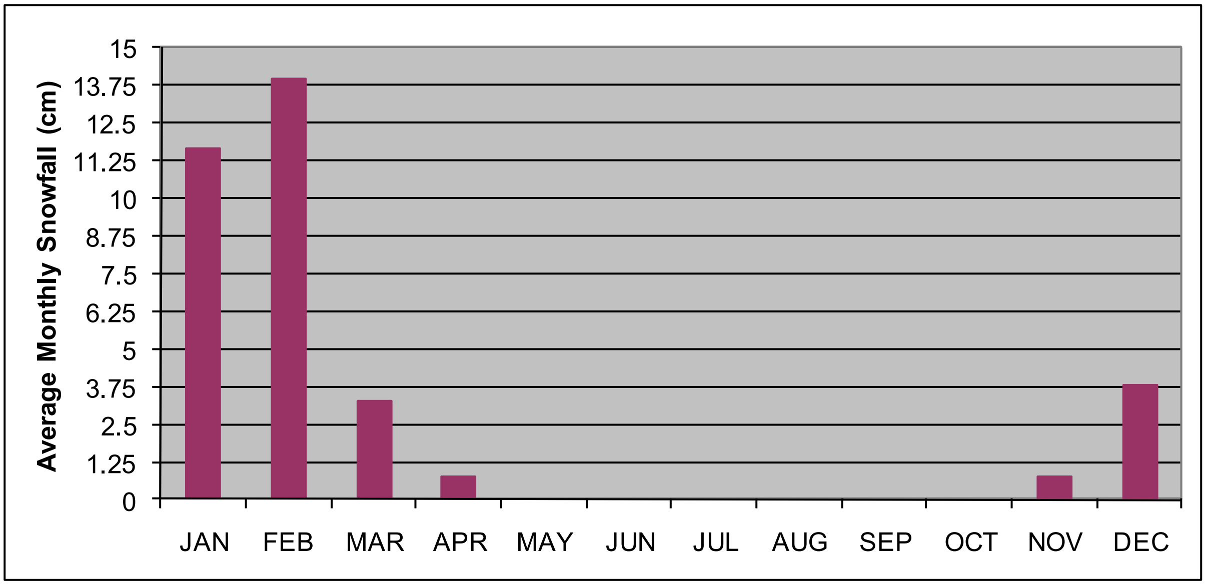

Figure 2-7. The mean monthly snowfall recorded from the climate tables for Atlantic City, New Jersey from 1971 to 2000 (NOAA 2004).[7]

The mean annual snowfall (between the years of 1971 and 2000) for Atlantic City, New Jersey was 34.80 cm (13.7 in.). The maximum average snowfall occurred in February (14.0 cm [5.5 in.]). The recorded average snowfall for January, February, March, April, November, and December was 12.2 cm (4.8 in.), 14.0 cm (5.5 in.), 3.3 cm (1.3 in.), 0.8 cm (0.3 in.), 0.5 cm (0.2 in.), and 4.2 cm (1.6 in.), respectively. Trace amounts of snowfall (non-zero values of less than 1.27 cm [0.50 in.]; Whitehurst 2010) were recorded in May and October while no snowfall occurred from June through September (NOAA 2004).[7] For records examined between 1895 and 2008 and for all of southern New Jersey, periods of snowfall generally range from mid-November to mid-April with an annual average snowfall of 25.4 to 38.1 cm (10 to 15 in.; Hammer 2006).

For records examined by Hammer (2006) between 1895 and 2008 for coastal New Jersey, an annual average precipitation of 1.07 m (42.03 in.) was cited. The wettest time of year was June to August, with an average precipitation of 29.23 cm (11.51 in.; Robinson 2008b). Too much precipitation can result in flooding, with tropical cyclones and their remnants being responsible for some of the most extreme precipitation events in the vicinity of the Study Area (Abbey et al. 2001; Konrad 2001; Shuman et al. 2001). On September 16, 1999, Hurricane Floyd produced very heavy rainfall and associated flooding in northern New Jersey with precipitation reports between 20.3 cm (8.0 in.) and 36.70 cm (14.45 in.) of rain (Cope 2001). Strong low pressure systems that move north/northeast between early winter and mid-spring cause most of the extreme snowfall precipitation in the Study Area. Coastal flooding (the accumulation of water within a water body with overflow onto adjacent areas) is the major type of flooding that could occur in the vicinity of the Study Area. Beach erosion, damage to dunes, and tidal flooding impacts are all caused by coastal flooding. According to NOAA's NCDC, the coastline of New Jersey has experienced 96 coastal flooding events out of a total 941 statewide floods between 1996 and 2007 (SNJ 2007).

Between 1895 and 2008, the driest time of the year for coastal New Jersey was September to November (Hammer 2006), with an average precipitation of 24.79 cm (9.76 in.; Robinson 2008a). Too little precipitation is manifested by drought, a period of drier than normal conditions that can reduce stream flows and the water levels in lakes and reservoirs (SNJ 2007). Historically, New Jersey has experienced several droughts with significant socioeconomic and environmental consequences (Ludlum 1983). In the 108-year record from 1893 to 2003, the coastal area of New Jersey experienced 63 dry periods which lasted 10 months on average. Of the decades recorded, the 1900s, 1970s, and 1990s have been relatively wet while the 1910s, 1930s, and 1960s have been relatively dry (Harnack and Small 2002; Harnack et al. 2005).

2.1.3 Winds

Atmospheric circulation at the middle latitudes over North America occurs predominantly west to east (“westerlies”). Westerlies that effect the Study Area exhibit variability in strength, pattern, and directionality (or meridional shifts, a shift of the winds to parallel a line of longitude) throughout the year (Glenn et al. 2004; 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. 2004; 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 seasons 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. 2004; Schofield et al. 2008).

Onshore breezes (or “sea breezes”) are mesoscale wind pattern events that form perpendicular to the coast and directly influence local temperatures. **Figure 2-8** 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 2-9** shows the inland progression of a sea breeze front.

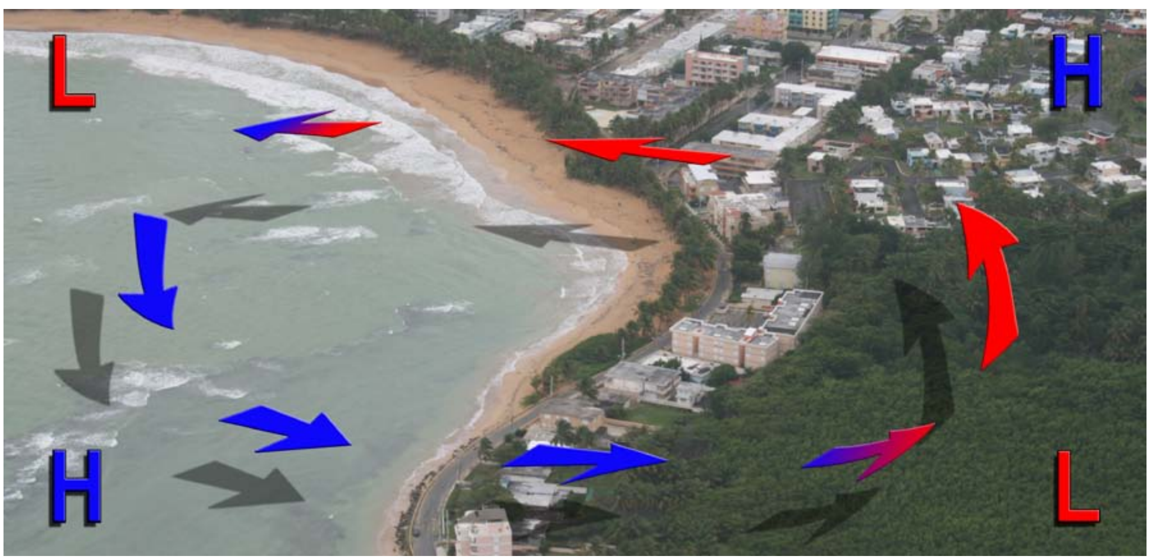

Figure 2-8. Characteristics of a sea breeze. An onshore wind (i.e., a wind blowing from the water onto the land), or sea breeze, results from atmospheric changes induced by the differing heat capacities of land and water. Land heats up and cools down much more quickly than the ocean. When the ambient 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. This rising air creates an area of high pressure in the upper atmosphere. 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 and high pressure in the lower atmosphere. 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).

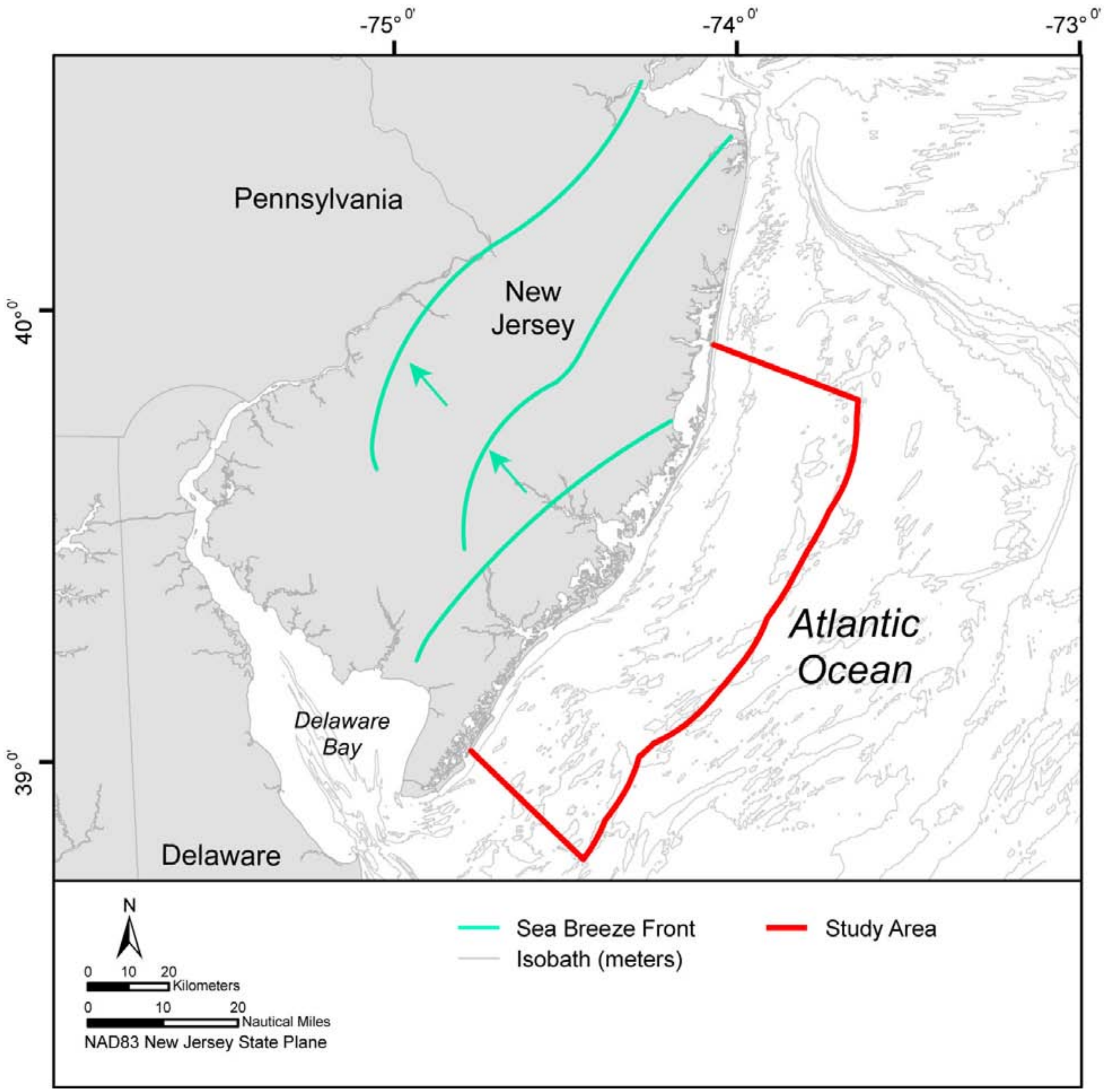

Figure 2-9. The inland progression of a sea breeze front. Map adapted from: Bowers (2004).

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).

2.1.4 Tides

Tide is the name given to the alternate rise and fall of sea level (Thurman 1997), which is caused by the gravitational forces exerted simultaneously by the moon, sun, and earth, and the revolution about one another. Due to the modification from varying depths, sizes, and shapes of ocean basins and the difference in response locally to the semi-diurnal and diurnal force constituents and to their relative phases, there is a considerable variety among observed tides (Pond and Pickard 1983). The classification of tides in many parts of the world exhibits different patterns based on the distinguishing features. There are diurnal tides (daily tides), semi-diurnal tides (twice daily), and mixed tides. For diurnal tides there is one high water and one low water in each lunar day (tidal period of about 24.8 hrs), while for the semi-diurnal tides there are two high and two low waters in the same interval (tidal period of about 12.4 hours; Pond and Pickard 1983). Mixed tides have characteristics of both diurnal and semi-diurnal tides with successive high and/or low tides (with significantly different heights) along with diurnal periods for a few days per month (Thurman 1997). The Study Area experiences semi-diurnal tides with an average period of 12 hrs 25 min (**Figure 2-10**; Moody et al. 1984; McBride and Moslow 1991)[8] and a maximum amplitude of about 10 to 15 centimeters per second (cm/s; 3.9 to 5.9 inches per second [in./s]). Over the New Jersey shelf, the semi-diurnal tides are oriented in the cross-shelf direction with a small, weaker diurnal component oriented in the along-shelf direction (Moody et al. 1984).

Ocean tides vary in ways other than the relative components of diurnal and semi-diurnal forces. The range of the tide will increase to a maximum during spring tides. This maximum occurs when the sun and moon come into phase on the same side of the earth or both on opposite sides. The range of the tide will decrease to a minimum during neap tides. The minimum occurs when the sun and moon are nearest to 90° to each other. Spring or neap tides occur at successive intervals of about 15 days (Pond and Pickard 1983). Along the New Jersey coast, the spring tides reach a maximum range of approximately 2.0 m (6.6 ft) and the neap tides reach a minimum range of approximately 1.0 m (3.3 ft; Byrnes et al. 2000). Tides are also modified as they travel up the mouths of river estuaries, progress up the estuaries, and sometimes up the rivers as well; however, there are variations of tide height as the tide wave penetrates up the estuary as a result of the change in width, change in depth, increased friction with the seabed, and river flow seaward (Pond and Pickard 1983).

For the Study Area, information can be extrapolated from a single station in the Study Area because the same type of tide is often found for long distances along a coast. The tide record at this single station is sufficient in determining the type of tide for the whole region. The differences that can possibly be expected are in the relative phase and amplitude of the tide at other points in the region (McBride and Moslow 1991). The tides for Atlantic City, New Jersey should be representative of the Study Area; they are shown in **Figure 2-11** for 01 January 2010.[8] Mean station datum of water elevation for the Atlantic City, New Jersey station between 1983 and 2001 are listed in **Table 2-1**.[8]

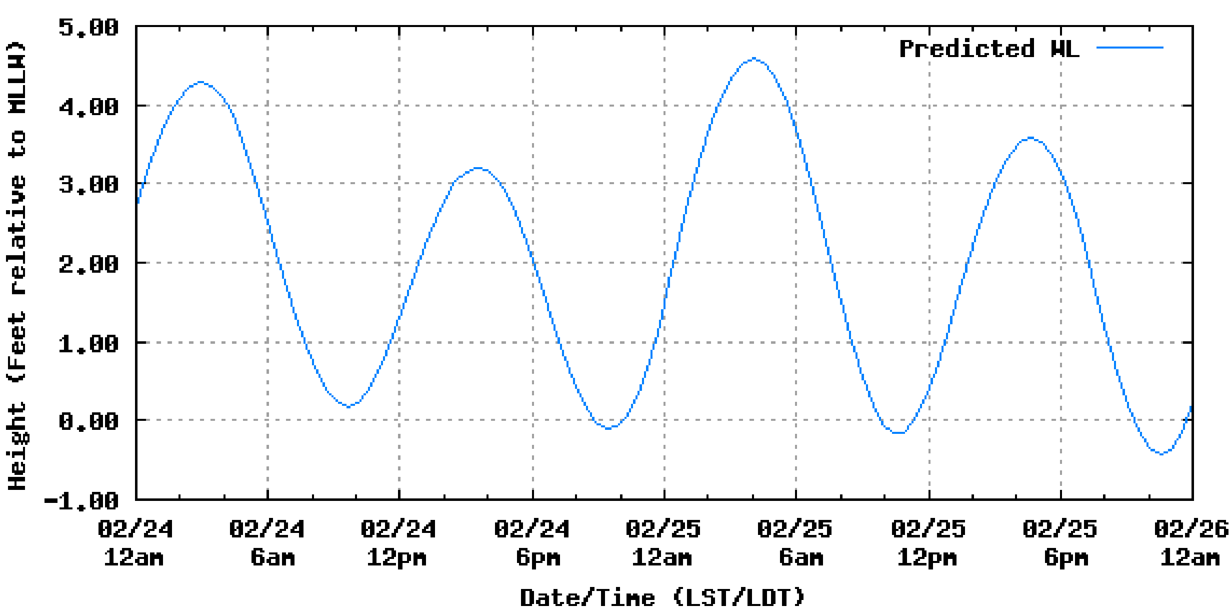

Figure 2-10. The predicted water level (WL; in feet) relative to the height of the mean lower-low water (MLLW) at the Atlantic City, New Jersey station for 24 Febuary 2010 and 26 February 2010.[8]

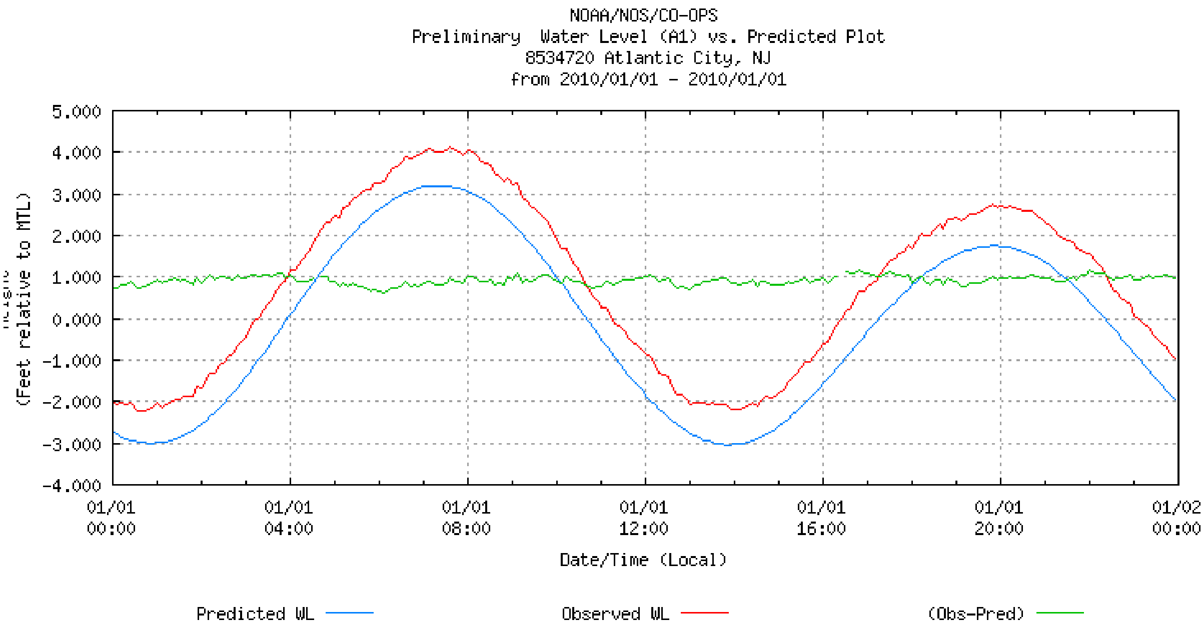

Figure 2-11. The predicted and observed water level (WL; in feet) relative to the Mean Tide Level (MTL) at the Atlantic City, New Jersey station for 01 January 2010.[8]

Table 2-1. Mean water elevation station datum for the Atlantic City, New Jersey, Station 8534720 between 1983 and 2001.[8]

Atlantic City, New Jersey, Station 8534720		
Datum	**Value (ft)**	**Description**
MHHW	9.56	Mean Higher-High Water
MHW	9.14	Mean High Water
DTL	7.26	Mean Diurnal Tide Level
MTL	7.13	Mean Tide Level
MSL	7.17	Mean Sea Level
MLW	5.13	Mean Low Water
MLLW	4.96	Mean Lower-Low Water
GT	4.60	Great Diurnal Range
MN	4.02	Mean Range of Tide
DHQ	0.42	Mean Diurnal High Water Inequality
DLQ	0.17	Mean Diurnal Low Water Inequality

In addition, unusual rises of sea level may occur as a result of other forces besides exceptionally high tides. Storm surges are the result of the frictional stress of strong winds blowing toward land and pushing up the water against the land and can cause the water level to rise significantly (by as much as several meters). In the past, storm surges have caused severe flooding of low-lying areas (Pond and Pickard 1983).

2.1.5 Storms and Hurricanes

Extratropical storms, including northeasters ("nor'easters"; FitzGerald et al. 2001; Hanson et al. 2007), 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, Halloween storm of 1991, and December Nor'easter of 1992; Bosart and Lin 1984; Uccellini et al. 1984; Young et al. 1995; Sallenger 2000; Wu et al. 2002; Donnelly et al. 2004; Hammer 2006). Thunderstorms also may arise (most areas receive 25 to 30 thunderstorms per year), but they are less common near the coast than inland. New Jersey can also potentially experience tornadoes (approximately five tornadoes occur each year); however, they are generally few in number and weak (Hammer 2006).

Tropical cyclones are non-frontal, low pressure, rotating storm systems originating over tropical waters and are essentially driven through heat transfer from the ocean. These systems include tropical depressions, tropical storms, and all hurricane categories and experience maximum sustained surface winds (averaged over 1 min) of less than 33 kts (38 miles per hour [mph]), between 34 kts and 63 kts (39 mph and 73 mph), and at least 64 kts (74 mph), respectively respectively (**Figure 2-12**; Elsner and Kara 1999; NOAA 2009b; NOAA/NWS 2010b). At least seven tropical cyclones (tropical storm designation for the New Jersey coastline, or higher) have impacted the Study Area between 1960 and 2008; Hurricane Donna (1960), Tropical Storm Doria (1971), Hurricane Belle (1976), Hurricane Gloria (1985), Hurricane Bob (1991), Tropical Storm Bertha (1996), Tropical Storm Floyd (1999), and Tropical Storm Hanna (2008). The average maximum sustained surface winds for all events were 32 kts (37 mph) with average gusts of 50 kts (56 mph; Dunn 1961; Simpson and Hope 1972; Ho et al. 1976; Lawrence 1977; Case 1986; Pasch and Avila 1992, 1999; Lawrence et al. 2001; Brown and Kimberlain 2009).

Hurricanes that travel along the coastline of the eastern U.S. have the potential to impact the Study Area with high winds, severe flooding, and substantial damage (Donnelly et al. 2004). Although the official Atlantic hurricane season begins 01 June and ends 30 November, most hurricane events generally occur from mid August to late October (Landsea 1993; Landsea et al. 1998; NOAA/NWS 2010b) with the majority of all events occurring in September (**Figure 2-13**; Landsea 1993; Landsea et al. 1998).

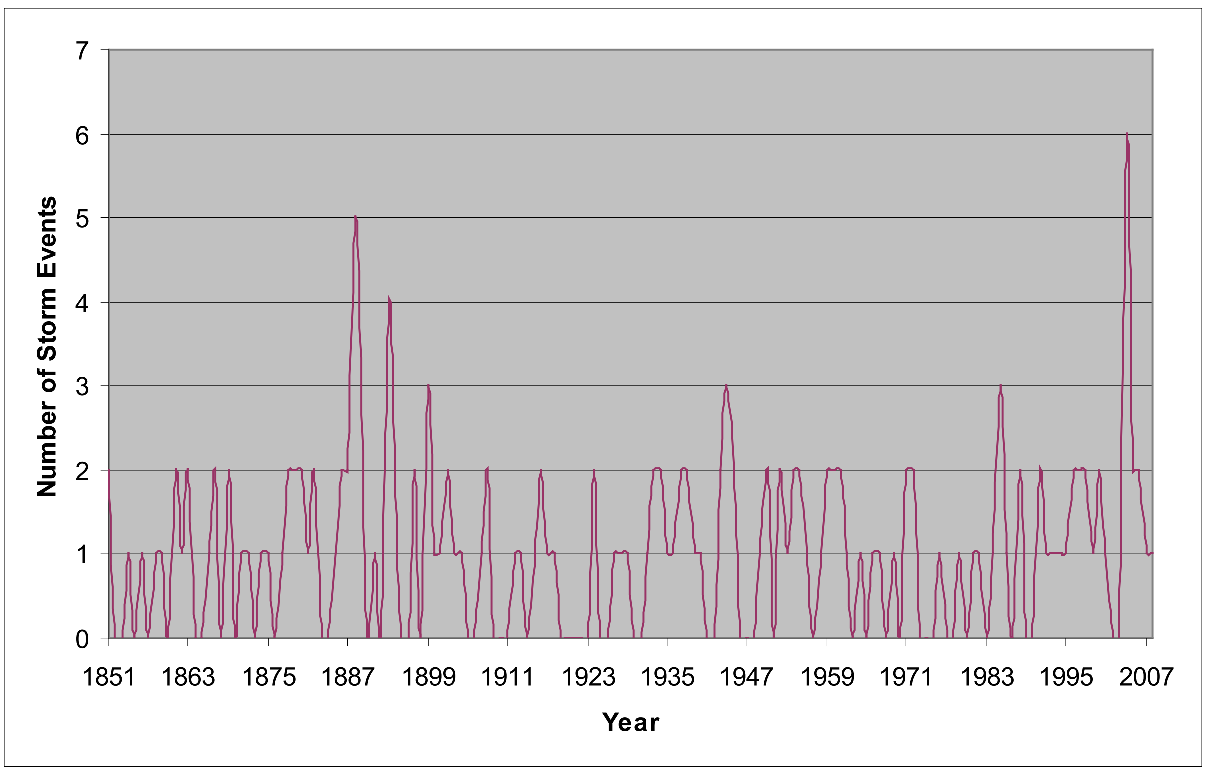

Figure 2-12. The total number of storm events (extratropical storms, subtropical depressions and storms, tropical depressions and storms, and hurricanes [all categories]) within 148 km (80 NM) of the southern coast and 145 NM (167 mi) of the northern New Jersey coast from 1851 to 2008 (NOAA 2009a). Years in which no storm events were recorded are represented as zero.

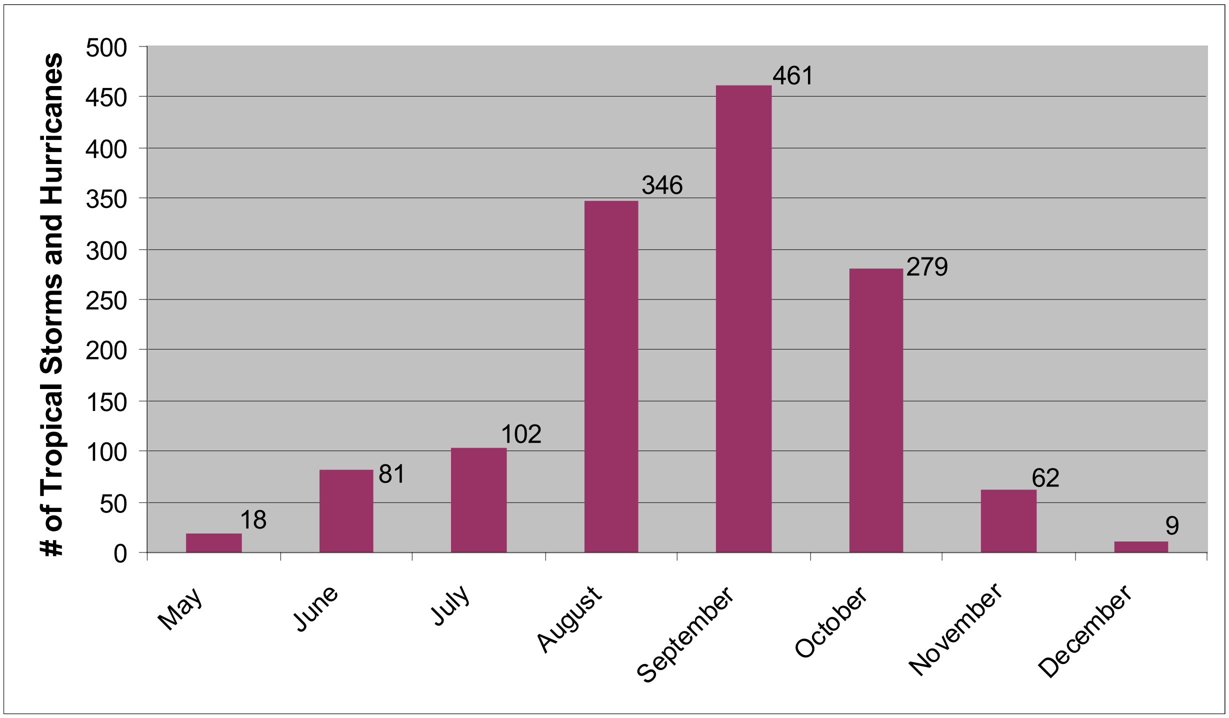

Figure 2-13. The total number of North Atlantic basin tropical storm and hurricane events per month for all years from 1851 to 2006 (McAdie et al. 2009).

Historically, hurricanes (all categories) have occurred within 80 NM (92 mi) of the southern coast and 145 NM (167 mi) of the northern New Jersey coast, on average, every 3.8 years. Intense or major hurricanes are those reaching category three or higher (wind speeds of 96 kts [111 mph] or more) on the Saffir/Simpson Hurricane Scale (Lehtola and Brown 1998). Nine intense hurricanes tracked within 80 NM (92 mi) of the southern coast and 145 NM (167 mi) of the northern New Jersey coast between 1851 and 2008: no name (1869), no name (1887), no name (1938), Hurricane Able (1950), Hurricane Edna (1954), Hurricane Daisy (1958), Hurricane Esther (1961), Hurricane Gerda (1969), and Hurricane Bob (1991; NOAA 2009a); the naming of hurricanes began in the 1950s.[9]

The rate of recurrence for a certain category of hurricane, expected within 75 NM (86 mi) of a given location, each 100 years, is referred to as the hurricane return period (NOAA 2009b). The return periods for the region encompassing the Study Area are given in **Table 2-2** (Neumann 2001e, 2001d, 2001c, 2001b, 2001a).

Table 2-2. Hurricane rate of recurrence for the Study Area. A category 1 hurricane has winds from 64 to 82 kts (74 to 95 mph), category 2 from 83 to 95 kts (96 to 110 mph), category 3 from 96 to 113 kts (111 to 130 mph), category 4 from 114 to 135 kts (131 to 155 mph), and a category 5 hurricane has winds greater than 135 kts (155 mph; Lehtola and Brown 1998; NOAA 2009b)

Hurricane Rate of Recurrence		
Hurricane Category	Return Period (Years)	Number Expected Every 100 Years
1	22	4.5
2	50	2
3	87	1.15
4	190	0.53
5	480	0.21

The occurrence of intense hurricanes making U.S. landfall decreases during El Niño years and increases during non-El Niño years (i.e., La Niña and neutral years; Gray 1984; Pielke and Landsea 1999). In fact, Gray (1984) identified a three-to-one ratio of intense hurricane landfall strikes; 0.74 per year for non-El Niño years and 0.25 per year during El Niño events (Gray 1984). According to the Japan Meteorological Agency (JMA), El Niño, or Warm Phase, events occur when the five-month running average of sea surface temperature varies more than 0.5°C for at least six consecutive months (starting before September and running through December) in the eastern tropical Pacific Ocean (from 4°N to 4° South [S] and 150°W to 90°W). In contrast, La Niña, or Cold Phase, events are when the running average of SST is 0.5°C below the mean from before September through December. Furthermore, years are termed neutral if the SST index is not more than 0.5°C above or below average (Bove et al. 1998). The region is currently experiencing an El Niño year and impacts are predicted to occur into spring 2010 (NOAA/NWS 2010a)

2.1.6 North Atlantic Oscillation

In the Study Area, fluctuations in sea surface and bottom water temperatures have been associated with trends in the 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 considered an index, which is indicative of the mean winter atmospheric pressure difference between the low- and high-pressure centers. It is calculated as the difference of atmospheric pressure at sea level between the Azores high and the Icelandic low. 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 exhibits considerable interseasonal and interannual variability, but tends to remain relatively stable for prolonged periods, e.g., the recorded NAO index was mainly positive from 1900 to 1950, mainly negative from the 1950s through the 1970s, and has been mainly positive since the late 1970s (Hurrell et al. 2001).[10]

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 (*Eubalaena glacialis*), which feeds principally on zooplankton, *Calanus finmarchicus*. Right whale calving rates are linked to the abundance of *C. 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 and sardines (Clupeidae), two tuna species (Scombridae), Atlantic salmon (*Salmo salar*), and swordfish (*Xiphias gladius*; Drinkwater et al. 2003).

2.2 PHYSICAL ENVIRONMENT

2.2.1 Marine Geology

2.2.1.1 Geologic Setting

Rifting between the North American and African plates initiated in the Triassic period and resulted in the development of the passive margin shelf along the Atlantic coast (Carey et al. 1998 after Grow et al. 1988). Over the time spanning from the beginning of the Cretaceous period through the Pliocene (~145 – 2 million years ago [Ma]), a basin developed above a cooling and contracting craton due to the progressive overlapping of marine and deltaic deposits, generating an extensive continental terrace, most of which presently lies beneath the Atlantic Ocean (Owens et al. 1998).

The hinge line (the boundary between a stable region and one undergoing relative vertical movement) parallels the New Jersey coast approximately 20 km (12 mi) offshore then curves to parallel Long Island, New York (Carey et al. 1998). This hinge line defines the boundary between the northern coast headland erosion and the southern coast barrier island systems (Uptegrove et al. 1999). Subsidence east of the hinge line measures about 0.0150 millimeter (mm; 0.0006 in.) per year declining towards the west to near zero (Carey et al. 1998). The northern zone is undergoing flexural uplift while the southern zone features a depression; there is somewhat greater accommodation space for deposition created by glacial rebound to the north and forebulge subsidence (Uptegrove 2003). The movement of salt intrusions near the deepest portion of the Baltimore Canyon Trough (north of the hinge line) could possibly account for local uplift uplift (Carey et al. 1998).

From the Pleistocene Epoch (~1.8 Ma) to the present, the Atlantic continental margin experienced sea level fluctuations caused by the advance and retreat of the Antarctic and Greenland ice sheets and northern continental glaciers (Ashley et al. 1991). There have been three sea level highstands along the coast in the Study Area and the Atlantic inner shelf (125 thousand years ago [ka], 55 ka, and modern). During these rises in sea level, barrier islands, tidal delta sands, and linear sand ridges formed in the high energy environments while lagoonal muds and marsh formed in the low-energy environments (Ashley et al. 1991; McBride and Moslow 1991). The ebb-tidal delta and the linear sand ridges shield underlying Holocene muds from wave and current erosion, producing a substrate of varying thickness and unconformable boundaries. Sediments that crop out on the ocean floor in the Study Area range in age from Miocene to Holocene (23 Ma to the present; Ashley et al. 1991). This includes the submarine sand ridges, which are composed of sediments that date to this time period. Marine sediments deposited during sea-level highstands typically are separated by layers of fluvial gravels and coarse sands deposited or reworked during sea-level lowstands. In the Study Area, during the most recent sea-level rise, older Holocene-age interbedded sand and muds have been eroded and/or overlain by younger Holocene-age barrier island and shoreface sands (Ashley et al. 1991). Some of the sand ridges are composed of this succession of deposits. Holocene, Eocene, Cretaceous, and Triassic subsurface layers overlie inlets and channels. These stratigraphic units are also found near sand ridges (McBride and Moslow 1991). McHugh and Olson (2002) proposed to provide a specific chronology of the Pleistocene sedimentation of the New Jersey continental margin as well as examine passive margin sedimentation models within the glacioeustasy framework. By constructing an oxygen isotope record from 520 m (1706 ft) of Pleistocene continental slope sediment, 16 glacial/interglacial fluctuations in ice volume were documented in sediments of the Hudson Apron (a plateau-like feature between the Hudson and Toms canyons). Contrary to predicted sedimentation models, mass-wasting was not restricted to glacial maximums, but was present during both glacial and interglacial events (McHugh and Olson 2002). Also, while the sedimentary record from glacial stages is dominated by fine-grained sediments, the sedimentary record from periods of glacial/interglacial transition periods is dominated by coard sands. Glacial and interglacial variability is not the main control on large-scale sediment deposition of the New Jersey margin (McHugh and Olson 2002).

Seismic stratigraphic and geohistory analysis techniques (to determine total basin subsidence) were applied to data from the Baltimore Canyon trough to interpret sea-level changes during the Tertiary by developing a stratrigraphic framework through interpretation of a region grid of shelf wells' seismic reflection data (Greenlee et al. 1988). These techniques concluded the presence of sudden basinward shifts in coastal onlap inferred as a sedimentary response to relative decreases in sea level. Geohistory analysis of one of the wells indicates this area underwent slow, continuous thermotectonic subsidence during the Tertiary (Greenlee et al. 1988). Using both techniques to interpret changes in eustatic sea level, it was discovered that this area underwent three orders of sea-level change during a long-term sea-level fall during this period and partially accounted for perpetual seaward movement of the shelf edge.

2.2.1.2 Physiography

The New Jersey shelf lies between the Hudson and the Delaware shelf valleys from 38°40' to 40°30'N and 72°30' to 74°40'W and covers a 25,000-km^2 (9,653-square mile [mi^2]) area; this shelf ranges from 120 to 150 km (75 to 93 mi) in width, sloping to the east (<0.001) and becomes steeper where the shelf break begins at the 120- and 160-m (394- to 525-ft) isobath (Carey et al. 1998). The storm-dominated shelf has a tidal range of 1.0 to 2.0 m (3.3 to 6.6 ft) and an average wave height of about 1.0 m (3.3 ft). The shelf accumulates mainly pelagic sediments as the majority of terrigenous supply is retained by coastal lagoons and estuaries. Barrier islands range from 8 to 29 km (5 to 18 mi) in length and extend from Manasquan Inlet to Cape May; these islands provide protection for the lagoons and estuaries from direct wave damage (Byrnes et al. 2000). The barrier islands are separated by 11 tidal openings. These openings, or inlets, can create convoluted currents which cause lateral migration of the inlets and the relocation of sand to nearby shorelines. Severe shoreline erosion can occur with some sections retreating up to 2.0 m (6.6 ft)/yr. At Manasquan Inlet alone, the regional longshore transport current carries an average of 57,000 cubic meters (m^3; 2,012,936 cubic feet [ft^3]) of sand per year (Burlas et al. 2001). A year-long monitoring study along the mid-Atlantic shelf by Butman et al. revealed intermittent movement of bottom sediments by currents, waves, and other forcing mechanisms (1979). Wind and wave stresses that influence bottom sediment mobility and stability must be considered when designing and constructing offshore structures (Butman et al. 1979; Vincent et al. 1981).

The continental shelf along the U.S. east coast extends from Maine to the Florida Keys and contains mostly linear symmetrical east-northeast oriented trending shoals that are up to 10 m (33 ft) thick and extend for several miles (Amato 1994). New Jersey's northern coastal region has a shoreface that is steep and narrow, having an average width of 0.64 km (0.40 mi). On average, 4.63 km (2.88 mi) separate the linear shoals from the coast, and they are each about 1.9 to 5.6 km (1.2 to 3.5 mi) in length and 0.5 km (0.3 mi) wide. The average water depth above the crests is 9 to 18 m (30 to 59 ft), while the relief is 3 to 11 m (10 to 36 ft; Duane et al. 1972). The shoals are mostly composed of a top layer of medium-grained quartzose sand, which is in turn on top of a layer of quartz and glauconite and a bottom layer of sands, silts, and clays. There are also some ridges and Tertiary coastal plain deposits in the area that were more than likely formed from erosion (Duane et al. 1972; Uptegrove et al. 1999). The quartzose shoals off the southern coast of New Jersey are mostly Holocene and are higher, longer, appear more frequently, and have a northeast and east-northeast orientation. The shoreface in this area is also broader and more irregular. The mean shoal crest depths are 7.6 to 9.1 m (24.9 to 29.9 ft) and show about 3 to 6 m (10 to 20 ft) of relief. The morphology of this area was produced by extensive marine reworking, mostly in the form of shifting of inlets (Duane et al. 1972; Uptegrove et al. 1999). 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.

2.2.1.3 Bathymetry

The bathymetry of the Study Area reveals a relatively shallow, gradually deepening region typical of a continental shelf located along a passive margin. The shelf is bounded by the Hudson Canyon in the north and the Wilmington Canyon to the south decreasing in depth north to south (130 to 100 m [427 to 328 ft]; Milliman et al. 1990). In general, passive continental margins (such as New Jersey) are characterized by subsidence, erosion, and variable sediment accumulations (Kennett 1982). The majority of the U.S. eastern continental shelf (from Florida to New Jersey) 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). The middle and outer shelf display a ridge-and-swale topography with local relief surpassing 20 m (66 ft) being more predominant in the middle shelf (Milliman et al. 1990). Slight escarpments (relief of 20 to 50 m

[66 to 164 ft]) are also evident along the New Jersey shelf theorized to be ancient shorelines. Bathymetrically, the Study Area consists of a nearly uniform, smooth, and shallow seafloor that slopes gently offshore (**Figure 2-14a**); however, one of the major bathymetric features of the Study Area include shoreface sand ridges. Dominating the inner-shelf topography, shoreface-attached and detached sand ridges are found along the Atlantic inner shelf of the U.S. oriented at oblique angles in relation to the shoreline (Duane et al. 1972; Figueiredo et al. 1981; Duane and Stubblefield 1988). 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). These shoreface-attached and detached sand ridges consist of unconsolidated fine-to-medium grained sand, are generally over 1,000 m (3,281 ft) long, have relief up to 10 m (33 ft), side slopes that average less than 1°, and are 1 to 3 km (0.6 to 1.9 mi) wide with wavelengths of 1 to 8 km (0.6 to 5.0 mi; 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). These ridges have been hypothesized as having two different origins: (1) some outer shelf ridges are post-transgressive features or (2) the shore-parallel mid-shelf ridges (20- to 30-m water depth) are degraded barriers consequently modified by shelf currents (Duane and Stubblefield 1988). New sediment, eroding from the shoreface as sea level rises, is accumulating nearshore despite most modern fluvial sediment being trapped within estuaries. It is hypothesized that this deposition is accompanied by trough erosion which increases the shelf's sediment budget (Duane and Stubblefield 1988).

Other notable bathymetric features in the vicinity of the Study Area include the Delaware Shelf Valley located just south of the Study Area and the Hudson Shelf Valley located to the north of the Study Area (**Figure 2-14b**). Several smaller canyons incise the shelf edge east of the Study Area. The mean flow over the shelf adjacent to the Delaware Bay is southward at speeds of about 10 cm/s (3.94 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.

Hudson Shelf Valley

The Hudson Shelf Valley extends in a southeasterly direction from Sandy Hook, NJ across the 180-km (119-mile) wide continental shelf north of the Study Area (**Figure 2-14b**). During the Last Glacial Maximum (approximately 25 to 18 ka), sea level was as much as 125 m below present day sea level, and the coastline was as far seaward as the shelf break (where the shelf slope gradient increases markedly). The Hudson Shelf Valley is the path of the ancestral Hudson River during periods of sea-level lowstand. The present day drainage route of the Hudson River across the shelf has been open since the late Pliocene (approximately 2 Ma; Stanford 2010). During the Last Glacial Maximum, the ice sheet extended as far south as Perth Amboy, New Jersey, and covered the entire present-day drainage area of the Hudson River. Braided stream discharge on the exposed shelf during the Last Glacial Maximum created fluvial deposits, including sands and gravels (Sheridan et al. 2000). These sediments largely now are buried beneath younger marine sediments on the submerged shelf. The Hudson River Valley may have been further incised by catastrophic flooding events during the retreat of the last glacier, as a series of moraine-dammed glacial lakes were breached upstream as the glacier retreated northward (around 14 ka; Newman et al. 1969; Clayton and Knox 2008). Besides the small volume of sediment that was eroded during the erosion of the Verrazano Narrows moraine dam approximately 15 ka, little sediment has left the Hudson Valley. Sediment was trapped in glacially overdeepened valleys in the present day lower Hudson Valley as the glacier retreated (Stanford 2010).

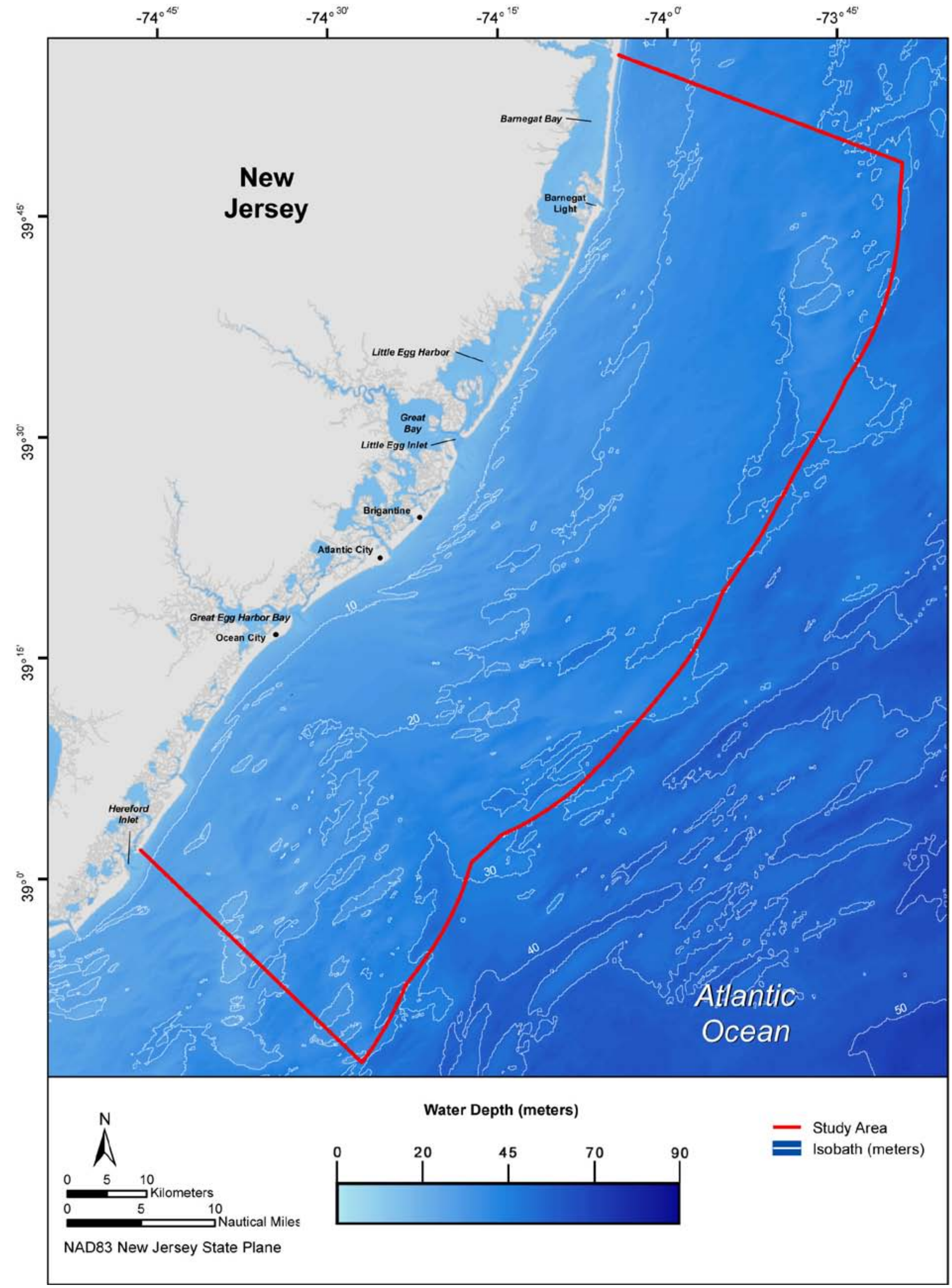

Figure 2-14a. Isobath bathymetry of the Study Area showing isobaths at a spatial scale appropriate for examining water depths within the Study Area. Source data: NOAA (1999).

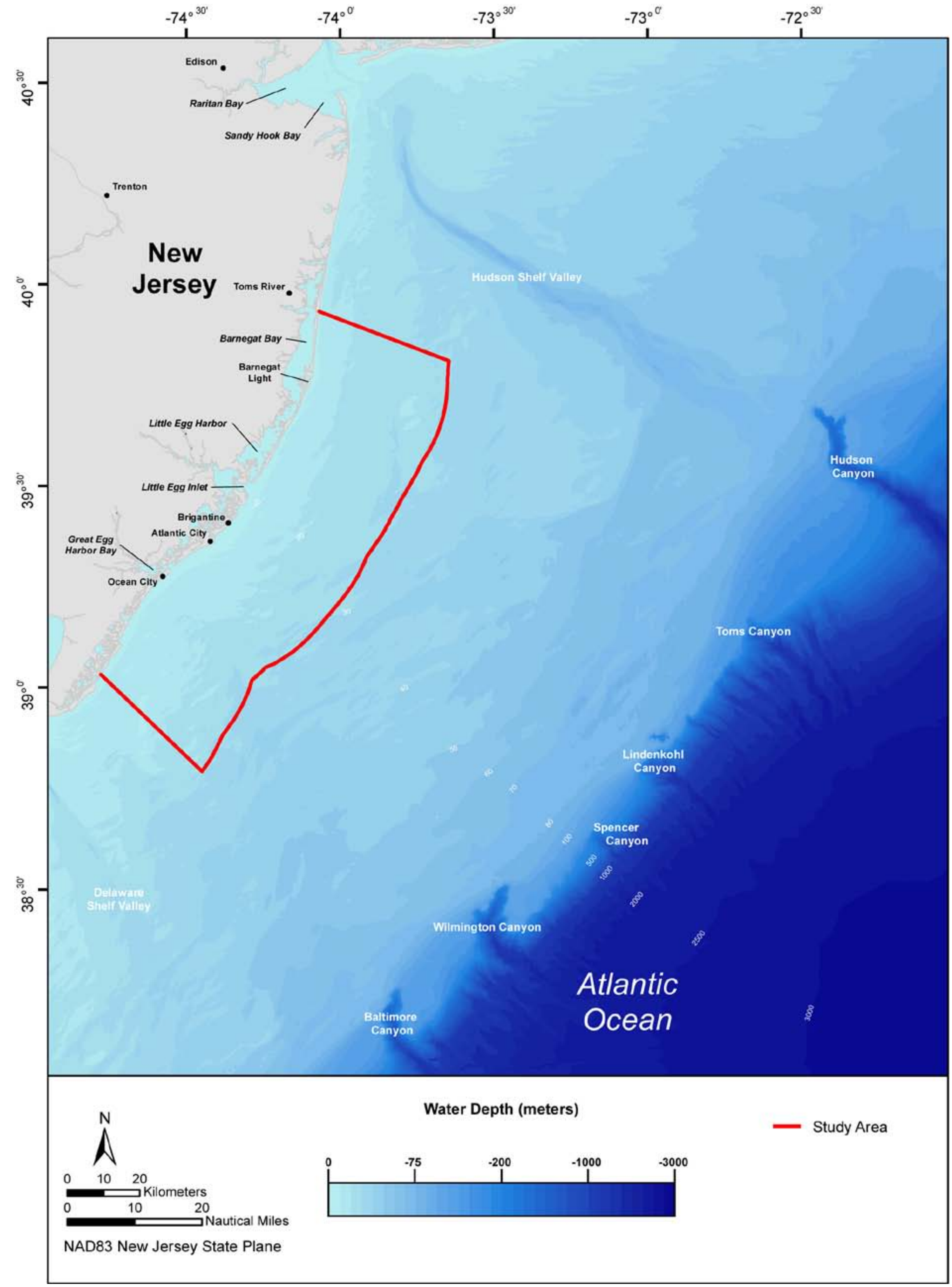

Figure 2-14b. Isobath bathymetry and bathymetric features of the Study Area and vicinity. Source data: NOAA (1999).

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 to 10 cm/s [1.97 to 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 to 40 cm/s [7.87 to 15.75 in./s]), and sea level set-down at the coast (Harris et al. 2003; Schofield et al. 2008). The valley acts a basin for the general southwest flow of sediment transportation along the shelf creating an effective sediment transport barrier as evident by the large gravel areas southwest of the valley (Vincent et al. 1981).

2.2.1.4 Sand Ridges

On the inner continental shelf of the Study Area, shore-oblique linear sand ridges are common features (Dragos and Aubrey 1990). Sand ridges are elongated, wave-like, topographic features composed of unconsolidated fine to medium sand, can be either attached to the shore or detached, typically have vertical relief up to 10 m (33 ft), and are generally oriented at oblique angles to the adjacent shoreline (Duane et al. 1972; Stahl et al. 1974; McBride and Moslow 1991). They can exist at various spatial scales on continental shelves worldwide. In general, when they are attached to the shore, they make an angle of about 35° with the shoreline. They can be 50 km (27 NM) long and 2 to 4 km (1 to 2 NM) wide, have wavelengths of 6 to 8 km, side slopes that average less than 1°, a relief of up to 10 m (33 ft), and can occur in depths ranging from 3 to 45 m (10 to 148 ft; Duane et al. 1972; Figueiredo et al. 1981; Figueiredo 1984). Along the continental shelf of the U.S. Atlantic, highly developed sand ridges can be found adjacent to coasts that are characterized by transgression, mixed energy, wave-dominated barrier islands, and laterally migrating tidal inlet systems (McBride and Moslow 1991). The sand ridges of the Study Area are part of a larger system of ridges in the MAB and along the U.S. Atlantic east coast. The ridges of the MAB have spacings of 2 to 4 km (1 to 2 NM), lengths of up to a few tens of kilometers, heights of several meters, depths of 10 to 20 m (33 to 66 ft), and form acute angles with the coast, open to the north, of some 20° to 30° (Dragos and Aubrey 1990).

Particularly well developed fields of shoreface-attached and detached sand ridges occur in the Study Area. There are 71 sand ridges in the Study Area; they have an average orientation of 26° with primary modes between 15° and 19° (McBride and Moslow 1991). Some of these sand ridge formations can be seen in the isobath bathymetery of **Figure 2-14**. Seaward of these is a 30-km (19-mi) wide sand ridge complex that have orientations that are parallel with the coast. Farther seaward near the outer shelf, sand ridges have orientations (20° to 30°) that are similar to the shore-attached sand ridges on the inner shelf. More than 1,000 ridges are located on the New Jersey shelf; these range in height from 3.5 to 18 m (11 to 60 ft), in width from 1 to 18 km (0.5 to 9.7 NM), and in length from 1.5 to 37 km (0.8 to 20 NM; Stubblefield 1980).

The upper crest of the ridges is composed of fine- to medium-grained sand, the underlying layer is one of shell-rich, poorly-sorted sand and mud, and the deeper layer is inferred to be mud strata (Figueiredo 1984). The surficial sediments over the nearshore ridges are distributed with the coarsest sands on the shoreward flank and the finer sands toward the seaward flank. For the mid-shelf, parallel ridges, the surficial sand distribution is more symmetrical with the courser sands located on the upper shoreward flank (Stubblefield 1980). In the Study Area, the Beach Haven Ridge, located northeastward from the ebb tidal delta of Little Egg Inlet, has two major substrate types on the seaward side: 1) coarse sand with shells of the Atlantic surfclam (*Spisula solidissima*) and 2) areas with a mixture of semilithified clay and sand. On the shoreward side of the ridge, there are also two major substrate types: 1) areas of sand and clay mixture and 2) patches of semilithified clay and sand mixture. In addition, it is common to find that the crests of the ridges are bare; however, the troughs tend to be filled with shell valves and shell hash (Vasslides and Able 2008).

The formation of these sand ridges has been a source for debate for some 60 years. Shepard (1948) theorized that the ridges were formed due to the stepwise retreat of a barrier island coast, while Duane et al. (1972), Swift et al. (1973) and Stahl et al. (1974) attributed the ridge's formation to storm flows causing the erosion of the shoreface in response to postglacial sea level rise. Stubblefield and McGrail (1979) argued that the ridges were formed in response to shear waves generated along the coast in northeastly storm flows (Figueiredo et al. 1981). Figueiredo (1984) hypothesized that the ridges began forming at inlets and as the sea level rose and the shoreface retreated the sand ridges developed. More recently, McBride and Moslow (1991) inferred that ebb-tidal deltas deposited sand along the inner continental shelf followed by transgression which reworked the sand deposits by shelf process into linear sand ridges at the shore face. Currently, it is generally accepted that the ridges are in equilibrium with the continental shelf hydraulic regime. In the Study Area it is has been suggested that the inner shelf ridges formed in response to intense storms, that the shore-parallel ridges form in association with degraded barrier islands, and that the sand source for the sand ridges is provided by the ebb-tidal deltas. Essential components of the origin and evolution of sand ridges includes erosional shoreface retreat, shoreface detachment, and storm-generated flows (McBride and Moslow 1991).

2.2.1.5 Bottom Substrate

Six stratigraphic units are present in the near-surface strata (from youngest to oldest): modern shoreface, upper ridge sand, lower ridge sand, swale/inlet-fill, Middle Holocene back-barrier, and Pleistocene strandplain (Snedden et al. 1994). Merged cross-sections of the upper Pleistocene shelf sequences slant to the southeast indicating a trend of the ancient Hudson River thalweg (Sheridan et al. 2000). The stratigraphic section is not entirely complete resulting from extensive sea-level changes (approximately 70 to 120 m [230 to 394 ft]) plus low subsidence rates (Uptegrove 2003). A “stratigraphic sequences project” by Austin et al. (1996) attempted to clarify the formation of preserved stratigraphy along the continental edge based on temporal and spatial geological processes by associating short-term physical and biological processes to stratigraphic facies sequences through coring and remote sensing. Results of this project demonstrated prominent shelf progradation along the New Jersey margin over the past 20 Ma; this was possibly caused by cross-shelf sediment movement or point sources of sediment. The New Jersey shelf stratigraphy also show spatial variations due to to possible changes in drainage basin area and sediment supply, large-scale drainage patterns, subsidence, compaction, isostasy, and/or gravity or current-driven sediment transport (Austin et al. 1996).

The surficial sediments of the New Jersey shelf generally consist of detrital sands with mixtures of silt or gravel (**Figure 2-15**). Gravel situated on the New Jersey shelf contains carbonates (shells and shell fragments), quartz pebbles, and rock fragments. Terrigenous (fluvial) sediments consist mainly of quartz and feldspar sand that is low in carbonates except for one carbonate high off central New Jersey (east of Manahawkin) where the carbonate content reaches 25% (Louis Berger Group Inc. 1999). Sediments offshore of Monmouth and Ocean counties have a larger gravel content than Atlantic and Cape May counties (Byrnes et al. 2000). While the modern shoreface and upper ridge sands are both still currently shaping, others were deposited somewhere from 10to 20 ka, but still experience erosion. The upper ridge sands range from fine- to coarse-grained. Evidence shows that as the temporal and spatial proximity between the mainland and the ridge shortens, the wave energy increases. The lower ridge sands do not exist in the most recent deposits of the ridge and are composed of a high organic content and various macrofauna and microfauna (Snedden et al. 1994). While upper ridge sands originated in the open marine environment, the lower ridge sands originated under more protected conditions. A barrier island was present in the area 3.5 ka, but was later removed by erosion. A strandplain formed in the Late Pleistocene, and hydrodynamic forces continually shaped that area into the ridge that exists today. All of this demonstrates that both eustatic and hydrodynamic factors typically help influence shelf and sand ridges (Snedden et al. 1994). Two inner shelf sand ridges can be found off the coast of Avalon Township, near the southern tip of New Jersey, which are composed of quartz sand and are found in water that is mostly less than 20 m (66 ft) deep (Smith 1996).

The Study Area was once 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 sand and gravel was reworked by the Atlantic leaving most of the area covered with a layer of sandy sediments (**Figure 2-15**; Glenn et al. 2008). Seismic analysis profiles have revealed buried paleochannels from nearshore to shelf edge (Louis Berger Group Inc. 1999). An 80-km (43-NM) buried channel extends southward from the Hudson Shelf Valley and is known to be a Hudson River ancestral pathway. During one of the pre-Wisconsin lowstands the channel was cut to 15 m (49 ft) below the exposed continental shelf. Sometime prior to 28 ka, the

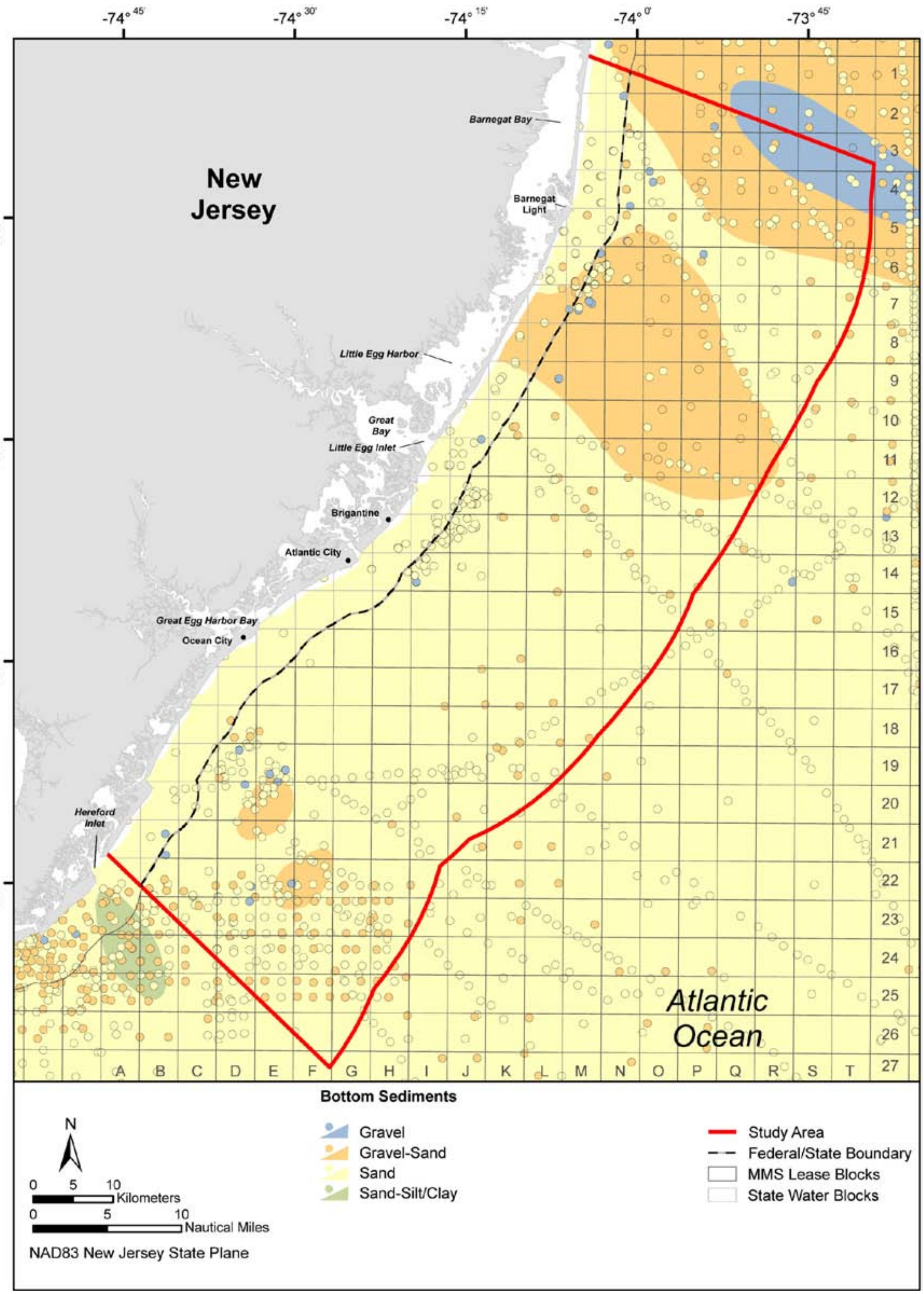

Figure 2-15. Bottom sediments in the Study Area. The circles represent core samples taken at discrete locations, while the general shading can be used as a gross overview of general textural trends. The shading gives only a general indication of surficial sediment type because the true boundaries between sediment types can be highly irregular or gradational and the characteristic textural variability is not available at this scale. The core samples represent a fine-scale depiction of the sediment type at each discrete location. Source data: USGS (2000) and Reid et al. (2005).

channel was filled with heterogeneous fluvial deposits then covered with 10 to 30 m (33 to 98 ft) of sediment (including an interbedded marine sand and mud upper layer). After being exposed during the last sea level regression the sediments underwent leaching and desiccation. As a result of these events, a thin, gravelly sand layer exists on top and low bedforms exist throughout the middle shelf (Knebel et al. 1979). The outer continental shelf of the Baltimore Canyon Trough off the coast of New Jersey has a mantle made up of shelly medium to coarse sand from the Holocene era. Underneath this is a Pleistocene mud layer. The sand cover in these areas averages from 5 to 7 m (16 to 23 ft) thick and is said to be similar to the bottom layer morphology (Knebel and Spiker 1977). The uneven distribution of sand in the area demonstrates fluvial and nearshore processes, configuration of the Pleistocene substrate, and the movement of sediments. During the last sea level transgression, medium to coarse nearshore sands (more than likely from the Hudson and either the Great Egg or Delaware rivers) were deposited above Pleistocene muds. At present, the sand layer continues to be shaped and modified (Knebel and Spiker 1977).

Barnegat Inlet, located within the Study Area, contains a main tidal channel that is 0.5 km (0.3 NM) wide and, at its deepest points, 15 m (49 ft) deep. There are three reflectors in the area that could represent erosional unconformities or seismic sequences. The uppermost reflector contains a tidal-cut ravinement 1 m (3 ft) below the Barnegat Inlet channel. Underneath the ravinement are Holocene intertidal sediments where it is speculated that channel erosion occurred (Wellner 1990; Ashley and Sheridan 1994). There is 1 m (3 ft) of sand overlying the ravinement suggesting that it was buried by the migration of the Barnegat Inlet ebb-tidal delta. The Barnegat Inlet channel has been affected by a great deal of erosion and truncation and is now being buried by another lobe of the delta. Evidence indicates that there used to be a barrier island between two of the ravinements which indicates, that at some point in the area, there was a highstand. A seismically transparent unit is located on the seaward side while the landward side illustrates a discontinuous lithofacies (Ashley and Sheridan 1994).

Although the Study Area is located south of the maximum Pleistocene ice advance, the bottom sediments are the result of the sand and gravel deposited by glacial meltwater streams (Glenn et al. 2008). Sediment supply, early transgressions, and continuous sea level cycles induced by climate change, provide evidence for glacial influence in the area. Eustatic changes have developed four late Pleistocene depositional sequences in the shelf stratigraphy, which are marked by tracts (Carey et al. 2005). These tracts, which are mostly transgressive systems tracts and lowstands systems tracts, are located in a 25,000 km^2 (7,289 NM^2) area off of New Jersey, at the shelf edge, and are 100 m (328 ft) thick (Carey et al. 1998). Two depositional sequences within the Study Area were formed glacio-eustatically over 125 ka (Ashley et al. 1991; Wellner et al. 1993). One of them consists of a submerged barrier island complex located 0.2 to 1.7 km (0.1 to 0.9 NM) off the coast and 20 m (66 ft) below the present sea level. The existence of this barrier island complex provides evidence for the Middle Wisconsin sea level highstand being located at 20 m (66 ft) below the present surface. During the Holocene transgression, the present day barrier island system had migrated landward due to the rise in sea level (Wellner et al. 1993).

Regional seismic reflection surveys conducted by Davies et al. (1992) characterized a Late Quaternary wedge of sediment extending from the Hudson Apron south 150 km (81 NM) along the edge of the New Jersey continental shelf. A prominent reflector defined the bottom of the wedge as a theoretical erosional surface incised during a lowstand (most likely the Wisconsinan glacial maximum). Coring and three-dimensional high resolution seismic reflection surveys reveal an elaborate internal structure within the outer wedge unrelated to the current seafloor morphology; this sedimentary sequence was developed by a series of depositional events related to glacial melting and interrupted by at least one erosional episode evident from a meandering channel system (Davies et al. 1992). The fauna studied within core samples indicate that the sediments were deposited at shallower depths than at present although no evidence exists for shallow water deposition or a nearer proximity to land than the current mid-shelf. Bottom substrate includes both the biotic surface layer and the abiotic sub-bottom, and the sediments which comprise these layers. According to Amato (1994), 75% of the sediment distribution for the shelf of the Study Area is composed of medium (0.025 to 0.05 cm [0.01 to 0.02 in.]) to coarse (0.05 to 0.2 cm [0.02 to 0.08 in.]) quartz sand grains, overlying larger scale shore-parallel ridges often found mid-shelf (Duane and Stubblefield 1988). Along a narrow band (approximately 10 km [5 NM] wide) 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, a narrow band of mixed medium to fine sand and silt is found, with deepwater sediments (>75% clay) located further offshore (Amato 1994). Parallel elongated bands of gravelly sand are located just south of the Hudson Shelf Valley; these were formed from ancient meanders of the Hudson River (Schlee 1964). Esker et al. (1996) designed a new technique to calculate alternative values for density by using the empirical relationships between median grain size, density, and the velocity of the acoustic wave through the sediment bed. The technique could avoid many of the issues associated with acoustic wave logs (provides sediment bed density) and shipboard measurements to construct artificial seismograms by groundtruthing and correlating across analog and digital shallow high-resolution seismic data along the New Jersey shelf. Determining median grain size with dry vibracores removes the negative effects that coring disturbances and preservation variables have on the core's water and sediment content (Esker et al. 1996).

Gas hydrates are present over a large area on the continental rise between Georgia and New Jersey (~1,000 km) as geophysically mapped by various agencies (Judd and Hovland 2007). These hydrates are most commonly found at depths greater than 2,000 m and in areas of rapid sediment deposition and salt diapirs (Judd and Hovland 2007). As a potential energy source, research of these hydrates and potentional slope failures has increased. Rapid sedimentation and compaction, expelled pore water (water retained within pore spaces of sediments) may force its way through the seabed in such a way to promote slope failure. During the Pleistocene, New Jersey's upper continental slope underwent rapid sedimentation that contributed to increase pore fluid pressures driving fluids laterally towards the middle and lower slope (Judd and Hovland 2007). As this increased pore fluid pressure reached the thinner sediment at the toe of the slope, the effective stress decreased prompting the slope to fail. A risk assessment analysis considering submarine mass movement was used to determine the stabilitiy of the New Jersey continental slope (Judd and Hovland 2007). From this analysis, it was determined that the slope was unstable 0.5 mya, but currently the continental slope is stabilized due to a large decrease in sedimentation rates.

Marine and aeromagnetic anomaly profiles taken from the middle of the New Jersey continental shelf revealed a high-amplitude, circular, positive abnormality approximately 20 km in diameter and 40 km west of the East Coast Magnetic Anomaly (ECMA; Grow et al. 1988). Termed "Great Stone Dome", the dome was determined by the U.S. Geological Survey (USGS) to most likely be a large mafic intrusion that crystallized during the Early Cretaceous as it uplifted Early Cretaceous and older strata, but is also truncated by an Early Cretaceous unconformity (Grow et al. 1988). Another anomaly was detected in the Baltimore Canyon Trough that appears to be a possible narrow salt diaper penetrating into Cenozoic strata through it has never been drilled into by exploration wells (Grow et al. 1988). If indeed a salt diaper, it is one of few along the Baltimore Canyon trough compared to the 23 diapiric structures found along the ECMA further south of the Study Area.

For the New Jersey Study Area, marine benthic mapping surveys were conducted to generally characterize the ocean floor and benthic environment; the surveys utilized a ship-deployed magnetometer and side scan sonar to provide baseline seafloor substrate information and evaluate seafloor conditions in the area proposed for construction of meteorological and wind tower pylons and structures. The data were examined for geological variations in surface sediments and the occurrence of any unknown obstructions in the proposed wind farm construction zone. Seabed morphology in the area surveyed consists of relatively flat, migrating sand waves and ripples with occasional larger sand ridges. Variable current and tidal hydraulics result in the development and migration of sand waves, dunes, and ripples by means of scour, deposition of terregenous sediments with erosion, and transport of sand and mud. This baseline data will allow for future assessments of local seafloor changes resulting from natural and anthropogenic events such as offshore wind farm development. For further explanation and data associated with the marine benthic mapping surveys conducted for the NJDEP EBS project see **Appendix A**.

2.2.2 Oceanographic Data Collected During Shipboard Surveys

During the shipboard surveys conducted aboard the *R/V Hugh R. Sharp*, oceanographic data were collected using the Surface Mapping System (SMS), Conductivity, Temperature, and Depth (CTD) profiles, and an Acoustic Doppler Current Profiler (ADCP). Measurements were conducted at point locations in the NJDEP Study Area.

2.2.2.1 Surface Mapping System (SMS)

The SMS collected measurements every 10 s during the shipboard surveys from the bow of the *R/V Hugh R. Sharp*. The static parameters that were measured included date and time, water depth (ft or m), and lat-lon location. The climatic parameters measured included windspeed (kt), wind direction (°), air temperature (°C), relative humidity (%), and atmospheric barometric pressure (millibar [mbar]). The dynamic oceanographic parameters that were measured included water temperature (SST, °C), salinity (practical salinity units [psu]), fluorometric chlorophyll and colored dissolved organic matter (CDOM; Turner raw), and photosynthetically available radiation (PAR; quanta per second [quanta/s]). Turner units are a spectral measurement of fluorescent material in the water at specific wavelengths. Chlorophyll has an absorption peak in the blue spectral region (440 nm [nanometer]) and a strong fluorescent peak at red wavelengths (670 nm), whereas CDOM absorbs strongly in the blue region (412 nm) and has a broad fluorescent peak at green-yellow wavelengths (530 nm). The PAR is measured with a Profiling Reflectance Radiometer System (PRR-600) light meter (spectral photometer) and is calculated from the spectral integration of light intensity measured at the following wavelengths: 443, 490, 510, 555, and 656 nm (spectral units: microwatts [µW] per square centimeter [cm^2] per nm).

2.2.2.2 Conductivity, Temperature, and Depth (CTD) Profiles

CTD casts were conducted at the beginning of the survey day, at noon, and the end of the survey day, as well as at the end of each trackline whenever possible. The CTD casts provided data as a function of water depth profiles (extending from the surface down to a depth corresponding to 30 decibel [dB] pressure). Measurements were generated for water temperature (°C), salinity (psu), dissolved oxygen (milligrams per liter [mg/L]), and conductivity (voltage) using CTD sensors throughout the profile. Depth profiles of these four parameters were combined into a single plot for each set of measurements.

2.2.2.3 Acoustic Doppler Current Profiler (ADCP) Measurements

In addition to SMS and CTD, ADCP measurements were collected at various site locations. ADCPs work by using sound energy to produce a record of water current velocities for a range of depths. As the sound energy leaves the ADCP it is shifted in frequency by the relative velocity of the water and the sound energy is returned (echo) by scatterers in the water. A water current profile over a range of depths is produced by repetitive sampling of the return echo as a function of time. The ADCP data were collected and processed using the VmDas (software package for use with vessel mounted ADCPs to support data collection and replay) or WIN-RIVER (a real-time discharge data collection program) software programs. The raw ADCP data were screened for RSSI (return signal strength, relative to the ADCP), correlated by VmDas or WIN-RIVER, and then bin-mapped and transformed to Earth coordinates.

2.2.3 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).

2.2.3.1 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).

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 to 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% 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).

Robinson (2008b) 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°C (53.4°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 2008b).

The local SSTs for the Study Area are shown in **Figures 2-16a** and **2-16b**. In the development of these figures, SST for the Study Area between was 01 January 2007 and 31 December 2009 was downloaded from the NASA Goddard Earth Sciences Data and Information Services Center. The data was collected on board the Aqua Earth Observing System satellite for MODIS Level 3 data and subsequently processed by the Rutgers Coastal Ocean Observation Lab. **Figures 2-16a** and **2-16b** are maps that use the same data but are displayed differently. **Figures 2-16a** provides the mean seasonal SSTs for the Study Area using a single scale from 0° to 24°C. Using a single scale to display each season allows an easy comparison of general temperature between seasons. **Figure 2-16b** also provides the mean seasonal SSTs for the Study Area; however, the data are displayed using scales that are concurrent with the minimum and maximum temperature values of each season. Using a different scale for each season allows higher resolution detail to display the spatial variabilities of SST that occur within the Study Area for each season.

During the shipboard surveys for marine mammals, sea turtles, and birds, oceanographic data were collected. **Figures 2-17a** through **2-17d** displays the SST data that were collected via the SMS and CTD casts on-board the *R/V Hugh R. Sharp* between 2008 and 2009 for the Study Area for each season.

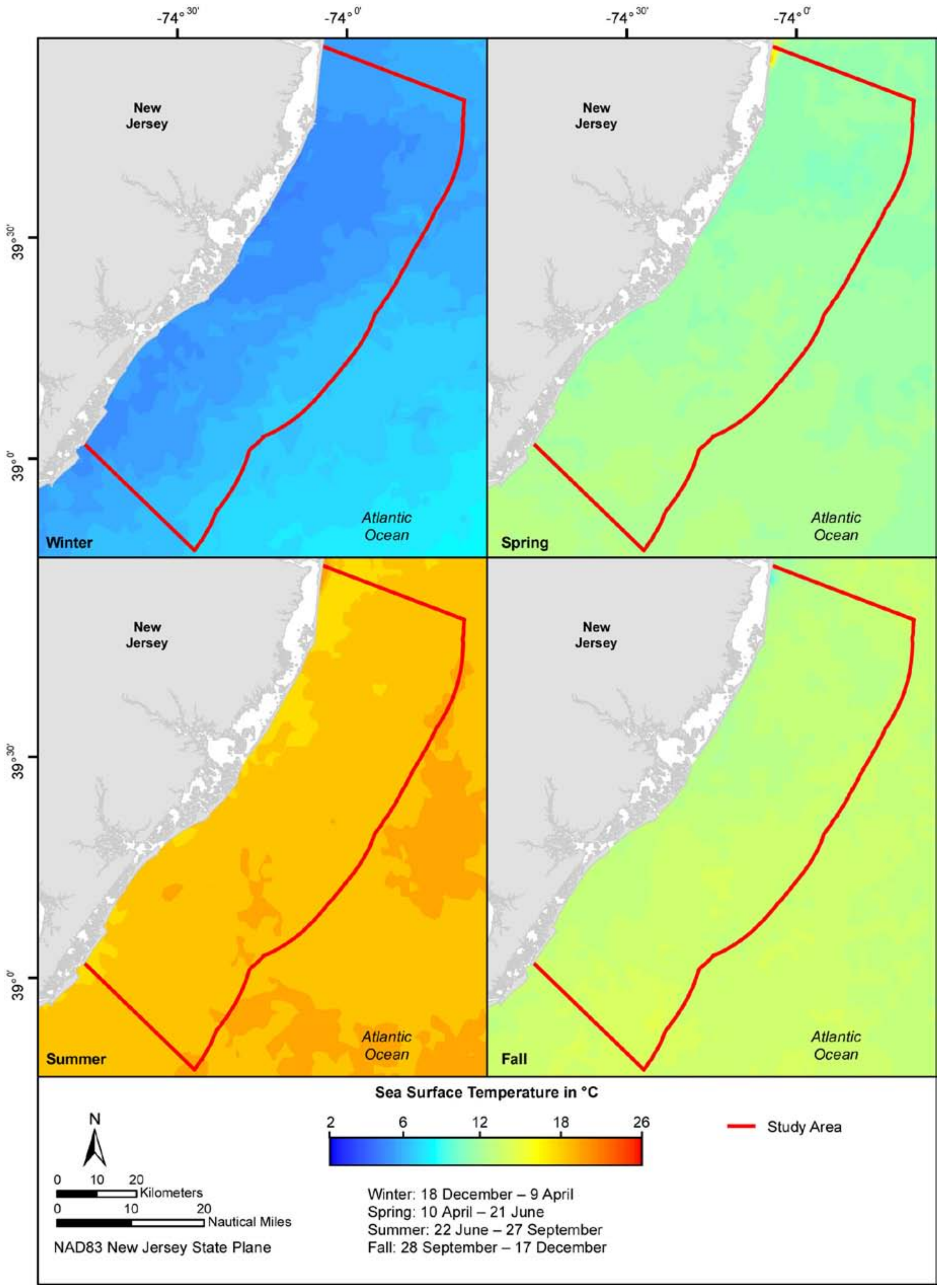

Figure 2-16a. Mean seasonal SSTs (°C) in the Study Area from 01 January 2007 through 31 December 2009. Data are displayed using a single scale from 0°C to 24°C to provide an overview of the SSTs in relation to season. Source data: NASA (2010).

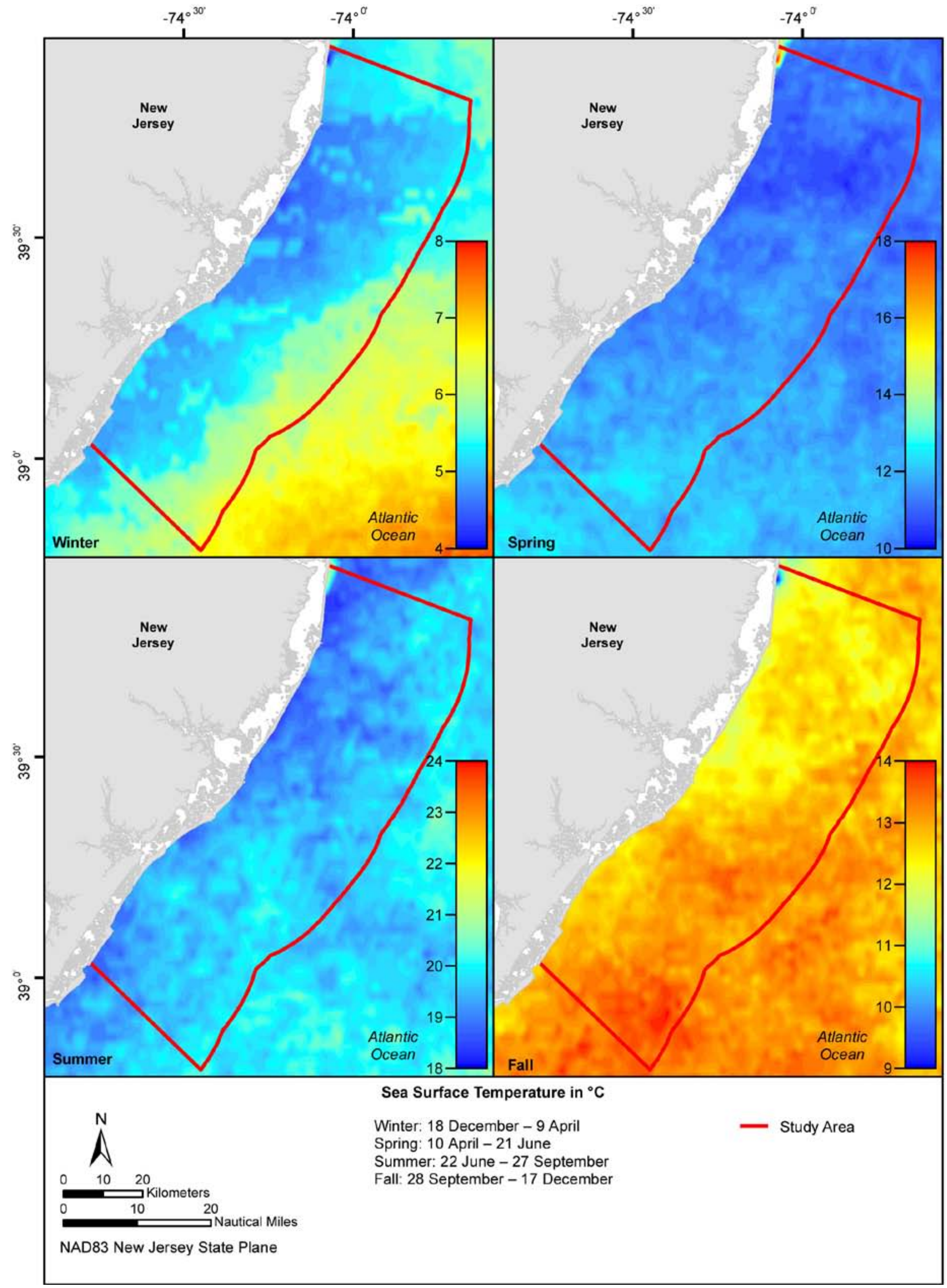

Figure 2-16b. Mean seasonal SSTs (°C) in the Study Area from 01 January 2007 through 31 December 2009. Data are displayed using scales concurrent with the minimum and maximum temperature values of each season to provide greater resolution. Source data: NASA (2010).

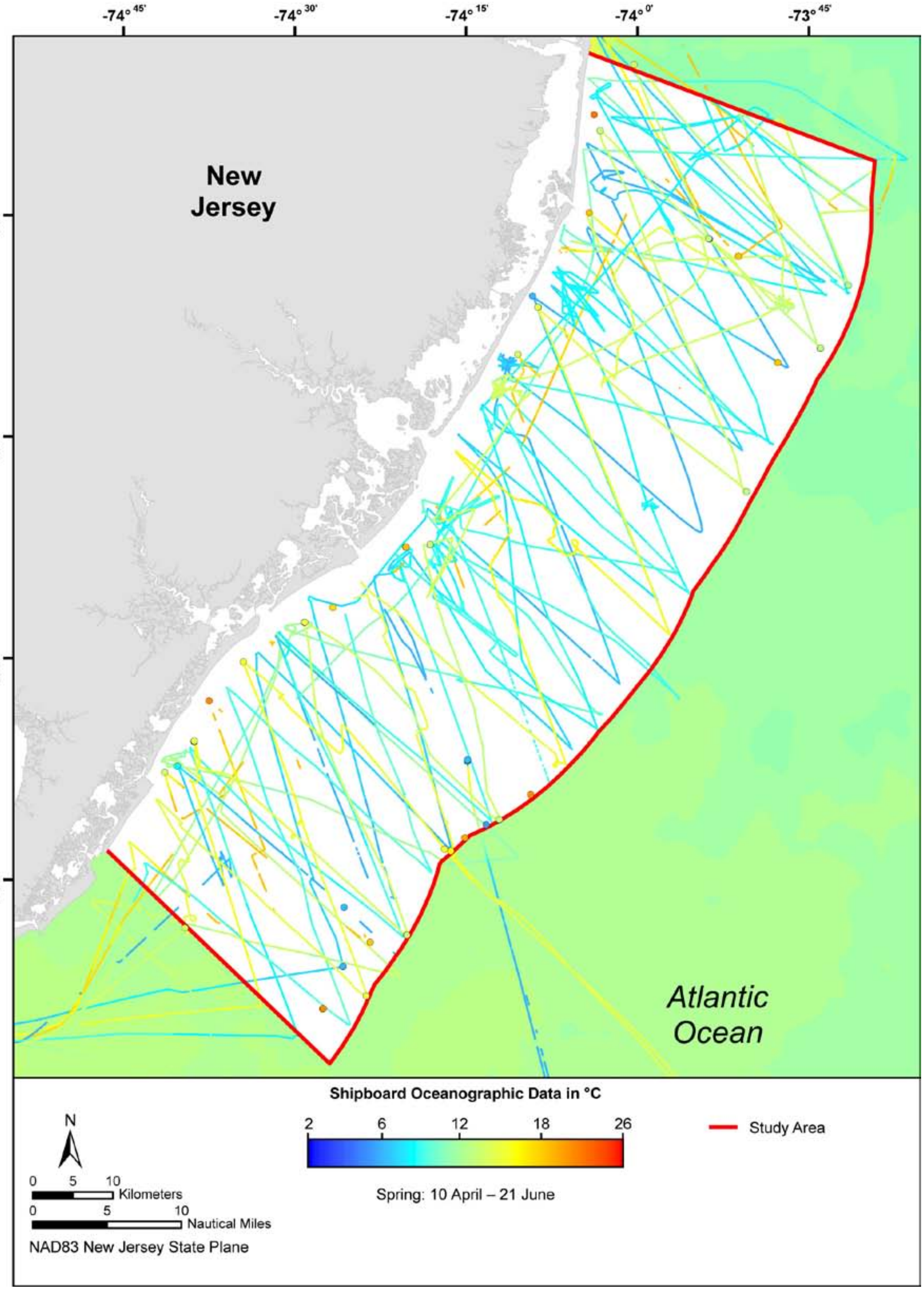

Figure 2-17a. SSTs for the winter season in the Study Area collected via the SMS and the CTD casts on board the *R/V Hugh R. Sharp*. SSTs were collected during the shipboard surveys of 2008 and 2009 with the SMS from the bow of the vessel every 10 s and CTD casts were conducted at the beginning of the survey day, at noon, the end of the survey day, as well as the end of each trackline whenever possible.

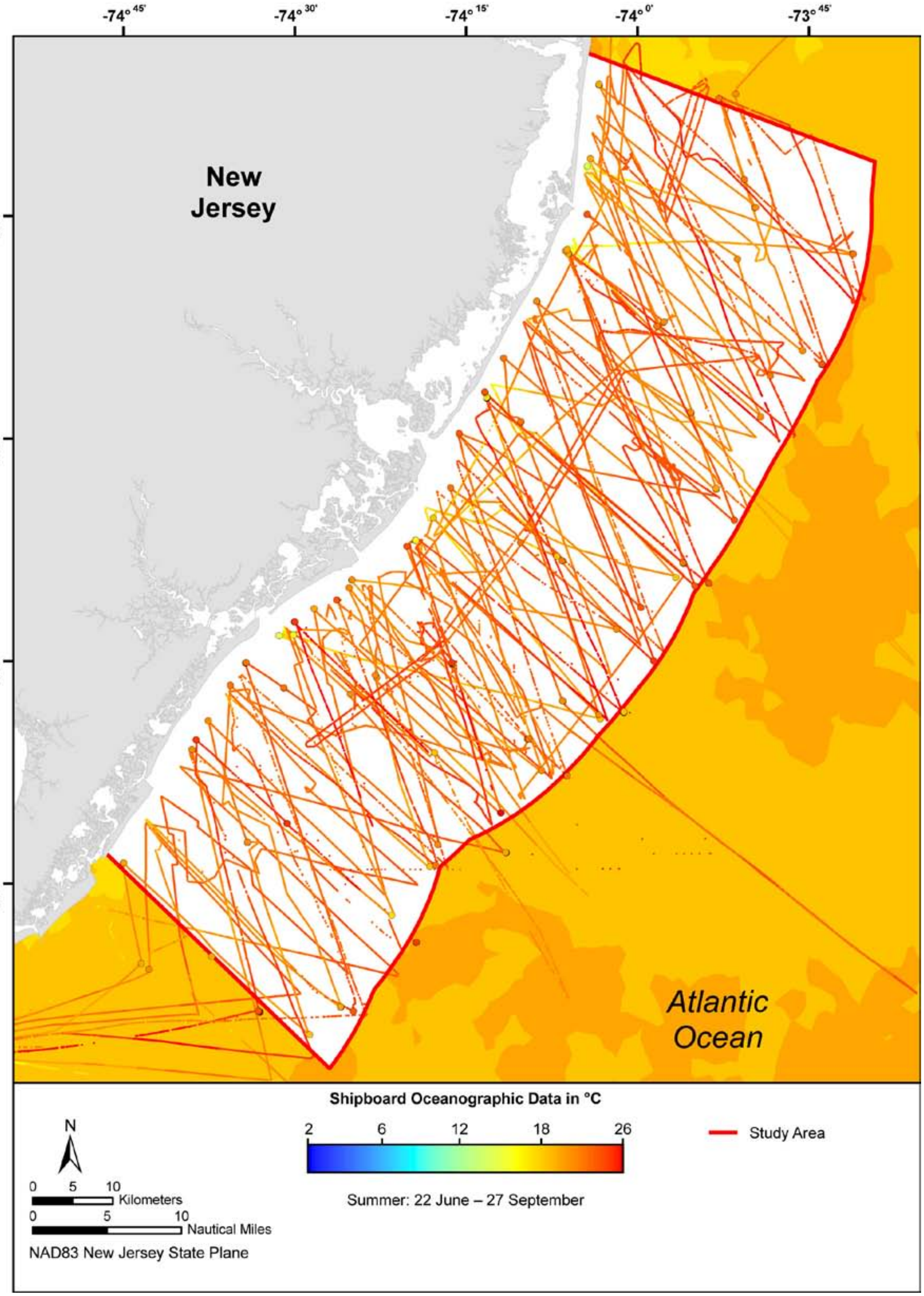

Figure 2-17b. SSTs for the spring season in the Study Area collected via the SMS and the CTD casts on board the *R/V Hugh R. Sharp*. SSTs were collected during the shipboard surveys of 2008 and 2009 with the SMS from the bow of the vessel every 10 s and CTD casts were conducted at the beginning of the survey day, at noon, the end of the survey day, as well as the end of each trackline whenever possible.

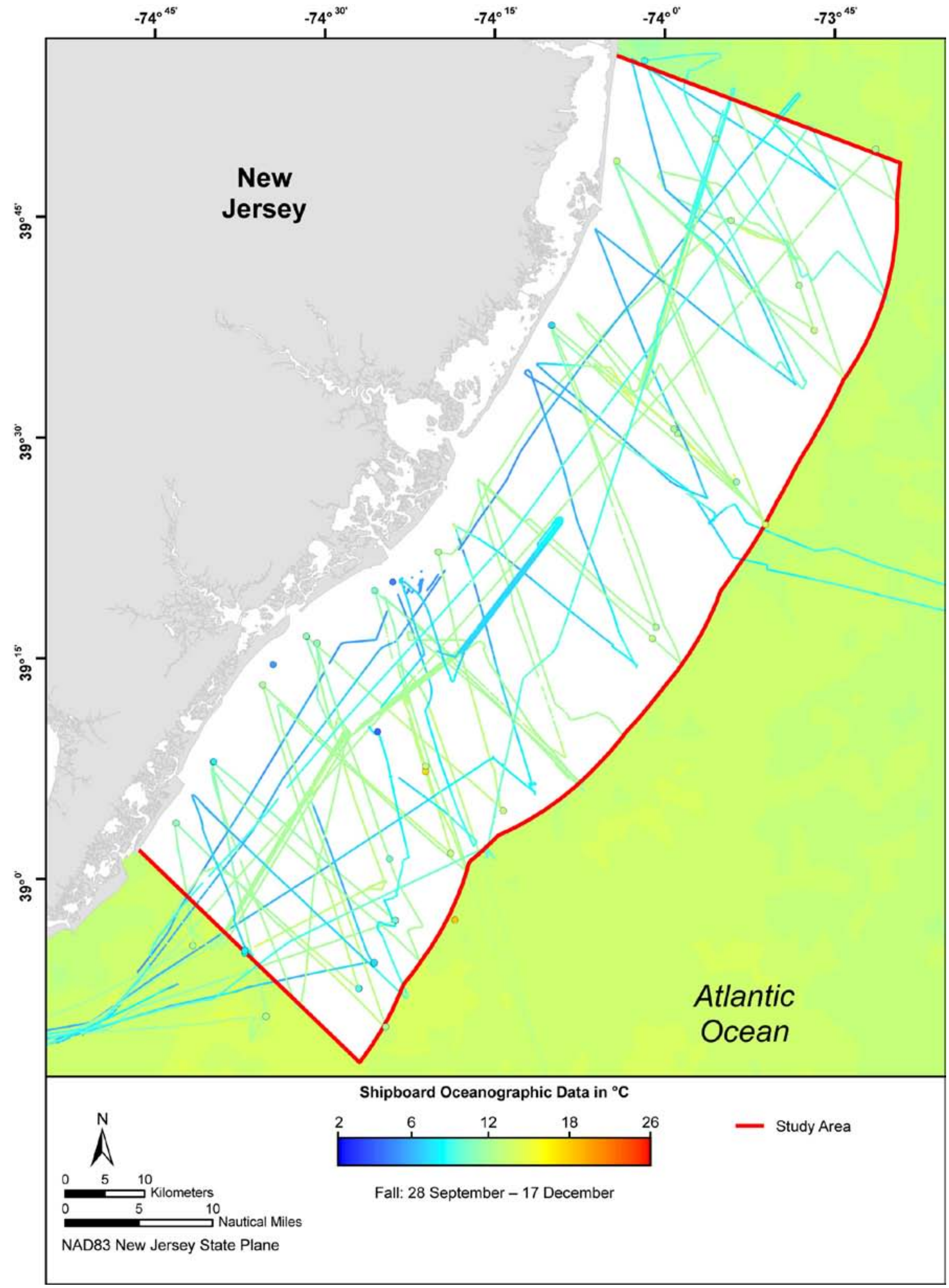

Figure 2-17c. SSTs for the summer season in the Study Area collected via the SMS and the CTD casts on board the *R/V Hugh R. Sharp*. SSTs were collected during the shipboard surveys of 2008 and 2009 with the SMS from the bow of the vessel every 10 s and CTD casts were conducted at the beginning of the survey day, at noon, the end of the survey day, as well as the end of each trackline whenever possible.

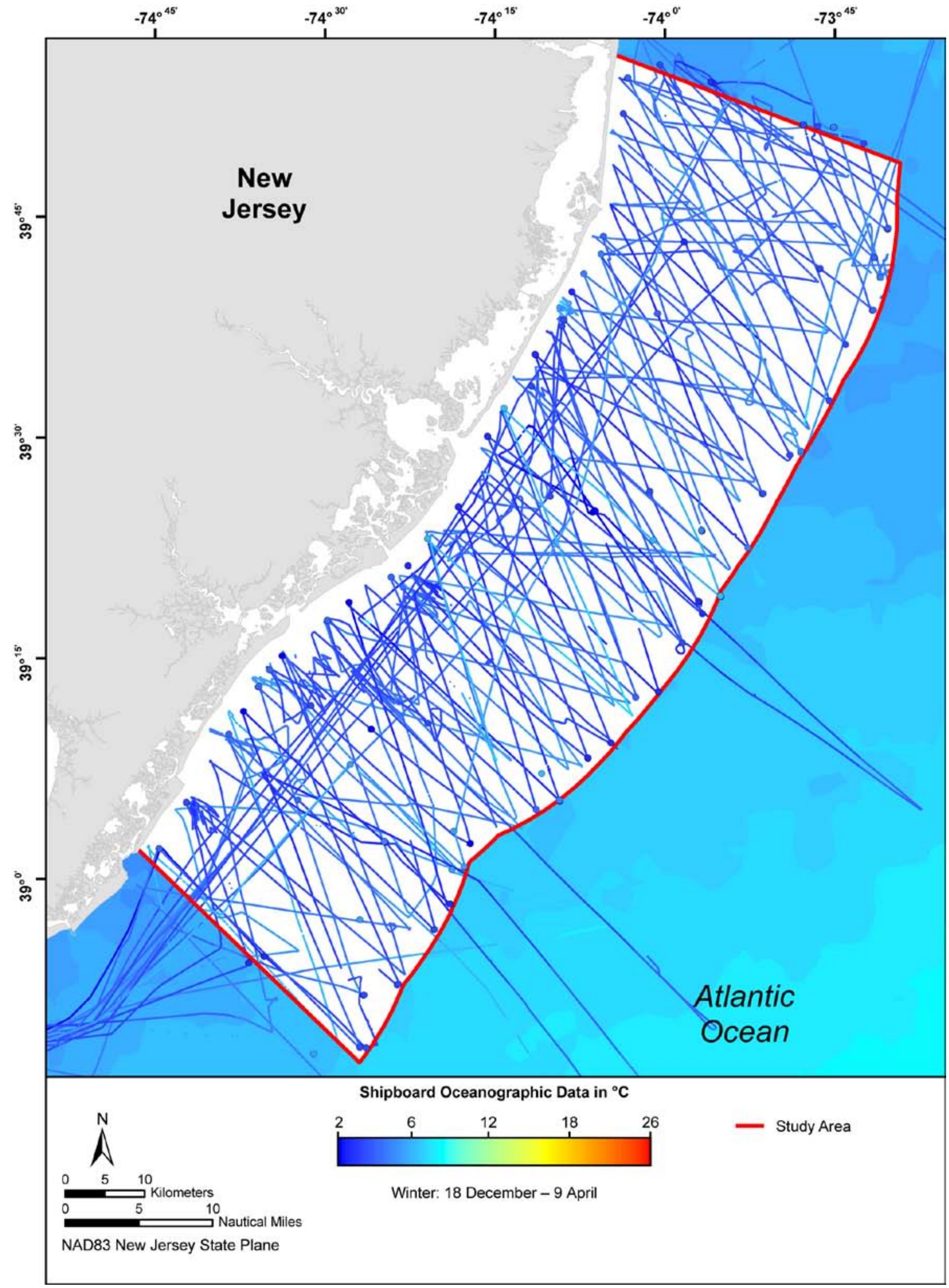

Figure 2-17d. SSTs for the fall season in the Study Area collected via the SMS and the CTD casts on board the *R/V Hugh R. Sharp*. SSTs were collected during the shipboard surveys of 2008 and 2009 with the SMS from the bow of the vessel every 10 s and CTD casts were conducted at the beginning of the survey day, at noon, the end of the survey day, as well as the end of each trackline whenever possible.

SSTs were collected from the bow of the vessel every 10 s through the SMS and CTD casts were conducted at the beginning of the survey day, at noon, the end of the survey day, as well as the end of each trackline whenever possible. The data matched up well with the remote sensed data displayed in **Figures 2-16a** and **2-16b**; the minimum SST value collected was 2°C during winter and the maximum SST value collected was 26°C during summer.

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). **Figure 2-18** displays the depth profile for water temperature (°C), salinity (psu), dissolved oxygen (mg/L), and conductivity (voltage) measured from a CTD cast on board the *R/V Hugh R. Sharp* during summer (02 August 2009). This cast shows a well established thermocline characteristic of the summer season in the Study Area.

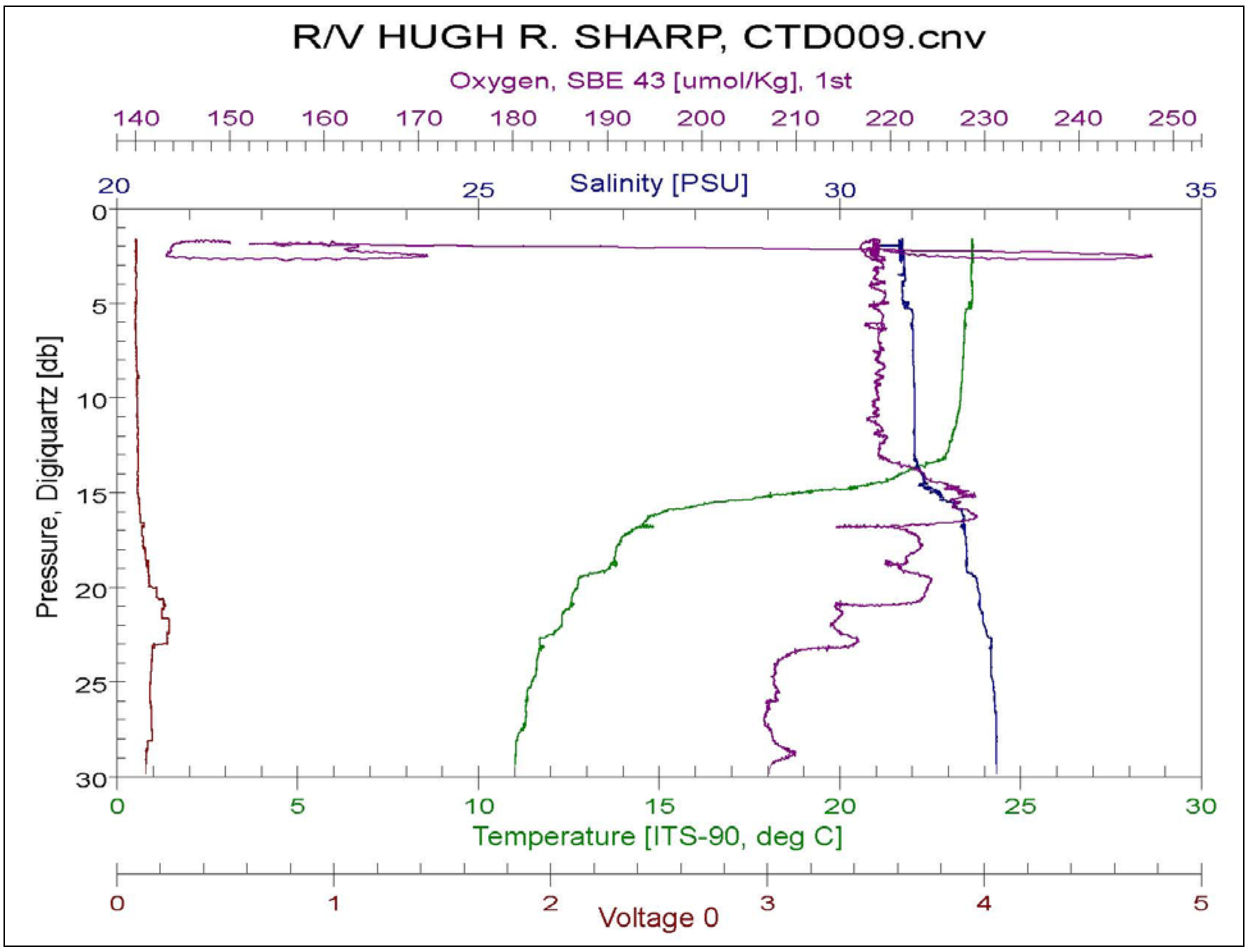

Figure 2-18. The measurements of water temperature (°C), salinity (psu), dissolved oxygen (mg/L), and conductivity (voltage) displayed as a profile of the water column (as a function of depth, pressure digiquartz [db]) taken from a CTD cast on board the *R/V Hugh R. Sharp* during the summer season on 02 August 2009 at 39°07.47 N, 74°07.65 W. This cast shows a well established stratified thermocline that is characteristic of the summer season in the Study Area.

The thermocline thickness increases in the offshore direction. Inshore of approximately 60 km (37.3 mi) from the coast, the thermocline is about 12 to 15 m (39.4 to 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). **Figure 2-19** displays the depth profile for water temperature (°C), salinity (psu), dissolved oxygen (mg/L), and conductivity (voltage) measured from a CTD cast on board the *R/V Hugh R. Sharp* during winter (15 February 2009). This cast shows a well mixed water column with no thermal stratificiation and is characteristic of the winter season in the Study Area.

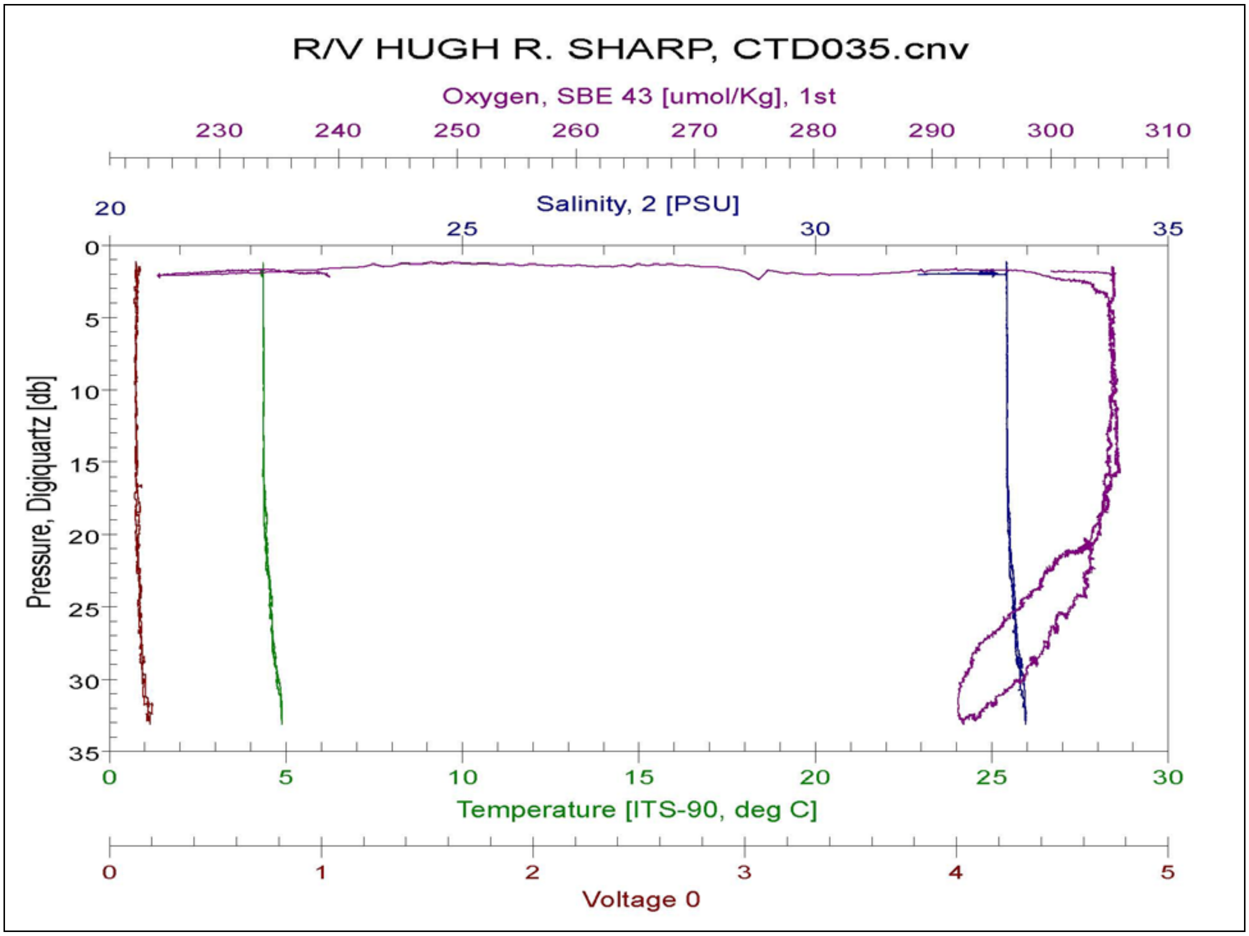

Figure 2-19. The measurements of water temperature (°C), salinity (psu), dissolved oxygen (mg/L), and conductivity (voltage) displayed as a profile of the water column (as a function of depth, pressure digiquartz [db]) taken from a CTD cast on board the *R/V Hugh R. Sharp* during the winter season on 15 February 2009 at 39°09.13 N, 074°04.80 W. This cast shows a well mixed water column with no thermal stratificiation and is characteristic of the winter season in the Study Area.

2.2.3.2 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 by 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 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. 2008b). 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 2-20 displays the mean seasonal Sea Surface Salinity (SSS) for the Study Area. The SSS data used for the development of this map includes historical data as well as data collected as a part of the oceanographic studies during the shipboard surveys for marine mammals, sea turtles, and birds. The historical SSS data collected between 24 July 1927 and 17 June 1989 was obtained from the NOAA, National Oceanographic Data Center (NODC), World Ocean database 2009 (WOD09). The WOD09 is a scientifically quality-controlled database of selected historical *in-situ* surface and subsurface oceanographic measurements produced by the Ocean Climate Laboratory (OCL) at the NODC. The WOD09 was created to provide the full set of data and quality control procedures used to calculate climatologies of temperature, salinity, oxygen, phosphate, silicate, and nitrate. The shipboard SSS data was collected during 2008 and 2009 by the SMS on board the *R/V Hugh R. Sharp* from the bow of the vessel every 10 s.

Hudson River Bulge

The anticyclonic rotating 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. 2008a). 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 an offshore directed jet that provides a direct pathway to transport the freshwater across the shelf (Castelao et al. 2008a; Chant et al. 2008b). The Hudson River bulge can limit the volume of freshwater that is advected away in a coastal current by 30 to 50% (Fong and Geyer 2002; Chant et al. 2008b).

2.2.4 Circulation

The circulation of ocean currents in the vicinity of the Study Area is affected by processes occurring at distances far from the Study Area. 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

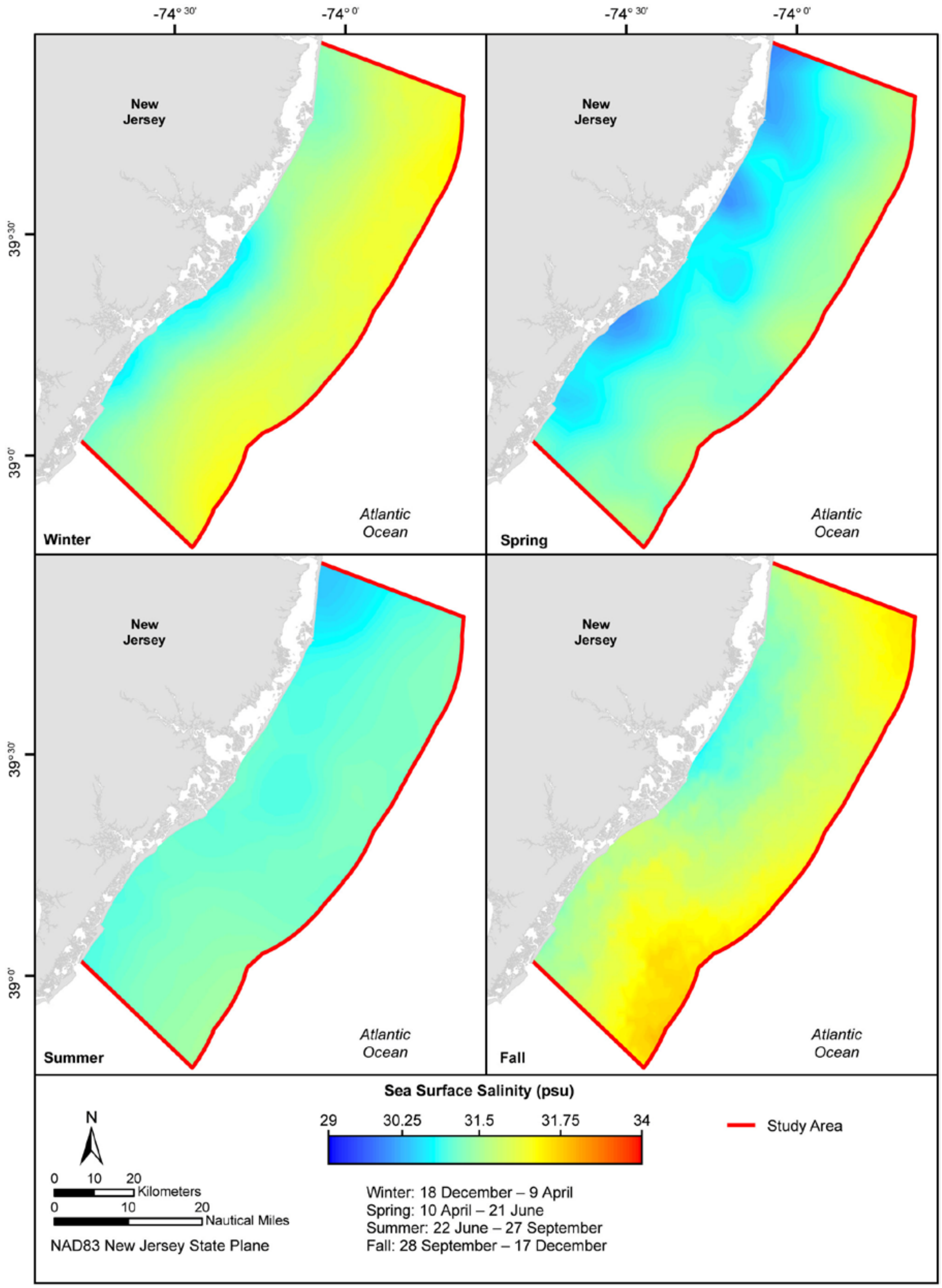

Figure 2-20. Mean seasonal SSS in the Study Area. SSS data included historical SSS data from the NODC WOD09 compiled from samples collected between 24 July 1927 and 17 June 1989. In addition, SSS data was collected by the SMS on board the *R/V Hugh R. Sharp* from the bow of the vessel every 10 s during the shipboard surveys of 2008 and 2009. Source data: NODC (2010).

the Study Area as the Western North Atlantic shelfbreak front and current (Chapman and Beardsley 1989). The coastal circulation flowing into the northern 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 (**Figure 2-21**; Beardsley and Boicourt 1981; Fratantoni and Pickart 2007). The southern extent of the Labrador Coastal Current flows along the shelf into the 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, including major currents and hypoxic (upwelling) centers, in the Study Area are depicted in **Figure 2-21**.

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. 2004). For instance, there are significant temporal and spatial variations in the longshore current pattern along the New Jersey coast. The longshore current is separated into two currents that flow in opposite directions from the bifurcation point: one flows northward along the coastline and the other flows southward along the coastline. The bifurcation point can vary in location; it can be located south of Barnegat Inlet (commonly south of Beach Haven Inlet) during the summer months (May to September) and well north of Barnegat Inlet (often to the north of Bradley Beach) during the winter months (December to February; Ashley et al. 1986).

Figure 2-22 displays the mean annual surface currents in the Study Area. Because **Figure 2-22** was developed over the range of one year (2004), the surface currents displayed are indicative of the major surface currents experienced long-term, not the episodic surface currents experienced on any given day. The data were collected by the long-range system Coastal Ocean Dynamics Applications Radar or Coastal Radar (CODAR) located in Sandy Hook, Loveladies, Wildwood, and Tuckerton, New Jersey. These CODARs are able to provide surface current speed and direction beyond the shelf break to approximately 100 km (54 NM) offshore New Jersey.

<u>**Shelfbreak Front and Current**</u>

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 (**Figure 2-21**; Fratantoni and Pickart 2007). 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 latitude 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 2-21** shows a generalized depiction of the location of the shelfbreak front/current system in relation to the Study Area.

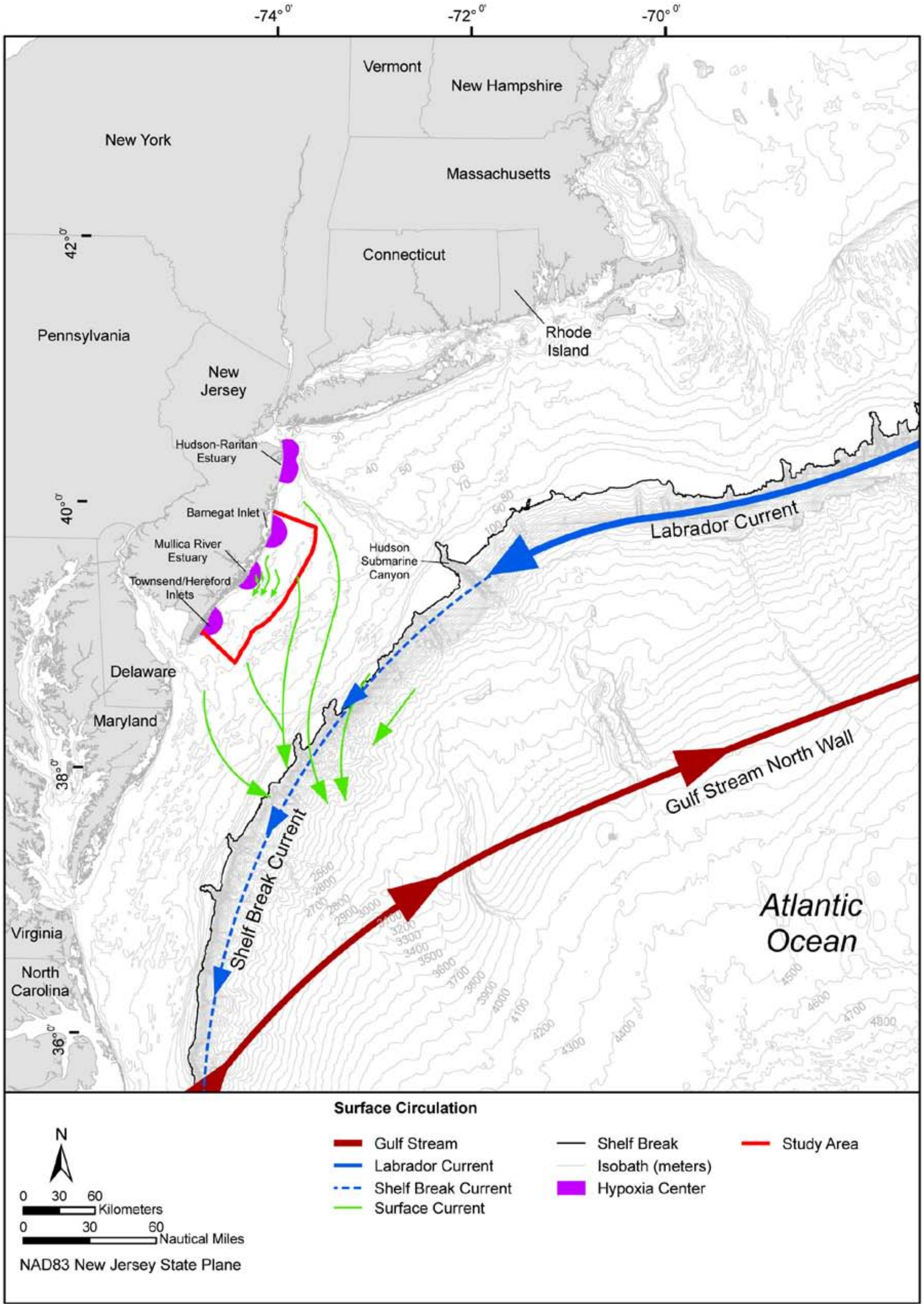

Figure 2-21. General surface circulation, including major currents and hypoxic centers, in the Study Area. Map adapted from: Gilman (1988), Glenn et al. (2004), Kohut et al. (2004), and Fratantoni and Pickart (2007).

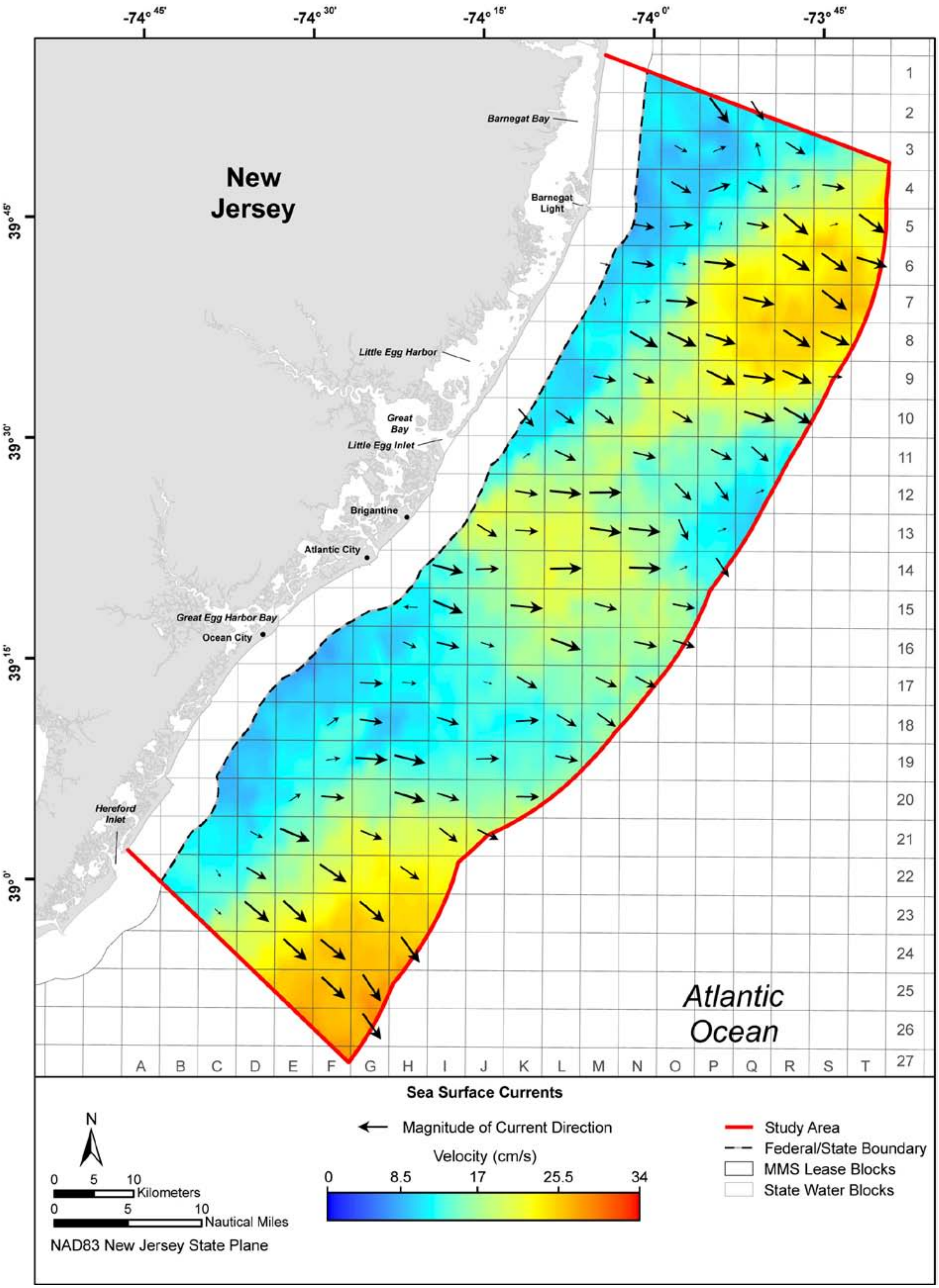

Figure 2-22. Mean annual surface currents in the Study Area as measured by CODAR over the year of 2004. Source data: Rutgers Coastal Ocean Observation Lab (2004).

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 leading edge is located as much as 40 km (22 NM) seaward of the 100-m (328-ft) 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).

2.2.5 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 bathymetric 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-mi 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. 2004).

These episodic upwelling events occur in the summertime and are driven by southwesterly winds associated with the atmospheric Bermuda High (Glenn et al. 2004). 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. 2004). The upwelling event located offshore of the Mullica River estuary is typically observed five times each summer, lasts for about a week each time, and covers an average area of about 150 km^2 (57.9 mi^2; Glenn et al. 2004).

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. 2004). These upwelling centers experience recurrent hypoxic conditions reflecting enhanced production and particulate organic carbon concentrations sufficiently high to deplete 75% of the oxygen in the bottom water (Chant et al. 2004; Glenn et al. 2004). With the onset of upwelling conditions, phytoplankton concentrations increase immediately; this indicates that phytoplankton transport to the upwelling center is dominated by advection.

2.3 BIOLOGICAL ENVIRONMENT (OVERVIEW)

2.3.1 Habitat

2.3.1.1 Continental Shelf

The Study Area encompasses approximately 4,665 km^2 (1,360 NM^2) of the New Jersey offshore environment. The northwest Atlantic Ocean creates a natural border to the east of New Jersey. The Study Area is part of the MAB which is comprised of the continental shelf from Cape Cod, Massachusetts, to Cape Hatteras, North Carolina (Steimle and Zetlin 2000). The shelf environment of the Study Area is characterized as being relatively flat and dominated by sandy to muddy-sandy sediments (Borondy 1997;

NJDEP 2000; Steimle and Zetlin 2000); however, it is not a homogeneous region because it contains natural ridge and shoal bathymetric features (Brooks et al. 2006). It can be described as a gently dipping offshore extension of the coastal plain (passive margin). The Study Area is bounded to the west by part of one of the longest barrier island chains in the world. On the east, the continental shelf ends and the continental slope begins at an average depth of 80 m (263 ft; McBride and Moslow 1991). On the inner continental shelf of the Study Area, shore-oblique linear sand ridges are common features (Dragos and Aubrey 1990). Sand ridges provide a distinct habitat for adults, settled juveniles, and larvae for a number of fish species indicating that they have a distinct influence on fish abundance and assemblages (Able et al. 2006). Relative to the surrounding continental shelf, sand ridge habitats have been shown to have higher species abundances, higher species richness, and distinct species assemblages, including recreationally and commercially important species (Vasslides and Able 2008). In a study conducted across the Beach Haven Ridge, Vasslides and Able (2008) documented dominant fish species from the following families: Paralichthyidae (flounders), Triglidae (sea robins), Gobiidae (gobies), Serranidae, Engraulidae (anchovies), Stromateidae (butterfishes), and Sciaenidae (drums and croakers; Vasslides and Able 2008). Sand ridges of the Study Area are discussed in greater detail in **Section 2.2.1.4** of this chapter. 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 1998; Steves et al. 1999; Ma et al. 2006b); more detailed information regarding the macrofauna that live on and in the continental shelf benthic environment is discussed further in **Section 2.3.2**.

2.3.1.2 Artificial Reefs

There are numerous artificial reef sites in the Study Area (no natural reefs are present; Figley 2005); **Figure 2-23**. 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% of recreational landings occurred on artificial reefs; up from 33% 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, decommissioned ships, and stainless steel subway cars from the New York City Transit Authority. Recent side scan sonar data, however, shows that many stainless steel cars have collapsed leading the NJDEP to state that they will no longer accept such materials (NJDEP 2008b; 2010). Furthermore, specially designed and manufactured artificial reefs have also been added to sites off New Jersey (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 2008b). 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 2008b). These 15 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 2008b). 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 years) breaks down into sand (Borondy 1997). The concrete has a potentiometric hydrogen ion concentration (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

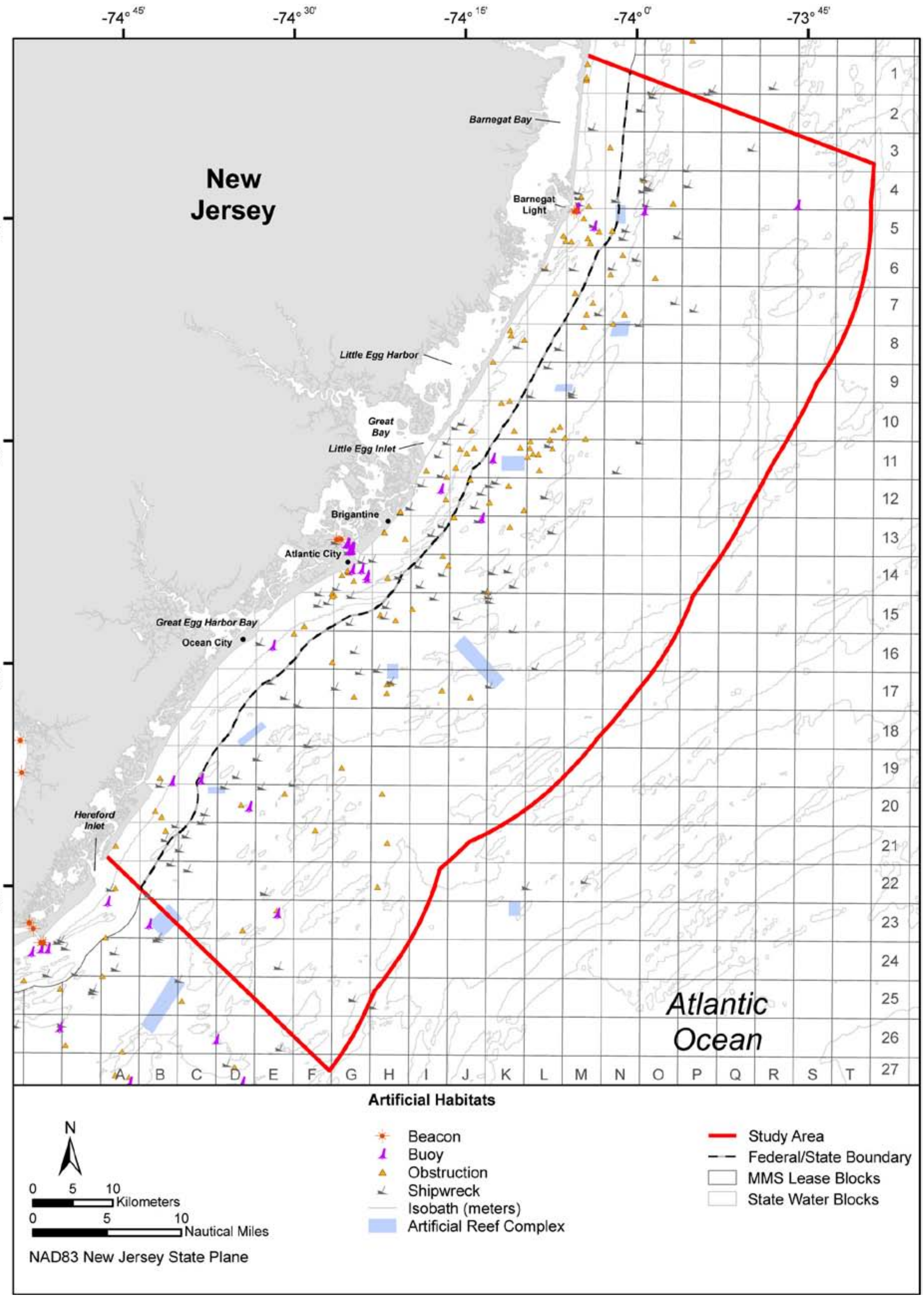

Figure 2-23. Location of artificial habitats found in the Study Area. Source data: NOAA/Office of Coast Survey (2008b) and NJDEP (2008a).

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).

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 two years. More than 39,900 organisms were counted on a 0.9 m (3 ft) by 0.3 m (1 ft) structure with blue mussels (*Mytilus edulis*) constituting more than 60% 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 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 18 m (60 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, Atlantic cod (*Gadus morhua*), gray triggerfish (*Balistes capriscus*), tautog (*Tautoga onitis*), black sea bass (*Centropristis striata*), scup (*Stenotomus chrysops*), ocean pout (*Zoarces americanus*), hake (*Urophycis*/*Merluccius* spp.), conger eel (*Conger oceanicus*), and cunner (*Tautogolabrus adspersus*; 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).

2.3.2 Flora and Fauna (Overview)

2.3.2.1 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 many 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 2-24**). 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 *a* (chl *a*) measured in the water column or at the sea surface. Thus the chl *a* concentration is often used as a proxy for phytoplankton abundance (**Figure 2-24**). In general, in continental shelf and slope waters, the concentration of chl *a* decreases with distance from shore and with increasing water depth. The peak chl

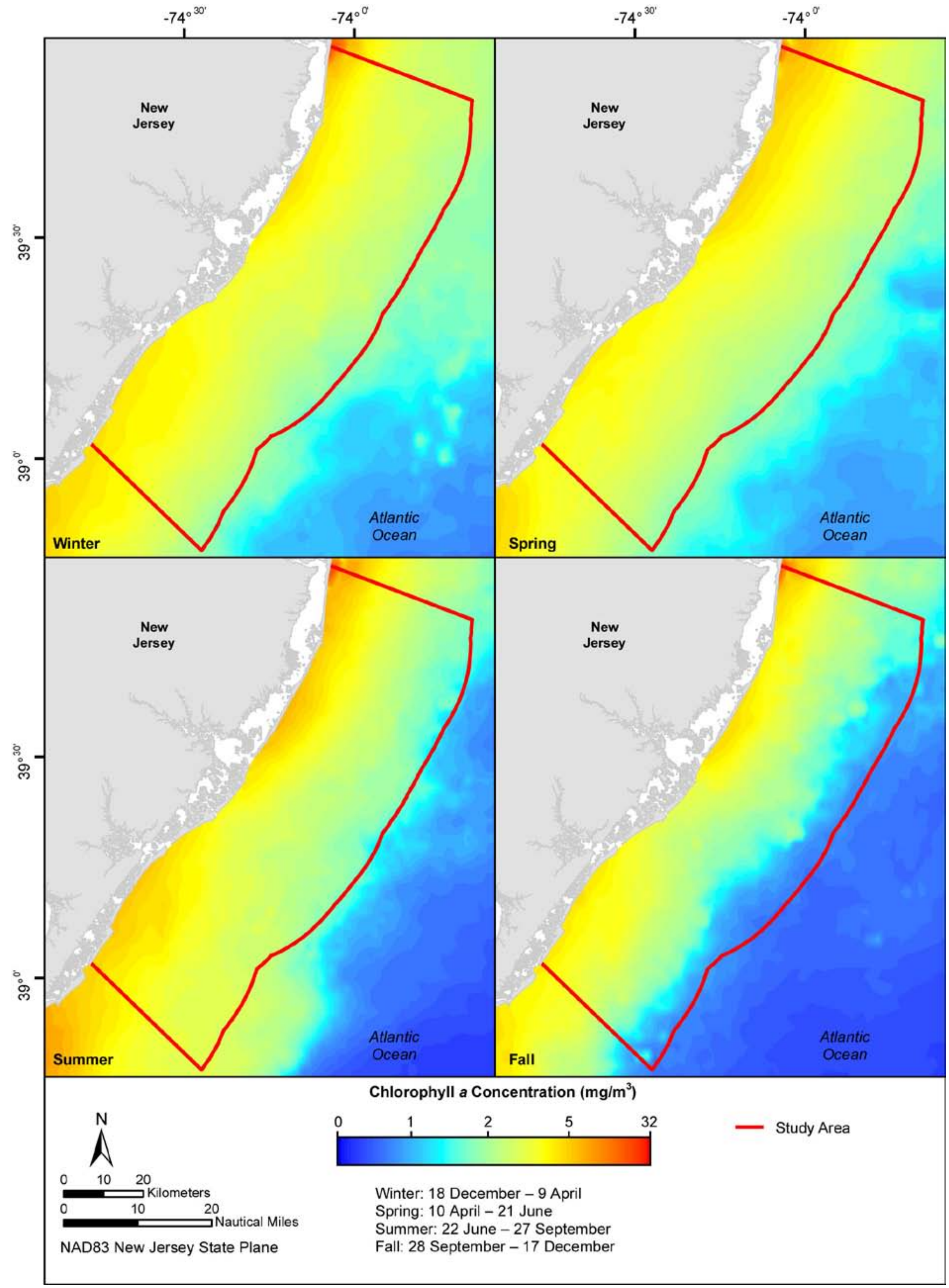

Figure 2-24. Mean seasonal surface chl a concentrations found in the Study Area from 01 January 2007 through 31 December 2009. Source data: NASA (2010).

a 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. 2004). In the coastal areas of the Study Area, chl *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. 2004). Phytoplankton within the upwelled waters are typically dominated by chromophytic algae with diatoms being the major phytoplankton taxa present (Glenn et al. 2004). 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 to 200 m (262.5 to 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) or approximately 44 km (24 NM) offshore.

Figure 2-24 displays the mean seasonal surface chl *a* concentrations found in the Study Area. In the development of this figure, chl *a* concentrations for the Study Area between was 01 January 2007 and 31 December 2009 was downloaded from the NASA, Goddard Earth Sciences Data and Information Services Center. The data was collected on board the Aqua Earth Observing System satellite for MODIS Level 3 data at a resolution of 1 km. The raw satellite data was processed by NASA by ratioing channel 9:channel 7 (green:blue) with SeaSpace Terascan software and subsequently processed further by the Rutgers Coastal Ocean Observation Lab.

2.3.2.2 Zooplankton

Zooplankton are aquatic animals ranging from the smallest protozoans to jellyfish (Wiebe et al. 1987). They can be classified according to logarithmic size classes, with picoplankton measuring 0.2 to 2 microns (µm), nanoplankton measuring 2 to 20 µm, microplankton measuring 20 to 200 µm, and mesoplankton measuring larger than 200 µm (Sieburth et al. 1978). Zooplankton can also be classified according to life cycle, with holoplankton spending their entire lives in the water column and meroplankton spending only certain stages (larvae) of their life cycle in the water column. Zooplankton form an essential link connecting fishes, birds, marine mammals, other large marine species and the primary producers (phytoplankton and marine bacteria) of the marine food web. They also contribute to the marine food web by providing a significant source of organic matter to the seafloor through the production of fecal pellets (marine snow). Although many are able to move sizable distances at moderate speeds and thus can perform diel vertical migrations of hundreds of meters, ocean currents and the suitability of the physical, chemical, and biological components of the hydrographic regimes they encounter determine their large-scale horizontal distributions. Zooplankton populations show heterogeneous dispersion patterns at a wide range of temporal and spatial scales, from hours to years and from meters to thousands of kilometers (Bucklin and Wiebe 1986). Zooplankton population oscillations tend to occur on the order of a month, those of primary producers (including marine bacteria) can be measured in days (Fenchel 1988).

The major zooplankton groups include chaetognaths, copepods, gelatinous zooplankton, icthyoplankton, amphipods, cladocerans, euphausiids, heteropods, polychaetes, and pteropods (Byrnes et al. 2000). Judkins et al. (1980) studied the zooplankton (sans ichthyoplankton) in the vicinity of the Study Area and found that, on the average, copepods comprised the majority (62%) of the zooplankton in the area with two species, *Pseudocalanus* sp. and *Centropages typicus,* accounting for at least 13% of the annual mean for total zooplankton and pteropods (almost exclusively of the species, *Limacina retroversa*) accounting for another 13%. The remaining groups (and percentage of relative abundance) that make up the zooplankton assemblage of the area included pteropods and gastropod veligers (15%), cladocerans *(Penilia avirostris* plus *Evadne* spp.; 10%), urochordates (doliolids and appendicularians; 6%), and all other groups (e.g., echinoderm plutei, medusae, polychaete larvae, chaetognaths; less than 1%; Judkins et al. 1980).

The Study Area exhibits large seasonal changes in water temperature (see **Section 2.2.2.1**); these temperature changes strongly regulate zooplankton productivity, species composition, and spatial distribution. For example, there is an increase in the incidence of subtropical-tropical species in fall and summer that is probably due to the annual intrusion of the warm waters of the Gulf Stream over the continental slope. In addition, there is an increase in the abundance of common coastal species and an increase in the abundance of several common oceanic species (e.g., *Calanus finmarchicus, Oithona atlantica, Clausocalanus pergens, Metridia lucens*) over the shelf and toward the coast during warmer seasons of the year due to the shoreward mixing of slope water with shelf water (Judkins et al. 1980). In general, zooplankton display a strong seasonal pattern with a spring enhancement of biomass within the upper 200 m (656 ft; Wiebe et al. 1987). Maximum abundances occur in spring between April and May (on the outer shelf; dominated by *Pseudocalanus* sp. and *C. finmarchicus*) and in late summer between August and September (on the inner shelf; dominated by *C. typicus* and *Ternora longicornis*; Judkins et al. 1980; Flagg et al. 1994b). The lowest abundance begins in November and reaches a minimum in February (Sherman et al. 1998).The relatively large size of the *Calanus* species and its annual cycle in the waters of the Study Area causes its growth to be prominent feature of the ecosystem in the spring (Flagg et al. 1994c). Increases in zooplankton biomass may occur when shelf water intrudes over slope water, creating a stratified water column. High nutrients and a shallow mixed layer will give rise to enhanced primary production, which in turn leads to an increase in zooplankton biomass or secondary production. The seasonality of zooplankton abundance is provided in **Table 2-3.**

Table 2-3. Zooplankton taxa abundance as a function of season for the vicinity of the Study Area.

Taxa common during all seasons
Copepods
Centropages typicus, Pseudocalanus sp., *Calanus finmarchicus, Paracalanus parous, Oithona atlantica, Metridia lucens, Clausocalanus pergens*
Chaetognaths
Sagitta elegans, Sagitta serratodentata
Pteropods, appendicularians, medusae, polychaete larvae, bivalve veligers, *Euphausiid furcilia,* calyptopsis stages
Maximum abundance in winter
Limacina retroversa
Maximum abundance in spring
Pseudocalanus sp., *Calanus finmarchicus, Oithona similis, Metridia lucens, Clausocalanus pergens, Evadne* spp., appendicularians, gastropod veligers, medusae, polychaete larvae
Maximum abundance in early summer
Centropages typicus, Temora longicornis, Sagitta elegans
Maximum abundance in late summer
Paracalanus parous, Penilia avirostris, doliolids, echinoderm plutei, *Acartia tonsa*

The zooplankton taxa that were more abundant on the inner shelf (less than 50-m [164-ft] water depth) included C. *typicus, Penilia avirostris, T. longicornis, Evadne* spp., *Acartia tonsa,* and doliolids while the taxa that were more abundant on the outer shelf (more than 50-m [164-ft] water depth) included *Calanus finmarchicus, Oithona similis,* O. *atlantica, M. lucens,* and *Clausocalanus pergens.* The outer shelf zooplankton assemblage reached maximum abundance during March (dominated by *L. retroversa*, *Pseudocalanus* sp., O. *similis, Paracalanus parvus,* and *M. lucens*) and again in May (dominated by *Pseudocalanus* sp., *Calanus finmarchicus,* and O. *similis*). The inner shelf zooplankton assemblage reached maximum abundance in July (dominated by *Centropages typicus* and *T. longicornis*). In general, those species which were abundant in the outer shelf region during winter and spring were much less abundant near the coast during those times; however, some species were seldom, if ever, abundant on the outer shelf; these include doliolids and the coastal-estuarine species *Penilia avirostris, T. longicornis,* and *A. tonsa* (Judkins et al. 1980).

Although many of these species display a seasonal signal, some species of zooplankton were ubiquitous near the coast, offshore, and seasonally; these include *Calanus finmarchicus*, *Pseudocalanus* sp., *Centropages typicus*, O. *similis, M. lucens*, *Centropages hamatus*, S. *elegans,* medusae, appendicularians, pteropods, gastropod veligers, and polychaete larvae (Judkins et al. 1980; Sherman et al. 1998).

In the Study Area, thermal stratification breaks down seasonally and nutrients are returned to the surface waters which results in high productivity; this explains the characteristic seasonal pulses in plankton biomass and species succession as well as the enhanced productivity of upwelling zones (Sherman et al. 1998). Zooplankton and phytoplankton spring blooms tend to occur simultaneously without lag between the two with high biological productivity located along the edge of the continental shelf (along the shelf-slope frontal zone; Flagg et al. 1994a). Zooplankton production in the vicinity of the Study Area is food-limited as the total phytoplankton biomass may not be available to the zooplankton as food. When phytoplankton are abundant in spring, zooplankton don't consume much of the spring bloom but during the fall, they graze intensely with ingestion rates equal to the rate of primary production (Durbin and Durbin 1996). In general, zooplankton are not capable of taking up particles of bacterial and ciliate size; however, consumption by heterotrophic nanoflagellates accounts for the majority of the bacterial production grazing (Fenchel 1988).

Meroplankton

Meroplankton are an important portion of the zooplankton that spends only part of its life as plankton; meroplankton can include the eggs, larval, and juvenile stages of many organisms (i.e., fish [icthyoplankton], some macroflora spores, and benthos [including, but not limited to, the trochophore, veliger, zoea, and nauplius larvae]). Meroplankters are carried by currents (not free swimming) which provide a means of dispersal; meroplankters also provide an important food source for other zooplankton and other organisms. In a study conducted in the Study Area, Judkins el al. (1980) collected samples and documented meroplankton that included anthozoan larvae, barnacle cyprises, barnacle nauplii, bivalve veligers, decapods larvae, echinoderm pleutei, ectoproct larvae, gastropod veligers (most abundant), polychaete larvae, and stomatopod larvae (Judkins et al. 1980).

In collections of icthyoplankton for the Study Area, sand lances (*Ammodytes* spp.), hakes (*Urophycis* spp.), and silver hake (*Merluccius bilinearis*) were the most represented larvae taxa (in order of decreasing abundance) accounting for 43% of the population. The larvae that represented less than 1 to 5% of the species included anchovies (Engraulidae), Atlantic herring (*Clupea harengus*), dogtooth lanternfish (*Ceratoscopelus maderensis*), Atlantic cod, haddock (*Melanogrammus aeglefinus*), bluefish (*Pomatomus saltatrix*), Atlantic mackerel (*Scomber scombrus*), butterfish (*Peprilus triacanthus*), and flatfishes including windowpane flounder (*Scophthalmus aqousus*), Gulf Stream flounder (*Citharichthys actifrons*), smallmouth flounder (*Etropus microstomus*), fourspot flounder (*Paralichthys oblongus*), and yellowtail flounder (*Limanda ferrugineus*; Doyle et al. 1993). The ichthyoplankton assemblages found in the Study Area display a seasonal signature with the larval taxa present generally corresponding with the existing adult fish assemblage and the seasonality of eggs and larval corresponding with the spawning times of adults (Smith 1988). While there are some endemic (resident) year-round species, the distinct larval community is probably due to the large number of spawning species, extensive dispersal of eggs and larvae, and spawning periods of long duration, as well as to the continuous influx/outflux of migrant northern and southern species (Olney and Bilkovic 1998). More than 200 taxa of fish eggs and larvae have been reported in the MAB region (Pacheco 1988; Smith 1988; Doyle et al. 1993). Eggs and larvae are most abundant in summer with maximum levels occurring in June, they reach relatively low abundance in late winter. The principal larval taxa that dominate the larval assemblages are dependent on season (**Table 2-4**; Colton et al. 1979; Sherman et al. 1984; Able and Fahay 1998).

Table 2-4. Dominant larval taxa for the Study Area by season in order of abundance (Colton et al. 1979; Sherman et al. 1984; Able and Fahay 1998).

Common Name	Scientific Name
Winter	
*Sand lances	*Ammodytes* spp.
Atlantic cod	*Gadus morhua*
Hakes: spotted and white	*Urophycis regia* and *U. tenius*
Winter flounder	*Pseudopleuronectes americanus*
Spot	*Leiostomus xanthurus*
Spring	
Glacier lanternfish	*Benthosema glaciale*
Atlantic mackerel	*Scomber scombrus*
Sand lances	*Ammodytes* spp.
Windowpane flounder	*Scophthalmus aqousus*
Butterfish	*Peprilus triacanthus*
Yellowtail flounder	*Limanda ferrugineus*
Weakfish	*Cynoscion regalis*
Summer	
Smallmouth flounder	*Etropus microstomus*
Gulf Stream flounder	*Citharichthys actifrons*
Anchovies	Engraulidae
Bluefish	*Pomatomus saltatrix*
Butterfish	*Peprilus triacanthus*
Searobins	*Prionotus* spp.
Atlantic menhaden	*Brevoortia tyrannus*
Atlantic croaker	*Micropogonias undulatus*
Tautog	*Tautoga onitis*
Fall	
Searobins	*Prionotus* spp
Hakes: spotted and white	*Urophycis regia* and *U. tenius*
Gulf Stream flounder	*Citharichthys actifrons*
Smallmouth flounder	*Etropus microstomus*
Windowpane flounder	*Scophthalmus aqousus*
Summer flounder	*Paralichthys dentalus*
Atlantic menhaden	*Brevoortia tyrannus*

***** comprise over 90% of all taxa in winter

2.3.2.3 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 [Paralichthyidae], smelt [Osmeridae], Atlantic striped bass [*Morone saxatilis*], Atlantic cod, lobsters, and blue mussels) as well as feeding and resting sites for birds (e.g., ducks [Anatidae], Canada Geese [*Branta canadensis*], and Atlantic Brant [*Branta bernicla hrota*]).

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% 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 years 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 trigger 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 dependent 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 [*Ruppia maritima*]); however, there are no current documented seagrasses within the Study Area (Macomber and Allen 1979; Green and Short 2003).

2.3.2.4 Benthic Invertebrates

The benthic invertebrate (epifauna) taxa that occur along the New Jersey inner shelf in the Study Area often exhibit seasonal and spatial variations in distribution and abundance (Byrnes et al. 2000). Some of the common macrofauna of the Study Area include species from several taxa including echinoderms (e.g., sea stars, sea urchins, and sand dollars), cnidarians (e.g., sea anemones and corals), mollusks (e.g., bivalves, cephalopods, and gastropods), bryozoans, sponges, amphipods, and crustaceans.

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 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; Viscido et al. 1997; Pearce et al. 2000).

Various cnidarians 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 Study Area include the deeplet sea anemone (*Bolocera tuediae*), North American tube anemone (*Ceriantheopsis americanus*), northern cerianthid (*Cerianthus borealis*), lined sea anemone (*Edwardsiella lineata*), 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 Study Area. Mollusks include bivalves (e.g., clams and mussels), cephalopods (e.g., octopus, squid, and cuttlefish), and gastropods (e.g., snails and slugs). Bivalves of the Study Area include the Atlantic surfclam. The Atlantic surfclam occurs in “beds” or aggregations on the sandy substrate of the continental shelf in the Study Area; they inhabit waters ranging in depth from nearshore to at least 80 m (262 ft; Byrnes et al. 2000). Cephalopods of the Study Area include the long-finned squid (*Loligo pealei*), short-finned squid (*Illex illecebrosus*), and common octopus (*Octopus vulgaris*; Vecchione et al. 1989). Some common gastropods that occur along the New Jersey inner shelf in the Study Area include whelks (*Busycon* spp.) and the moon snails *Euspira heros* and *Nevirita duplicate* (Viscido et al. 1997; Pearce et al. 2000). Larval and adult stage mollusks are eaten by many organisms including sea turtles (young green [*Chelonia mydas*], loggerhead [*Caretta caretta*], hawksbill [*Eretmochelys imbricata*], Kemp’s ridley [*Lepidochelys kempii*], olive ridley [*Lepidochelys olivacea*], and flatback [*Natator depressus*]), fishes, filter feeders, and sea stars (Bjorndal 1997). 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. While encrusting species form "sheets", erect species form uncalcified (soft) dense bushes, calcified (hard) coral forms, and branched forms. Erect bryozoans of the 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 crustaceans. The mid-shelf is dominated by sand dollars and surf clams from about 40 to 70 m (131 to 230 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. 2006a). Some common crustaceans that occur along the New Jersey inner shelf in the Study Area include hermit crabs (*Pagurus* spp.), Atlantic rock crab (*Cancer irroratus*), and sevenspine bay shrimp (*Crangon septemspinosa*; Viscido et al. 1997; Pearce et al. 2000).

In the southern end of the Study Area is the Dr. Carl N. Shuster, Jr. Horseshoe Crab Reserve. It is located 6 km (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 American horseshoe crab (*Limulus polyphemus*) in the western Atlantic (NMFS 2001b; Walls et al. 2002).

The horseshoe crab has existed for more than 200 Ma. 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, 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 to 18 m (20 to 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 (*Triakis semifasciata*), eels, and loggerhead sea turtles (Walls et al. 2002).

Of specific mention to the benthos of the Study Area are sand ridge habitats discussed in **Section 2.2.1.4**. In a study sampling the benthos of the Beach Haven Ridge, Viscido et al. (1997) found that the sevenspine bay shrimp was the most abundant, followed by Atlantic rock crab, lady crab (*Ovalipes ocellatus*), and spider crab (*Libinia emarginata*). The most common pattern of distribution found by the Beach Haven sand ridge studies was that benthos were abundant around (landward and seaward), but not on top of the ridge and that the abundance of most taxa (with some exceptions) was low in winter and reached maximum densities in summer (Viscido et al. 1997). **Table 2-5** provides a list of common benthos that inhabit the Study Area.

Table 2-5. A summary of common benthic invertebrate species that inhabit the Study Area (Serafy and Fell 1985; Vecchione et al. 1989; Ryland and Hayward 1991; Viscido et al. 1997; Sebens 1998; Byrnes et al. 2000; Pearce et al. 2000; Walls et al. 2002).

Common Name	Scientific Name
Echinoderms	
N/A	*Cidaris abyssicola*
Purple-spined sea urchin	*Arbacia punctulata*
Northern sea urchin	*Strongylocentrotus droebachiensis*
Common sand dollar	*Echinarachnius parma*
Five-slotted sand dollar	*Mellita quinquiesperforata*
N/A	*Schizaster orbignyanus*
Sea potato	*Echinocardium cordatum*
Cnidarians	
Deeplet sea anemone	*Bolocera tuediae*
North American tube anemone	*Ceriantheopsis americanus*
Northern cerianthid	*Cerianthus borealis*
Lined sea anemone	*Edwardsiella lineata*
Plumose anemone	*Metridium senile*
Mollusks	
*Atlantic surfclam	*Spisula solidissima*
*Long-finned squid	*Loligo pealei*
*Short-finned squid	*Illex illecebrosus*
Common octopus	*Octopus vulgaris*
*Whelks	*Busycon* spp.
Northern moon snail	*Euspira heros*
Shark eye	*Nevirita duplicata*
Bryozoans	
N/A	*Bowerbankia imbricata*
N/A	*Bugula fulva*
N/A	*Nolella stipata*
Crustaceans	
Hermit crabs	*Pagurus* spp.
Atlantic rock crab	*Cancer irroratus*
Sevenspine bay shrimp	*Crangon septemspinosa*
American horseshoe crab	*Limulus polyphemus*
Lady crab	*Ovalipes ocellatus*
Spider crab	*Libinia emarginata*

* Important fishery resource in the Study Area

2.3.2.5 Birds

Although most of the Study Area is considered marine, the avifauna is dominated by coastal species during all seasons (Walsh et al. 1999, see **Volume II: Chapter 2.0**). Gulls (Larinae) form the backbone of the bird life, with three common breeding species, two of which (Herring Gull [*Larus argentatus*] and Great Black-backed Gull [*Larus marinus*]) are common year-round. In most years, Laughing Gull (*Leucophaeus atricilla*) is the most numerous species in the project area during the north-temperate breeding season (April to July; Sibley 1997; Walsh et al. 1999). Laughing Gull numbers typically peak in July with the fledging of young and prior to southward migration in fall. Herring Gull numbers in coastal New Jersey usually peak in mid-fall, before many of the young-of-the-year have departed for the winter; however, arrivals of large numbers of wintering individuals from farther north probably keep the local population at or near peak size well into winter (Sibley 1997). Great Black-backed Gull probably exhibits population peaks similar to that of Herring Gull, but at lower absolute numbers (Sibley 1997). Common Tern (*Sterna hirundo*) and Forster's Tern (*Sterna forsteri*; particularly the former), account for most of the non-gull birds found in the project area during the breeding season (See **Volume II: Chapter 2.0**). Royal Tern (*Thalasseus maxima*), a recent addition to the New Jersey breeding avifauna, is much less common here than are the other two tern species (see **Volume II: Chapter 2.0**). A few species of austral migrant Procellariiformes seabirds arrive in the Study Area in May to June (Walsh et al. 1999). These migrants, Greater Shearwater (*Puffinus gravis*), Sooty Shearwater (*Puffinus griseus*), and Wilson's Storm-Petrel (*Oceanites oceanicus*), are considerably more common over deep water than over shelf waters, though Wilson's Storm-Petrel can still be found here in fairly significant numbers (Sibley 1997; Walsh et al. 1999). Additionally, Cory's Shearwater (*Calonectris diomedea*), breeding in the eastern Atlantic, arrives in the western Atlantic during the same time (Walsh et al. 1999; Onley and Scofield 2007). The summer season is typically the season of lowest bird abundance.

The migration seasons (March to May and August to December) bring large numbers of individuals of arctic- and subarctic-breeding species into the Study Area. Of particular note is the massive autumn (September to December) flight of waterfowl (particularly scoters [*Melanitta* spp.]), loons [*Gavia* spp.], Double-crested Cormorants (*Phalacrocorax auritus*), and Northern Gannets (*Morus bassanus*) into and through New Jersey waters. Cape May Bird Observatory has been monitoring this passage of nearly one million birds annually since 1993 from a station at Avalon, Cape May County.[11] The spring passage of migrants is relatively minor (See **Volume II: Chapter 2.0**); however, the spring passage greatly increases the numbers of birds present in the Study Area. Spring passage is dominated by Double-crested Cormorants, scoters, and Northern Gannets. From late August through early October, southbound waterbird migration is dominated by greater than 100,000 Double-crested Cormorants that pass through the state's coastal areas. In October, and continuing through mid-November, waterfowl (particularly Surf Scoter [*Melanitta perspicillata*] and Black scoter [*Melanitta nigra*]), with greater than 500,000 birds in passage, are the dominant component of the waterbird migration (Cape May Bird Observatory unpubl. data). From mid-November through mid-December, Red-throated Loon (*Gavia stellata*) and Northern Gannet provide most of the remaining migrants (Sibley 1997). The annual count at Avalon ends 22 December, but the later-migrating species continue to trickle through into January (e.g., Razorbill [*Alca torda*]).

Winter (December to March) bird numbers are dominated by the piscivorous Northern Gannet, although actual numbers of that species vary from year to year, almost certainly due to varying prey populations (Walsh et al. 1999, see **Volume II: Chapter 2.0**). Surf Scoter and Black Scoter, the two year-round gull species and Red-throated Loons and Common Loons (*Gavia immer*) account for most of the rest of the Study Area avifauna at this season (see **Volume II: Chapter 2.0**). In some years (as in 2009), there is an influx of relatively large numbers of alcids (auks; Alcidae) in New Jersey shelf waters January to March, with Razorbill being, by far, the most numerous species of the group here. This group, as in the Procellariiformes (the albatrosses, procellariids, storm-petrels and diving petrels), is much more numerous over deep water than over the shelf (Walsh et al. 1999).

2.3.2.6 Marine Mammals

Marine mammals are an important and federally protected marine resource that occurs in the Study Area. Forty-two marine mammal species have confirmed or potential occurrence in the Study Area based on known distribution and habitat associations (**Table 2-6**). Known or potential species include 35 cetaceans (whales, dolphins, and porpoises), six pinnipeds (seals), and one sirenian (manatee). All marine mammal species are afforded protection under the U.S. Marine Mammal Protection Act (MMPA). Seven of these marine mammal species are designated as threatened or endangered under the U.S. Endangered Species Act (ESA) and, therefore, are provided additional legal protection.

Prior to this project, marine mammal distribution in the nearshore waters of New Jersey was not well known. Besides providing possible habitat for nearshore toothed whales [e.g., bottlenose dolphins (*Tursiops truncatus*)] and pinnipeds [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 species recorded during the baseline study are discussed in more detail in **Volume III**. More information about the other marine mammal species included in **Table 2-6** can be found in Jefferson et al. (2008) and Waring et al. (2009).

Table 2-6. 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 (Waring et al. 2009).

Common Name	Scientific Name	ESA Status
Order Cetacea		
Suborder Mysticeti (baleen whales)		
Family Balaenidae		
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	*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*	
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*	
Short-beaked 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		
Harbor porpoise	*Phocoena phocoena*	

Table 2-6 (*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 (Waring et al. 2009).

Common Name	Scientific Name	ESA Status
Order Carnivora		
Suborder Pinnipedia (seals, sea lions, fur seals, walruses)		
Family Phocidae (true 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

2.3.2.7 Sea Turtles

Five sea turtle species have confirmed or potential occurrence in the Study Area based on known distribution and habitat associations (**Table 2-7**). All sea turtle species are designated as threatened or endangered under the ESA.

Table 2-7. 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*	Endangered*
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.

Sea turtle distribution in the nearshore waters of New Jersey is not well known. Leatherback turtles (*Dermochelys coriacea*) undergo extensive migrations in the western North Atlantic. A regular, seasonal occurrence of leatherbacks is known to occur along the northeast U.S. Atlantic coast, particularly in late spring/early summer when leatherbacks begin to appear off the mid-Atlantic and New England coasts, (CETAP 1982; Shoop and Kenney 1992; Thompson et al. 2001; James et al. 2006). Loggerhead occurrence north of Cape Hatteras, North Carolina is highly seasonal, primarily from May to October, although sightings have occurred in all months of the year (CETAP 1982; Lutcavage and Musick 1985; Shoop and Kenney 1992). Other sea turtle species may also occur in New Jersey's nearshore waters on a seasonal basis when water temperatures exceed 15ºC (Shoop and Kenney 1992; Morreale and Standora 1998). Juvenile Kemp's ridley and green turtles are known to occur regularly in inshore areas such as Delaware Bay, Long Island Sound, and Cape Cod Bay throughout the summer months (Bleakney 1965; Lazell 1980). Hawksbill turtles have also been recorded in nearshore waters of this area during the summer months, although their presence in the area is considered to be rare (Lazell 1980; Prescott 2000).

The species recorded during the baseline study are discussed in more detail in **Volume III**. More information on the other sea turtle species included in **Table 2-7** can be found in the following: Bjorndal (1995), Lutz and Musick (1997), Lutz et al. (2003), Gulko and Eckert (2004), Plotkin (2007), and the Proceedings from any of the Annual Symposia on Sea Turtle Biology and Conservation.[12]

2.3.2.8 Fish

The ichthyofaunal community within the Study Area is dynamic and highly variable due to seasonal and climatic changes, varying life history strategies, hydrographic phenomena, fishing pressure, and natural cycles of abundance. It is composed of both northern (boreal) and southern (warm-temperate/sub-tropical) demersal and pelagic fish populations that undergo extensive migrations as they follow temperature isotherms (Musick et al. 1985; Olney and Bilkovic 1998). Occurring 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, the marine ichthyofauna in the Study Area consists of 336 fish species represented by 116 families (Able 1992). Along the Study Area's coastline, various inshore (e.g., estuaries, bays, salt marshes, tidal creeks, and coastal beaches), and offshore (e.g., sand ridges, continental shelf, canyons, hard bottom, and artificial reefs [ship wrecks and man-made structures]) environments are important to fishes and fisheries (Roman et al. 2000) as nursery areas (Able and Fahay 1998; Byrnes et al. 2000). The ichthyoplankton assemblage found within the Study Area's shelf waters corresponds with the existing adult fish assemblage and consists of more than 200 taxa of fish eggs and larvae (Pacheco 1988; Smith 1988; Doyle et al. 1993).

Commercial and recreational fisheries are among the most important and economically valuable natural resources within the Study Area. From 2003 to 2007, the five top commercial species were Atlantic surfclam, Atlantic sea scallop (*Placopecten magellanicus*), ocean quahog (*Arctica islandica*), goosefish/monkfish (*Lophius americanus*), and summer flounder (*Paralichthys dentatus*). The clam dredge is the primary commercial fishing gear employed in terms of value and landings (43%). The Atlantic surfclam is the primary landed commercial species, while the Atlantic sea scallop is the most economically valuable species.[13] According to the Marine Recreational Information Program (MRIP), the dominant recreational species landed from 2003 to 2007 was summer flounder. Summer flounder represented 40.8% of the total landings, while bluefish and black sea bass represented 18.9 and 18.2%, respectively.[14] Approximately 141 fishing hotspots, consisting various structural features (e.g., shoals, ridges, shipwrecks, artificial reefs) are located within the Study Area with the highest concentration (57%) located in the southern half of the Study Area (Saltwater Directions 2003c, 2003b, 2003a; NJDEP 2008a). The Study Area also provides important habitats to many juvenile fish and invertebrates having economic and ecological importance. From 2003 through 2008, the most numerically abundant juvenile species were butterfish, scup, squid (Cephalopoda), and Atlantic herring. In terms of economic value, the most abundant species were squid. Summer and fall were the most important seasons in terms of relative juvenile fish abundance (NJDEP 2009).

Currently, there are 40 fish/invertebrate species in the Study Area that have designated EFH and are grouped as temperate (23 species), subtropical-tropical (three species), and Highly Migratory Species (HMS; 14 species). Of the total number of temperate EFH species found within the Study Area, 11 are managed by the NEFMC, seven are jointly managed by the MAFMC and ASMFC, and five are managed by the MAFMC (MAFMC 1998; MAFMC and ASMFC 1998a; MAFMC and ASMFC 1998b; NEFMC 1998; NEFMC 1999; NEFMC 2003). All three subtropical-tropical species of the coastal migratory pelagic complex are managed by the South Atlantic Fishery Management Council (SAFMC 1998). NMFS manages and designates EFH for 14 HMS (NMFS 2003; NMFS 2006; NMFS 2009a). In state waters, the ASMFC through the Interstate Fisheries Management Program (IFMP) coordinates the conservation and management of 22 Atlantic coast fish species or two species groups (shad/river herring and 20 coastal sharks), which are found in the Study Area or vicinity.[15]

There are five species of concern and one candidate species found within or in the vicinity of the Study Area.[16] The migratory Atlantic sturgeon (*Acipenser oxyrinchus oxyrinchus*), the candidate species, commonly aggregates in shallow (10 to 50 m [32.8 to 164.1 ft]) near shore areas (Stein et al. 2004; Atlantic Sturgeon Status Review Team 2007). NMFS is currently preparing a determination on whether listing the species or multiple distinct population segments (DPS) of the Atlantic sturgeon as threatened or endangered is warranted (NMFS 2010). The Atlantic sturgeon is scheduled to be listed as New Jersey State endangered in the near future. The state of New Jersey and federally endangered shortnose sturgeon (*Acipenser brevirostrum*) does not occur in the Study Area.[17] For more in-depth information, see **Volume IV**.

2.3.2.9 Bats

Ten bat species have confirmed or potential occurrence in New Jersey (**Table 2-8**). Only one species, the Indiana bat (*Myotis sodalist*), is considered endangered under both the ESA and state of New Jersey. Most bat communities in the northeast U.S. are comprised of cave-dwelling *Myotis* species (Reynolds 2006), while the hoary bat (*Lasiurus cinereus*), Eastern red bat (*Lasiurus borealis*), and silver-haired bat (*Lasionycteris noctivagans*) are tree-roosting species and migrate long distances (Cryan 2003; Cryan and Brown 2007; Kunz et al. 2007) and are present in New Jersey from spring through fall (MMS 2009a). White-nose syndrome is an emerging disease in hibernating bats in the northeast and was first discovered in New York in 2006. Since then it has spread to nine northeastern states (Reichard and Kunz 2009), including northern New Jersey by January 2009 (Boyles and Willis 2010). Bats afflicted with white-nose syndrome have a white fungus covering the nose, ears, and wings. They suffer massive mortality, presumably through starvation from depleted fat reserves and reduced foraging ability caused by wing damage (Reichard and Kunz 2009; Boyles and Willis 2010).

Bat occurrence within the Study Area is poorly understood (MMS 2009a). In a literature review, Goodale and Divoll (2009) noted that Eastern red bats travel along the coast from Maryland to Maine and have been observed offshore as far as 209 km (130 mi). Silver-haired bats were recorded on Assateague Island, Maryland, and were presumed spring and fall migrants (Johnson and Gates 2008).

Cryan (2003) noted that tree-roosting bats occur along northern coastlines more often during the autumn than the spring, and that this occurrence may be associated with coastal navigation. Hoary bats are known to migrate to the Farallon Islands off the California coast, a distance of 32 km (19.9 mi; Cryan 2003; Cryan and Brown 2007). Cryan et al. (2004) noted that hoary bats are capable of traveling distances greater than 2,000 km (1,242.7 mi). Hoary and Eastern red bats have been seen migrating in diurnal flocks, and Eastern red and silver-haired bats have been observed landing on ships at sea (Cryan 2003). Bat migration pathways and behavior are poorly understood and there have been several calls for further studies (Cryan 2003; Reynolds 2006; Kunz et al. 2007; Arnett et al. 2008). Ahlén et al.(2007) noted that migrating bats over the Baltic Sea flew at altitudes between 0 to 10 m (1 to 32.8 ft) and hunt during migration. Non-migrating bats have been observed hunting at distances far from land as well (Ahlén et al. 2007). The authors stated that the majority of bats flew across the sea only during calm or light winds, and that hunting was conducted during calm weather. Cryan and Brown (2007) remarked that little is known of the effects of wind speed on bat migration.

The species recorded during the baseline study as part of a research project conducted by a graduate student at the University of Maryland Center for Environmental Science are discussed in more detail in **Appendix B**.

Table 2-8. Bats potentially located within New Jersey (MMS 2009a).

Common Name	Scientific Name	ESA Status
Order Chiroptera		
Family Vespertilionidae		
Big brown bat	*Eptesicus fuscus*	
Silver-haired bat	*Lasionycteris noctivagans*	
Eastern red bat	*Lasiurus borealis*	
Hoary Bat	*Lasiurus cinereus*	
Northern yellow bat	*Lasiurus intermedius*	
Eastern small-footed bat	*Myotis leibii*	
Little brown bat	*Myotis lucifugus*	
Northern long-eared bat	*Myotis septentrionalis*	
Indiana bat	*Myotis sodalis*	Endangered
Eastern pipistrelle bat	*Pipistrellus subflavus*	

2.3.3 Listed Species

2.3.3.1 Federal

Birds

Federally listed threatened, endangered, and candidate bird species were not observed during the study (**Volume II: Section 2.3.2** and **Chapter 4.0**). Federally listed avian species of concern listed that were documented previously in the Study Area or have the potential to occur as breeding birds based on their habitat requirements were listed for the Study Area (**Table 2-9**). The USFWS federal species of conservation concern list for the Middle Atlantic coast was developed primarily for coastal plain terrestrial species. Fourteen Federal avian species of conservation concern were observed during the study (**Table 2-10**; **Figure 2-25**).

Table 2-9. Federal threatened, endangered, and candidate species listed for the Study Area. The naming convention for the family, common, and scientific names are consistent with the American Ornithologists' Union (AOU 1998).

Common Name	Scientific Name	List Status
Family Charadriidae (plovers)		
Piping Plover	*Charadrius melodus*	Threatened
Family Scolopacidae (sandpipers)		
Red Knot	*Calidris canutus*	Candidate
Family Laridae (gulls, terns, and skimmers)		
Roseate Tern	*Sterna dougallii*	Endangered

Table 2-10. Federal species of conservation concern for Bird Conservation Region 30 (New England/Mid-Atlantic coast; USFWS 2008). The naming convention for the family, common, and scientific names are consistent with the American Ornithologists' Union (AOU 1998).

Common Name	Scientific Name	Study Occurrence Status
Family Gaviidae (loons)		
Red-throated Loon	*Gavia stellata*[NB]	Observed
Family Podicipedidae (grebes)		
Pied-billed grebe	*Podilymbus podiceps*	Observed
Horned grebe	*Podiceps auritus*	Observed
Family Procellariidae (petrels, shearwaters)		
Greater Shearwater	*Puffinus gravis*[NB]	Observed
Audubon's Shearwater	*Puffinus iherminieri*[NB]	Observed
Family Ardeidae (herons and egrets)		
Snowy Egret	*Egretta thula*	Observed
Family Accipitridae (kites, hawks, eagles)		
Bald Eagle	*Haliaeetus leucocephalus*[BR]	Not Observed[1]
Peregrine Falcon	*Falco peregrinus*[BR]	Not Observed[1]
Family Rallidae (rails)		
Black Rail	*Laterallus jamaicensis*	Not Observed
Family Charadriidae (plovers)		
Wilson's Plover	*Charadrius wilsonia*	Not Observed
Family Haematopodidae (osystercatchers)		
American Oystercatcher	*Haematopus palliates*	Observed
Family Scolopacidae (sandpipers)		
Lesser Yellowlegs	*Tringa flavipes*[NB]	Observed
Whimbrel	*Numenius phaeopus*[NB]	Observed
Hudsonian Godwit	*Limosa haemastica*[NB]	Not Observed
Marbled Godwit	*Limosa fedoa*[NB]	Observed
Semipalmated sandpiper	*Caldris pusilla*[NB]	Observed
Purple Sandpiper	*Calidris maritime*[NB]	Observed
Short-billed Dowitcher	*Limondromus griseus*	Observed
Family Laridae (gulls, terns, and skimmers)		
Least Tern	*Sterna antillarum*[2]	Observed
Gull-billed Tern	*Gelochelidon nilotica*	Not Observed
Black Skimmer	*Rynchops niger*	Not Observed

[1] Observed only during non-breeding season (winter)
[2] Non-listed subspecies or population of threatened or endangered species
[BR] = breeding season only
[NB] = non-breeding

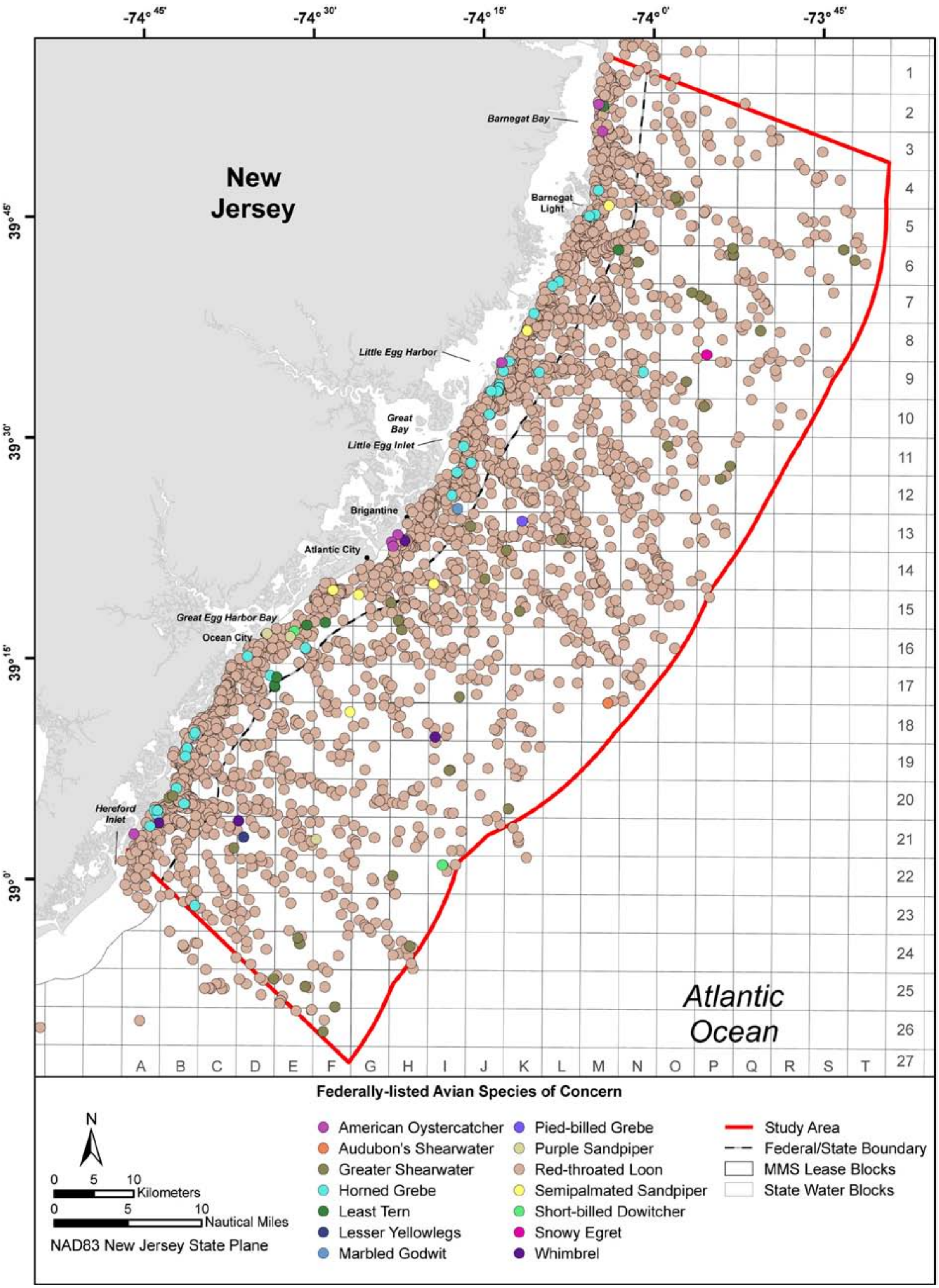

Figure 2-25. Observation locations of federally listed avian species of concern in the Study Area.

Marine Mammals and Sea Turtles

All marine mammal species are afforded federal protection under the MMPA. Seven of the 41 marine mammal species with known or potential occurrence in the Study Area are designated as threatened or endangered under the ESA (**Table 2-11**). Three of these species were recorded in the Study Area during the baseline studies (**Table 2-11**; **Figure 2-26**). All sea turtle species are designated as threatened or endangered under the ESA. Two of the five sea turtle species with known or potential occurrence in the Study Area were recorded in the Study Area during the baseline studies (**Table 2-11; Figure 2-26**).

Table 2-11. Federally listed species with known or potential occurrence in the Study Area. Naming conventions for marine mammals are consistent with the NOAA Stock Assessment Report (Waring et al. 2009). Taxonomy for turtles follows Pritchard (1997).

Common Name	Scientific Name	ESA Status	Observed During Baseline Study
Marine Mammals			
North Atlantic right whale	*Eubalaena glacialis*	Endangered	Yes
Humpback whale	*Megaptera novaeangliae*	Endangered	Yes
Sei whale	*Balaenoptera borealis*	Endangered	No
Fin whale	*Balaenoptera physalus*	Endangered	Yes
Blue whale	*Balaenoptera musculus*	Endangered	No
Sperm whale	*Physeter macrocephalus*	Endangered	No
West Indian manatee	*Trichechus manatus*	Endangered	No
Sea Turtles			
Leatherback turtle	*Dermochelys coriacea*	Endangered	Yes
Loggerhead turtle	*Caretta caretta*	Threatened	Yes
Kemp's ridley turtle	*Lepidochelys kempii*	Endangered	No
Green turtle	*Chelonia mydas*	Endangered*	No
Hawksbill turtle	*Eretmochelys imbricata*	Endangered	No

* 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.

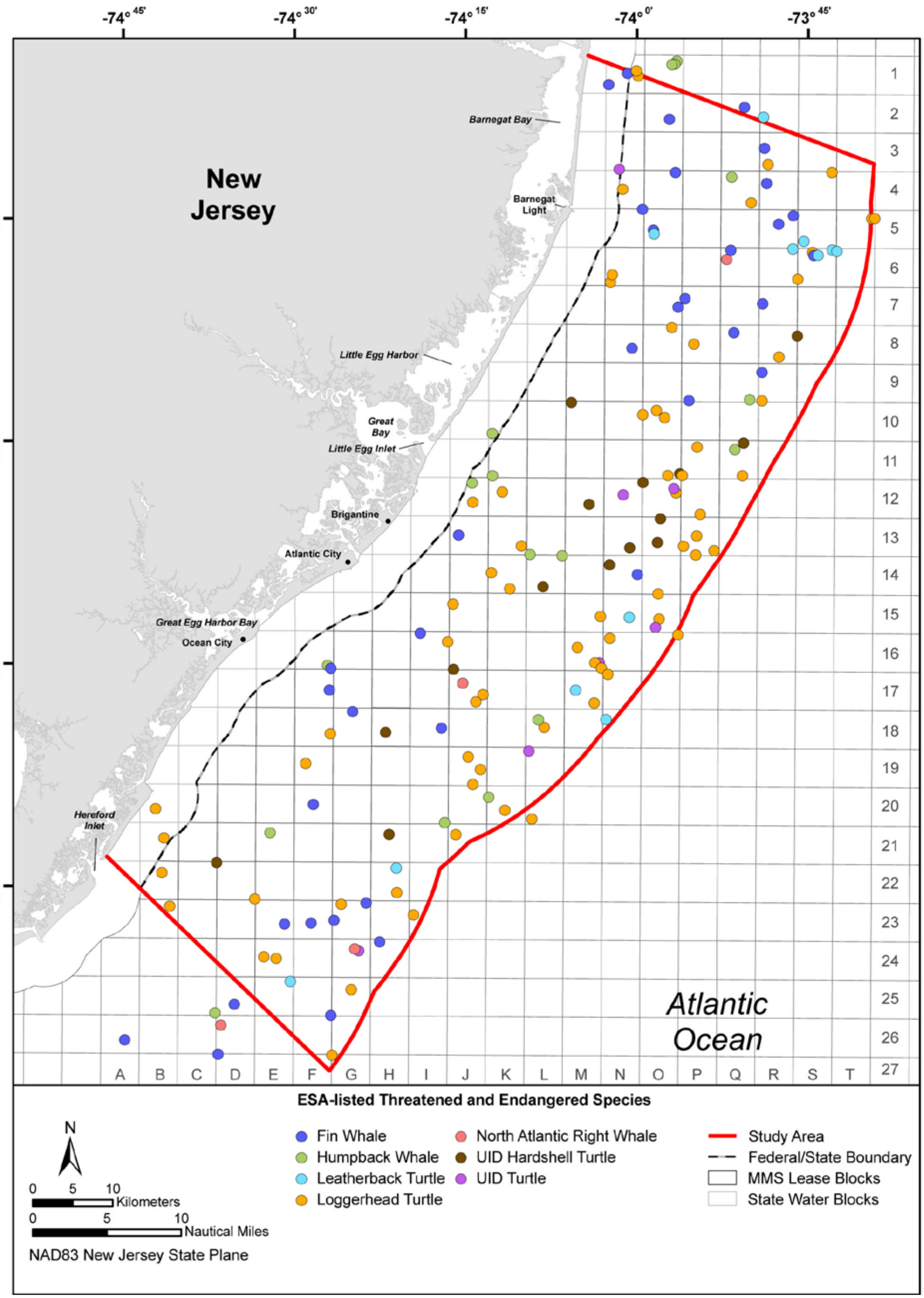

Figure 2-26. Observation locations of federally listed threatened and endangered species in the Study Area. 'UID' is unidentified.

2.3.3.2 State

Birds

State-classified threatened, endangered, and special concern bird species of coastal and offshore habitats within the Study Area are listed in **Table 2-12**. All state-classified birds, with the exception of American Bittern (*Botaurus lentiginosus*), Black Rail (*Laterallus jamaicensis*), and Black Skimmer (*Rynchops niger*), were observed during the study. The observation location for state-classified threatened and endangered species (**Figure 2-27**) and state-classified species only for the breeding season (**Figures 2-28** and **2-29**) were mapped. Common tern, a state-classified species of concern during the breeding season, was mapped separately because of the high number of observations.

Table 2-12. New Jersey state-classified threatened, endangered, and special concern avian species potentially occurring in the Study Area. The naming convention for the family, common, and scientific names are consistent with the American Ornithologists' Union (AOU 1998). The New Jersey State classification status is based on data from the New Jersey Division of Fish and Wildlife.[17]

Common Name	Scientific Name	New Jersey Status	Study Occurrence Status
Family Podicipedidae (grebes)			
Pied-billed Grebe	*Podilymbus podiceps*	E ^{BR}, SC ^{NB}	Observed ^{NB}
Family Ardeidae (bitterns, egrets, and herons)			
American Bittern	*Botaurus lentiginosus*	E	Not Observed
Great Blue Heron	*Ardea herodias*	SC ^{BR}	Observed
Black-crowned Night-heron	*Nycticorax nycticorax*	T ^{BR}, SC ^{NB}	Observed ^{BR}
Yellow-crowned Night-heron	*Nyctanassa violacea*	T	Observed
Family Accipitridae (eagles and hawks)			
Osprey	*Pandion haliaetus*	T ^{BR}	Observed
Bald Eagle	*Haliaeetus leucocephalus*	E ^{BR}, T ^{NB}	Observed ^{NB}
Northern Harrier	*Circus cyaneus*	E ^{BR}, SC ^{NB}	Observed ^{NB}
Family Falconidae (falcons)			
Peregrine Falcon	*Falco peregrinus*	E	Observed
Family Rallidae			
Black Rail	*Laterallus jamaicensis*	T	Not Observed
Family Haematopodidae (oystercatchers)			
American Oystercatcher	*Haematopus palliatus*	SC	Observed
Family Scolopacidae (sandpipers)			
Whimbrel	*Numenius phaeopus*	SC ^{NB}	Observed ^{NB}
Red Knot	*Calidris canutus*	SC ^{BR}	Not Observed
Sanderling	*Calidris alba*	SC ^{NB}	Observed ^{NB}
Semipalmated Sandpiper	*Calidris pusilla*	SC ^{NB}	Observed ^{NB}
Family Laridae (gulls and terns)			
Least Tern	*Sterna antillarum*	E	Observed
Caspian Tern	*Hydroprogne caspia*	SC ^{BR}, RP ^{NB}	Observed ^{NB}
Common Tern	*Sterna hirundo*	SC ^{BR}, RP ^{NB}	Observed ^{NB}
Royal Tern	*Thalasseus maximus*	RP ^{NB}	Observed
Black Skimmer	*Rynchops niger*	E ^{BR}, T ^{NB}	Not Observed

E = Endangered
T = Threatened
SC = Special Concern
RP = Regional Priority
^{BR} = Breeding population
^{NB} = Non-breeding population

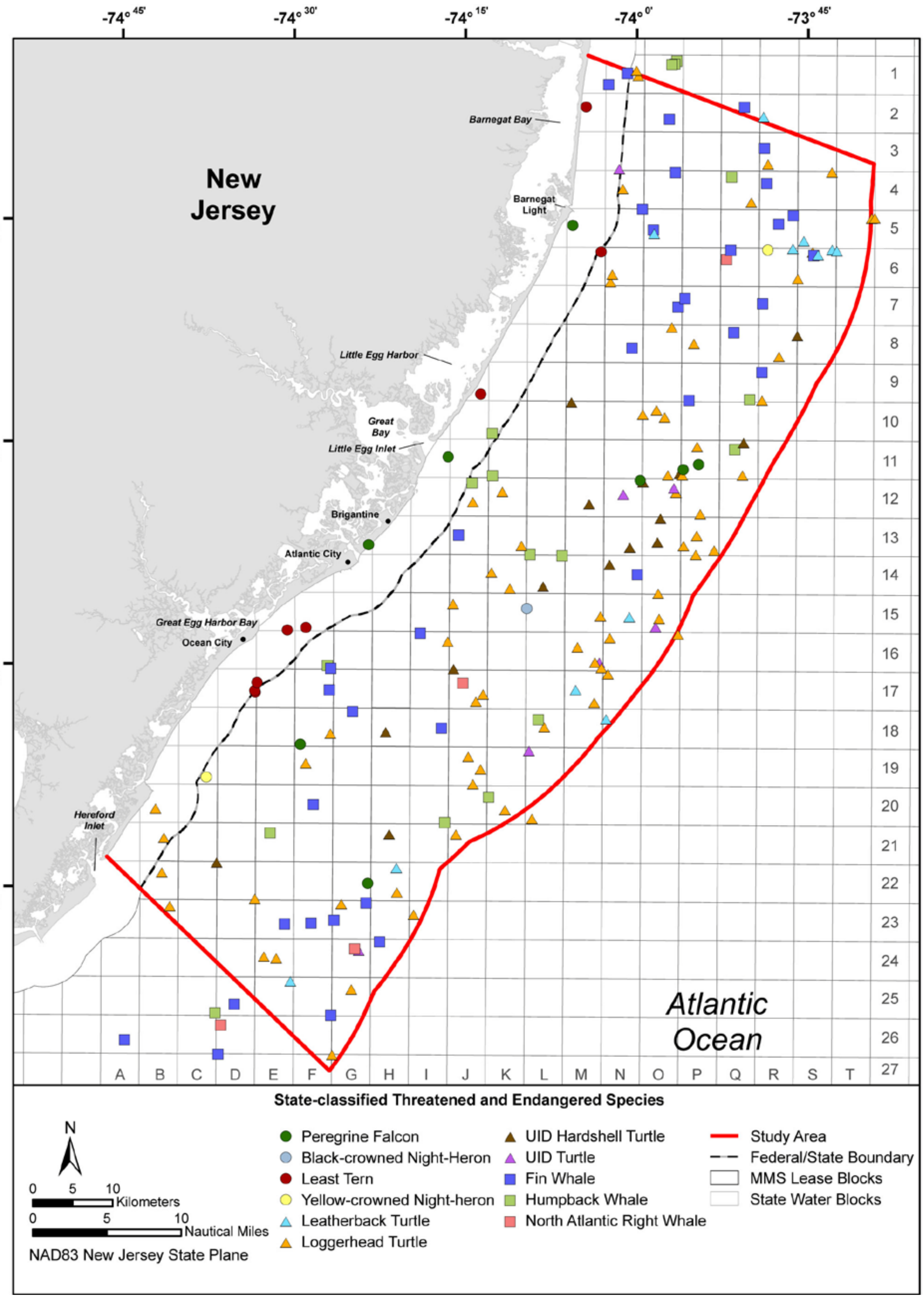

Figure 2-27. Observation locations of state-classified threatened and endangered species in the Study Area. 'UID' is unidentified.

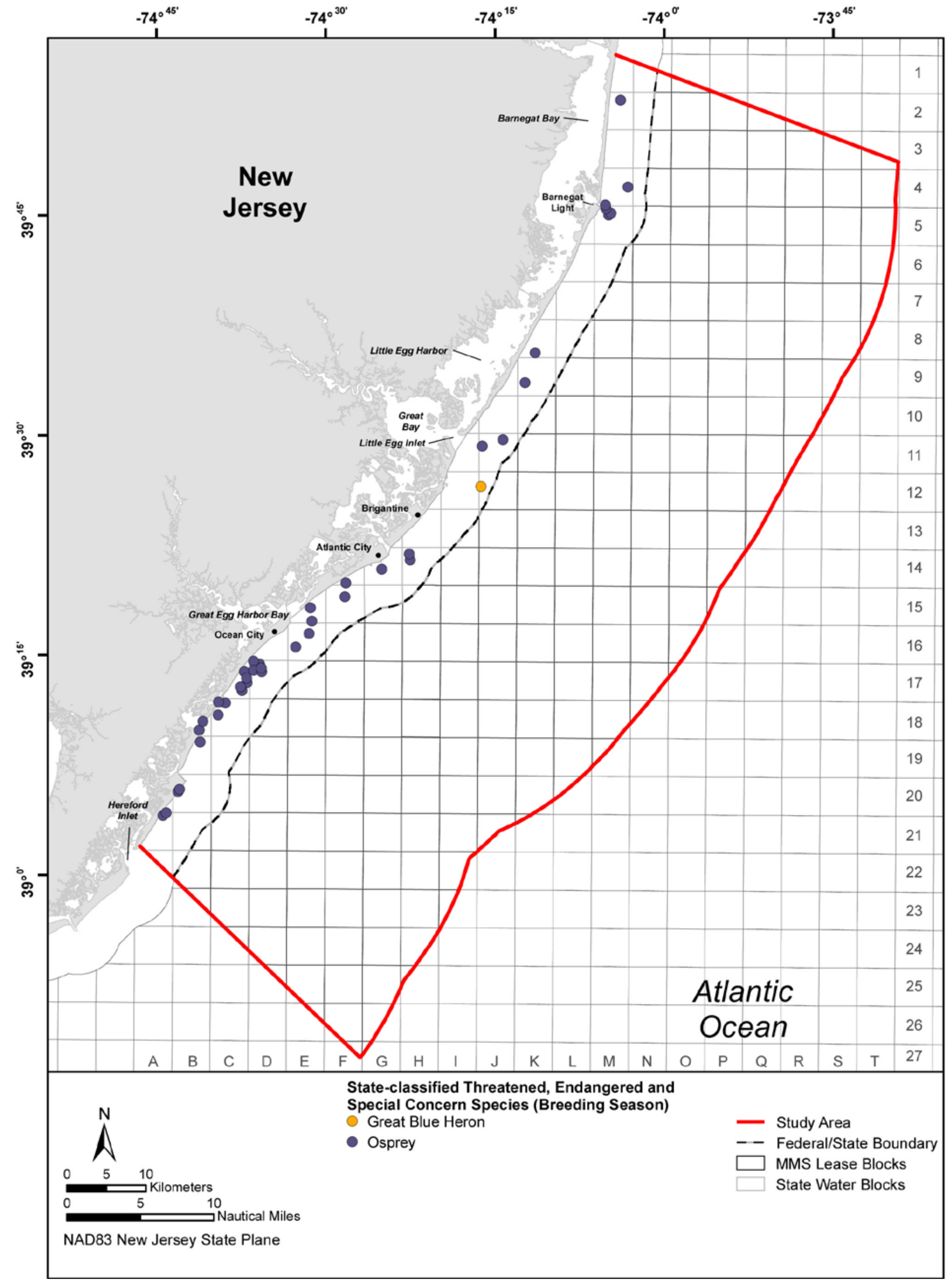

Figure 2-28. Observation locations of state-classified threatened and endangered species in the Study Area during the breeding season.

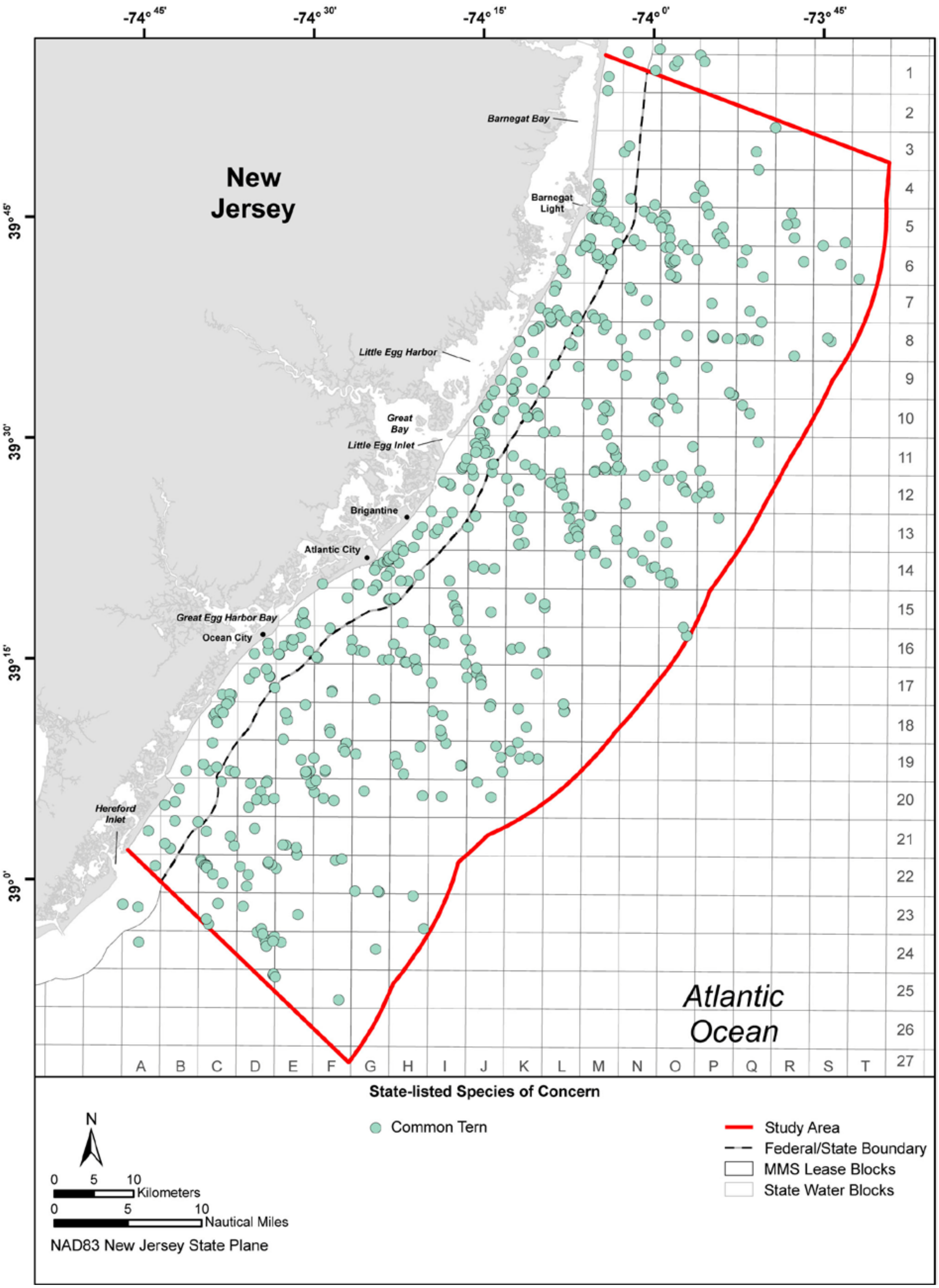

Figure 2-29. Observation locations of state-classified species of concern (Common Tern only) in the Study Area, during the breeding season (June, July).

State special concern species which were classified as non-breeding only were not mapped. While state-listed species were part of the avian model, they were in insufficient numbers to produce a model of just state-listed avian species, which would have weighted those areas used frequently by threatened and endangered species. Therefore, **Figures 2-25**, **2-27**, **2-28**, and **2-29** should be considered in addition to the sensitivity index when making decisions for impacts of wind turbine farms on avian species.

Marine Mammals and Sea Turtles

Six of the 41 marine mammal species with known or potential occurrence in the Study Area are designated as threatened or endangered for the State of New Jersey (**Table 2-13**). Three of these species were recorded in the Study Area during the baseline studies (**Table 2-13**; **Figure 2-27**). Five sea turtle species are designated as threatened or endangered for the State of New Jersey. Two of these species were recorded in the Study Area during the baseline studies (**Table 2-13**; **Figure 2-27**).

Table 2-13. State-listed species with known or potential occurrence in the Study Area. Naming conventions for marine mammals are consistent with the NOAA Stock Assessment Report (Waring et al. 2009). Taxonomy for turtles follows Pritchard (1997).

Common Name	Scientific Name	State of New Jersey Status	Observed During Baseline Study
Marine Mammals			
North Atlantic right whale	*Eubalaena glacialis*	Endangered	Yes
Humpback whale	*Megaptera novaeangliae*	Endangered	Yes
Sei whale	*Balaenoptera borealis*	Endangered	No
Fin whale	*Balaenoptera physalus*	Endangered	Yes
Blue whale	*Balaenoptera musculus*	Endangered	No
Sperm whale	*Physeter macrocephalus*	Endangered	No
Sea Turtles			
Leatherback turtle	*Dermochelys coriacea*	Endangered	Yes
Loggerhead turtle	*Caretta caretta*	Endangered	Yes
Kemp’s Ridley turtle	*Lepidochelys kempii*	Endangered	No
Green turtle	*Chelonia mydas*	Threatened	No
Hawksbill turtle	*Eretmochelys imbricata*	Endangered	No

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3.0 RESULTS SUMMARY

3.1 SUMMARY

Persuant to recommendation four of the BRP's Final Report, the NJDEP designed a study to collect scientific data regarding the distribution, abundance, and migratory patterns of birds and mammals within the New Jersey's OCS. Specifically, in order to comply with the Panel's recommendations, NJDEP advertized a Solicitation for Research Proposals for Ocean/Wind Power EBS. GMI was ultimately contracted to conduct this study. To meet the project goal, baseline data were to be collected on avian species, marine mammals and sea turtles, fish and shellfish, and other natural resources over an 18-month period to fill major data gaps identified for each of these categories; the sampling duration was later extended to 24 months. This Ecological Baseline includes the first year-round, systematic survey effort in nearshore waters of New Jersey between Stone Harbor and Seaside Park. The collected data were used to conduct a predictive modeling of species distribution and abundance. An environmental sensitivity index (ESI) was then developed to synthesize the physical, biological, and socioeconomic resources data of the Study Area (**Chapter 4.0**).

This section provides a summary of the results of the avian, marine mammal, sea turtle, and fish and fisheries studies.

3.1.1 Avian Study Results

3.1.1.1 Avian Shipboard and Small Boat Surveys

Avian shipboard offshore surveys were conducted January 2008 through December 2009, with associated small-boat coastal surveys being conducted each month after completion of the shipboard offshore survey. A total of 15,483 km (8,360 NM) and 2,700 km (1,457 NM) of trackline were surveyed on the offshore and coastal surveys, respectively, with >1,100 hrs of combined survey effort. The resultant dataset fills a large gap in the understanding of at-sea bird distribution in the western North Atlantic Ocean.

Species Occurrence

A total of 176,217 birds representing 153 species were recorded; 84,428 birds of 145 species were recorded during the shipboard offshore surveys and 91,789 birds of 82 species were recorded during the small-boat coastal surveys. Federal endangered, threatened, and candidate species were not detected during avian surveys. Fourteen of the 21 federally listed species of concern and 16 of the 20 state-classified endangered, threatened, and special concern species potentially occurring in coastal and offshore waters were observed during the survey.

Avian Density

Avian densities were highest near shore at all seasons, although this finding was much more pronounced in winter than in summer (ratio of abundance on offshore surveys vs. small-boat coastal surveys ranged from 2:5 to 1:5). This was due primarily to the large numbers of coastal-breeding gulls and terns and wintering waterfowl along the New Jersey coast. Although large numbers of Wilson's Storm-Petrels, an austral migrant from the Southern Ocean, were present offshore in the summer, the overall lack of true pelagic seabirds in the Study Area concentrated data in the near shore. Overall, inshore waters supported the highest abundances of birds, and in particular in areas south and east of Hereford Inlet, south and east of Ocean City, and east of Atlantic City. In the offshore area, birds were consistently concentrated near a shoal area east of Barnegat Inlet. The summer data exhibited the lowest absolute abundance of birds, with the majority (54.4%) of individuals being locally-breeding species, primarily Common Tern and the Laughing, Herring, and Great Black-backed gulls.

There was a noticeable geographical shift of the relative abundance of birds between the summer and winter. During the summer, blocks with the highest abundance of birds were located offshore (56% or 37 of 66 highest-abundance blocks) whereas in the winter the highest abundance was in nearshore (3% or 2 of 65 blocks). The winter avifauna was dominated by inshore-foraging species (e.g., scoters) and the summer avifauna by offshore-foraging species (e.g., Common Tern).

There was little change in the seasonal composition of species between 2008 and 2009. Black Scoter was the most abundant bird in winter for both years, as was Northern Gannet in spring and Laughing Gull in summer. In fall, Laughing Gull and Northern Gannet were the two most abundant species in both years. While numbers of many species fluctuated from 2008 to 2009, some of the differences observed between years could be attributed to differences in survey timing. For example, in fall 2008, surveys were evenly spaced compared to those conducted in 2009 which were concentrated at the beginning and end of fall. Thus, species such as Surf Scoter (a mid-season migrant) that migrates through New Jersey in large numbers during mid-fall showed a large decrease in fall abundance from 2008 to 2009.

Avian Flight Altitudes

In addition to examining abundance and distribution, data were also analyzed to determine frequency of occurrence within the potential rotor-swept zone (RSZ) of power-generating wind turbines, defined as 100 to 700 ft (30.5 to 213.4 m). Of the >70,000 flying birds recorded, 3,433 (4.8%) occurred in the RSZ, with 33 species recorded in the RSZ at least once. More species occurred in the RSZ in fall (21 species) than any other season, followed by winter (16), spring (15), and summer (five). Scaup (*Aythya* spp.) accounted for 54.5% of all birds in the RSZ for the small-boat coastal surveys, and 31.8% of all birds in the RSZ overall. The only three species to occur in the RSZ in all four seasons were Northern Gannet, Herring Gull, and Great Black-backed Gull. Red-throated Loon, Common Loon, Osprey (*Pandion haliaetus*), and Laughing Gull were recorded in the RSZ in three of the four seasons. Nearly all scaup in the RSZ (1,088 of 1,091) were recorded during a severe cold snap in January 2009, illustrating the potential effects of a major weather event on avian movements. Offshore, Northern Gannet was the species that occurred most often in the RSZ (594 individuals), though the percentage of the species detected within the RSZ was small (3.9%).

Supplemental Surveys

A supplementary study was conducted (October to December 2009) to determine the seaward distribution of the massive fall migration of waterbirds along New Jersey's coast. The data resulting from conducting boat transects perpendicular to the shore and running from the immediate coast out to the Study Area offshore boundary (20 NM), showed that most migrating waterbirds (77%) were less than 5.56 km (5 NM) from shore. Of the species studied (scoters, Common and Red-throated loons, Northern Gannet, and Herring and Great Black-backed gulls), only Common Loon was found throughout the width of the Study Area in roughly equal numbers.

3.1.1.2 Avian Aerial Surveys

Three avian aerial surveys were initially scheduled: spring 2008, fall 2008, and spring 2009. After the April survey the efficacy of such limited surveying was discussed by the NJDEP committee members, and the pros and cons of conducting aerial surveys were compared. Benefits consisted of a better detection of peak activity (if conducted during peak activity) and a "snapshot" of diurnal bird abundance. 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 validation surveys.

3.1.1.3 Avian Radar Surveys

Vertically scanning radar (VerCat) and horizontally scanning radar (TracScan) data were analyzed and data filters were developed to remove detections from rain (especially virga) and sea clutter, because these detections generate false tracks. Track counts were adjusted for dropped tracks that received a new track ID when the target was the same as the original track. The thermal imaging-vertically pointing radar (TI-VPR) system sampled targets passing through a 20° cone directed vertically to determine the proportion of each type of biological target (e.g., birds, bats, insects) detected by VerCat. The TI-VPR data were used to develop a correction factor for insects in the radar count data from the VerCat. Data from barge-based, boat-based, and onshore-based observer validation surveys were analyzed and used to evaluate the results of radar analyses.

The results of the studies with VerCat are expressed in terms of three metrics: **median altitude quartile** (the 50% quartile containing the altitude at which half the total number of birds observed were flying below the median, and half were flying above the median), **flux** (adjusted number of bird tracks per cubic kilometer per hour [abt/km^3/hour]), and **adjusted migration traffic rate** (AMTR-number of bird tracks crossing over a kilometer per hour). Data related to cumulative diurnal and nocturnal flux were sorted into three altitude bands with reference to the potential RSZ: (1) below the RSZ (low altitude band, 1 to 99 ft AMSL); (2) within the RSZ (middle altitude band, 100 to 700 ft AMSL); and (3) above the RSZ (high altitude band, 701+ ft AMSL). The AMTR provides a quantitative passage rate. Although many variables affect the possibility of bird-turbine collision risk, in general the greater the AMTR value the greater the potential for bird-turbine collision.

Median altitude quartiles provide information on the frequency of occurrence of birds in the RSZ. The AMTR provides a quantitative passage rate. Although many variables affect the possibility of bird-turbine collision risk, in general the greater the AMTR value the greater the potential for bird-turbine collision. Flux is a measure of bird density in the RSZ and is the most important metric for determining bird collision risk impacts.

Based on the direct visual validation studies, only 10 to 20% of the birds flying at very low altitudes were detected with the radar. This was because of constraints of the marine radar detecting wave clutter that obscured return from low flying birds. Consequently, in the lowest altitude quartile the reported bird counts were underestimated (i.e., lower than the number actually present) and the radar measured median altitudes were likely lower than those given in this report. Bird counts in the RSZ were affected less by return from wave clutter, because the effect was reduced as the height of the radar beam increased.

The TracScan radar was used primarily to determine direction of target movement. Because different offshore study sites were sampled at different times during a season, it was difficult to attribute changes to time of season, or location, or both. Monitoring all offshore sites throughout each season would have been prohibitively expensive even if equipment and personnel had been available.

Offshore Spring 2008

During spring of 2008 the VerCat radar operated for 940.5 hrs and the TracScan radar operated for 1,044.3 hrs. Daytime flux values gradually decreased within the low altitude band and gradually increased within the RSZ for nearshore and offshore sites. During the night greater flux values occurred within the RSZ than below the RSZ as the spring season advanced for both nearshore and offshore grids. The dominant diurnal and nocturnal nearshore and offshore flux directions during most of the survey weeks were from the south and southwest to the north and northeast. AMTR increased as season progressed near shore and offshore. The peak diurnal AMTR occurred offshore on Grid 26 (137.0 abt/kph) from 24 to 30 April and on Grid 17 (113.0 abt/kph) from 07 to 11 May 2008. Peak nocturnal AMTR occurred 30 April to 07 May (320.3 abt/kph) on Grid 26 and from 07 to 11 May 2008 (333.5 abt/kph) on Grid 17. Because the offshore grids were sampled later in the season, one cannot conclude that more birds were offshore than nearshore, because the high counts may have been the result of more migration occurring later in the season than earlier in the season.

Offshore Fall 2008

During fall 2008 radar surveys were limited to two offshore sampling grids in the southern section of the Study Area. The VerCat operated for 442.5 hrs and the TracScan operated for 415.1 hrs. The data are limited and insufficient to make any conclusions. All the median altitudes were within the RSZ for daytime and nighttime samples. The flux was greater in the RSZ than the low altitude band during daytime and nighttime and there was no difference in flux between daytime and nighttime. Cumulative diurnal and nocturnal AMTR decreased from Grid 22 to Grid 26, but Grid 26 was sampled later in the fall. Peak diurnal AMTR was 104.3 abt/kph and peak nocturnal AMTR was 134.3 abt/kph from 30 September through 12 October 2008. The direction of movement was from the north to the south.

Offshore Spring 2009

The VerCat radar operated for 39.8 hrs and the TracScan radar operated for 41.3 hrs. The data collected were limited and insufficient to analyze and make any conclusions. Three onshore sites were sampled: Island Beach State Park (IBSP), Brigantine, and Corson's Inlet-Sea Isle City (CI-SIC).

Onshore Spring/Early Summer 2008

VerCat operated for 657.9 hrs and TracScan operated for 657.3 hrs. The majority of the median altitude quartiles were within the RSZ at all of the onshore sites. The cumulative diurnal flux values varied within and between the onshore sites and were in general greater during the daytime than at night in the RSZ. The cumulative nocturnal flux values were greater within the low altitude band than within RSZ at all onshore sites. At IBSP and CI-SIC flux values were generally similar for low altitude and RSZ. At Brigantine, cumulative diurnal flux values were greater within the low altitude band than within the RSZ. This difference may be the result of the different migratory species passing the site or the behavior of resident species at the site. AMTR values were similar between the onshore sites during the daytime. AMTR values were greater at night than during daylight indicating that some nocturnal migration was probably still in progress from mid-May into mid-June. The cumulative peak diurnal AMTR (17.6 abt/kph) occurred at Brigantine from 29 May through 01 June 2008. The cumulative peak nocturnal AMTR (66.2 abt/kph) was at IBSP from 15 to 18 May 2008. Overall, as expected during spring migration, the dominant movement of birds was from the south and southwest to the north and northeast.

Onshore Fall/Early Winter 2008

VerCat operated for 2,090.2 hrs and TracScan operated for 2,039.4 hrs. Most of the cumulative median diurnal altitude quartiles were within the RSZ at IBSP in early fall 2008, and the majority of the cumulative median altitude quartiles were within the low altitude band at Brigantine, CI-SIC, and at IBSP from mid-fall into early winter 2008. Most of the cumulative nocturnal altitude quartiles were within the RSZ. The majority of the cumulative diurnal flux values were greater within the low altitude band than within the RSZ. For most of the survey dates, the cumulative nocturnal flux values were generally similar between the low altitude band and the RSZ. Cumulative diurnal AMTR values were 10 abt/kph or less and cumulative nocturnal AMTRs were 30 abt/kph or less at all of the onshore sites. At each onshore site peak cumulative AMTR occurred at night. The dominant direction of movement during most weeks was from the north and northeast to the south and southwest.

Onshore Spring/Early Summer 2009

VerCat operated for 1,902.1 hrs and TracScan operated for 1,872.2 hrs. All of the cumulative weekly median altitude quartiles during the daytime were within the low altitude band at IBSP while at Brigantine cumulative weekly altitude quartiles during the day were split almost equally between the low altitude band and the RSZ. At CI-SIC, the cumulative weekly median altitudes during the daytime were all within the low altitude band. Most of the cumulative weekly median altitude quartiles at night at IBSP were within the RSZ. At Brigantine most of the cumulative weekly median altitude quartiles during the night were in the high altitude band (above the RSZ), and at CI-SIC all of the cumulative median altitude quartiles at night were within the RSZ. Cumulative weekly flux values during daylight were greater within the low altitude band than within the RSZ. Cumulative weekly flux values at night varied among sample periods and were likely dependent on when conditions were favorable for migration. The trend was for greater flux values in the low altitude band during migration events. Cumulative diurnal AMTR values were 10 abt/kph or less and cumulative nocturnal values were less than 80 abt/kph at all of the onshore sites. At each onshore site, peak cumulative AMTR occurred at night. The dominant direction of migration was from the south and southwest to the north and northeast. Some of these movements occurred even though winds were unfavorable, and one small scale reverse migration (towards the southwest) was recorded.

Onshore Fall 2009

VerCat operated for 1,299.5 hrs and TracScan operated for 1,372.9 hrs. Most of the median quartiles were below the RSZ during daylight, but most were in the RSZ at night. Flux values in the RSZ were greater at night than during the day and this was particularly so during migration events. The exceptionally high flux rate during the period 08 to 16 November 2009 was associated with a 22 minute period of high winds and many birds aloft. Cumulative AMTR values during daylight hours were less than 20 abt/kph during the majority of the study. The only exception was during the week of 08 to 16 November at CI-SIC when the AMTR increased dramatically but only in the 16+ mph wind category. Except for the peak cumulative nocturnal migration period 05 to 11 October 2009, when the AMTRs were approximately 90 abt/kph, the cumulative weekly AMTRs at night were below 50 abt/kph. The direction of migration during most sample weeks was from the north and northeast to the south and southwest, and many movements occurred with opposing winds from the south to the north.

Offshore-Onshore Comparisons

It is important to realize that statistical comparisons between onshore and offshore samples were possible only when the samples were collected at the same time. Concurrent offshore radar (Grid 22 and Grid 26; 30 September to 12 October 2008) and onshore radar (CI-SIC; 05 to 19 October 2008) sampling only occurred during 05 to 19 October 2008. Radar data from these locations were compared statistically to provide quantitative information on any onshore-offshore differences in cumulative median flight altitudes, cumulative flux values, and cumulative AMTR. The cumulative median altitude quartiles over the offshore girds were all within the RSZ during the daytime, while over the onshore site half of the cumulative altitudes during daylight were within the RSZ and the other half below the RSZ. The cumulative median altitude quartiles over the offshore grids and over the nearshore site at night were all within the RSZ. Cumulative flux values were higher over the offshore grids than the onshore site during daylight and dark. The cumulative AMTRs were noticeably greater over the offshore grids than over the onshore site. For the limited time period of 05 to 19 October 2008, avian activity was concentrated at the offshore sites.

3.1.1.4 Thermal Imaging Vertically Pointing Radar

Use of thermal imagery and vertically pointing radar proved to be very valuable in identifying the sources of echoes detected in VerCat. The TI-VPR system could easily detect targets flying through the rotor swept zone. The vertically pointing radar provided accurate altitudes of flight and the thermal imaging video provided enough information on targets to identify them as birds, foraging bats, or insects. We recommend that all future studies use this technique to validate the identity of the sources of radar echoes.

Offshore Spring 2008

TI-VPR offshore barge-based surveys were conducted at six sites for a total of 180 hrs. Grid 23, approximately 10 miles offshore, in the southern section of the Study Area , showed the highest total target count for the season (783 targets), of which 570 targets (73%) were identified as birds, 204 as insects, and 9 as foraging bats. Other grids had fewer birds (ranging from 6 to 69 birds), and overall 75% of birds were within the RSZ. The mean directions of the movements were towards the north-northwest-northeast and one movement was a reverse migration toward the south-southwest.

Offshore Fall 2008

TI-VPR offshore barge-based surveys were conducted at two sites for a total of 161 hrs. Grid 23 once again showed the highest total target count (1,252 targets) for fall, of which 985 targets were identified as birds (79%), 243 as insects, and 24 as foraging bats. The second grid sampled (Grid 26, also approximately 10 NM offshore in the southern section of the Study Area) had a total target count of 249, and 192 were identified as birds (77%), 57 as insects, and no foraging bats. The mean directions of the movements for both grids were towards the southwest.

Offshore Spring 2009

TI-VPR offshore barge-based surveys were conducted at two sites for a total of 15 hrs. Grid 16 (nearshore in the central section of the Study Area) showed the highest total target count (97 targets), of which 39 were identified as birds (41%), 57 as insects, and no bats. Grid 22 (nearshore in the southern section of the Study Area) had a total target count of 57 targets, with 39 targets being identified as birds (68%) and18 as insects. The majority of the bird movements aloft (96% in Grid 16 and 94% in Grid 22) occurred within the RSZ. The mean directions of the movements for Grids 16 and 22 were towards the north-northeast.

Onshore Fall 2008

TI-VPR surveys were conducted at the Sea Isle City (SIC) site from 08 to15 December for a total of 48 hrs. The site had a total target count of 285. Of this total, 270 targets were identified as birds (95%), 9 as insects, and 6 as foraging bats. Despite the late sampling date, the mean direction of the movement toward the south-southwest suggested a migratory movement; 90% of the birds flew at altitudes within the RSZ.

Onshore Spring 2009

TI-VPR surveys were conducted at the IBSP site during the period 21 to 22 and 27 March 2009 for a total of 17 hrs. The site had a total target count of 54, of which 21 targets were identified as birds (95%), and 33 as insects. Foraging bats identified were not identified. The mean direction for movement was towards the northeast, and100% of the birds were at altitudes above the RSZ.

Onshore Fall 2009

TI-VPR surveys were conducted at SIC, IBSP, and Brigantine Beach (BB) for a total of 10 hrs. SIC had the highest total target count for the season (1,133 targets), of which 738 targets were identified as birds (65%), and 395 as insects (both season highs). IBSP had the second highest total target count with 219 targets, of which 144 were identified as birds (66%), 69 as insects and 6 as foraging bats. BB had 138 targets detected, with 39 targets being identified as birds (28%) and 99 as insects. Two-thirds of the birds (66.2%) were flying in the RSZ and the remainder (33.8 %) flew above the RSZ. The mean directions of the movements over the three sites were toward the southwest-south-southeast, but the movements over IBSP and BB showed some variability in direction.

3.1.1.5 NEXRAD

Year-to-Year Pattern of Migration

During the spring the sum of nightly bird peak density (birds/km^3) differed from year-to-year. As expected, the maximum density of bird migration measured over the coastal sampling areas differed from the maximum density over the offshore sampling areas. This could be attributed to a migrating bird's tendency to follow the coastline. Over the five years of spring data the sum of the nightly peak densities measured over the coastal areas ranged from 347 in the spring of 2006 (area 1A) to 2,836 in the spring of 2009 (area 1A), and the maximum density recorded was 569 in the spring of 2004 (area 1A). The sum of nightly peak densities recorded over the offshore areas ranged from 58 (area 2B) in the spring of 2008 to 264 in the spring of 2007 (area 1B), with a maximum density of 103 recorded in the spring of 2007 in area 1B. Thus during the five-year study the amount of migration in spring passing over the onshore areas was much higher than the amount of migration measured over the offshore areas.

During the fall the sum of nightly peak density also differed from year-to-year. Over the five years of fall data the sum of the nightly peak densities measured over the onshore areas ranged from 1,445 (area 3A) in the fall of 2004 to 4,078 (area 1A) in the fall of 2005, with a maximum density of 705 recorded in the fall of 2005 (area 1A). The range of the sum of nightly peak densities over the offshore areas ranged from 273 (area 1B) in the fall of 2004 to 658 (area 2B) in the fall of 2005, with a maximum density of 144 recorded in the fall of 2005 (area 2B). Just as in the spring the amount of migration passing over the onshore areas was much higher than the amount of migration measured over the offshore areas. Once again, these results suggested that birds have a tendency to follow the coast line during migration. Overall, the density of migration during the fall was on average two to three times greater than the density of migration observed during the spring.

Night-to-Night Pattern of Migration

Nocturnal migration during the spring and fall showed considerable night-to-night variability. In the spring, migration began to build in late April, peaked near the middle of May, and then declined towards the end of May. This pattern could be seen in both the onshore and offshore sampling areas. Within the three onshore areas there were five nights with a mean density of 100 birds/km^3 or greater over the sampling areas during the five years of spring migration (21 April, and 01, 04, 07, 11 May), while within the offshore sample areas the maximum was 21 on 21 April [area 1B]). Within the offshore areas the mean migration density was considerably less than that measured over the onshore areas (mean peak density of 21 birds/km^3). Though sizable flights could occur at anytime from the middle of April through the middle of May, the peak of migration through the area was in early to mid-May. Fall migration intensified in early September and peaked in mid-October to early November. After the peak in late October/early November the density of migration declined, and by mid-November very little migratory movement took place. This pattern was seen both within the onshore and offshore sampling areas. There were 17 nights with a mean density of 100 birds/km^3 or more within the onshore areas during the five years of fall migration (31 August; 01, 10, 13, 15, 23, 26, 29 September; 05, 12, 14, 15, 17, 20, 25 October; and 02, 09 November), while within the offshore sample areas there were no nights with a mean density of 100 birds/km^3 or more. Area 1A measured the highest density for the fall season on 15 October with a mean density of 258 birds/km^3. Similar to the spring, the offshore sample area mean migration densities were considerably less than those measured within the onshore sample area. The maximum mean density was only 34 birds/km^3 on 12 September within Area 1B.

Hour-To-Hour Pattern of Migration

The hour-to-hour pattern of migration over the sampling areas during the spring (2005 to 2009) typically started 30 to 45 min after sunset, peaked on most evenings between 02:00 to 06:00 Coordinated Universal Time (UTC; 11:00 PM to 2:00 AM Eastern Standard Time [EST]), and declined until sunrise. In the fall (2004 to 2008) the quantity of migration was greater than in the spring (see above section on Year-to-Year Pattern of Migration), and the hour-to-hour pattern of percentage of peak hourly density during the evenings was shifted slightly earlier in the evening compared to that observed in spring. Like the spring, migration typically started 30 to 45 min after sunset and the peak of a nightly movement generally occurred from 01:00 to 05:00 UTC (10:00 PM to 12:00 AM EST). The peak density for the night in the spring appeared to be slightly later in the evening and more defined when compared to the peak density for the night in the fall.

Direction of Migratory Movements

In the spring the mean directions (μ) from which the movements originated were 203.58° in 2005, 205.14° in 2006, 205.44° in 2007, 207.37° in 2008, and 211.35° in 2009. The flights were oriented toward the north-northeast (between 23° and 32°). There was some variability in mean direction from year to year but within each year there was relatively strong directionality as indicated by the length of the mean vector [r] (a statistical measure of concentration). All yearly mean directions showed low circular variance and were highly significant ($p<0.0001$). In the fall the mean directions were from 33.57° in 2004, 28.18° in 2005, 17.68° in 2006, 17.72° in 2007, and 28.55° in 2008. The flights were oriented toward the southeast to south-southwest between 197° and 214°. The lengths of the mean vectors from the fall data were comparable to those in spring data. Topographic features such as the shoreline likely influenced the directions of seasonal migrations, particularly those occurring at lower altitudes.

Migration, Weather Conditions, and Collisions

During the five years of spring data, 79 of 365 nights (21.6%) had conditions that would cause birds to fly lower - sometimes with reduced visibility. Twenty-nine of these nights had migration densities of 25 birds/km^3 or greater. During the five years of fall data, 102 of 465 nights (21.9%) had weather conditions that might have caused birds to migrate at low altitudes and 24 of these nights had bird movements of 25 birds/km^3 or greater. There were 23 more total nights over the five fall seasons than in five spring seasons with weather conditions that could have caused birds to fly at low altitudes and sometimes in poor visibility, but generally on these nights there was little or no migration.

3.1.1.6 Avian Predictive Modeling

The primary goal of the study was to develop spatial models for predicting changes in density and spatial distribution of birds and to identify important regions used by birds within the Study Area. The objective was to quantify where birds are most likely to concentrate in relation to geophysical habitat features (e.g., depth, shoals) and predict where birds were likely to occur seasonally. The following questions were addressed: (1) Where and when are birds (species) most likely to concentrate within the Study Area? (2) Are birds more or less concentrated evenly along the coast, or do some species exhibit specific spatial gradients (i.e., lat-lon variation)? (3) What is the relationship between bird density/distribution and depth, distance to shoreline, distance to shoals, and slope?

Interpolation (e.g., kernel density), spatial regression, and generalized additive models (GAMs) were used to quantify the relationship between spatial covariates (e.g., bathymetric and distance based metrics) and birds. The spatial models were developed to quantify the effect of each spatial covariate for predicting changes in bird density and distribution. In summary, along with the kernel density maps (**Volume II: Appendix M**) that identified where and when birds were likely to concentrate, spatial covariates were calculated to develop insight into the geographic distribution and describe the basic attributes of habitat utilized by birds. By incorporating these data in a GIS, changes in bird density were determined as a function of depth, slope, distance to shoreline, distance to shoals, and whether there was a spatial gradient in bird density (north/south or east/west) for a variety of species. Collection of kernel density maps was a valuable tool for identifying important locations where and when (by month and season) birds were most likely to concentrate.

Kernel Density Interpolation

Kernel density maps were estimated for all-behavior and sitting densities (number of birds/km^2) in 2008 and 2009, and the combined two-year period 2008 to 2009. Numerous localized density maxima for all-behavior and sitting birds were located nearshore, midshore, and far-offshore, with the vast majority of these maxima occurring nearshore. A small portion of these density maxima for all-behavior birds were mirrored by the sitting birds, reflecting differences in the numbers of flying and sitting birds. For example, eight and 15 localized sitting density maxima occurred in 2008 and 2009, respectively; and 24 such maxima occurred in the overall cumulative two-year period, most of which occurred nearshore. In 2008, the eight sitting density maxima ranged from 110 to 830 (the latter occurring between Barnegat Light and Seaside Heights); and in 2009, the 15 sitting density maxima ranged from 115 to 735 (the latter occurring north of Little Egg Inlet). In the overall cumulative two-year period, the 24 sitting density maxima ranged from 115 to 1,480 (the latter occurring north of Little Egg Inlet). For the all-behavior birds, the highest density maxima were 1,425 in 2008 (midshore southeast of Little Egg Inlet), 1,730 in 2009 (nearshore north of Little Egg Inlet), and 1,805 (on the offshore edge of the nearshore region, between Little Egg Inlet and Brigantine).

Observing these annual and overall cumulative spatial kernel density maps, the following general conclusions can be made:

- Nearshore densities were higher than offshore densities, supporting an offshore gradient of decreasing densities with increasing offshore distance.
- Within the offshore region, midshore densities were generally higher than far-offshore densities.
- All-behavior densities were higher than sitting densities, reflecting the presence of both all-behavior and sitting birds.
- The highest nearshore densities occurred up against the coastline rather than on the offshore edge of the nearshore region.
- All-behavior density maxima that are mirrored by sitting birds reflected a balance between flying and sitting birds. If the sitting density was less than the all-behavior density, then both flying and sitting birds were present. If the sitting density was equal to or near the all-behavior density, then most/all of the birds in the given region were sitting rather than flying.
- All-behavior density maxima that were not mirrored by sitting birds indicated that the majority of birds in the given region were flying rather than sitting.

Total Birds Seasonal Analysis

For most seasons, nearshore densities were higher than offshore densities (for both all-behavior and sitting birds). Within the offshore region, densities were generally higher midshore than far-offshore.

In fall 2008, numerous localized density maxima were located nearshore, midshore, and offshore as a result of contributions of individual species. A total of 24 detectable density maxima occurred for all-behavior birds within the Study Area, ranging in magnitude from 105 to 1,740 (the latter was located midshore southeast of Little Egg Inlet). The majority of these maxima were not mirrored by the sitting birds, indicating that most of the total birds in the regions of these density maxima were flying rather than sitting. Compared to 24 density maxima for all-behavior birds, only four density maxima occurred for the sitting birds: (1) 945 nearshore between Barnegat Light and Seaside Heights (compared to 1,420 for all-behavior birds); (2) 120 nearshore in the region midway between Little Egg Inlet and Barnegat Light (compared to 135 for all-behavior birds); (3) 145 midshore southeast of Hereford Inlet (compared to 170 for all-behavior birds); (4) 140 far-offshore southeast of Hereford Inlet (compared to 565 for all-behavior birds). Except for this far-offshore density maximum, far-offshore densities were generally lower than midshore densities. Total bird density (all-behavior and sitting) were generally lower in fall 2009 than in fall 2008 (a year earlier). In fall 2009, five localized density maxima occurred for all-behavior birds: (1) 180 nearshore at Barnegat Light (compared to 125 for sitting birds); (2) 260 nearshore between Barnegat Light and Little Egg Inlet (compared to 145 for sitting birds); (3) 300 midshore southeast of Little Egg Inlet (compared to 215 for sitting birds); (4) 300 nearshore just south of Atlantic City (compared to 235 for sitting birds); (5) 100 nearshore just south of Ocean City (mirrored by a sub-maximum density on the order of 50). In addition, numerous density maxima (on the order of 50) for all-behavior birds also occurred, both nearshore and midshore, some of which were mirrored by the sitting birds.

Comparing spring and fall for the 2008 and 2009, densities were relatively lower in spring than in fall. In spring 2008, three distinct localized density maxima occurred for all-behavior birds: (1) 745 nearshore just off Ocean City (compared to 730 for sitting birds, indicating that the majority of the birds in this region were sitting rather than flying); (2) 335 nearshore off Hereford Inlet (mirrored by a sub-maximum density on the order of 50 for sitting birds); (3) 135/km^2 midshore southeast of Ocean City (which is not mirrored by the sitting birds). In spring 2009, four distinct localized density maxima occurred for all-behavior birds: (1) 585 nearshore just south of Barnegat Light (compared to 370 for sitting birds); (2) 130 offshore east of Barnegat Light (which is not mirrored by the sitting birds); (3) 150 nearshore between Great Egg Harbor Bay and Atlantic City (compared to 140 for sitting birds); (4) 120 nearshore just off Hereford Inlet (compared to 110 for sitting birds).

Overall densities were generally lower in summer than in fall and spring for 2008 and 2009. In summer 2008, only one distinct localized density maximum occurred: 110 nearshore off Ocean City. Several sub-maximum densities (on the order of 25) occurred for all-behavior birds around Atlantic City and Brigantine. Densities were generally higher nearshore than offshore, and offshore densities were more patchily distributed for sitting birds than for all-behavior birds. Overall densities were slightly lower in summer 2009 than in summer 2008. In summer 2009, the spatial distribution of all-behavior density was more uniform nearshore than offshore. Nearshore sitting bird densities were lowest around Ocean City and Great Egg Harbor Bay, the region between Brigantine and Little Egg Inlet, and a small region just north of Little Egg Inlet.

Among winter and summer, overall densities were generally higher in winter than in summer (for both all-behavior and sitting birds). Among the three winter seasons, densities were generally lowest in 2008, highest 2009, and intermediate in 2010, partly reflecting the lower survey effort in the latter season. In all three winter seasons, densities were higher nearshore than offshore, and all-behavior densities were higher than sitting densities, reflecting the presence of both flying and sitting birds. In winter 2008, two localized density maxima occurred for all-behavior birds: (1) 475 nearshore between Atlantic City and Brigantine; and (2) 120 nearshore between Great Egg Harbor Bay and Atlantic City. In winter 2009, densities were higher than in winter 2008, with 13 localized nearshore density maxima occurring for all-behavior birds (ranging from 125 to 1,740) along the entire coastline, from the vicinity of Barnegat Light to Hereford Inlet. Eight of these 13 density maxima were mirrored by the sitting birds (ranging from 170 to 1,715). In winter 2010, five localized nearshore density maxima occurred: (1) 135 nearshore in the vicinity of Barnegat Light (compared to 110 for sitting birds); (2) 105 nearshore between Little Egg Inlet and Barnegat Light; (3) 235 nearshore between Brigantine and Little Egg Inlet (compared to 105 for sitting birds); (4) 120 nearshore at Brigantine (compared to 50 for sitting birds); (5) 105 nearshore midway between Ocean City and Hereford Inlet (compared to 50 for sitting birds).

Modeling Results

Modeling results are outlined in **Table 3-1** and **Table 3-2**. In general, depth and distance to shoreline were found to be important predictors of bird density and distribution. For example, using the combined two year dataset, it was determined that bird density and distribution declined in waters greater than 20 m (65.6 ft) in depth and 12.2 km (7.6 mi) from the coastline; however, there was a strong seasonal effect in these values that is important to consider. Although bird density was generally greater in the fall (i.e., migration and seasonal visitors take up residence along the New Jersey coastline), birds were principally concentrated in waters up to 20 m (65.6 ft) in depth and 12.2 km (7.6 mi) from the coastline; the same result was observed for the entire dataset. When the spring season was modeled, birds were found concentrated in deeper waters (>20 m [65.6 ft]) than in the fall (<20 m [65.6 ft]). Moreover, in summer, bird density ranged further offshore (18.3 km [11.4 mi]) and increased significantly in waters greater than 30 m (98.4 ft) in depth. In winter, bird density was concentrated in waters less than 15 m (49.2 ft) in depth and within 12.2 km (7.6 mi) from the coastline.

Total sitting bird density was modeled to identify where birds were most likely to reside, concentrate, and for some species, feed (i.e., loons, ducks, and gulls sitting on the water may indicate foraging locations). In general, sitting birds were most likely to occur in waters less than 15 m in depth and within 3.8 mi from the coastline. In fact, in fall, spring, and winter, sitting bird density was concentrated in waters within 6.1 km (3.8 mi) of the coastline, whereas in summer the distance increased to 18.3 km (11.4 mi).

The seasonal changes in density and distribution of total birds were dynamic and related to changes in bird community composition. For example, in the fall and winter there were dense concentrations of diving ducks that were absent in the summer when the bird community was primarily composed of terns, gulls and petrels. This difference in community composition was likely responsible for the varying degree of bird density clustered inshore and offshore. The models detected this and quantified habitat use by total birds as a function of depth and distance to shoreline. These dynamics were investigated further to quantify the effect of covariates for predicting changes in species distribution. Scoter density and distribution exhibited a peak in waters 10 m (32.8 ft) in depth and were concentrated within 6.1 km (3.8 mi) from the coast and decreased offshore to approximately 30.6 km (19 mi) from the coast. Northern Gannets, which were present in each season, were generally concentrated in waters greater than 10 m (32.8 ft) in depth that were within 25.3 km (9.5 mi) from the coastline. Laughing Gulls and Common Terns, which were seasonal summertime breeders in New Jersey, displayed interesting distribution patterns. Laughing Gulls were generally concentrated within 7.6 km (4.7 mi) from the coast and decreased in waters greater than 15 m in depth. On the other hand, Common Terns ranged further offshore and their density declined around 18.3 km (11.4 mi) from the coast, and thereby occupied a wider range of coastal habitat than Laughing Gulls. The density and distribution of Cory Shearwaters, which were also summertime visitors, showed an increase in density offshore in waters greater than 30 m (98.4 ft) in depth to approximately 27.3 km (17 mi) from the coastline.

Table 3-1. General summary of effect of spatial covariates on bird density based on GAM results: (a) description of effect. [DistShore = distance from shoreline; DistShoal = distance to shoal]

Covariate	Effect on bird density		
	+	-	+/-
Depth	Density increased in shallower water	Density increased in deeper water	Effect on density was mixed
Slope	Density increased with slope	Density decreased with slope	Effect on density was mixed
DistShore	Density increased with distance from shoreline	Density decreased with distance from shoreline	Effect on density was mixed
DistShoal	Density increased with distance to nearest shoal	Density decreased with distance from nearest shoal	Effect on density was mixed
Longitude	Density increase indicated more birds in the eastern portion of the Study Area	Density decrease indicated more birds in the western portion of the Study Area	Effect on density was mixed
Latitude	Density increase indicated more birds in the northern portion of the Study Area	Density increase indicated more birds in the southern portion of the Study Area	Effect on density was mixed

Table 3-2. Covariate effect on bird density. [DistShore = distance from shoreline; DistShoal = distance to shoal]

Bird Variable	Depth	Slope	DistShore	DistShoal	Longitude	Latitude
Total birds	+		-		+	-
Total birds 'Fall'	+		-		+	-
Total birds 'Spring'	-		-		-	
Total birds 'Summer'	+/-		-	+/-	+	-
Total birds 'Winter'	+	-	-		+	-
Total sitting birds	+	-				
Total sitting birds 'Fall'	+	+	-			+/-
Total sitting birds 'Spring'	-	+/-			-	+
Total sitting birds 'Summer'	+/-		+/-	+/-	+/-	
Total sitting birds 'Winter'	+		-			
Northern Gannet			-	+	+	-
Scoter Species			+/-	+	-	+
Long-tailed Duck		+/-	-		+	-
Common Loon	-				-	
Red-throated Loon			+/-	+	-	
Herring Gull	+		+	+	-	+
Laughing Gull	+		-		+	-
Common Tern			-	+/-	+	-
Wilson's Storm Petrel			+		-	+
Cory Shearwater	-		+/-	+/-	+/-	

Overall, bird density and spatial distribution exhibited a striking onshore to offshore gradient that was highly variable among seasons and lined to changes in community composition. The results pinpoint where repeated maximum densities are likely to occur in relation to a variety of species. This information was integral to the understanding of the spatial ecology of marine birds along the New Jersey coastline and should be used to examine potential changes in habitat due to environmental changes from human activity (e.g., offshore wind development, water quality degradation).

Along with the kernel density maps that show where and when birds are likely to concentrate, it was determined that distance to shoreline and depth were useful and important predictors of changes in bird density and distribution. Kernel density maps were a valuable tool for identifying important locations where and when (by month and season) birds are most likely to concentrate. Depth and distance to shoreline were important predictors of bird density and distribution. Overall, bird density declined significantly in waters greater than 20 m (65.6 ft) and 12.2 km (7.6 mi) from the coastline. Total bird density was greater within the southeast portion of the Study Area during fall, summer, and winter but was more concentrated in the north section of the Study Area during spring.

3.1.2 Marine Mammal and Sea Turtle Study Results

This baseline study included the first year-round, systematic survey effort for marine mammals and sea turtles in nearshore waters of New Jersey. Both aerial and shipboard surveys were designed to estimate marine mammal and sea turtle distribution and abundance using standard systematic line transect methodology. The objective of this survey was to determine the spatial distribution and to estimate the abundance/density of marine mammals and sea turtles in the Study Area. This baseline survey was conducted over a 24-month period between January 2008 and December 2009. The three sampling techniques conducted during this study included aerial line transect surveys, shipboard line transect surveys, and PAM.

Shipboard and aerial line transect surveys are a type of distance sampling method and were used to collect data on marine mammal and sea turtle species found in the Study Area. The surveys covered 26,377 km (14,243 NM) of effort. A total of 615 sightings of marine mammals and sea turtles were recorded; 486 of these sightings were recorded while the survey teams were on effort in the Study Area. The on-effort sightings data collected via these surveys were used to assess spatial and temporal distributions in abundance for all species (or groups) for which there were a sufficient number of sightings. Both Conventional Distance Sampling (CDS, design-based approach) and Density Surface Modeling (DSM, model-based approach) methods were used to estimate abundance/density for these species or groups. The CDS method was used to generate abundance/density estimates for the overall Study Area, and the DSM method was used to generate surface maps of predicted density at a finer spatial resolution using various environmental covariates as predictors of density. These spatial outputs were combined with the other natural resource layers of the environmental sensitivity index which can be used to assess more or less suitable portions of the Study Area for energy power facilities based on potential ecological impacts.

Stationary PAM was conducted using autonomous marine audio recorders (pop-ups) for six three-month deployment periods to determine the presence of vocalizing cetaceans in the Study Area. Because whales and dolphins produce sounds in distinctly different frequency ranges, two sampling frequencies were employed to detect for baleen and toothed whales. Baleen whales typically produce sounds below 2 kHz while toothed whales, especially dolphins, produce sounds between about 1 and 130 kHz. Therefore, 2-kHz and 31.25-kHz sample rates were coded into different pop-ups during each deployment to facilitate potential detection of marine mammal vocalizations. The PAM acoustics data often provided additional information on species occurrence in the Study Area that was not captured from visual observations. The data were analyzed with custom software algorithms to detect fin whale and North Atlantic right whale calls. The data were also manually reviewed for delphinid calls because call detection algorithms were not available for other cetacean species. Because a cumulative 4.42 years of audio data were collected during the course of the study, manual review for species with highly variable calls (humpback whales [*Megaptera novaeangliae*]) was not possible.

Ten of the 47 possible species to occur in the Study Area were detected visually and/or acoustically during the baseline study period. Detected species included the following five federally threatened or endangered species: North Atlantic right whale, fin whale (*Balaenoptera physalus*), humpback whale, leatherback turtle, and loggerhead turtle. The minke whale (*Balaenoptera acutorostrata*), bottlenose dolphin, short-beaked common dolphin (*Delphinus delphis*), harbor porpoise (*Phocoena phocoena*), and harbor seal were also detected.

Some clear seasonal patterns in distribution were evident from our study. Although all of the 10 species detected during this survey could occur in the Study Area at any time, only the North Atlantic right whale, fin whale, humpback whale, and bottlenose dolphin were detected during all seasons. The occurrence of dolphins and porpoises, as well as turtles, was largely seasonal. Bottlenose dolphins, loggerheads, and leatherbacks mostly occured in the Study Area in the summer while short-beaked common dolphins and harbor porpoises were common in the Study Area during the winter and spring. The fall season appeared to be a transitional period for seasonal cetacean species. Few sightings of bottlenose dolphins and short-beaked common dolphins were recorded during the fall despite the large amount of survey effort. It is likely that most bottlenose dolphins move south of the Study Area, and most short-beaked common dolphins and harbor porpoises are farther north during this time of year.

Of particular ecologic importance are the sightings/acoustic detections of endangered large whale species, the North Atlantic right whale, fin whale, and humpback whale. Each of these species was detected during all seasons, including those seasons during which North Atlantic right and humpback whales are known to occupy feeding grounds north of the Study Area or breeding/calving grounds farther south of the Study Area. Cow-calf pairs of each of these species were also observed in the Study Area. Two North Atlantic right whales exhibited possible feeding behavior, and one humpback whale was observed lunge feeding off the coast of Atlantic City. Based on these occurrences and behavioral observations, the nearshore waters off New Jersey may provide important feeding and nursery habitat for these endangered species. Peak densities were predicted throughout the Study Area for these species and, although the overall abundance estimates of the whale species were relatively low, the Study Area is only a very small portion of the known ranges of these species. These species may use the waters of the Study Area for short periods of time as they migrate or follow prey movements or they may remain in the Study Area for extended periods of time. High concentrations of these species were not documented in the Study Area at any time during the survey period; however, the presence of these endangered large whale species in New Jersey waters indicated that these animals used the area as habitat. The detections of these species in the Study Area, particularly during times of the year when they are thought to be in other areas, demonstrated the potential importance of the Study Area. The occurrence of these endangered species provided critical information on the distribution of the species in this region.

The density and abundance of the dolphin and porpoise species were relatively high for the Study Area. The highest abundances of marine mammals in the Study Area were estimated for the bottlenose dolphin during spring and summer. These bottlenose dolphins are thought to belong to the coastal northern migratory stock which occupies a small range between Long Island, New York and southern North Carolina. The high abundances of bottlenose dolphins in the Study Area coincided with the known movement of this stock into the northern portion of their range. High abundances of short-beaked common dolphins in the Study Area coincided with their known movement patterns south of 40ºN in the winter/spring. High abundances of harbor porpoises also occurred during the winter when the New Jersey waters and the waters of the New York Bight provide an important habitat for this species.

More information on the results of this baseline survey is summarized below for each species.

3.1.2.1 Endangered Marine Mammals

North Atlantic Right Whale

There is little information on the geographic and temporal extent of the North Atlantic right whale's migratory corridor (Winn et al. 1986); however, our sightings data of females in the Study Area and subsequent confirmations of these same individuals in the breeding/calving grounds a month or less later indicate that the nearshore waters of New Jersey are part of the migratory corridor between feeding grounds in the northeast and breeding/calving grounds in the southeast. The cow-calf pair sighted in the Study Area in May 2008 was previously confirmed in the southeast in January and February and subsequently sighted in the Bay of Fundy in August. Our observations and acoustic detections are consistent with the known migration time periods. Between mid-January and mid-March 2009, North Atlantic right whale calls were detected on the pop-up located 21.4 km (11.6 NM) from shore. All North Atlantic right whale sightings in the Study Area were recorded within 32 km (17 NM) from shore, and high densities of endangered marine mammals were predicted throughout the Study Area between 2 and 37 km (1 and 20 NM) from shore. These distances from shore are consistent with a review of previous sightings data collected in the mid-Atlantic that found that 94% of all sightings of North Atlantic right whales were within 56 km (30 NM) from shore (Knowlton et al. 2002).

The seasonal movement patterns of North Atlantic right whales are well-defined along the U.S. Atlantic coast; however, not all individuals adhere to these patterns and the seasonal distribution of these individuals is unknown. For example, a majority of the population is not accounted for on the breeding/calving grounds during winter, and not all reproductively-active females return to these grounds each year (Kraus et al. 1986). Some individuals, as well as cow-calf pairs, can be seen throughout the fall and winter on the northern feeding grounds with feeding observed (e.g., Sardi et al. 2005), and about half of the population may reside in the Gulf of Maine between November and January based on recent aerial survey data (Cole et al. 2009). Right whale sightings and acoustic detections in the Study Area provide additional evidence of occurrence outside of the typical seasonal migration periods. Although actual feeding could not be confirmed during our survey, the January 2009 sighting of two adult males exhibiting skim feeding behavior off Barnegat Light suggests that feeding may occur outside the typical feeding period of spring through early fall and in areas farther south than the main feeding grounds (Winn et al. 1986; Gaskin 1987; Hamilton and Mayo 1990; Gaskin 1991; Kenney et al. 1995). Acoustic detections of North Atlantic right whale calls confirm the occurrence of this species in the Study Area during all seasons with a peak number of detection days in March through June. The documented detections and sightings of North Atlantic right whales in the Study Area suggest that some individuals occur in the nearshore waters off New Jersey either transiently or regularly.

Due to the low number of sightings recorded during the study period, no estimates of abundance could be generated for this species. The pooled year-round abundance of endangered marine mammals, including North Atlantic right whales, in the Study Area was three individuals which should be considered an underestimate due to perception bias and availability bias for large whales which can make long dives; however, based on the migratory nature of this species, a low abundance of this species could be expected for the Study Area, particularly if the North Atlantic right whales mainly use the nearshore waters of New Jersey as a migratory corridor and are not spending a significant amount of time in the region. This estimate is also reasonable due to the low overall abundance (438 individuals) of this stock of North Atlantic right whales (NARWC 2009). Based on the endangered status and low overall abundance of this species, the detection of even one right whale in the Study Area is an important occurrence. We recommend the inclusion of nearshore waters off New Jersey in future North Atlantic right whale studies to better understand the importance of these waters to this species, particularly during the winter months when migrating individuals and possible feeding were documented in the Study Area.

Humpback Whale

Humpback whales were recorded in the Study Area during all seasons. Seven of the 17 sightings were recorded during the winter when many individuals are known to occur on breeding/calving grounds in the West Indies (Whitehead and Moore 1982; Smith et al. 1999; Stevick et al. 2003). Our winter sightings are consistent with other observations of this species in mid- and high latitudes during this time of year (Clapham et al. 1993; Swingle et al. 1993; Charif et al. 2001). Humpback whales could not be acoustically detected during our study period because of the lack of call detection software for this species which has highly variable vocalizations.

Humpback whale feeding grounds are typically over shallow banks or ledges with high sea-floor relief (Payne et al. 1990; Hamazaki 2002). The main feeding locations off the northeastern U.S. are north of the

Study Area in waters off Massachusetts, in the Gulf of Maine, in the Bay of Fundy and surrounding areas (CETAP 1982; Whitehead 1982; Kenney and Winn 1986; Weinrich et al. 1997). There are documented feeding areas for this species south of the Study Area near the mouth of Chesapeake Bay, as well (Clapham et al. 1993; Swingle et al. 1993; Wiley et al. 1995; Laerm et al. 1997; Barco et al. 2002). The lunge feeding behavior observed by one individual humpback whale in September indicates that New Jersey nearshore waters may also be an alternate feeding area for this species. This humpback whale was lunge feeding in the vicinity of an individual fin whale; multi-species feeding aggregations that include humpback whales have also been observed over the shelf break on the southern edge of Georges Bank (CETAP 1982; Kenney and Winn 1987) and in shelf break waters off the U.S. mid-Atlantic coast (Smith et al. 1996).

An abundance estimate for the humpback whale in the Study Area was generated using the pooled detection function for the endangered marine mammals group. The year-round abundance of this species was estimated at one individual; however, this should be considered an underestimate due to perception and availability bias (i.e., diving). The humpback whales occurring in the Study Area are most likely part of the Gulf of Maine stock. In fact, one individual photographed in the Study Area in August 2009 was previously sighted in the Gulf of Maine the year before. Due to the migratory nature of the humpback whale, the relative low estimated abundance in the Study Area is not unexpected.

Fin Whale

The fin whale was the most commonly-detected baleen whale species in the Study Area during the study period. This is the most commonly sighted large whale in shelf waters of the U.S. north of the mid-Atlantic region (CETAP 1982; Hain et al. 1992; Hamazaki 2002). Fin whales were visually detected in the Study Area during all seasons which is consistent with previous sightings of fin whales year-round in the mid-Atlantic region (CETAP 1982; Hain et al. 1992). Fin whale pulses and downsweeps were detected in every month of acoustic monitoring during this baseline study. Fin whales are believed to follow the typical baleen whale migratory pattern consisting of movement between northern summer feeding grounds and southern winter breeding/calving grounds (Clark 1995; Aguilar 2009); however, not all individuals in the western North Atlantic stock undergo this seasonal migration (Aguilar 2009). Our year-round sightings and acoustic detections further support the occurrence of fin whales in this region outside of the typical migratory periods.

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 (Hamazaki 2002). Relatively high densities of fin whales were predicted throughout most of the Study Area including in waters as shallow as 12 m (39 ft) and very close to shore (2 km [1 NM]). The year-round estimated abundance (two individuals) is low for the Study Area; however, abundance should be considered an underestimate due to perception and availability bias in large whales (i.e., whales making long dives are not available for detection at the surface). The occurrence of fin whales in the Study Area is important due to the endangered status of this species. In addition, the occurrence of a fin whale calf with an adult in August 2008 suggests that nearshore waters off New Jersey may provide important habitat for fin whale calves.

3.1.2.2 Non-Threatened or Endangered Marine Mammals

Minke Whale

Minke whales are most likely to occur in the mid-Atlantic region during winter, but this species is widespread in U.S. waters. Sightings of this species in the Study Area during winter are consistent with the known movement of minke whales southward from New England waters from November through March (Mitchell 1991; Mellinger et al. 2000). Occurrence of minke whales in New England waters increases during the spring and summer and peaks from July through September (Murphy 1995; Risch et al. 2009; Waring et al. 2009). The June sightings recorded during our study period may have been of individuals moving back to New England waters for the summer. Because only four sightings of minke whales were recorded during the study period, no abundance estimates could be generated for this species.

Bottlenose Dolphin

The bottlenose dolphin was the most frequently-sighted species in the Study Area. Although this species was sighted during all seasons, bottlenose dolphin distribution was highly seasonal with most sightings occurring during the spring and summer months, particularly May through August. These sightings data are consistent with the known seasonal distribution patterns of the coastal northern migratory stock of bottlenose dolphins which occur in waters from New York to North Carolina in the summer and are found from southern Virginia to Cape Lookout, North Carolina in the winter (CETAP 1982; Kenney 1990; Garrison et al. 2003; Hohn and Hansen 2009; Waring et al. 2009; Toth et al. in press). Based on our sightings data, bottlenose dolphins move into the Study Area as early as the beginning of March and occur there until at least mid-October. The delphinid whistles detected between March and October are most likely of bottlenose dolphins. The estimated abundances of bottlenose dolphins in the Study Area during the spring (mostly June; 722) and summer (289 ship analysis, 1,297 aerial analysis) are comparable to the estimated abundance of the coastal northern migratory stock (7,789; Waring et al. 2009). A peak number of days (69) with delphinids whistle detections were also recorded during spring and summer. Only seven sightings were recorded during the fall/winter; therefore, abundance is likely much lower during this time of year when most of the coastal northern migratory stock is farther south off the coasts of Virginia and North Carolina. The seasonal occurrence of bottlenose dolphins off New Jersey is thought to be due to the presence of preferred prey species that also occur seasonally in New Jersey waters (Able and Fahay 1998; Gannon and Waples 2004).

Bottlenose dolphins are known to have a fine-scale distribution within the Study Area based on research by Toth-Brown et al. (2007) who found a significant break in the habitat usage of bottlenose dolphins in New Jersey's nearshore waters (out to 6 km [3.2 NM] from shore). One group appeared to utilize waters within 2 km (1.1 NM) of the shore while the other group occupied waters outside of 2 km (1.1 NM) of shore. Due to limitations obtaining high quality photo-identification data during the baseline survey, this fine-scale distribution pattern was not evident from our results; however, our results emphasize the importance of New Jersey's nearshore waters to bottlenose dolphins. Sightings were recorded close to shore (minimum 0.3 km [0.16 NM]), and peak densities were predicted in state waters (0 to 5.5 km [0 to 3 NM] from shore) off Atlantic City north to Brigantine and Little Egg Inlet during spring and farther north off Barnegat Light and Barnegat Bay during summer. Toth et al. (in press) identified higher levels of use and increased presence of young individuals in the very nearshore waters off Brigantine, just north of Atlantic City.

Several bottlenose dolphin sightings were also recorded in deeper waters (34 m [112 ft]) of the Study Area and farther offshore (maximum 38 km [21 NM] from shore), suggesting that their distribution within the Study Area is not limited to a particular depth range or distance from shore. High densities were predicted in some regions of the Study Area up to 28 km (15 NM) from shore in the spring and 36 km (19 NM) from shore in the summer. Predicted densities were more interspersed throughout the northern/southern range of the Study Area during summer, indicating that higher densities of bottlenose dolphins extend into the northern portion of the Study Area (north of Barnegat Light) during this time of year. Peak densities were predicted from the shoreline to 36 km (19 NM) offshore of Barnegat Light/ Barnegat Bay and along the federal/state boundary (5.5 km [3 NM] from shore).

Short-beaked Common Dolphin

The occurrence of this species in the Study Area was strongly seasonal; sightings were only recorded during fall and winter, specifically late November through mid-March. The short-beaked common dolphin was the only delphinid species sighted during the winter, except for one bottlenose dolphin sighting recorded in early March. Therefore, the delphinid whistles recorded from December through at least February were likely of short-beaked common dolphins. This occurrence pattern is consistent with the known seasonal movements of short-beaked common dolphins offshore of the mid-Atlantic in colder months (Payne et al. 1984; Jefferson et al. 2009; Waring et al. 2009).

Although short-beaked common dolphins primarily occur offshore (>37 km [20 NM]) in waters of 200 to 2,000 m in depth (656 to 6,562 ft; Ulmer 1981; CETAP 1982; Canadian Wildlife Service 2006; Jefferson et al. 2009), our sightings data support the occurrence of this species in shallower waters close to shore. Short-beaked common dolphins were sighted throughout the Study Area in waters 3 to 37 km (2 to 20 NM) from shore and 10 to 31 m (33 to 102 ft) in depth. Almost all of the sightings of delphinids recorded during winter were of short-beaked common dolphins. High densities of delphinids were predicted south of Barnegat Light during the winter. Peak densities were predicted in nearshore waters (0 to 5.5 km [0 to 3 NM] from shore) from Brigantine to Little Egg Inlet and 30 km (16 NM) offshore of Little Egg Harbor. Peak densities were also predicted between 21 and 32 km (11 to 17 NM) from shore in the southeastern portion of the Study Area.

A winter abundance estimate was generated for this species using the pooled detection function of all delphinids during this season. The estimated abundance was 82 individuals; this estimate may be high due to the attraction of delphinids to the ship (e.g., bowriding); however, because perception and availability bias were not accounted for, the abundance estimate should be considered underestimated. Only eight short-beaked common dolphin sightings were recorded during the fall. Although abundance estimates could not be generated for this season, the abundance of this species is expected to be lower during this time of year. No sightings of short-beaked common dolphins were recorded during spring or summer. Although this species has been recorded near the Study Area during these seasons (CETAP 1982; Canadian Wildlife Service 2006), abundance in the Study Area is expected to be very low during this time of year.

Harbor Porpoise

Harbor porpoise distribution in the western North Atlantic is seasonal, and New Jersey waters are a known important habitat for harbor porpoises from January through March (Westgate et al. 1998). The sightings of harbor porpoises recorded during the study period support this statement with over 90% of sightings recorded during winter (mainly February and March). Few sightings were also recorded in April, May, and July which indicates that this species could occur in the Study Area during other times of the year. No harbor porpoise sightings were recorded during the fall surveys; however, weather conditions were often above a Beaufort sea state (BSS) of 2 which makes sighting this species very difficult. The densest concentrations of harbor porpoises are thought to occur from New Jersey to Maine from October through December (NMFS 2001a). Therefore, harbor porpoises are likely to occur in the Study Area throughout the fall. Due to the low number of sightings throughout the year, an abundance estimate for the harbor porpoise could only be generated for the winter. The winter abundance of harbor porpoises in the Study Area was estimated at 98 individuals. Abundance is likely underestimated due to this species' known responsive movement away from ships and perception and availability bias (Barlow 1988; Polacheck and Thorpe 1990; Palka and Hammond 2001).

Harbor porpoises are known to occur most frequently over the continental shelf and are most often found in waters cooler than 17°C (Read 1999). Sightings data from the study period provide support for these habitat associations of the harbor porpoise. Sightings of this species were recorded between 1.5 and 37 km (1 and 20 NM) from shore in waters ranging from 12 to 30 m (39 to 98 ft). SSTs for the harbor porpoise ranged from 4.5 to 18.7°C (40.1 to 65.7°F) which is just slightly higher than the typical maximum SST of 17°C (Read 1999). High densities of harbor porpoises were predicted in the center of the Study Area between 39°04'10"N and 39°45'34"N and between -74°26'41"W and -73°53'36"W. Peak densities were predicted between 5.5 and 15 km (3 and 8 NM) from shore and also 34 km (18 NM) from shore north of Brigantine.

Harbor Seal

Only one harbor seal was recorded in the Study Area during the study period. This seal was sighted in shallow waters east of Little Egg Inlet in June. Other unidentified pinnipeds recorded near Ocean City in April were likely also harbor seals but could not be confirmed. Harbor seals regularly haul out near Great Bay inshore of the Study Area and along the northern shore of the New York Bight, including Sandy Hook and the coasts of Rhode Island, Connecticut, and Massachusetts (Payne and Selzer 1989; Barlas 1999;

Schroeder 2000; DeHart 2002; Di Giovanni et al. 2009; Antonucci et al. n.d.). The harbor seal observed in June was likely from one of these haulout regions. No haulout sites were detected along the beach adjacent to the Study Area during the shoreline aerial surveys. Although harbor seals could be found in the Study Area during any time of year, they are known to make seasonal movements in New Jersey waters during the winter (Slocum et al. 1999). Although no sightings of harbor seals were confirmed in the Study Area during winter, one probable harbor seal was sighted south of the Study Area near Lewes, Delaware, where the survey vessel was docked in March 2008.

3.1.2.3 Sea Turtles

Leatherback Turtle

Leatherback turtles have a seasonal occurrence in the mid-Atlantic; they are most common off the mid-Atlantic and southern New England coasts in the spring and summer (CETAP 1982; Shoop and Kenney 1992; Thompson et al. 2001; James et al. 2006). All 12 sightings of this species were recorded in the Study Area during summer. Sightings were recorded in deeper, offshore waters of the Study Area ranging from 10 to 36 km (5 to 19 NM) from shore and water depths of 18 to 30 m (59 to 98 ft). Leatherbacks foraging in the western North Atlantic are known to associate with waters between 16 to 18°C (60 to 64°F; Thompson et al. 2001; James et al. 2006), and SSTs between 10 to 12°C (50 to 54°F) may represent the lower thermal limit of this species (Witt et al. 2007). The sightings recorded during the study period had a mean SST of 19.0°C (66°F) which is only slightly higher than the preferred SST for foraging leatherbacks; the lack of sightings during the colder months is consistent with this species preference for warmer SST. Abundance of leatherback turtles in the Study Area is unknown because abundance estimates could not be generated for this species.

Loggerhead Turtle

Loggerhead turtle occurrence along the U.S. Atlantic coast is strongly seasonal. Although sightings are recorded in mid-Atlantic and northeast waters year-round, loggerheads occur mainly north of Cape Hatteras between May and October (CETAP 1982; Lutcavage and Musick 1985; Shoop and Kenney 1992). Loggerheads sighted during the study period were consistent with this seasonal occurrence pattern; sightings were recorded between June and October. The mean SST associated with these sightings was 18.5°C (65.3°F) which is within the preferred SST range for this species (13° to 28°C [55° to 82°F]; Mrosovsky 1980). Sightings were recorded throughout the Study Area from 1.5 to 38 km (1 to 21 NM) from shore and in water depths ranging from 9 to 34 m (30 to 112 ft). Due to difficulties in measuring the perpendicular distances of the loggerhead sightings from the aerial survey tracklines, abundance estimates could not be generated for the Study Area.

3.1.3 Fish and Fisheries Results

3.1.3.1 Commercial Fisheries

Fish and fisheries are among the most important and economically valuable natural resources to the State of New Jersey. In terms of economic value, the total value of commercial fisheries landed in New Jersey from 2003 through 2007 was nearly one billion dollars; however, the actual value to the region is likely far greater in terms of the jobs, goods, and services associated with these fisheries. In 2007, commercial fisheries in New Jersey ranked eighth in value and tenth in landings in the U.S.[13] The top 5 commercial species landed in New Jersey during this five-year period were Atlantic surfclam, Atlantic sea scallop, ocean quahog, goosefish (monkfish), and summer flounder. Within the Study Area, the clam dredge, targeting Atlantic surfclam and ocean quahog, is the primary commercial fishing gear utilized in terms of value and landings (43%). The Atlantic surfclam is the primary landed commercial species, whereas the Atlantic sea scallop is the most economically valuable species.[13]

3.1.3.2 Recreational Fishing Locations

Recreational fishing within and adjacent to the Study Area is an important social and economic activity. The annual number of angler trips in New Jersey from 2003 through 2007 ranged from 6.5 million in 2004 to 7.4 million in 2007. According to NMFS (MRIP), the primary species landed from 2003 to 2007 was summer flounder. Summer flounder represented 40.8% of the total landings, while bluefish and black sea bass represented 18.9 and 18.2%, respectively.[14] There are numerous fishing hotspots (143 – see **Volume IV: Figure 3-18**) with 57% of these located in the southern half of the Study Area. These areas consist of structural features, such as shoals, ridges, lumps, banks, shipwrecks, and reefs (artificial and natural: rocks). Each of these structural features provides prime fishing sites for anglers targeting specific species, such as Atlantic striped bass and bluefish around shoals; bluefish and flounder near ridges; and black sea bass and tautog around shipwrecks/reefs (Saltwater Directions 2003c; 2003b; 2003a). In addition, the New Jersey Artificial Reef Program is one of the largest on the East Coast consisting of over 1,000 reefs and 100 vessels dispersed among 15 ocean sites of which 9 sites are located within the Study Area (NJDEP 2008a). Organized fishing tournaments are popular public events that take place within or in the vicinity of the Study Area.[18,19,20]

3.1.3.3 New Jersey Fisheries Independent Monitoring Data

The Study Area also provides important habitats to many juvenile fish and invertebrates having economic and ecological importance. Trends in these juvenile fish and invertebrate populations were analyzed by utilizing the ocean trawl data (New Jersey OSA survey program) from 2003 to 2008. New Jersey Fisheries independent monitoring program provided information on the spatial and temporal variability of the fish community in the Study Area (NJDEP 2009). Data were compiled and sorted into two separate groups according to landings (i.e., top 10 species numerically collected) and economic value (i.e., top 5 species [$US]). According to the New Jersey OSA defined strata (areas 15 to 23: see **Volume IV: Figure 4-1**), it was demonstrated that the coastal fishery landings within the Study Area are equally important numerically to juvenile butterfish, scup, squid, and Atlantic herring and economically to squid. Numerically, scup was the dominant fishery in 2003, squid in 2004 and 2005, and butterfish from 2006 to 2008. Economically, squid was dominant from 2003 to 2008. Summer and fall were the most important seasons in terms of relative juvenile fish abundance, while winter and spring the least important. Summer was dominated numerically by butterfish, spring and fall by Atlantic herring and scup, and winter by Atlantic herring, with squid economically dominating both summer and fall. Juvenile butterfish abundance was widely distributed and numerically dominant in 56% of OSA defined areas. In summer, butterfish abundance was highest in areas 16 and 19 and scup and squid abundance highest in areas 17 and 23, respectively. Atlantic herring abundance was highest in area 22. Economically, the squid abundance was highest in all areas in the summer except areas 18 and 21, which were the most diverse areas within the Study Area (NJDEP 2009).

3.1.3.4 Essential Fish Habitat

Marine resources (fish and invertebrates) that are found within the Study Area are managed through an elaborate process that includes the State of New Jersey, Fishery Management Councils (FMCs), ASMFC, and NMFS. The Magnuson-Stevens Fishery Conservation and Management Act (MSFMCA), as amended by the Sustainable Fisheries Act (SFA), requires the identification and description of EFH in the fishery management plans (FMPs) and the consideration of actions to ensure the conservation and enhancement of such habitat. The EFH regulatory guidelines (50 Code of Federal Regulations [CFR] 600.815) state that NMFS should periodically review and revise EFH, as warranted, based on available information.

On June 12, 2009, NMFS announced the availability of a final integrated EIS and Amendment 1 to the 2006 Consolidated Atlantic HMS FMP pursuant to the National Environmental Protection Act (NEPA) that amended the existing EFH identifications and descriptions for 44 managed (NMFS 2009b). Currently, 14 managed HMS species occur within the Study Area. Updated EFH descriptions and maps for all 14 species are described in **Volume IV: Appendix A** and illustrated in **Figures A-25** through **A-38**.

In addition to the updated EFH for the Atlantic HMS managed by NMFS, both the NEFMC and the MAFMC are also in the process of proposing changes to the EFH components of the FMPs under their jurisdiction (NEFMC 2007; MAFMC 2010). Approval of the updated textual descriptions and geographical identifications of EFH may result in changes to the EFH designations for some of the current species and/or add new (i.e., juvenile Atlantic sea scallop) species in the Study Area.

3.1.3.5 Federal Protected Species

Within or near the vicinity of the Study Area, there are various fish species found that are either protected by the federal government (e.g., USFWS and NMFS) and/or State of New Jersey.[16,21] Although the endangered shortnose sturgeon is the only federally listed fish species that may be found in the vicinity of the Study Area (i.e., Delaware River), there are also no known shortnose sturgeon populations in the rivers between the Hudson and Delaware rivers (NMFS 1998). This species is not known to make coastal migrations (Dadswell et al. 1984). In addition, there are five species of concern (alewife [*Alosa pseudoharengus*], blueback herring [*Alosa aestivalis*], dusky shark [*Carcharhinus obscures*], sand tiger shark [*Carcharias taurus*], and barndoor skate [*Dipturus laevis*]) and one candidate species found within or in the vicinity of the Study Area. The migratory Atlantic sturgeon, a candidate species, commonly aggregates in shallow (10 to 50 m [32.8 to 164.1 ft]) near shore areas within the Study Area (Stein et al. 2004; Atlantic Sturgeon Status Review Team 2007). NMFS is currently preparing a determination on whether listing the species or multiple DPSs of the Atlantic sturgeon as threatened or endangered is warranted (NMFS 2010).

4.0 SENSITIVITY INDEX

4.1 OVERVIEW

GMI developed an ESI that synthesizes the physical, biological, and socioeconomic resources data of the Study Area. This ESI was designed to be a planning guide to assist regulatory agencies, developers, and the public with the rapid evaluation of environmental sensitivity and ecological importance of discrete areas within the Study Area (**Figure 4-1**). The collection of additional physical, biological, and socioeconomic data may be required by state and/or federal agencies for offshore development at specific sites for in-depth site-specific assessments.

4.2 INDEX DEVELOPMENT

The environmental sensitivity index was developed using data on physical, biological and socioeconomic resources (features) collected during field studies from January 2008 through December 2009, data published in the literature, and data gathered by governmental agencies such as NJDEP, NOAA, NMFS, and MMS. The resources (features) considered for the index included:

- Artificial reefs
- Marine protected areas (MPAs)
- Shoals
- Habitat areas of particular concern (HAPCs)
- EFH
- Known obstructions
- Known shipwrecks
- Unexploded ordnance (UXO)
- Shipping lanes
- Utility cables
- Modeled avian and marine mammal density data
- Sea turtle sightings per unit effort (SPUE) data
- Commercial fishing grounds
- Recreational fishing grounds

During development of the index, it was determined that shipping lanes, utility cables, obstructions, shipwrecks, and UXO were “prohibited development areas”; therefore, those features were shaded black on the index map (**Figure 4-1**). Two of the above listed resources were not included in the index, HAPCs and UXO. Only one designated HAPC was found within the Study Area. This HAPC is immediately adjacent to the Atlantic City/Brigantine areas (**see Volume IV: Appendix C**, **Figure C-32**). Since the HAPC was for a single, non-listed species, it was not included in the index but but should be noted for potential future development. As for the documented presence of UXO, no data could be obtained that corroborate local knowledge on locations of UXO within the Studty Area.

4.2.1 Spatial Index Creation with Geographic Information Systems

To create the map depicting the spatial relevance of independent physical, biological, and socioeconomic features within the Study Area, selected features were represented as mapping layers which were additively combined and displayed within a continuous surface. The manipulation and conversion of these selected input features allowed for different feature types to be combined for analysis. The majority of the features used to develop the index were in a vector format, either derived from hard copy georeferenced sources or existing databases. The vector data were converted into Boolean grids, a raster format which was classified as having either a presence (1) or absence (0). The production of these raster grids facilitated the use of features created by statistical and geographic analyses. The Inverse Distance Weighted Interpolation (IDWI) technique (GeoStatistical Analyst Tool for ArcGIS 9.3.1) was used to create mapping layers. The IDWI technique is driven by local variation, and the variation of values among the evenly distributed sample points throughout the Study Area. IDWI is an exact deterministic interpolator and was preferred over other methods such as Kriging. Kriging is most commonly used when a spatially correlated distance or directional bias in the data is known, when data come from a stationary process are normally distributed. For this study, the data were variable and dynamic.

The IDWI technique assumes that features that are closest to each other are more alike than those that are further apart. Values from features closest to the prediction location have a greater influence on the interpolated value for the prediction location than do values from features that are further away. Once the surface interpolation was complete, the features were ranked by classifying the data by the most appropriate means, such as Geometric Interval, Equal Interval, or Natural breaks and converted to raster grids using assigned rank values. The classification method used for the Marine Mammals Density and Sea Turtle SPUE data was Geometric Interval. Geometric intervals work well with data that are not normally distributed and heavily skewed with duplicate values, which was the case with the marine mammal and sea turtle data. The geometric interval classification scheme uses class breaks that are based on class intervals within a geometrical series, ensuring that each class range has approximately the same number of values and a consistent change between intervals. The Avian Density and EFH data were classified using Equal Interval breaks. This method was chosen for the avian data to simplify the interpretation of density contours and to highlight bird concentrations. In doing so, examples were followed of well known seabird density databases (e.g., Certain et al. 2007; McKinnon et al. 2009). Equal Interval for EFH was chosen as a simplistic means of assigning higher ranking to areas with the greatest EFH overlap.

Instead of a multi-classed representation, we used the largest number of classes possible for the ESI while still preserving the spatial distribution of the data. The processed, ranked, and classified data were then incorporated into a Boolean addition overlay. By adding rasters, the physical, biological, and socioeconomic features were synthesized to produce a comprehensive visual output.

The data collected for this study, whether physical or biological, were not combined and holistically modeled to develop the ESI. The differences in data collection techniques, acceptable models for different types of species, and the high variability among the numbers of sightings and individuals, would have generated outputs significantly skewed towards the species and/or groups with the highest number of individuals. Instead, the ESI is a compilation of the data that were modeled for the avian and marine mammal groups, layered with the feature data, and interpolated using IDWI, as described above.

4.2.2 Ranking Data

Physical, biological, and socioeconomic resources data were layered and mapped using the GIS techniques mentioned above to develop and display the ESI; however, each feature had to be assigned a weight or rank to show its environmental or ecological importance. Given the difficulty of ranking one physical resource over another; especially considering that shoals, artificial reefs, and shipwrecks each potentially support high species diversity and abundance, each physical resource was weighted equally with a ranking of 1. Yet, since almost 40 species of fish have designated EFH within the Study Area, all EFH layers were compiled and ranked from 1 to 3. For biological data, the modeled density data were ranked with a minimum value of 1 to a maximum value of 6, with higher densities receiving the highest rankings. By layering all of these features together, the ESI shows an effective index rating (sum of the rankings for all resources within a given location) for the entire Study Area.

4.2.3 Physical Features

The physical features within the Study Area were mapped by gathering available data from the NJDEP, NOAA, NMFS, MMS, U.S. Army Corps of Engineers (USACE), and published literature. The data were mapped in the most precise manner possible to limit distortion or exaggeration of the areal coverage of any given feature. Shipping lanes and utility cables, however, were given a 30.5-m (100-ft) buffer so that these features could be clearly identified on the map. Likewise, shipwrecks and obstructions, which are both point data, were represented by the smallest symbol possible (48-m [150-ft] diameter) that would be visible on a map even though it may not represent an actual size. All other physical resources data were polygons developed from the actual boundaries of each feature (**Figures 4-2** and **4-3**).

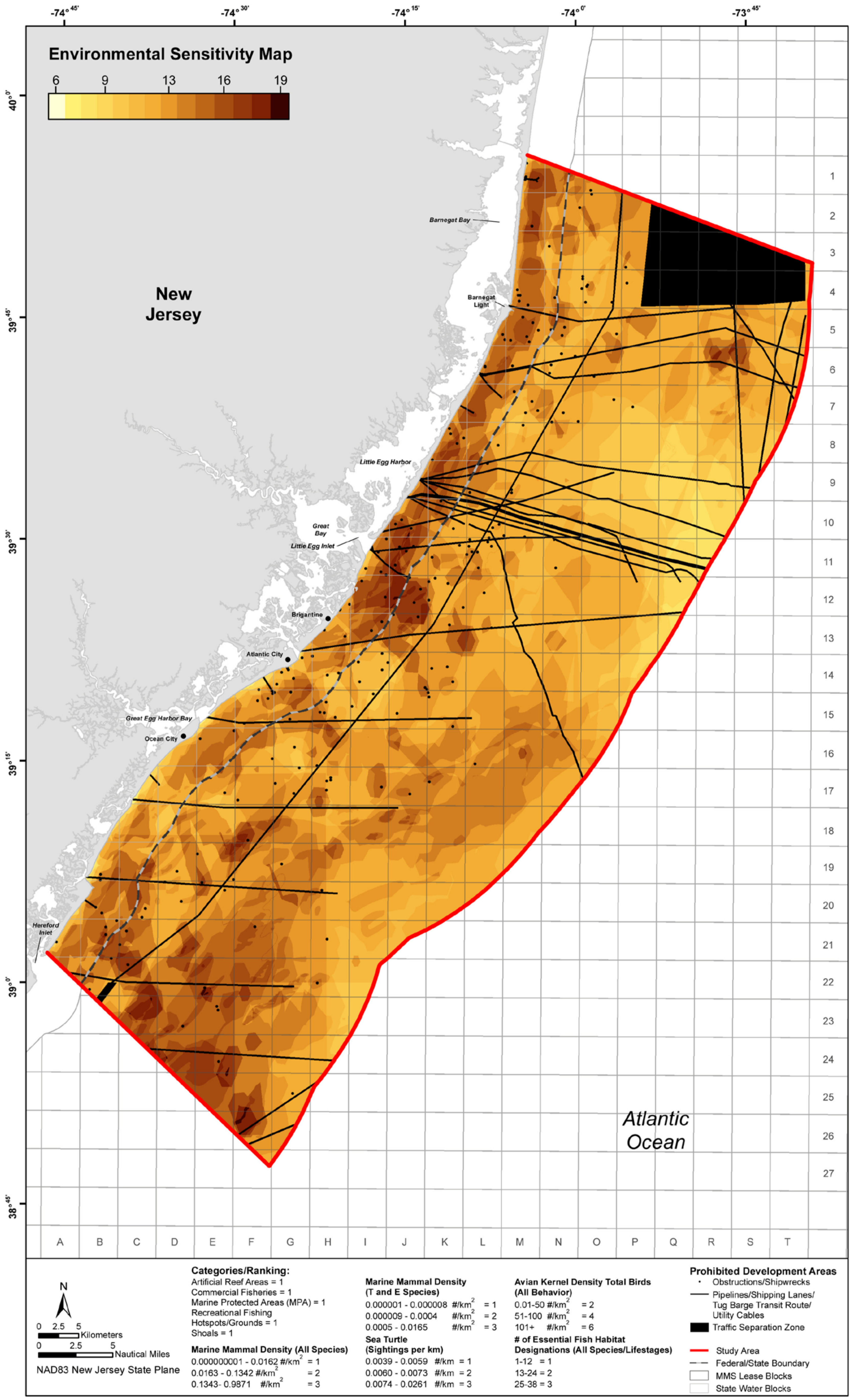

Figure 4-1. Map of the Environmental Sensitivity Index for the New Jersey Study Area.

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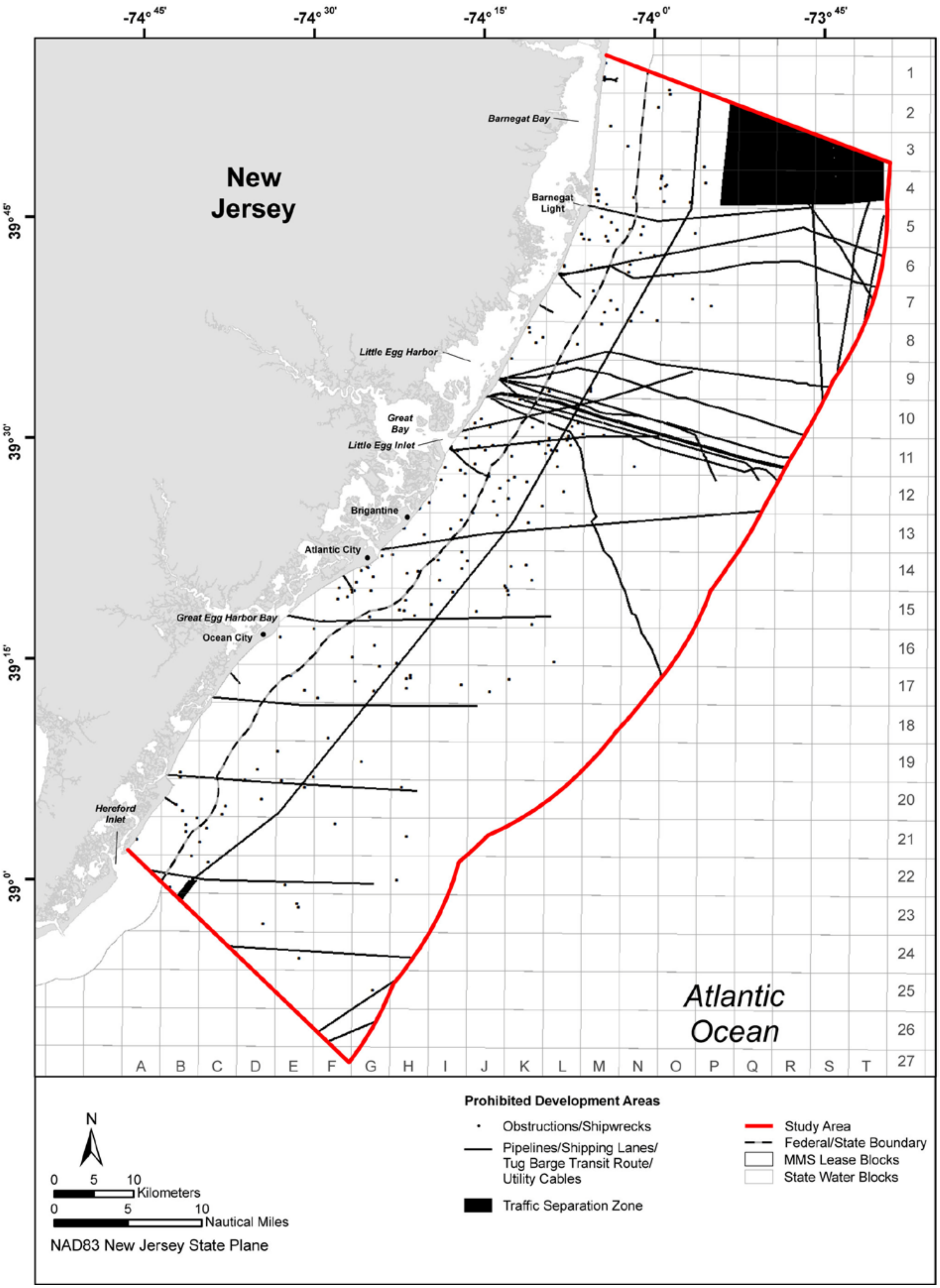

Figure 4-2. Prohibited development areas designated in the Environmental Sensitivity Index.

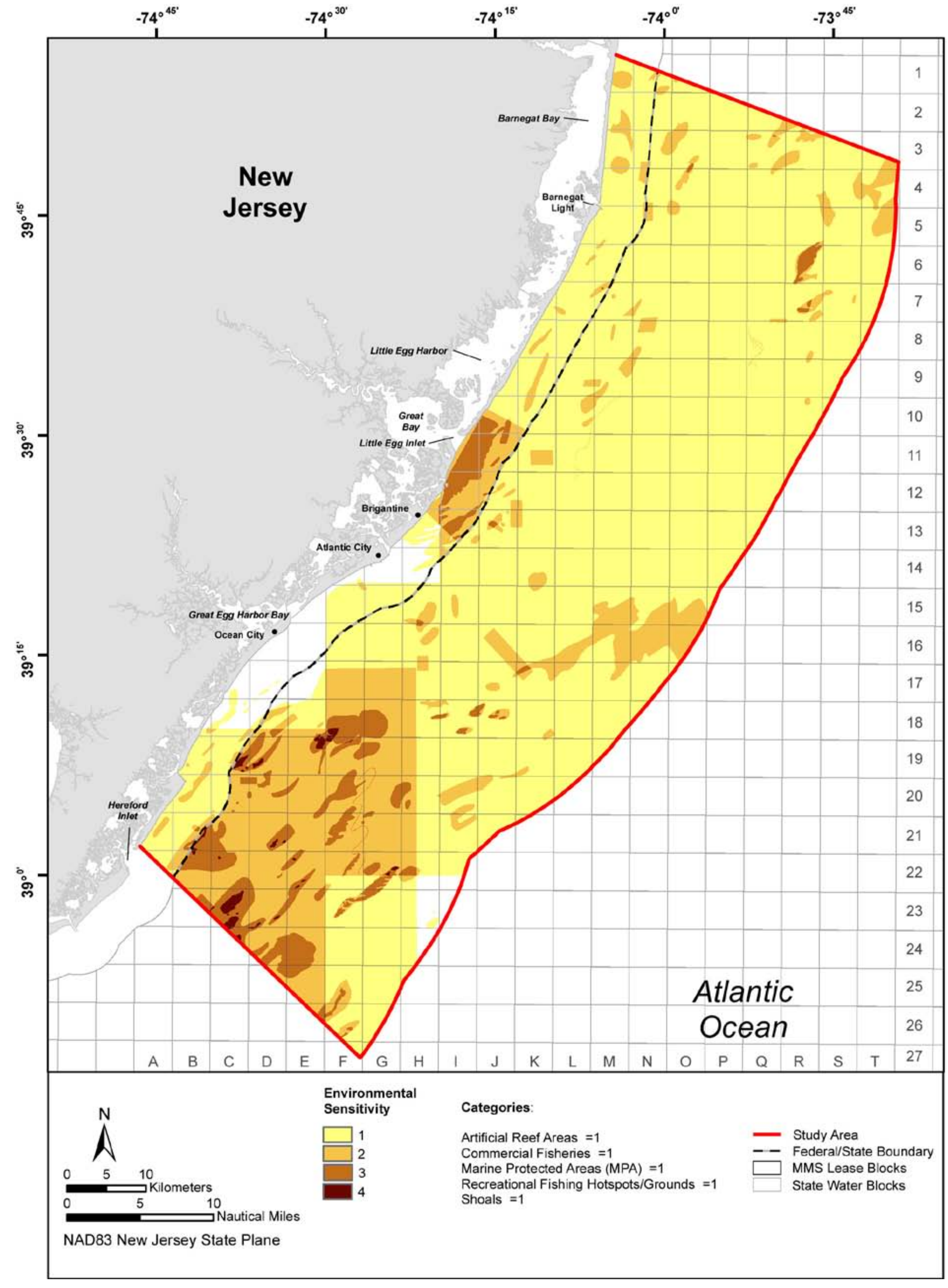

Figure 4-3. Physical features used in the Environmental Sensitivity Index.

4.2.4 Avian Density Data

The avian layer component of the ESI was developed from estimates of total species, all-behavior avian density (number/km^2) calculated through kernel density spatial interpolation (see **Volume II: Chapter 8.0** for more detail). Spatial maps were generated for each time period using the 1-km MMS lease block grid system, with 8,364 total gridpoints (82 longitude values by 102 latitude values). Each gridpoint represented an unsampled site, and avian density was estimated at each gridpoint by calculating a kernel function (modulated by bandwidth h) based on observed counts at neighboring sampled sites (i.e., lon-lat locations along transects passing in proximity to the gridpoint), with the degree of weighting being inversely related to the separation distance between the gridpoint and observation location. The h value governed the degree of dispersion of mass about the central (observed) value, and hence affected the amount of spatial detail in the density estimates. A wide bandwidth (high h value) reflected high dispersion and smoothed out small-scale fluctuations in density, whereas a narrow bandwidth (low h value) captured small-scale variability and structure in the density estimates.

For the sensitivity index, the avian density data were divided into a 3-level ranking system, with the higher the avian density, the higher the index value. The data were divided and ranked as follows:

1. 0.01-50 birds/km^2, which was assigned a weighted or ranking value of 2;
2. 51-100 birds/km^2, which was assigned a ranking value of 4;
3. 101+ birds/km^2, which was assigned a ranking value of 6.

The avian data were ranked higher than other biological data because the probability of impacts from offshore wind energy development over the life of the facility was greater than those expected for other groups. Using this 3-level step function, spatial variations in avian density were reflected in corresponding spatial variations in the ESI, with the strength and degree of correlation depending on the relative influence/contribution of other physical and biological resources affecting the index. **Figure 4-4** shows the avian density layer used in the ESI.

There were insufficient recorded sightings to model the data and calculate densities for threatened and endangered avian species. Because the target species are highly mobile and often use many locations within the Study Area, the index was developed using predicted densities or numbers of biological resources in efforts to minimize skewing data to exact locations where resources were observed. Therefore, raw sighting data were not included in the index. See **Volume I: Section 2.3.3** for details and a map of the listed avian species observed during surveys.

4.2.5 Marine Mammal Density Data

The marine mammal layer incorporated into the ESI was composed of predicted density surfaces estimates generated from habitat modeling. The DSM method was used to generate the surface maps of predicted density in the Study Area at a fine spatial resolution. The data collected from the shipboard and aerial surveys of the baseline study were included in the models (see **Volume III: Chapter 2.0** for more information on survey methodology). Only on-effort sightings and on-effort portions of the tracklines surveyed in a BSS of ≤5 were used in the density surface models for all species/groups except the harbor porpoise. On-effort harbor porpoise sightings used in the model for this particular species were limited to those recorded in a BSS of ≤2 due to the difficulty in detecting this species in a higher BSS. The modeling analyses were limited to species/groups which had 20 or higher on-effort sightings with valid perpendicular sighting distances. There were a sufficient number of sightings to run separate analyses for three species. To account for other species for which there were an insufficient number of sightings, several species were pooled into taxonomic groups, and a pooled density surface was generated. Density surfaces were generated for the following species/groups:

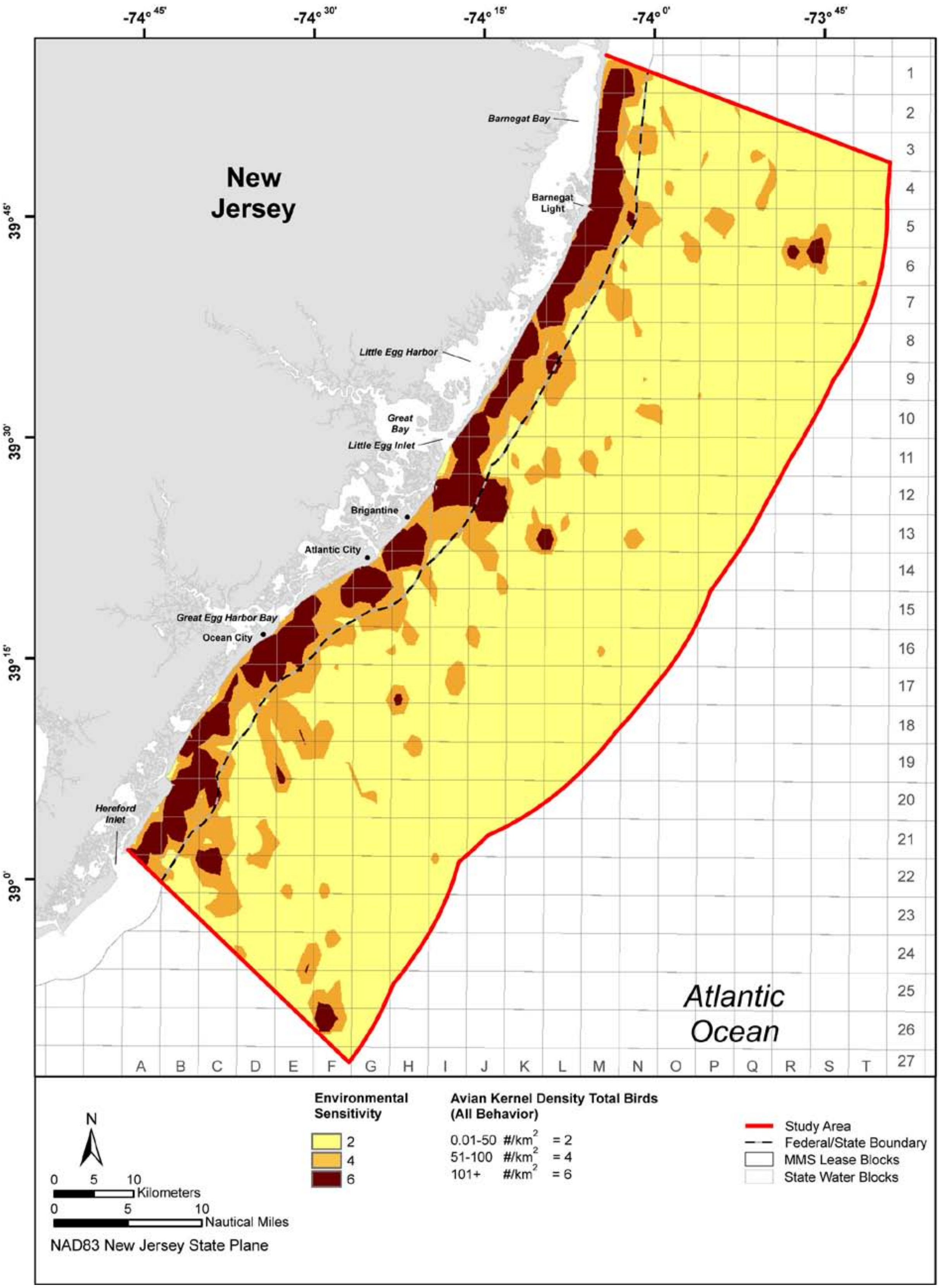

Figure 4-4. Total avian density for all birds/behaviors used in the Environmental Sensitivity Index.

1. Threatened and endangered (T&E) marine mammals year-round: North Atlantic right whale, fin whale, humpback whale
2. Delphinids winter: Short-beaked common dolphin and unidentified dolphin
3. Bottlenose dolphin spring/summer (ship analysis)
4. Harbor porpoise winter

For some species and groups, sufficient sightings data were recorded such that density surfaces could be generated for different seasons. Year-round analyses were limited to those species and groups for which sightings were recorded throughout the year, but not enough sightings were recorded for any particular season. Note that no aerial surveys were conducted in the fall, and the small number of sightings from the shipboard fall surveys prevented the generation of density surfaces for this season.

All analyses were carried out using Distance 6.0 release 2 and the statistical program R (see **Volume III: Chapter 3.0** for more details). The first phase of DSM involved partitioning the survey effort (tracklines) into segments. The DSM analysis engine in Distance utilizes the "count method" in which segment counts (sightings/detections) are modeled as a function of covariates (Hedley and Buckland 2004). The sightings within each segment were converted into an abundance estimate for each segment. The area of the segment (based on chosen segment length and the truncation distance) served as an offset (Thomas et al. 2010). GAMs (Wood 2006) were used to estimate the spatial distribution of abundance/density or counts (the response variable) as a function of numerous geographical, physical, and environmental covariates (explanatory variables), such as longitude, latitude, water depth, distance from shore, bathymetry, SST, and surface chl *a* concentration. After fitting GAMs to the survey data, the resulting DSM (the chosen model) was applied to a prediction grid (composed of 5,000 grid cells) superimposed upon the Study Area so that animal abundance/density could be predicted for any portion of the Study Area and related to specific covariates. The variance of the predicted abundance/density was estimated using the bootstrapping resampling technique (Hedley and Buckland 2004). See **Volume III** for more information on the DSM analyses and the results for each species/group.

The density surfaces generated for each species/group listed above, except the T&E marine mammals, were combined to create a single density surface layer for marine mammals (non-T&E marine mammal layer). Unlike the avian T&E data, enough sightings of T&E marine mammals were obtained during surveys to calculate density estimates. Therefore, a separate layer for T&E marine mammal density was included in the ESI.

The marine mammal density data (non-T&E) were divided into a 3-level ranking system, with the higher the density, the higher the index value. The data were divided and ranked as follows:

1. 0.000000001 – 0.0162 per km^2, which was assigned a weighted or ranking value of 1;
2. 0.0163 – 0.1342 per km^2, which was assigned a ranking value of 2;
3. 0.1343 – 0.9871 per km^2, which was assigned a ranking value of 3.

The T&E marine mammal density data were also divided into the following 3-level ranking system:

1. 0.0000001 – 0.000008 per km^2, which was assigned a weighted or ranking value of 1;
2. 0.000009 – 0.0004 per km^2, which was assigned a ranking value of 2;
3. 0.0005 – 0.0165 per km^2, which was assigned a ranking value of 3.

Figures 4-5 and **4-6** show the two layers for marine mammals included in the ESI.

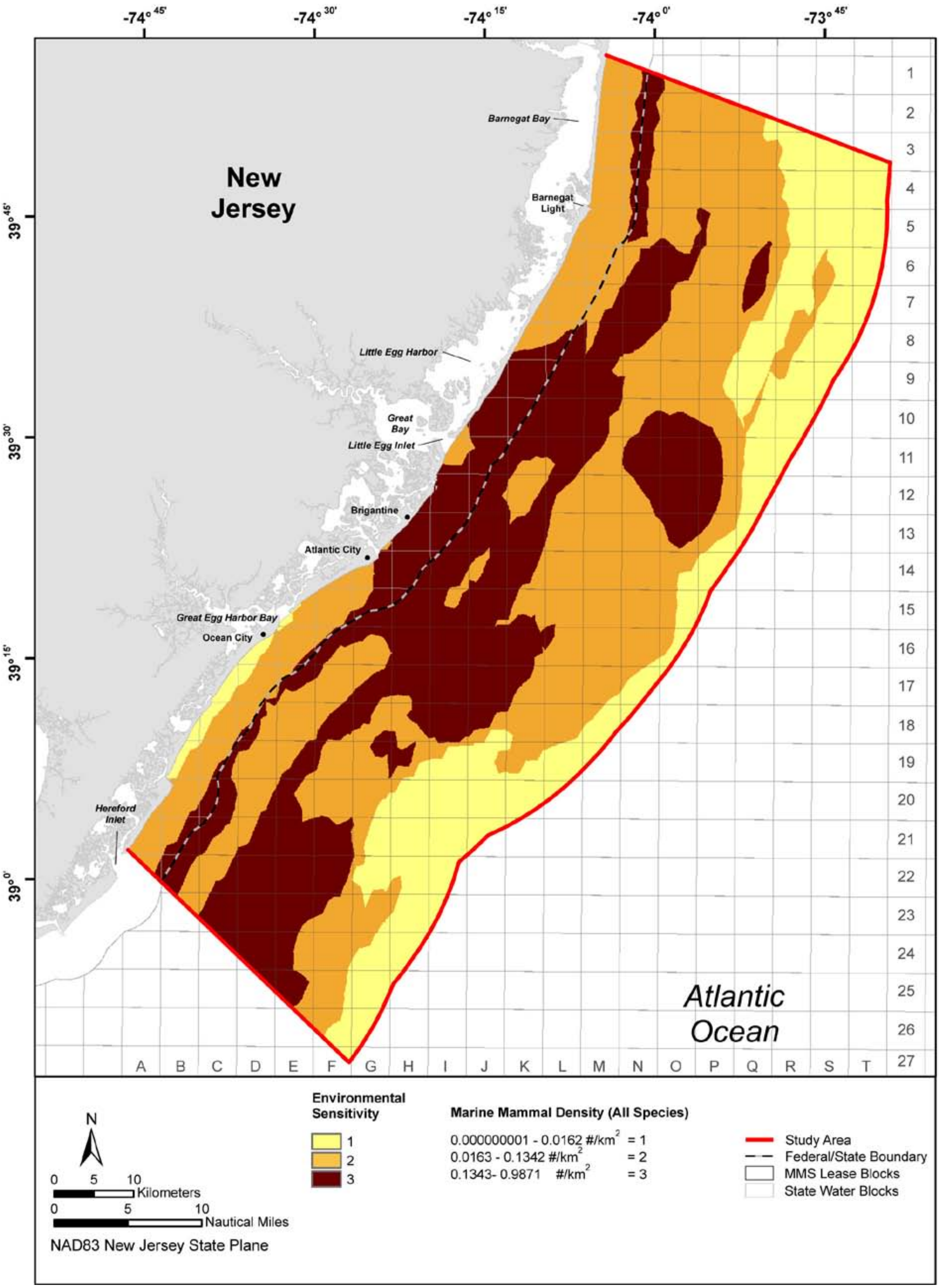

Figure 4-5. Grouped marine mammal density data used in the Environmental Sensitivity Index.

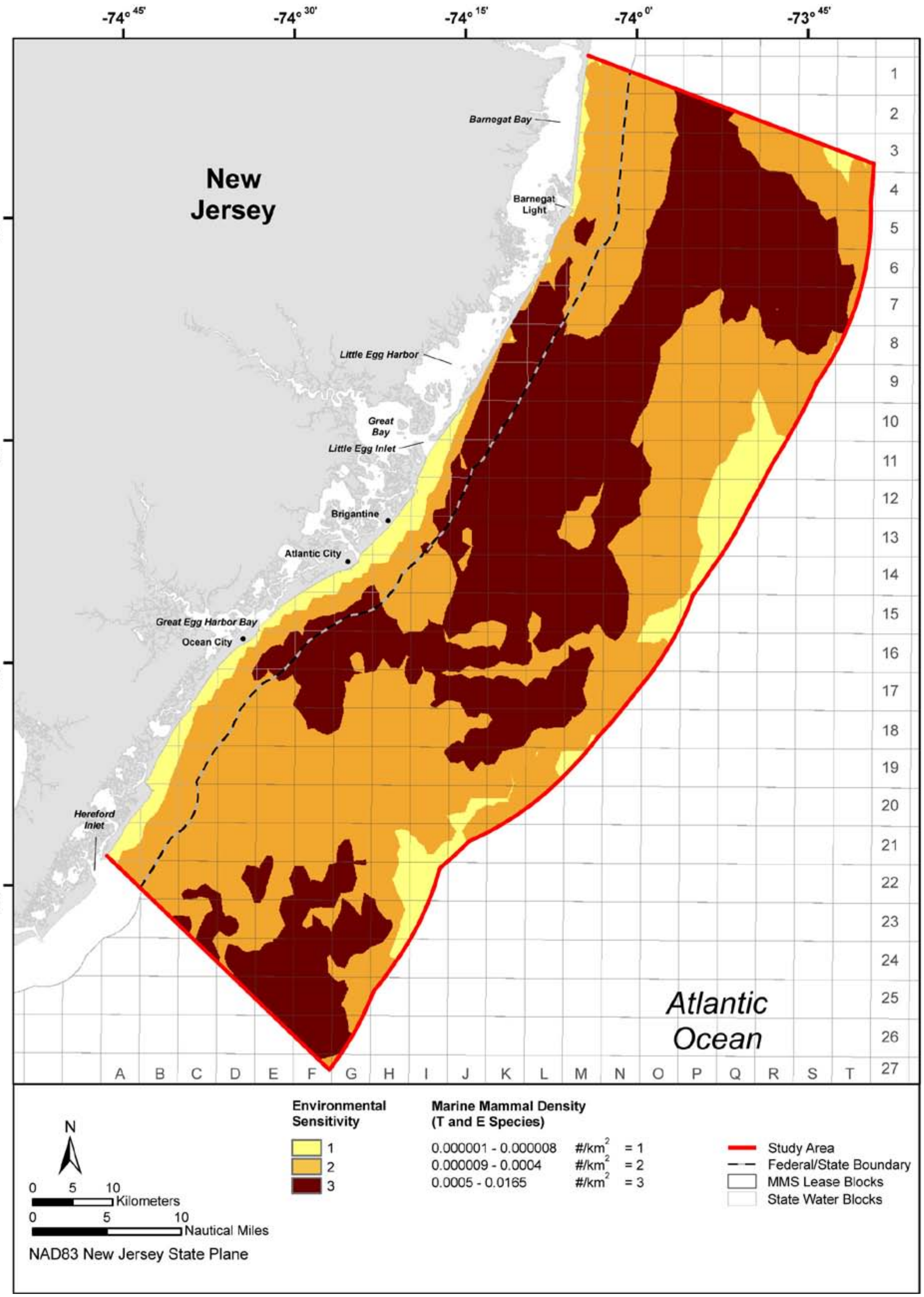

Figure 4-6. Threatened and endangered marine mammal species data used in the Environmental Sensitivity Index.

4.2.6 Sea Turtle Sightings Data

Sea turtle spatial distribution was estimated at each gridpoint using the SPUE method and kriging spatial interpolation. For each observation (sampled site), SPUE (number of sightings/km^2) was calculated by dividing the number of sightings by the effort associated with the given sighting. Knowing the SPUE values at each sampled site, kriging was then applied to estimate SPUE at each gridpoint (unsampled site).

Kriging provides a best linear unbiased estimate (BLUE) of the SPUE value at each gridpoint (unsampled site) based on known SPUE values at neighboring sampled sites, using a set of linear least squares weighted regression estimation algorithms (routines) that minimize estimation variance (error) from a predefined covariance or semivariance model. Unlike trend surface methods, kriging is an exact interpolator, such that the interpolated SPUE value calculated at a sampled site coincides with its known SPUE value (i.e., the kriged surface passes through the data points), provided that the spatially uncorrelated random residual variation ("noise") is zero. Five components of kriging include detrending, semivariogram modeling, neighborhood search, interpolation, and cross-validation.

Kriging is quasi-random in that it contains both deterministic and random components, and only the stationary (random residual) component is kriged. The deterministic (trend) component is subtracted out (separated) from the residual component, the latter of which is kriged, and then the trend component is added back into the kriged residual. A semivariogram model describes the asymptotic relationship between semivariance (or, inversely, covariance) and separation distance between two locations (i.e., an unsampled gridpoint and a sampled site), and a "range" is calculated as the distance beyond which the two points are spatially uncorrelated (independent of each other). For each unsampled gridpoint, a neighborhood search is conducted to identify all sampled sites within the gridpoint's range, and spatial interpolation is then conducted to estimate SPUE at the gridpoint based on the SPUE values at these neighboring sampled sites, using a least squares weighted regression function that minimizes estimation variance. Generally, the relative weight (influence) of a sampled site's SPUE value in affecting the estimated SPUE value at the unsampled site correlates negatively with separation distance.

For the sensitivity index, the sea turtle SPUE data were divided into a 3-level ranking system based on the three quantiles of the SPUE values. The data were divided and ranked as follows:

1. 0.0039 – 0.0059 Sightings per km, which was assigned an index value of 1;
2. 0.0060 – 0.0073 Sightings per km, which was assigned an index value of 2;
3. 0.0074 – 0.0261 Sightings per km, which was assigned an index value of 3.

Using this 3-level step function, spatial variations in sea turtle SPUE were reflected in corresponding spatial variations in the index. **Figure 4-7** shows the sea turtle SPUE layer used in the sensitivity index.

4.2.7 Essential Fish Habitat

Nearly 40 fish and fisheries species of various life stages have EFH designated within the Study Area. It was difficult to rank one species or life stage as more important than the next, so all EFH layers were added to the ESI. To equalize the weighting and ranking of EFH with other resources shown in the index, the data were divided into a three level ranking system, where areas with the most overlap in EFH layers received the highest index ranking. The data were divided and ranked as follows:

1. 1-12 EFH designations, which was assigned an index value of 1;
2. 13-24 EFH designations, which was assigned an index value of 2;
3. 25-38 EFH designations, which was assigned an index value of 3.

Figure 4-8 shows the combined EFH layers used in the ESI. **Volume IV: Appendix A** provides details and maps for each of the EFH species.

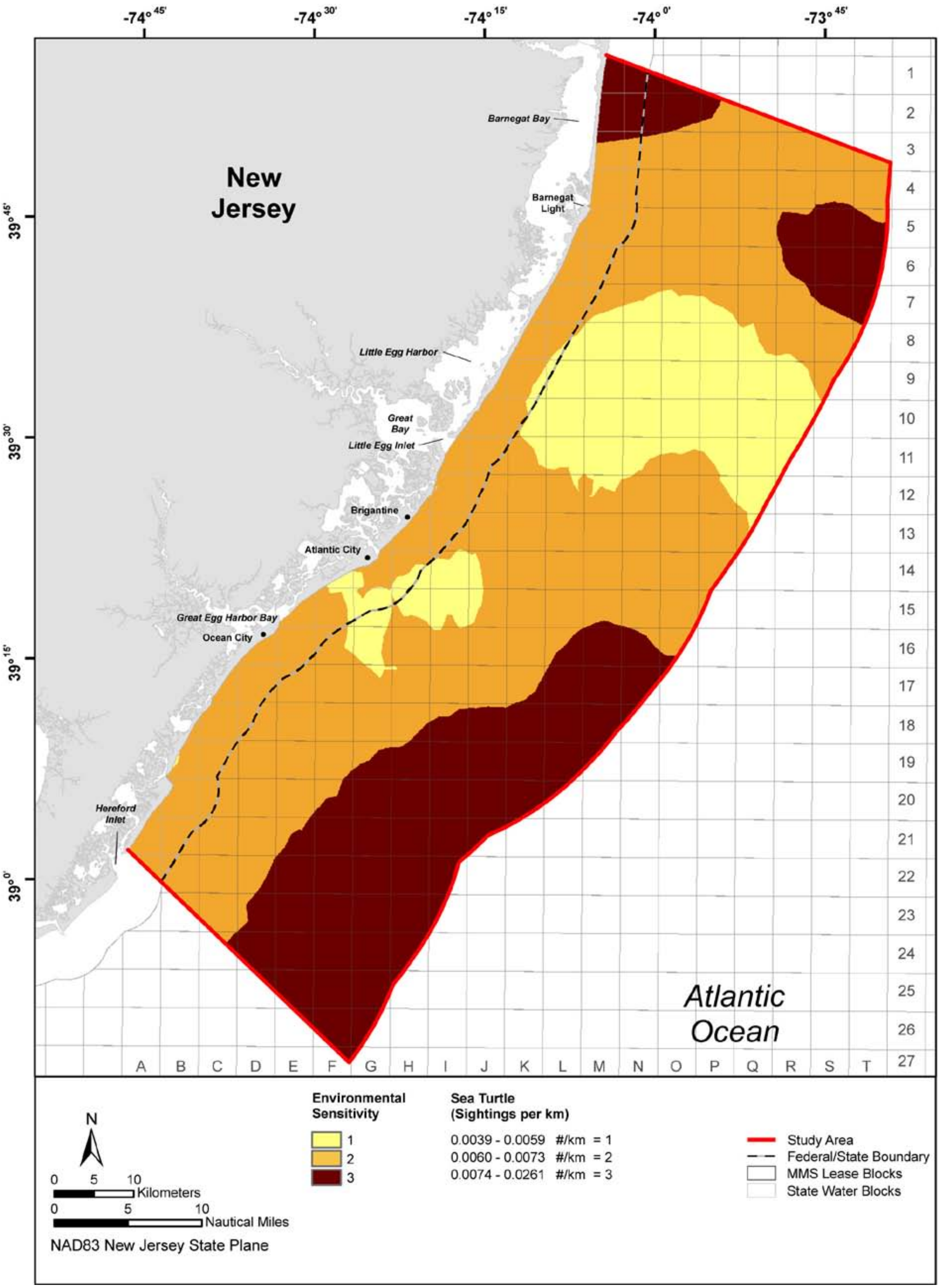

Figure 4-7. Sea turtle data used in the Environmental Sensitivity Index.

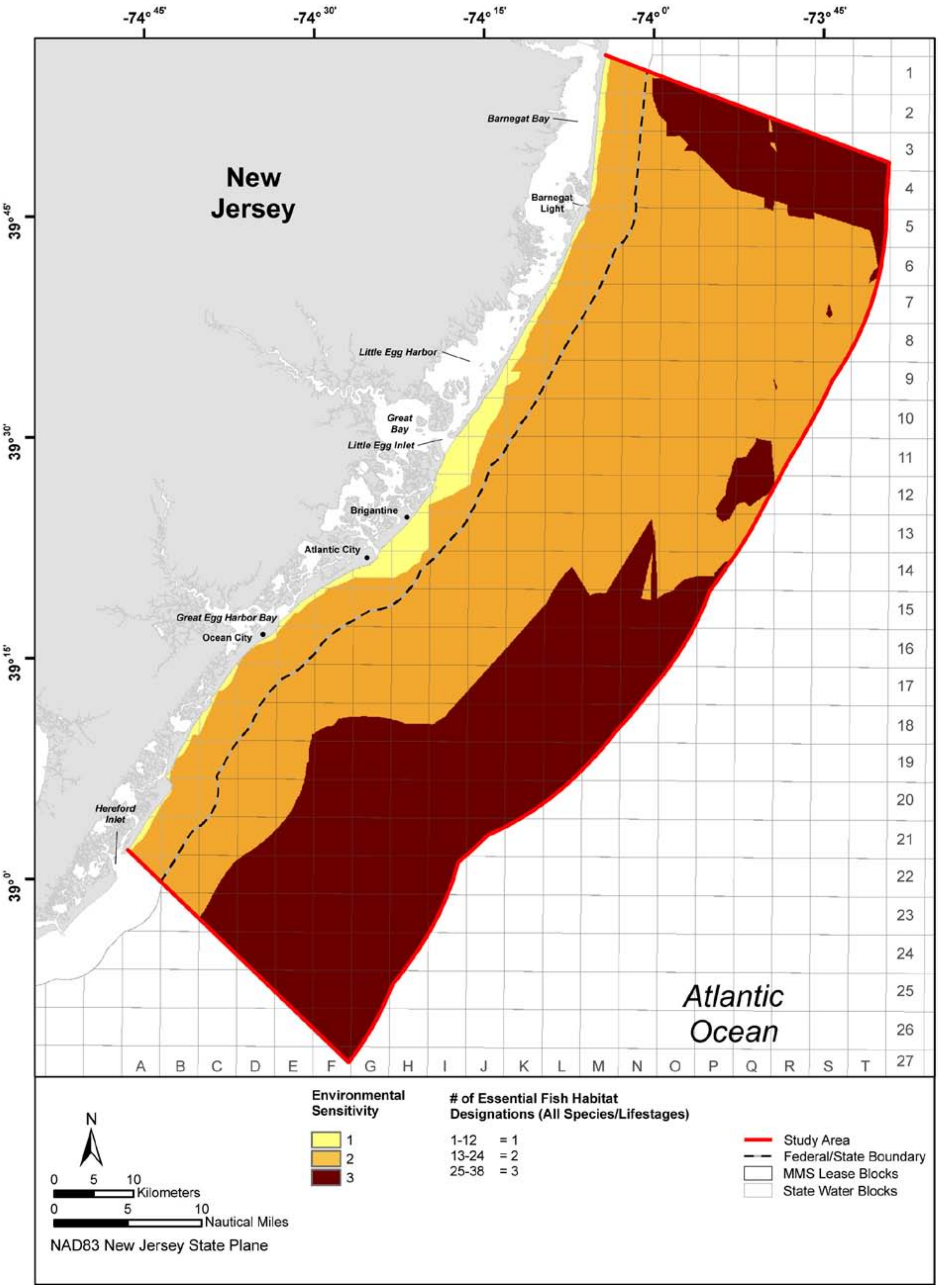

Figure 4-8. Essential Fish Habitat data used in the Environmental Sensitivity Index.

4.3 USING THE ENVIRONMENTAL SENSITIVITY INDEX

The ESI provides a visual representation of the number and distribution of physical, biological, and socioeconomic resources within the Study Area. Although the ESI clearly shows areas with high resource use and overlap, the user cannot discern which resources are found within each of the grid blocks by simply looking at the map (**Figure 4-1**). As such, a table of the resources (features) that make up the contents of each grid block is located in **Table C-1** in **Appendix C**. This table not only details the resources found within a given area, but it also provides the ranking for the biological resources to providce an understanding of the environmental sensitivity for each grid within the Study Area. For example, in block H18 of the ESI (see **Figure 4-1**), portions of the block have rankings of 11, 12, 13, 14, and 15, as well as a prohibited development area. As shown in **Table C-1**, block H18 is comprised of: avian densities with rankings of 2, 4, and 6; marine mammal densities with rankings of 1 and 2; T&E marine mammal density with a ranking of 2; sea turtle densities with rankings of 2 and 3; EFH with rankings of 2 and 3; commercial fishing grounds; a marine protected area; recreational fishing areas; shoals; and shipping lanes.

Using the true boundaries of physical features and the spatial varability of the modeled biological data, it is impossible to assign a single index value to the individual grid blocks. Instead, index values are assigned to the actual area that is overlapped by the data. Therefore, within a single grid block, there may be areas with moderate and low index ratings, such as P12. **Table 4-1** was developed to show index users the breakdown of index values within the Study Area. Index values between 11 and 15 comprised 82.2% of the Study Area. Only 9.3% of the Study Area had an index value of 10 or less, while 8.5% had an index value of 16 or greater. The majority of the areas with highest values were located along the coast, especially near Brigantine and north, as well as the southern extents of the Study Area. Several areas with high values were associated with shoal areas, especially those found in R6, R7, C23, C22, E25, F25, and F26. The lower index values were found primarily in the middle to northern sections of the Study Area that were farthest from shore.

Table 4-1. Percent breakdown for each of the index values with the Study Area. Note these percentages include the environmental resources in the prohibited development areas.

Index value	Area (km^2)	%
6	0.06	0.001
7	1.38	0.029
8	36.31	0.761
9	136.66	2.864
10	267.07	5.596
11	587.23	12.305
12	1211.91	25.395
13	944.66	19.795
14	741.18	15.531
15	439.35	9.206
16	243.50	5.102
17	120.92	2.534
18	39.69	0.832
19	2.27	0.047
Total		100
Prohibited Development Areas	215.44	4.514%

In general, the ESI is a useful tool for preliminary planning for both developers and stakeholders. It provides a quick overview of the potentially sensitive resources off the New Jersey coast, and the areas where these resources are most abundant; however, this index should be used only as a guide to help determine which locations within the Study Area may be suitable for offshore development, as well as those areas that may need to be avoided due to ecological importance. While the ESI should not be used in lieu of site specific resource studies, it provides a good synthesis of baseline data for initial planning purposes and future impact assessments.

5.0 POTENTIAL IMPACTS OF RENEWABLE ENERGY DEVELOPMENT

This section presents a discussion of the potential environmental impacts related to the construction and operation of offshore wind power facilities in the Study Area. The potential temporary changes and the potential permanent changes associated with all phases of wind power development are discussed. This discussion is not, however, an assessment of specific impacts relating to any specific development off the New Jersey coastline, nor is this discussion intended to provide sufficient evaluation of the potential impacts to satisfy the requirements of the NEPA.

There are presently no offshore wind facilities within the OCS of the U.S. The Cape Wind Energy Project is a proposal to construct and operate an offshore wind facility consisting of 130 turbines covering 62 km^2 (24 mi^2) located 12.2 km (4.7 mi) offshore Cape Cod, Massachusetts, on Horseshoe Shoal in Nantucket Sound. The Department of the Interior's MMS completed a Final EIS and an EA—Draft Finding of No New Significant Impacts (FONNSI) for the project (MMS 2009c; MMS 2010) and on April 28, 2010, Secretary of the Interior Ken Salazar approved the project.[22] In addition to Cape Wind, in June 2009, the MMS issued five leases, four in New Jersey and one in Delaware for wind energy resource data collection and technology testing activities (with no subsequent commercial rights).[23]

Northern Europe has been in the forefront of development of offshore renewable energy resources. As of the end of 2009, there were 38 existing offshore wind farms in the U.K., Denmark, Sweden, Germany, the Netherlands, Ireland, Norway, Belgium, and Finland.[24] In the last five years the U.K. has put more than 750 megawatts (MW) online. For 2010, the European Wind Energy Association (EWEA) expects the completion of 10 additional European offshore wind farms, adding 1,000 MW.[25] Denmark started in the early 1990s and has done considerable post-construction monitoring to identify actual impacts on the environment from the wind farms. The Horns Rev offshore wind farm is located in the North Sea south of the actual reef, Horns Rev, in the southwestern part of Denmark. The Horns Rev wind farm is about 14 km (8.7 mi) from the closest land, in water that is between 6.5 and 13.5 m (21 and 44 ft) deep. The Nysted offshore wind farm is located in the Baltic Sea south of Nysted in the southeastern part of Denmark (Petersen et al. 2006). It is about 10 km (6.2 mi) from the closest point to shore in water depths between 6 and 9.5 m (20 and 31 ft). The data gathered from these projects is used throughout this analysis to identify some of the actual impacts observed at these wind farms.

5.1 REGULATORY CONSIDERATIONS

5.1.1 Juridiction and Permitting

As directed by the Energy Policy Act of 2005, MMS has primary authority to authorize renewable energy projects on the OCS of the U.S. The OCS consists of submerged lands extending from the seaward extent of a state's jurisdiction to the seaward extent of federal jurisdiction. In most areas (including the entire Study Area), the OCS covers the area between 5.6 km and 370.4 km (3.0 NM and 200.0 NM) from the coast. In addition to MMS's authority, several federal agencies have regulatory authority over actions within the 22 km (12 NM) territorial sea or the 370 km (200 NM) limit to the Economic Exclusive Zone (EEZ). **Table 5-1** presents a summary of these authorities and the permits or approvals that would be required of any wind farm project.

In addition to federal permits and approvals, any aspect of the project within a state's territorial limits (out to 5.6 km [3.0 NM] in New Jersey) would be subject to state regulatory authority as granted by the Submerged Lands Act (43 U.S. Code [U.S.C.] §§130-1315). Individual projects would need to identify and consult with the relevant state agencies for those aspects of the project within state waters and on shore.

5.1.2 Navigable Waterways and Utilities

Navigable waterways of the U.S. are those waters that are presently used to transport interstate or foreign commerce. A determination of navigation, once made, applies laterally over the entire surface of the water body and is not extinguished by later actions or events that impede or destroy navigable capacity (33 CFR Part 329). The northwestern Atlantic Ocean has some of the busiest shipping lanes in

Table 5-1. Relevant federal compliance laws, regulations, and statues for renewable energy on the OCS. Adapted from: MMS (2009c).

Statute/Executive Order (EO)	Responsible Federal Agency/Agencies	Summary of Pertinent Provisions
Outer Continental Shelf (OCS) Lands Act, as amended by the Energy Policy Act of 2005 (Title 43 Section 1337 of the U.S. Code [43 U.S.C.] 1337 *et. seq.*)	Department of the Interior Minerals Management Service (MMS)	Authorizes the issuance of lease, easement, or right-of-way on OCS for activities not otherwise authorized by the OCS Lands Act or other applicable laws
National Environmental Policy Act (NEPA) of 1969, as amended (42 U.S.C. 4321 *et. seq.*)	Council on Environmental Quality (CEQ)	Requires federal agencies to prepare an environmental impact statement to evaluate the potential environmental impacts of any proposed major federal action that would significantly affect the quality of the human environment, and to consider alternatives to such proposed actions
Endangered Species Act (ESA) of 1973, as amended (16 U.S.C. 1513 *et. seq.*)	U.S. Fish and Wildlife Service (USFWS); National Oceanic and Atmospheric Administration's (NOAA) National Marine Fisheries Service (NMFS)	Requires federal agencies to consult with the USFWS and the NMFS to ensure that proposed federal actions are not likely to jeopardize the continued existence of any species listed at the federal level as endangered or threatened, or result in the destruction or adverse modification of critical habitat designated for such species
Marine Mammal Protection Act (MMPA) of 1972, as amended (16 U.S.C. 1361-1407)	USFWS (walruses, sea and marine otters, polar bears, manatees, and dugongs); NMFS (seals, sea lions, whales, dolphins, and porpoises)	Prohibits, with certain exceptions, the take of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammal products into the U.S.
Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA – also known as the Fishery Conservation and Management Act of 1976, as amended by the Sustainable Fisheries Act [SFA]; 16 U.S.C. 1801 *et. seq.*)	NMFS	Requires federal agencies to consult the NMFS on proposed federal actions that may adversely affect Essential Fish Habitats (EFH) that are necessary for the spawning, breeding, feeding, or growth to maturity of federally managed fisheries
Marine Protection, Research, and Sanctuaries (MPRSA) of 1972 (also referred to as the Ocean Dumping Act), as amended (33 U.S.C. 1401 *et. seq.*)	U.S. Environmental Protection Agency (EPA); U.S. Army Corps of Engineers (USACE)	Prohibits, with certain exceptions, the dumping or transportation for dumping of materials including, but not limited to, dredged material, solid waste, garbage, sewage, sewage sludge, chemicals, excavation debris, and other waste into ocean waters without a permit from the U.S. EPA. In the case of ocean dumping of dredged material, U.S. EPA designates authorized disposal sites; however, individual projects are permitted by USACE

Table 5-1 (*continued*). Relevant federal compliance laws, regulations, and statues for renewable energy on the OCS. Adapted from: MMS (2009c).

Statute/Executive Order (EO)	Responsible Federal Agency/Agencies	Summary of Pertinent Provisions
National Marine Sanctuaries Act (NMSA) of 1972 (16 U.S.C. 1431_*et. seq.*)	NOAA	Prohibits the destruction, loss of, or injury to, any sanctuary resource managed under the law or permit, and requires federal agency consultation on federal agency actions, internal or external to national marine sanctuaries, that are likely to destroy, injure, or cause the loss of any sanctuary resource
Migratory Bird Treaty Act (MBTA) of 1918 (16 U.S.C. §§ 703 et seq.)	USFWS	Prohibits the taking, transporting, and harming of migratory birds and their parts, eggs, nests, and young unless permitted by federal regulations. Gives USFWS the authority to enforce the act's provisions, which includes determining periodically when the taking of migratory birds may occur.
EO 13186, "Responsibilities of Federal Agencies to Protect Migratory Birds (January 10, 2001)	USFWS	Requires that federal agencies taking actions likely to negatively affect migratory bird populations enter into Memorandum of Understanding (MOU) with the USFWS, which, among other things, ensure that environmental reviews mandated by NEPA evaluate the effects of agency actions on migratory birds, with emphasis on species of concern
Coastal Zone Management Act (CZMA) of 1972, as amended (16 U.S.C. 1451 *et. seq.*)	NOAA's Office of Ocean and Coastal Resource Management (NOAA OCRM)	Specifies that coastal states may protect coastal resources and manage coastal development. A state with a coastal zone management program approved by NOAA OCRM can deny or restrict development off its coast if the reasonably foreseeable effects of such development would be inconsistent with the state's coastal zone management program
Clean Air Act (CAA), as amended (42 U.S.C. 7401 *et. seq.*)	U.S. EPA; MMS	Prohibits federal agencies from providing financial assistance for, or issuing a license or other approval to, any activity that does not conform to an applicable, approved implementation plan for achieving and maintaining the National Ambient Air Quality Standards (NAAQS). Section 328 states that for OCS sources located within 25 miles of the seaward boundary of coastal states, air quality requirements shall be the same as would be applicable if the source were located in the corresponding onshore area.

Table 5-1 (*continued*). Relevant federal compliance laws, regulations, and statues for renewable energy on the OCS. Adapted from: MMS (2009c).

Statute/Executive Order (EO)	**Responsible Federal Agency/Agencies**	**Summary of Pertinent Provisions**
Clean Water Act (CWA), Section 311, as amended (33 U.S.C. 1321); EO 12777, "Implementation of Section 311 of the Federal Water Pollution Control Act (FWPCA) of October 18, 1972, as amended, and the Oil Pollution Control Act of 1990"	U.S. EPA; U.S. Coast Guard (USCG); MMS	Prohibits discharges of oil or hazardous substances into or upon the navigable waters of the U.S., adjoining shorelines, or into or upon the waters of the contiguous zone, or in connection with activities under the OCS Land Act, or which may affect natural resources belonging to the U.S. Authorizes U.S. EPA and the USCG to establish programs for preventing and containing discharges of oil and hazardous substances from non-transportation-related facilities and transportation-related facilities, respectively.
CWA, Sections 402 and 403, as amended (33 U.S.C. 1342 and 1343)	U.S. EPA	Requires a National Pollutant Discharge Elimination System (NPDES) Permit from U.S. EPA (or authorized state) before discharging any pollutant into territorial waters, the contiguous zone, or the ocean from an industrial point source, a publicly owned treatment works, or a point source composed entirely of storm water
CWA, Section 404, as amended (33 U.S.C. 1344)	USACE; U.S. EPA	Requires a permit from the USACE before discharging dredged or fill material into waters of the U.S., including wetlands
Ports and Waterways Safety Act, as amended (33 U.S.C. 1221 *et. seq.*)	USCG	Authorizes the USCG to implement, in waters subject to the jurisdiction of the U.S., measures for controlling or supervising vessel traffic or for protecting navigation and the marine environment. Such measures may include but are not limited to; reporting and operating requirements, surveillance and communications systems, routing systems, and fairways
Marking of Obstructions (14 U.S.C. 86)	USCG	USCG may mark any sunken vessel or other obstruction existing on the navigable waters or waters over the continental shelf of the U.S. in such manner and for so long as, in their judgment, the needs of maritime navigation require it
Rivers and Harbors Appropriation Act of 1899 (33 U.S.C. 401 *et. seq.*)	USACE	Section 10 (33 U.S.C. 403) delegates to the USACE the authority to review and regulate certain structures and work that are located in or that affect navigable waters of the U.S. The OCS Land Act extends to the jurisdiction of the USACE, under Section 10, to the seaward limit of federal jurisdiction

Table 5-1 (*continued*). Relevant federal compliance laws, regulations, and statues for renewable energy on the OCS. Adapted from: MMS (2009c).

Statute/Executive Order (EO)	Responsible Federal Agency/Agencies	Summary of Pertinent Provisions
Resource Conservation and Recovery Act (RCRA), as amended by the Hazardous and Solid Waste Amendments (HSWA) of 184 (42 U.S.C. 6901 *et. seq.*)	U.S. EPA	Requires waste generators to determine whether they generate hazardous waste and, if so, to determine how much hazardous waste they generate and what they do with it. Requires hazardous waste treatment storage and disposal facilities to obtain permits
National Historic Preservation Act of 1966, as amended (16 U.S.C. 470-470t); Archaeological and Historical Preservation Act of 1974 (16 U.S.C. 469-469c-2)	National Park Service (NPS); Advisory Council on Historic Preservation; State or Tribal Preservation Office	Requires each federal agency to consult with the Advisory Council on Historic Preservation and State or Tribal Historic Preservation Officer before allowing a federally licensed activity to proceed in an area where cultural or historic resources might be located; authorizes the Interior Secretary to undertake the salvage archaeological data that may be lost due to a federal project
American Indian Religious Freedom Act of 1978 (42 U.S.C. 1996); EO 13007, "Indian Sacred Sites" (May 24, 1996)	NPS; Advisory Council on Historic Preservation; State or Tribal Preservation Office	Requires federal agencies to facilitate Native American access to and ceremonial use of sacred sites on federal lands, to promote greater protection for the physical integrity of such sites, and to maintain the confidentiality of such sites, where appropriate
Federal Aviation Act of 1958 (49 U.S.C. 44718); 14 Code of Federal Regulations (CFR) Part 77	Federal Aviation Administration (FAA)	Requires that, when construction, alteration, establishment, or expansion of a structure is proposed, adequate public notice is to be given to the FAA as necessary to promote safety in air commerce and the efficient use and preservation of the navigable airspace

the world and a large volume of ship traffic transits the Study Area containing several primary shipping lanes leading from New York City and Newark to ports in Delaware Bay and the mid-Atlantic U.S. (**Figure 5-1**). The Port of New York and New Jersey includes the ports of Jersey, Elizabeth, and Newark, and is the third largest port system in the country by cargo volume. The ports of Paulsboro and Camden-Gloucester, New Jersey, and Philadelphia, Pennsylvania, are also included among the top 100 leading U.S. ports and produce vessel traffic going through Delaware Bay, south of the Study Area[26]. Traffic Separation Schemes (TSSs) located at the north and south ends of the Study Area are internationally fixed plans for vessel traffic in congested areas operating one-way shipping lanes to avoid collisions.

The U.S. Submarine Cable Act of 1888 (47 U.S.C. Chapter 2) prohibits damage to submarine telecommunication cables (intentional or accidental). Numerous submarine cables and pipelines populate the New Jersey coastline with all telecommunication cables (in- and out-of-service) emanating from the central part of the state (**Figure 5-1**).

5.2 GENERAL NOISE

This section provides general information about underwater noise and its effects on marine species. The noise associated with different aspects of offshore wind farms is discussed in the Noise sections within each phase of a wind farm project (see **Sections 5.4.2.3**, **5.5.2.4**, **5.6.2.4**, and **5.7.2.1**). The ocean is a naturally noisy environment (Scheifele and Darre 2005), with noise defined as “unwanted” sound that may clutter or mask signals of interest to the biota present in the area (Au 1993). The National Research Council (NRC) on ocean noise reported that overall anthropogenic noise is increasing on average throughout the world’s oceans at a rate of 3 dB per decade (NRC2003).

Sound is energy transmitted by pressure waves and is transmitted extremely efficiently through water. For identical sound source intensity in water and in air, the acoustic pressure generated in water is 60 times greater than in air. This means that detection of underwater noise created by ships or other human activities may occur many kilometers from the source. Marine species, especially fish and marine mammals, use sound for basic functions such as communication and navigation (Richardson et al. 1995; Popper and Hastings 2009a). An animal will detect a signal in water (or in air) only if the received level of that sound exceeds the animal’s detection thresholds with respect to the noise level of the environment in which it is broadcast. If the signal that reaches the animal is weaker than the background noise, the probability of detection will be low. An increase in ambient noise levels, such as those associated with the development of a wind farm, might prevent detection of certain sounds (e.g., from peers or prey) (Richardson et al. 1995). This could result in behavioral disruption or hearing impairment, whether temporary or permanent (Erbe and Farmer 2000).

Exposure to noise from anthropogenic sources has the potential to elicit a range of responses from single or multiple animals in the marine environment; responses can be minimal (e.g., no response or slight behavioral changes) to severe (e.g., mortality or injury to an individual or group of individuals; Balcomb and Claridge 2001). Physical injury can include damage to sinuses or hearing organs (e.g., cilia hair cells of the cochlea of a marine mammal) or to non-auditory tissues, such as a tear or rupture to the swim bladder in fish (Popper and Hastings 2009a). Injury can result in either a temporary or permanent threshold shifts (TTS or PTS, respectively) in the hearing of animals, specifically marine mammals and fish, if received levels of the noises result in physical damage to the hearing structures (Southall et al. 2007). Knowing the level at which PTS or TTS may occur in a particular animal or species assumes that the hearing response – specific frequencies to which that animal or species responds – is known and documented for the individual(s) under concern. Hearing response information can be obtained via auditory brainstem response (ABR) tests or from examination of the cochlear anatomy of the species in question (Ketten 1998b; 2000). Still, studies of the TTS or PTS of a species are often conducted with respect to behavioral responses or present a comparison of results from both behavioral and ABR responses (e.g., Nachtigall et al. 2007; Nachtigall et al. 2008; Mooney et al. 2009b; Mooney et al. 2009a).

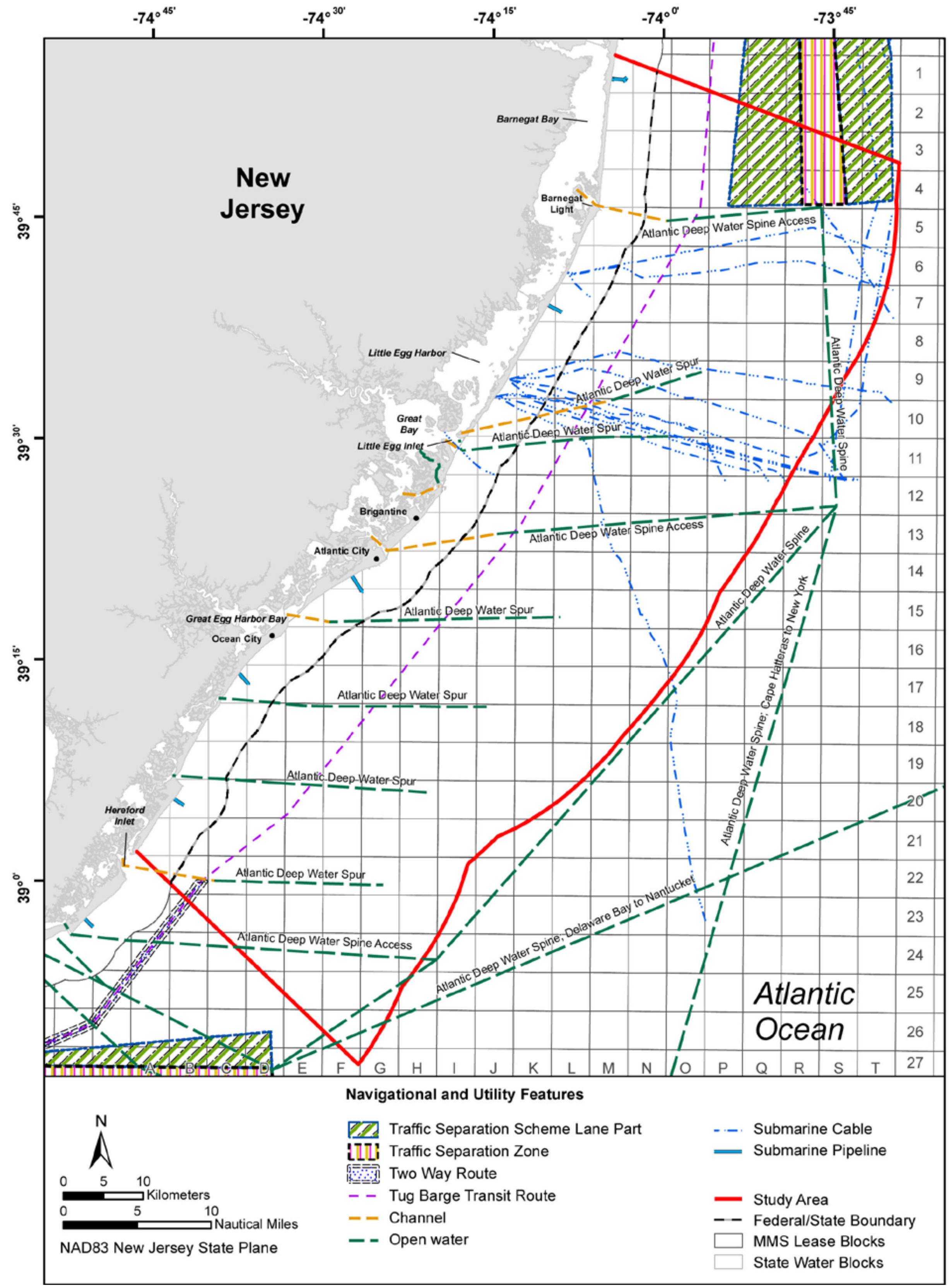

Figure 5-1. Navigational and utility features within and surrounding the Study Area. Source data: USACE (2009) and NOAA (2008a).

Few detailed studies are available on the PTS levels for pinnipeds or cetaceans, though work has been conducted on the hearing and threshold of received levels for some species (e.g., bottlenose dolphins and beluga whales [*Delphinapterus leucas*]; see Southall et al. 2007 for summary; and harbor seals, California sea lions [*Zalophus californianus*], and northern elephant seals [*Mirounga angustirostris*]; see Reichmuth 2008) to assess frequency response(s) in hearing with extrapolation to threshold shift response. Several fish species have been measured for hearing loss (e.g., goldfish [*Carassius. auratus*], fathead minnow [*Pimephales promelas*], northern pike [*Esox lucius*], lake chub [*Couesius plumbeus*], and rainbow trout [*Oncorhynchus mykiss*]; for discussion see Popper and Hastings [2009]). Because of differences in hearing systems, extrapolation of results among fish species is not recommended.

Very little research has been conducted to assess noise or vibration effects on benthic communities. There are large differences between the vibrational behavior of concrete and steel monopile foundations; however, unless the turbine tower vibration cause changes in the physical composition of the seabed (e.g., liquefaction) little or no remarkable effect would be expected on benthic communities (Gerdes et al. 2005).

5.2.1 Marine Mammal/Sea Turtle Hearing

Sound waves are classified in relation to human hearing ability, which is generally 20 to 20,000 hertz (Hz). Infrasound refers to sound energy at frequencies too low to be audible to humans (below 20 Hz) and ultrasound refers to sound energy at frequencies too high to be audible to humans (above 20,000 Hz). An animal's sensitivity to sound will vary with frequency and the size of the animal; typically for mammals, the larger species respond better to lower frequencies (often infrasound) while smaller-sized species have better hearing ability in the higher frequencies (including ultrasounds). Thus, an individual's response to a sound depends on the presence of the range of frequencies to which the animal is sensitive (i.e., its hearing ability; Richardson et al. 1995). If a sound is not within the hearing range of an animal, the animal will likely not hear the sound; thus, the sound itself should not affect the behavior of that animal. Similarly, any response (i.e., behavioral impact) to a noise depends on an animal's hearing sensitivity. The hearing of baleen whales has not been examined directly for sensitivity, although the cochlea of several species have been examined leading to the suggestion that baleen whales typically hear well in the infrasonic range (below 200 Hz; Ketten 1998a). The hearing of some toothed whale species (e.g., bottlenose dolphins, belugas, and false killer whales [*Pseudorca crassidens*]; Nachtigall et al. 2007; Nachtigall and Supin 2008) has been measured directly (Ketten 1998b, 2000). Dolphins and porpoises hear well between about 2 to 150 kHz (Ketten 2000; Kastelein et al. 2002; Nachtigall et al. 2007). Pinniped underwater hearing is best between 1 kHz and 40 kHz, although some species may hear well below 1 kHz (e.g., harbor seals and northern elephant seals; Kastak and Schusterman 1999; Kastelein et al. 2009).

Sea turtles have been shown to have low-frequency hearing with their highest sensitivity ranging between 200 Hz and 700 Hz (Samuel et al. 2005).

5.2.2 Fish Hearing

Most fish species for which hearing ability is known can hear between 0.05 kHz and 1.50 kHz (Wahlberg and Westerberg 2005; Popper and Hastings 2009a). Fish with hearing capabilities over a narrow frequency bandwidth are referred to as 'hearing generalists' or hearing 'non-specialists' and include salmonids (Salmonidae), cichlids (Cichlidae), and tunas (Scombridae). Other species can detect sounds from 0.05 kHz to 3.00 kHz or to even greater then 100.00 kHz. These fish are hearing specialists with specialized structures enhancing hearing. Additionally, shad (*Alosa sappidissima*) might detect ultrasound. Hearing data has only been collected for approximately 0.3% of fish species and differences in hearing capabilities and estimated response to noise warrant careful extrapolation among species (Popper et al. 2003; Popper and Hastings 2009a).

The effects of noise on fish can be: (1) primary: immediate or delayed fatal injuries (ruptures to swim bladders); (2) secondary: injuries such as deafness that may impact survival, particularly among species that hunt by acoustic methods; or (3) tertiary (behavioral): these effects may be milder but experienced over a greater area and may include avoidance (Nedwell and Howell 2004). The degree to which an individual fish exposed to noise will be affected by is dependent upon a number of variables: (1) species of fish, (2) fish size, (3) presence of swimbladder, (4) physical condition of fish, (5) peak sound pressure and frequency, (6) shape of the sound wave water (rise time), (7) depth of the water, (8) depth of the fish in the water column, (9) amount of air in the water, (10) size and number of waves on the water surface, (11) bottom substrate composition and texture, (12) effectiveness of bubble current sound/pressure attenuation technology, (13) tidal currents, and (14) presence of predators (Hanson et al. 2004).

5.2.3 Noise Exposure Criteria

Once the hearing ability and response to noise have been assessed for a study species, then criteria pertaining to “do not exceed” limits can be reliably set from a governing agency. While the number of experiments being conducted (and subsequent reports in the peer-reviewed literature) is growing for marine mammals, fish, and other marine species, results from these experiments do not equate to accepted criteria related to noise exposure limits.

In 1995, NMFS set underwater “do not exceed” criteria for exposure of marine mammals to continuous and impulse noise. The current exposure level criteria used for injury are 180 decibels with a reference pressure of one micropascal at 1 m (dB re 1 μPa-m) for cetaceans and 190 dB re 1 μPa-m for pinnipeds (level A harassment under MMPA). Current exposure level criteria for harassment are 160 dB re 1 μPa-m for impulse noise and 120 dB re 1 μPa-m for continuous noise (level B harassment under MMPA).

A review panel exists to set criteria for noise exposure limits for fish (Wahlberg, M., Fjord and Baelt, University of Southern Denmark, pers. comm. 04 March 2010). This panel is currently reviewing results from hearing studies on fish, both hearing specialists and generalists, to establish a set of criteria that would limit the level of exposure to noise experienced by fish. A number of agencies on the West Coast have agreed in principle to use interim criteria for injury to fish from pile driving activities. The agreed upon criteria are a Sound Pressure Level (SPL) of 206 dB re 1 μPa-m and accumulated Sound Exposure Level (SEL) of 187 dB re 1 μPa-m for fish over 2 grams (g; 0.071 ounces [oz]). For fish under 2 g (0.071 oz), accumulated SEL is 183 dB re 1 μPa-m (CADoT2009). Although these criteria are in use by general agreement, they do not represent legal limits for exposure thresholds.

ABR tests suggest that sea turtles in general respond to underwater sound between 100 Hz and 1,000 Hz (however, there is variation amongst species and age classes; see [Ketten and Bartol 2006] for discussion). Behavioral responses of sea turtles to low frequency sounds have been documented. In one study, loggerhead and Kemp’s ridley sea turtles displayed abrupt body movement, such as blinking, head retraction, and flipper movement when presented with sound at 430 Hz and 1.5 dB re 1 μPa-m in 189.25 liter (L; 50-gallon [gal]) tanks (Lenhardt et al. 1996); however, testing responses in a small space may have skewed the results; however, altered swimming patterns and orientation were also reported when loggerhead sea turtles in outdoor enclosures were exposed to high pressure airgun pulses of 120 dB re 1μPa-m (O'Hara and Wilcox 1990). Significant behavior variability has been noted in “typical” behavioral responses to anthropogenic noise in the sea (see Southall et al. 2007 for a discussion). Still, no criteria currently exist in the literature for limiting sea turtle exposure to noise in the underwater environment.

5.3 LIFECYCLE OF AN OFFSHORE WIND FARM

Four Phases of a Wind Farm

The lifecycle of an offshore wind farm can be divided into four phases:

- Preconstruction/Exploration
- Construction
- Operations/Maintenance
- Decommissioning

Each phase presents a different set of activities and potential impacts from those activities. **Figure 5-2** illustrates some of the activities conducted in each phase. The average lifetime of an offshore wind farm is assumed to be about 30 years, with 1 to 5 years for the preconstruction/exploration phase, 1 year for construction, 20 to 25 years for the operation/maintenance of the wind turbines, and 1 year for decommissioning (Nedwell and Howell 2004).

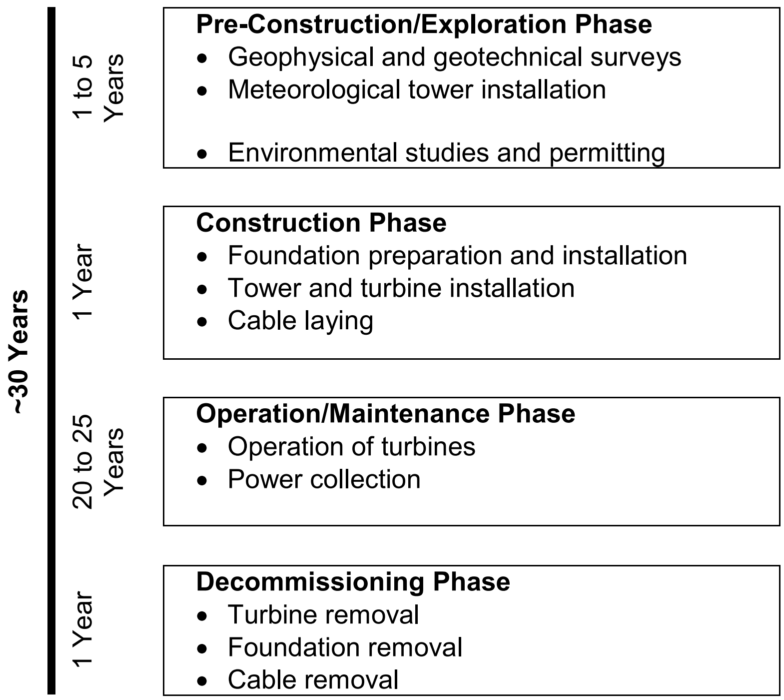

Figure 5-2. The life cycle of an offshore wind farm. Adapted from Nedwell and Howell (2004).

5.4 PRECONSTRUCTION/EXPLORATION PHASE

5.4.1 Description of the Preconstruction/Exploration Phase

The preconstruction/exploration phase is that time period after a project proponent has selected a general project area based on wind energy and hydrographic information until a specific plan has been approved and construction begins. During this phase, site-specific surveys would be conducted to collect data on ocean-bottom and sub-bottom characteristics, such as water depth contours, geologic structure and sediment type, stratigraphy and sediment transport, benthic habitats, and potential cultural resources (shipwrecks, archeological material). Local meteorological and oceanographic information, such as wind speed and direction, wave height, currents, and seasonal fluctuations, also need to be gathered. Lastly, depending on the existing information available for the proposed location, surveys for the biological resources of an area that could be affected by either the construction or operation of a wind farm would need to be conducted. **Figure 5-3** illustrates the activities likely to occur in the preconstruction/exploration phase and the potential environmental impacts associated with these activities (Hiscock et al. 2002).

Collection of local meteorological and oceanographic data requires installation of a meteorological (met) tower to which the survey instruments are attached. Met towers are typically of a steel lattice construction or monopile, and are built on similar foundations as the wind turbine. These foundations can be monopile, tripod or a gravity structure. The height of a met tower is generally at least as high as the anticipated hub height for the size of turbine (output) desired (MMS 2007). Under good conditions, a met tower should take less than a week to install (Nedwell and Howell 2004).

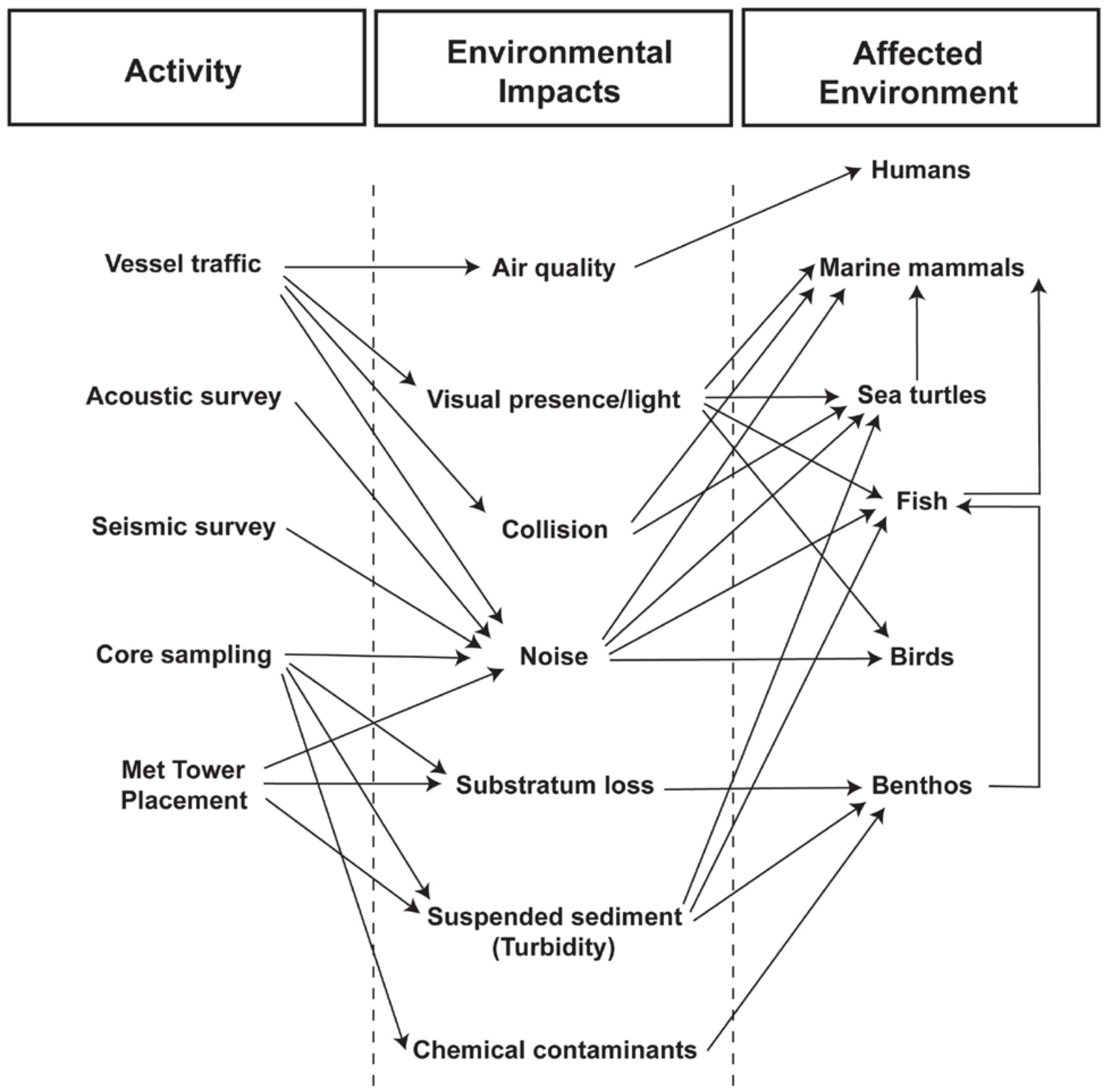

Figure 5-3. Potential impacts and targets of the preconstruction/exploration phase (Hiscock et al. 2002).

Geotechnical and geophysical (G&G) surveys are used to provide information about the depth and content of the seafloor and substratum and include sediment sampling, acoustic scanning, and seismic surveys. Sediment sampling is conducted to obtain samples of the seafloor for physical and/or chemical analyses. The three bottom sampling devices consist of a piston or gravity core, grab or dredge sampler, and rotary drill. These devices penetrate between a few centimeters to a few meters below the seafloor and do not use high energy sound sources to penetrate the sea bed. Vibracore samplers use compressed air to operate a vibratory hammer that propels a core barrel into the sub-bottom materials. These samplers can generally penetrate from 6.1 to 12.2 m (20.0 to 40.0 ft). Deep borings are usually collected by cable-tool or drive-and-wash drilling techniques. A cable-tool drill rig raises and drops a drill string with a heavy carbide-tipped drill bit that chisels through the rock by finely pulverizing the subsurface materials.[27] The drive-and-wash method uses water to bring the drill cuttings up to the surface. Cable-tool drilling is loud and slow, but can penetrate several hundred feet below the surface.

G&G surveys may consist of seismic surveys, side-scan sonar imaging, and magnetometer surveys. There are numerous methods for conducting each of these surveys; they are described here in generalities only to the extent necessary to discuss potential impacts on the surrounding environment. A typical seismic survey operation consists of a ship towing an air gun behind the ship and a streamer cable with a tail buoy behind the air gun. The distances separating the air gun and buoy vary depending on the depth and resolution of the data required. The air guns produce sudden, short bursts of sound at high sound levels over a range of low frequencies between 10 to 1,000 Hz with most energy between 10-20 Hz. While surveying, air-guns may fire every few seconds, e.g. an array of 32 air guns may produce a peak sound level of 210 dB at 50 Hz, whereas larger arrays may produce up to 259 dB (Richardson 1995; Hiscock et al. 2002). Side-scan sonar is used for evaluating surface sediments, seafloor morphology, and surface obstructions. To conduct the survey, a ship tows a sensor package, or “fish”, above the seafloor in overlapping parallel lines. Line spacing is directly related to water depths and widens as depth increases. The frequency of sound emitted by the “fish” determines the width of each scan and the resolution of bottom features detectable. The lower the frequency (around 150 kHz), the wider the scan-range possible (up to 400 m [1,312 ft]). Higher frequencies (around 1,800 kHz) can only scan a width of about 15 m (49 ft); however, they produce higher resolution and can detect smaller objects or features on the bottom. Typical surveys are conducted at speeds between 5.6 kph and 9.3 kph (3.0 kts and 5.0 kts).[28]

5.4.2 Potential Impacts of the Preconstruction/Exploration Phase

The potential impacts generated during the preconstruction/exploration phase would result from the vessels and equipment used to conduct site characterization and construct the met tower. The noise and seafloor disturbance resulting from the installation of the met tower would be similar to the noise and seafloor disturbance generated by construction of the wind turbine foundations, which is described in detail in **Section 5.5.2**. **Table 5-2** summarizes these potential impacts.

Table 5-2. Summary of potential effects of the preconstruction/exploration phase of offshore wind farm development (Hiscock et al. 2002; Nielsen 2006).

Activity	Potential Effect	Level of Effect
G&G surveys	Air Quality Vessel collisions Noise Seafloor disturbance	**Local, short term** • Diesel emissions from vessels conducting surveys • Noise from a range of acoustic surveying methods **Area, short term** • Displacement of fish, seabirds, marine mammals, and sea turtles from the affected area • Indirect effects on predatory seabirds **Area, long term** • Potential injury or mortality of marine mammals or sea turtles
Core sampling	Substratum loss Suspended sediment Physical disturbance Chemical contaminants	**Local, short term** • Direct removal of samples of benthos and substratum, resulting in very localized increases in suspended sediment and turbidity and extraction of the benthic macrofauna.

5.4.2.1 Air Quality

Section 328 of the Clean Air Act (CAA; 42 U.S.C. 7627) states that for OCS sources located within 40.2 km (25.0 mi) of the seaward boundary of coastal states, air quality requirements for emission controls, emission limitations, offsets, permitting, monitoring, testing, and reporting shall be the same as would be applicable if the source were located in the corresponding onshore area. OCS sources include such activities as platform and drill ship exploration, construction, development, production, processing, and transportation. Emissions from any vessel servicing or associated with an OCS source, including emissions while at the OCS source or en route to or from the OCS source within 40.2 km (25.0 mi) of the OCS source, shall be considered direct emissions from the OCS source.

The U.S. EPA and the NJDEP have established federal and state ambient air quality standards (AAQS) for six criteria pollutants and for determining which Air Quality Control Regions (AQCR) are in attainment of the AAQSs and which are non-attainment areas. New Jersey coastal counties are in attainment for all criteria pollutants except ozone. The state of New Jersey is designated as non-attainment for 8-hr ozone.[29]

During the preconstruction/exploration phase, the equipment associated with the site characterization surveys, which would include marine vessels and boring equipment, would be considered OCS sources and would have to conform to U.S. EPA and NJDEP requirements for diesel- or gasoline-powered equipment.

Preconstruction/exploration air quality effects on seabirds and marine life from these temporary activities have not been documented and there are no known documented air quality effects on birds, mammals, sea turtles, and fish.

5.4.2.2 Vessel Traffic

During the preconstruction/exploration phase, there would be an increase in vessel traffic conducting the site characterization surveys and constructing the met tower. Vessel traffic may affect birds through displacement and marine mammals by direct injury (collision) or behavioral modification.

Results from other studies indicate displacement of sea ducks and loons during vessel approach with a return to the area after the vessel leaves the area (MMS 2009c). Northern Gannets on the water generally allow a close approach before moving and sometimes follow ships to forage. Gannets, gulls and terns forage near boats and other man-made structures (MMS 2009c). Gulls are often attracted to areas of human activity and overall seem to have a lower sensitivity to these activities (Borberg et al. 2005); (Drewitt and Langston 2006).

In one study of vessel collisions with whales, the whales were either not seen beforehand or were spotted too late to avoid collision (Laist et al. 2001). Whale strikes have been recorded at vessel speeds of 3.7 to 94.4 kph (2.0 to 51.0 kts), with most severe or lethal injuries occurring when the vessels were moving at more than 26 kph (14 kts; Jensen and Silber 2003; Vanderlaan and Taggart 2007). Collisions can occur with any size vessel; however, impacts with larger vessels (more than 80 m [262 ft] in length) are generally more severe or result in lethal injuries (Vanderlaan and Taggart 2007).

Typically, G&G surveys are conducted at vessel speeds of between 5.6 kph and 9.3 kph (3.0 kts and 5.0 kts). The vessel used for the marine mammal and sea turtle surveys conducted as part of this EBS was 44.5 m (146.0 ft) long and surveyed at 18.5 kph (10.0 kts). Construction vessels on site would move at similarly slow speeds while activities are being conducted. At these sizes and speeds, the vessels used for the preconstruction surveys would have a lower risk than would larger, faster vessels of injuring animals should a collision occur; however, all of these vessels will likely transit to the site at higher speeds and may have more of an impact should a collision occur.

Many species of marine mammal and sea turtle, including all of the species sighted during this survey, are known to react behaviorally to the presence and movement of vessels (Koski et al. 1998; Hazel et al.

2007; Smultea et al. 2008). This reaction may be in response to the noise the vessel makes or may result from a visual cue the animal receives that causes that individual to engage in reactionary behavior. Responses to vessels may include attraction, indifference, or avoidance.

Sea turtles are likely to dive at the approach of a vessel; however, they are still at risk for injuries due to collisions with vessels. Between 1987 and 1993, up to 17% of all stranded sea turtles along the Atlantic Coast had vessel collision-related injuries. As with whales, sea turtles are more prone to collision with high-speed vessels than with vessels traveling at the slower speeds that construction barges would travel. In addition, when foraging, sea turtles spend large amounts of time submerged, reducing the potential for vessel collision (USACE 2004). Underwater feeding times can last more than 2 hrs (Renaud and Carpenter 1994). Hardshell sea turtles, such as the loggerhead, can be prone to a phenomenon known as "cold-stunning" in areas where water temperatures can be colder than an animal's lower thermal limit. Cold-stunning can result in lethargy that makes it difficult for an individual to evade an approaching vessel, increasing the chances for collision.

5.4.2.3 Noise

Typically, preconstruction/exploration periods represent the phase of a study during which noise levels from biological and ambient sources are assessed. Baseline levels prior to construction activities facilitate a direct comparison between noise levels generated by construction activities (e.g., pile driving or pile drilling) with those measured in the absence of anthropogenic action related to construction and are necessary for quantitative acoustic impact assessment and the implementation of exclusion zones.

Noise generated during the preconstruction phase comes from vessel traffic, G&G survey equipment, and installation of the met tower. The frequency of sound emitted by G&G survey equipment may be low frequency (750 to 3,500 Hz) or very high frequency (150 to 1,800 kHz). The noise from pile driving for installing the met tower is discussed in **Section 5.5.2.4**.

Noise from pre-construction activities may impact birds, mammals, and fish. Very few studies have been conducted on G&G study effects on marine life. Based on a review of these studies, seabirds in open water do not appear to be affected by G&G noise (Mosbech et al. 2000). Noise from pile driving has the potential to temporarily displace prey fish from the area around the met tower (Jarvis 2005) and temporarily decrease forage fish for fish-eating seabirds.

5.4.2.4 Disturbance of Seafloor

Most site characterization surveys would not disturb the seafloor; however, the collection of sediment cores would disturb localized areas of seafloor right where the core is collected. This may produce local, short-term impacts on benthic communities at the point of sample collection, from which the benthic communities can easily recover (Leonhard 2006). Negligible impacts are expected on birds, marine mammals, and fish because of the temporary nature of the activities.

5.5 CONSTRUCTION PHASE

5.5.1 Description of the Construction Phase

The construction phase can be divided into four potential impact-producing activities as shown in **Figure 5-4**:

- Vessel or helicopter traffic
- Sediment removal and disposal
- Foundation construction
- Cable laying

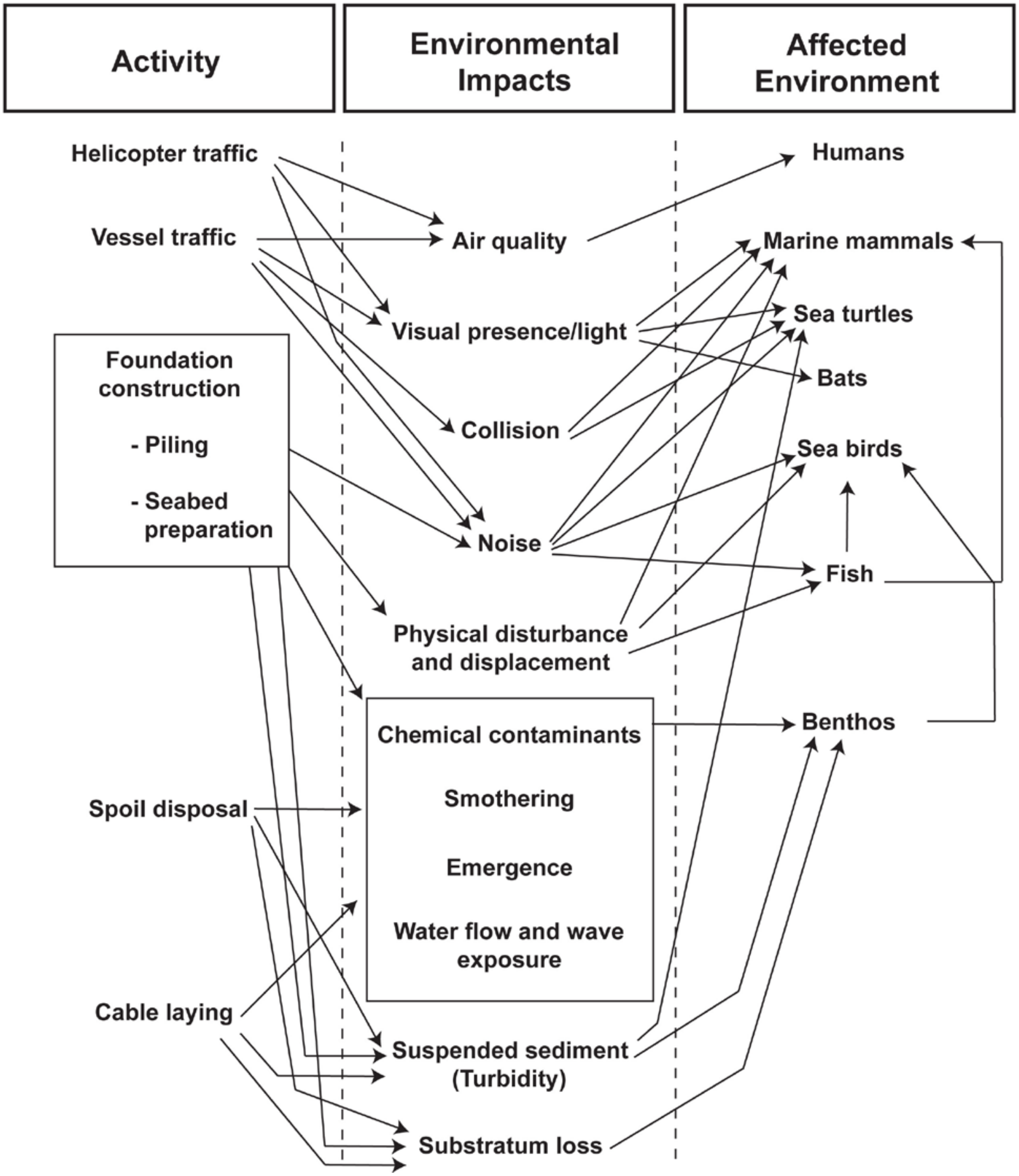

Figure 5-4. Potential impacts and targets of the construction phase (Hiscock et al. 2002).

Intense vessel traffic occurs during the construction phase. Generally, most construction materials and equipment are staged onshore and then transported to the construction site(s) by construction vessel or barge and tug. Actual construction is performed on jack-up or drilling barges. The number and type of vessels used would be dependent on the size of the wind farm being constructed, the distance from shore, water depth, and the amount of assembly performed onshore. Smaller vessels or helicopters could be used to transport personnel to and from the construction sites (MMS 2007).

Currently, most turbine foundations for offshore wind farms fit one of three types: gravity foundations, monopiles, or tripods (Hiscock et al. 2002; Jensen et al. 2006); however, the use of larger turbines in deeper water may require more sturdy designs, such as the jacket foundation. **Figure 5-5** depicts examples of these four foundation styles.

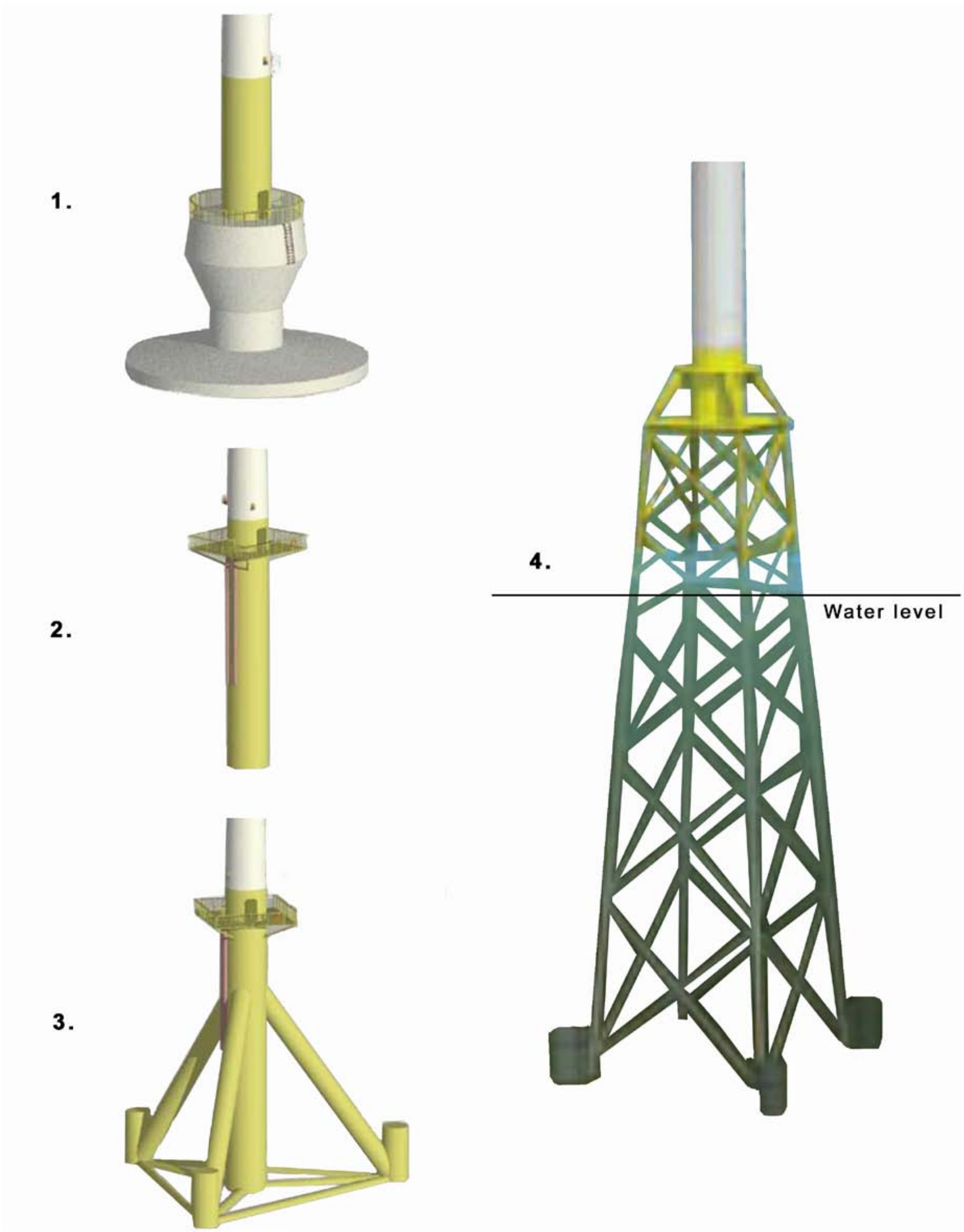

Figure 5-5. Potential styles of offshore wind turbine foundations. 1. Gravity, 2. Monopile, 3. Tripod, and 4. Jacket or Derrick. Adapted from (AWS 2009).

Gravity foundations consist of either concrete or steel caisson structures typically measuring about 15 m (50 ft) in diameter at the base (Hiscock et al. 2002). These foundations rest on the seafloor; however, the do require seabed preparation, which often includes removal of silt and placement of a layer of gravel to support the base evenly (Hiscock et al. 2002; Leonhard and Pedersen 2006). The depth of silt removal would depend on the stratigaphy of the turbine location. Seafloor sediment removed (dredged) in order to create this support base for the foundation would need to be disposed of in accordance with regulations and permits approved by the USACE and the U.S. EPA.

A monopile foundation is a steel pile roughly 4 to 7 m (13 to 23 ft) in diameter driven 10 to 20 m (33 to 66 ft) into the seabed. The pile diameter and the depth of penetration are determined by the size of the turbine and the sediment characteristics. Unlike the gravity foundation, no seafloor preparation is typically needed. The required size of the monopile increases disproportionately as turbine size or water depth increases making this foundation option less suitable for larger turbines in water more than about 20 m (66 ft; AWS 2009).

Tripod foundations consist of three steel legs fixed to the bottom by a steel pile driven 10 to 20 m (33 to 66 ft) into the seafloor. The diameter of the pile for these legs is smaller than the monopile, about 0.9 m (3.0 ft). Tripod foundations are suitable for deeper waters, but not for waters shallower than 6 to 7 m (20 to 23 ft; Hiscock et al. 2002). The impacts from tripod foundations are similar to those from monopile foundations, so they will not be discussed separately in the potential impact discussions.

For larger turbines or deeper waters, jacket or derrick foundations can provide greater stability. These foundations are four-sided, A-shaped lattice structures that are commonly used by the offshore oil and gas industry. Piles are driven into each of the four legs to secure them on the seabed (AWS 2009).

Scour protection is necessary around gravity foundations and might be necessary around other foundations to minimize erosion around the base. Typical scour protection lies approximately 1.0 to 2.0 m (3.3 to 6.6 ft) in height above the original seabed and consists of a protective rock mattress of large rocks sitting on top of a layer of smaller rocks (Leonhard 2006).

Once the foundation is in place, the turbine tower, nacelle, hub, and blades are lifted into place using a crane or derrick on a jack-up barge. An electrical service platform (ESP) is constructed near the center of the turbine array or at the end closest to shore to connect all of the turbines with circuit breakers and transformers. The ESP often contains a helicopter pad for transporting personnel or equipment to and from the shore. **Figure 5-6** presents a stylized layout of an offshore wind farm.

In order to use the electricity produced by the turbines, cables are laid to connect the turbines to the ESP and then transmit the electricity to facilities onshore. The power generated by the turbines is collected by cables that are operated at a distribution grade voltage (such as 13.2 kilovolts [kV]) and combined at the ESP, where it is stepped up in voltage (such as 69, 115, or 138 kV) for transmission to shore. The transmission cable(s) delivers the wind farm's total output to the onshore electric grid, where the power is then delivered to loads. Both types of cable may have trenching requirements and specifications for armoring (Habig et al. 2004). 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. Horizontal directional drilling (HDD) is typically used to transmit the cable under the shoreline (MMS 2007).

5.5.2 Potential Impacts of the Construction Phase

The potential impacts generated during the construction phase would result from the vessels used to transport equipment, supplies, and workers to the wind farm site, the seafloor preparation and construction of the foundations, and the installation of the power cables within the wind farm and to the onshore facilities. **Table 5-3** summarizes these impacts.

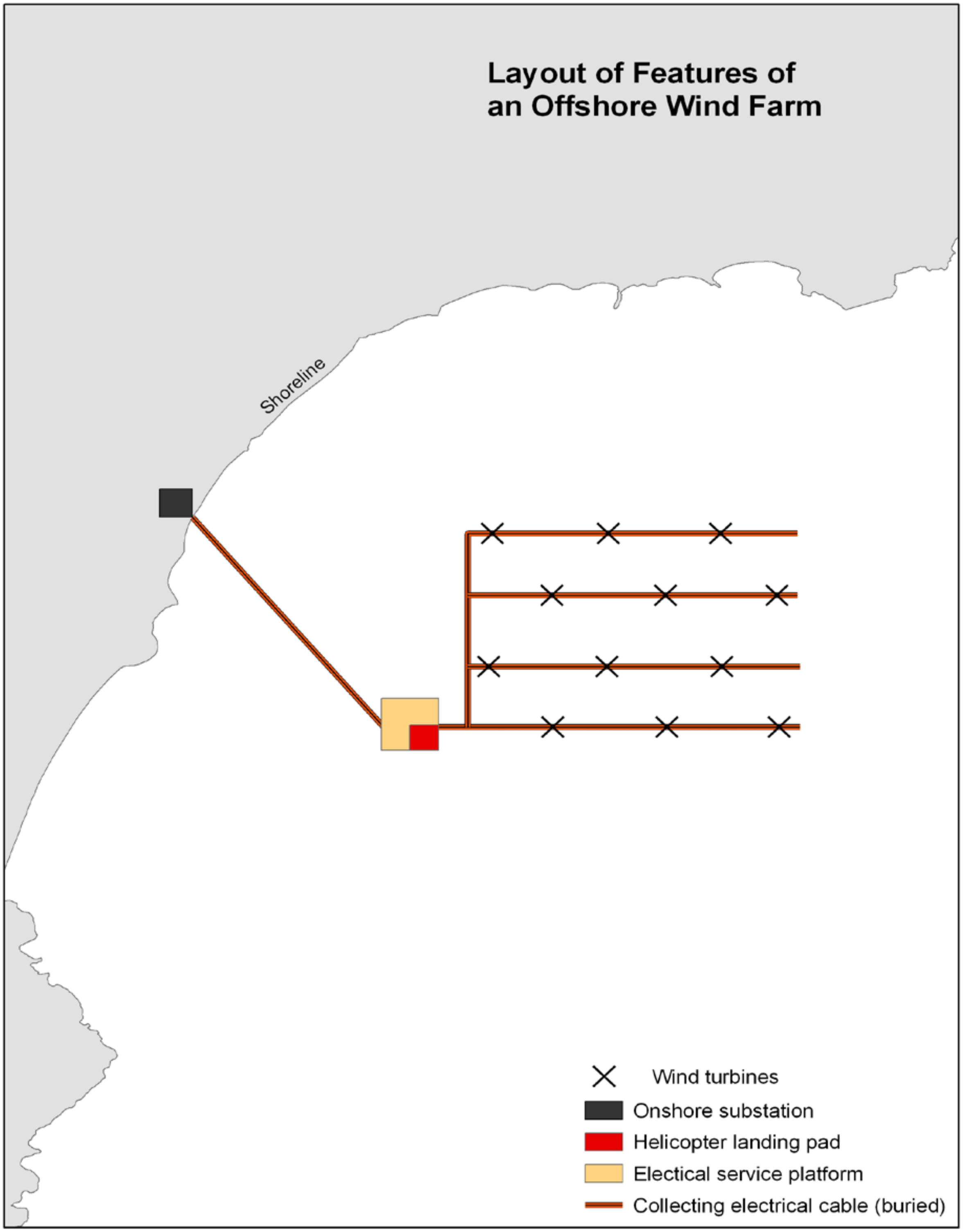

Figure 5-6. Potential layout of features of an offshore wind farm.

Table 5-3. Summary of potential effects of the construction phase of offshore wind farm development. Adapted from Hiscock et al. (2002) and Nielsen (2006).

Activity	Potential Effect	Level of Effect
Vessel traffic	Air quality Vessel Collision Visual presence/lighting	**Local, short term** • Physical disturbance of benthic macrofauna due to anchoring and legs of jack-up barges and other vessels at construction sites • Light attraction of birds, bats, fish or their prey **Area, short term** • Displacement of birds, marine mammals, sea turtles, and fish from the affected area **Area, long term** • Potential injury or mortality of marine mammals or sea turtles
Foundation construction-Gravity	Noise Disturbance of seafloor Chemical contaminants Turbidity	**Local, short term** • Removal of sediment and associated macrofauna • Physical disturbance and damage of benthic macrofauna • Sediment plumes with increased turbidity • Burial of benthic fauna from settlement of sediment plume • Release of contaminants and nutrients in the sediment, if present **Area, short term** • Noise and general disturbance of the area • Displacement of seabirds, fish, marine mammals, and sea turtles • Displacement of forage species and disruption of habitat
Foundation construction-Monopile	Noise Disturbance of seafloor Chemical contaminants Turbidity	**Local, short term** • Sediment disturbance and turbidity plume from scour protection placement • Physical disturbance and damage of benthic macrofauna • Release of contaminants and nutrients in the sediment, if present **Area, short term** • Behavioral response to noise • Masking of local sounds needed for communication and safety • Displacement of forage species and disruption of habitat
Cable installation	Noise Disturbance of seafloor Chemical contaminants Turbidity	**Local, short term** • Physical disturbance of benthic macrofauna • Sediment plumes with increased turbidity • Disturbance of shoreline habitats where cables come onshore **Area, short term** • Potential changes in macrofaunal communities with indirect effects on fish and their predators
Sediment disposal	Disturbance of seafloor Chemical contaminants Turbidity	**Area, short term** • Burial of benthic macrofauna • Sediment plumes and turbidity at the construction site • Sediment plumes and turbidity at the disposal site • Sediment plumes could reduce the availability of prey • Release of chemical contaminants **Area, long term** • Changes to seafloor height and sediment dynamics

5.5.2.1 Air Quality

Construction phase impacts on air quality would result from both offshore and onshore activities. The offshore activities would consist of the installation of foundations, scour protection, turbines, and ESP, as well as laying cable between turbines and to the shore. OCS air emission sources would include jack-up barges, because they would be attached to the ocean floor, and the diesel-powered cranes and hydraulic rams on those barges. The vessels that service the barges would also be OCS sources while en route to or from the stationary platform within 40 km (25 mi) of the OCS source. Section 328 of the CAA requires the equipment associated with the construction phase to conform to U.S. EPA and NJDEP requirements for diesel- or gasoline-powered equipment.

Construction air quality effects on seabirds and marine life have not been documented and there are no known documented air quality effects on birds, mammals, sea turtles, and fish. Negligible impacts are expected on birds, marine mammals, and fish because of the temporary nature of the activities.

5.5.2.2 Helicopter and Vessel Traffic

Helicopters may be used occasionally to transport construction workers to the site and vessel traffic would be continuous during the construction phase. Helicopters and vessel traffic may impact birds through displacement and marine mammals by direct injury (collision) or behavioral modification.

During the construction phase displacement of some bird species from helicopter and vessel traffic would occur until the construction is completed. Helicopters are known to temporarily displace birds. Scoters are normally displaced by boats and loons often fly or dive when a boat approaches its location. Northern Gannets on the water generally allow a close approach before moving and sometimes forage by following ships, Gulls are often attracted to areas of human activity and overall seem to have a lower sensitivity to these activities (Borberg et al. 2005; Drewitt and Langston 2006). Increases in gull abundance during construction are documented in Europe at the Nysted and Horns Rev wind energy development construction sites (Petersen et al. 2006). Terns forage around commercial and recreational fishing vessels and other manmade structures and are known to habituate to some levels of human activities (MMS 2009c).

As discussed in **Section 5.4.2.2**, the potential for injury to marine mammals from vessel collision increases with the size and speed of the vessel. Most vessels used during construction would move at speeds of less than 5.4 kph (10.0 kts), which may reduce the likelihood of collision or the damage done should one occur. Crew vessels may transit to and from the work site at about 28 kph (15 kts); however, these vessels would be smaller and with less momentum would be easier to slow or stop to avoid collisions (MMS 2007).

Many species of marine mammal and sea turtle, including all of those sighted during this EBS survey, are known to react behaviorally to the presence and movement of vessels and helicopters (Koski et al. 1998; Hazel et al. 2007; Smultea et al. 2008). This reaction may be in response to the noise the vessel or aircraft makes or may result from a visual cue the animal receives that causes that individual to engage in reactionary behavior. Responses to vessels may include attraction, indifference, or avoidance. The reaction to aircraft will depend upon the altitude above the water; helicopters bringing equipment to construction sites will be very near to the surface when arriving and departing and may elicit behavioral response in marine mammals and sea turtles that are in the area.

Sea turtles are likely to dive at the approach of a vessel; however, they are still at risk for injuries due to collisions with vessels. Between 1987 and 1993, up to 17% of all stranded sea turtles along the Atlantic Coast had vessel collision-related injuries. As with whales, sea turtles are more prone to collision with high-speed vessels than with vessels traveling at the slower speeds that construction barges would travel. In addition, when foraging, sea turtles spend large amounts of time submerged, reducing the potential for vessel collision (USACE 2004). Underwater feeding times can last more than 2 hrs (Renaud and Carpenter 1994). Hardshell sea turtles, such as the loggerhead, can be prone to a phenomenon known as “cold-stunning” in areas where water temperatures can be colder than an animal’s lower thermal limit. Cold-stunning can result in lethargy that makes it difficult for an individual to evade an approaching vessel, increasing the chances for collision.

5.5.2.3 Visual Presence/Lighting

Extended vessel presence and lighting of cranes and non-operating turbines will occur during the construction phase. These factors may impact birds and marine mammals.

The presence of construction vessels would alter the visual characteristics of the wind farm area during the construction phase. Many of the vessels, such as derrick crane barges, are quite large and would be visible at greater distances than fishing or recreational vessels. They would also be on station for several days (and nights) at a time, so they would be a lighted presence offshore at night that would likely not be there otherwise. Any onshore visual impact from night lighting would be dependent on the distance or location of the viewer and the intensity and orientation of the lighting (MMS 2009c).

As previously discussed in **Section 5.4.2.2** and **Section 5.5.2.2**, visual presence (vessel traffic) may impact birds by displacement. Constant artificial night lighting tends to disorient birds accustomed to navigating in a dark environment. Birds can be disoriented and entrapped by lights at night. Once a bird is within a lighted zone at night it may become “trapped” and not leave the lighted area. Large numbers of nocturnally migrating birds could therefore be affected when changes in meteorological conditions (e.g., fog, rain, wind direction/speed) bring them close to lights (Longcore and Rich 2004). Songbirds that migrate at night are attracted to sources of light, especially under overcast or foggy weather conditions. Birds that are not killed outright by collisions with the light sources can succumb to exhaustion brought upon by prolonged fluttering around a light source or to predation upon individuals in weakened states (Jones and Francis 2003).

Some of the construction equipment and erect turbines may be lighted at night and have the potential to attract birds. Many studies have been conducted regarding the bird collision impacts associated with various types, frequencies, and intensities of lights. These studies have found that steady burning Federal Aviation Administration (FAA) obstruction lights on tall buildings and structures can attract or disorient birds that can result in bird-collision structures. These collisions have been found to be more frequent during poor weather conditions (e.g., fog, rain, and low ceilings; Huppop et al. 2006); however, fewer waterbirds were found to migrate in strong head winds and when visibility was poor. In addition, the overall volume of migrating birds was noted to decrease significantly during weather conditions of elevated collision risk (Petersen et al. 2006).

Flying insects often seek out light sources, thereby attracting hunting bats to the light sources (Ahlén et al. 2007). During construction, night lighting on the barges and other stationary structures would only be temporary, and would not necessarily present a hazard to bats.

There is little, if any, literature discussing the interaction of marine mammals with sources of light.Sea turtle nesting activities are seriously affected by artificial light along nesting beaches (Salmon 2003); however, since sea turtles are not known to nest on the shores of New Jersey[30], onshore lighting is not a concern. Lighted offshore structures may attract young turtles and make them more susceptible to predation (Coston-Clements and Hoss 1983).

Unexpected lighting has been observed to disrupt the predator–prey relationship of fish and zooplankton. After sunset, zooplankton often migrate to the surface to forage on algae under cover of darkness, only to be illuminated by the rising moon and subjected to intense predation by fish. This “lunar light trap” illustrates a natural occurrence, but unexpected illumination from human sources could disrupt predator–prey interactions in a similar manner, often to the benefit of the predator (Longcore and Rich 2004). Fish are also attracted to the light itself, not just to the prey. Lights have been used to attract fish to fish ladders, allowing them to bypass dams and power plants. Similarly, lights have been used to attract larval fish to coral reefs (Longcore and Rich 2004); therefore, the construction vessels are likely to be a gathering spot for fish in the vicinity.

5.5.2.4 Noise

Activities associated with vessel operations, pile driving, and other associated construction activities would occur during the construction phase, Noise associated with these construction activities may impact birds, marine mammals, and fish.

The installation of offshore wind farms involves several activities with the potential to produce strong noise and vibrations under water. These activities include ship and barge noise, pile driving/drilling, general construction noise, and helicopter and crew boat operations. Ship and barge noise would be similar to that of general ship traffic with the low-frequency sound having possible masking effects on the communicative vocalizations of baleen whales. Additional construction noises include the use of hand tools and small machinery, such as air compressors; helicopters or crew boats used to ferry workers or materials to offshore work sites also contribute noise both in air and under water. The in-air noises do not penetrate the water to much depth due to the air-water surface tension, although they might cause short-term individual behavior and communication disturbances to terrestrial species (Medwin et al. 1973; Wahlberg and Westerberg 2005).

It is likely that ship noise would have a minimal impact on fish, bat, or avian populations, assuming the species in question had hearing capabilities outside the noise levels of the anthropogenic activities; however, if the frequency composition of the ship engine noise is within the hearing sensitivity range of fishes that do not or cannot escape extended noise exposure, an elevation of the fishes' auditory threshold is possible (Scholik and Yan 2002). When smaller vessels (e.g., trawlers and ferries) are detected, fish typically exhibit a variety of behaviors (e.g., induced avoidance, altered schooling, and altered swimming speed and direction; Engås et al. 1995; 1998; Sarà et al. 2007); undergo hearing impairment (i.e., long-term, continuous exposure: 2 hrs; Scholik and Yan 2001; Vasconcelos et al. 2007); or increase cortisol levels (i.e., stress levels continuous exposure 30 min; Wysocki et al. 2006). With larger size vessels, pelagic fish tend to dive deeper in the water column, while demersal species make lateral movements. Whether a pelagic or demersal species, most fishes have been observed to increase their swimming speed when approached by a vessel. Gadids and herring respond to approaching vessels with both diving and horizontal movements (Vabø et al. 2002; Handegard et al. 2003). Impacts would be expected to be minor and may be similar to the above behaviors that are probably occurring with the existing vessel activity (e.g., pleasure boat activities or fishing activities; MMS 2009c).

Nesting seabirds and shorebirds would be the species most likely to be affected by noise from the installation of transmission lines, because of the need to install the cable across the beach area. Similarly, shorebirds that nest on beaches could be driven from an area because of noise from construction and may or may not return. If the cable landing must occur on a beach where birds nest, construction should be scheduled to avoid the nesting season.

Pile driving/drilling has the greatest potential for impact and is the primary concern with respect to construction noise from offshore projects. Pile driving procedures produce intense sound pulses in water, often with peak sound pressure levels of 230 dB re 1 μPa-m with pulse durations of 0.15 to 0.40 s for approximately 40 min per operation (Lepper et al. 2009). In shallow water with a sandy bottom, a received noise level of 180 dB re 1 μPa-m at distances of 2.8 km (1.5 mi) has been measured (Lepper et al. 2009).

Normal behaviors of marine mammals, sea turtles, and fish, such as feeding, traveling, communicating with con-specifics, mating, and sensing predators can be disrupted by noise masking and site avoidance related to pile driving. Responses are also dependent upon the individual- or species-in-question's hearing sensitivity and their distance from the noise source (see **Section 5.2** on hearing ability) (Nedwell and Howell 2004; Nedwell et al. 2007). Changes to normal behavioral activity might be incurred at ranges of many miles depending on an individual's ability to detect the sound. Physical injury such as hearing impairment (PTS and TTS) or mortality could occur at close range. Underwater noise levels assessed for bottlenose dolphins during pile-driving operations at an offshore wind farm (Moray Firth, Scotland) showed that auditory injury would have only occurred within 100 m (328 ft); however, behavioral disturbance could occur up to 50 km (27 NM; Bailey et al. 2010). For that study, behavioral disturbance included any modifications in behavior that indicated a response, but not necessarily an avoidance reaction to the sound. It has been suggested that pile driving kills fish in close vicinity (within 1.0 to 2.0 m [3.3 to 6.6 ft]), while fishes just outside of that area could be physically injured in such a manner that might lead to death (Popper and Hastings 2009a). Studies so far indicate that pile-driving sound could kill or injure fish in close vicinity of a construction site and it seems plausible that temporary hearing loss could also occur at slightly farther ranges depending on whether fish move in response to the sound (Götz et al. 2009; Popper and Hastings 2009b; Thomsen and Judd in press). Noise from pile driving operations could have significant effects on fish (Hoffmann et al. 2000) such as preventing fish from reaching breeding or spawning sites, finding food, and acoustically locating mates (Mueller-Blenkle et al. 2010). Current studies conducted by (Mueller-Blenkle et al. 2010) on the effects of pile driving noise on the behavior of marine fish (Atlantic cod and flatfish) confirms the assessment of (Thomsen et al. 2006) and Thomsen and Judd (in press) that behavioral response of fish to pile-driving sound might happen at relatively large spatial scales.

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 has been documented for the New Jersey coast.[3030]

5.5.2.5 Disturbance of Seafloor

Pile driving and cable-laying activities would be the major disturbances to the seabed floor during construction. Habitat loss could occur depending on the habitat type present on seafloor. Birds, marine mammals, and benthic and pelagic fish could be impacted by these activities.

Seafloor Disturbance

During the construction phase, both seafloor preparation for foundations and cable-laying activities (e.g., jet plow embedment, scour protection devices, and vessel positioning and anchoring) will disturb the seafloor resulting in temporary sediment resuspension and redeposition. The level of disturbance during foundation construction is dependent on the type and diameter of the foundations used for the turbines and electrical service platform. Monopiles would induce less impact to the benthos compared to gravity foundations due to the amounts of foundation material to be laid out and the volumes of sediments to be removed from the seafloor for gravity foundations. Assuming removal of 1.5 m (4.9 ft) of silt for a gravity foundation 15 m (50 ft) in diameter, the amount of sediment removed per turbine would be approximantely 1,060 m^3 (39,275 ft^3 or 1,455 cubic yards [yd^3]). The disposal of excavated sediments would also result in sediments released onto the seafloor potentially burying sediment habitats (Hiscock et al. 2002). Cable-laying would result in the physical disturbance, damage, and displacement of benthos.

Seafloor disturbance may result in the localized habitat loss of demersal fish species (winter flounder, summer flounder, and little skate) and benthic invertebrates (clams and quahogs) that prefer unstructured habitats for feeding, spawning, and nursery areas. The adult/juvenile demersal fish and benthic invertebrates in direct path of bottom disturbing activities may experience some direct mortality or injury. During winter construction periods, demersal fish may experience higher levels of injury/mortality due to sluggish response under cold water conditions (MMS 2009a). Seafloor disturbance may affect the eggs of demersal spawners (fish spawning at the bottom) and newly settled larvae (e.g., EFH species); however, the areas of sediment disturbance are generally small compared to the total wind farm area (Jensen et al. 2006). Because the duration of the impact is short and the areal extent small, the effects are considered short term and minor.

In general, infaunal benthic communities are adapted to and tolerant of sediment disturbances and are very insensitive to smothering. Smothering with redeposited sediment would temporarily halt feeding and respiration, which requires the infauna to relocate to their preferred depth. Feeding and respiration would return to normal soon after relocation and recoverability is presumed very high (Leonhard and Pedersen 2006). Many benthic invertebrate species easily recolonize sediments after disturbance (Nedwell et al. 2004; MMS 2007).

At Nysted, dredging activities in connection with the excavation of the gravity foundations contributed to an increase in turbidity and sedimentation. The impacts on infaunal benthic communities were temporary and of limited spatial importance (Leonhard and Pedersen 2006). Surveys conducted along the cable trench at Nysted revealed that eel grass, macroalgae and benthic infauna were affected close to the trench. Within two years, the eel grass had recovered, but recovery of macroalgae and benthic infauna was still in progress after two years (DONG Energy 2006). At Horns Rev, sediment spillage from dredging for foundations showed only very local and short-term impact of increased turbidity, and a thin accumulation of spilled sediment. The impacts were much lower than the natural disturbance of sediment in the area from currents and winds (Elsam Engineering and ENERGI E2 2005).

Habitat Loss

Marine and coastal birds could also be displaced from normal feeding grounds during construction if the wind farm is constructed in offshore foraging areas. This displacement would likely be related to surface activity, as opposed to underwater noise production and could impact onshore nesting sites or rookeries because adults might be required to travel greater distances from the nest to forage. As a result, adults would be required to stay away from the nest longer to forage to feed their young (MMS 2007). Many of these impacts could be reduced or eliminated by careful planning of a wind farm site relative to the habits and habitats of marine mammals, sea turtles, fisheries, and marine and coastal birds.

Sea ducks are one of the most sensitive guilds to habitat loss associated with wind development (MMS 2009c). Foraging areas, including shoals and surrounding waters are important for sea ducks and gannets during migration and winter. Preferred sea duck foraging areas are usually not deeper than 50 m (164 ft; Robertson and Savard 2002). In the Study Area, Surf Scoter and Black Scoters were the most prevalent species of sea duck observed. Scoters displaced from foraging sites during construction must locate alternate foraging sites. If these sites are used by other sea ducks, overcrowding can result in increased competition for food resources that in turn can cause an increase in mortality (Maclean et al. 2006). In contrast to scoters, loons do not usually forage in large flocks. Northern Gannets forage alone and at times in flocks (usually <50 individuals). Although marine foraging habitat loss has not been studied in loons and Northern Gannet, habitat impacts similar to those described for scoters would be expected.

Water withdrawals associated with the jet plow embedment (cable-laying operation: which injects water at high pressures into the sediment to loosen and liquefy), ballast water exchange, and engine cooling would be withdrawn from the near-surface habitat. Any eggs or larval life stages of certain fish species (e.g., black sea bass, winter flounder [*Pseudopleuronectes americanus*], summer flounder, and Atlantic butterfish) that may be present in the immediate area of water withdrawal would likely have the potential to be entrained and would likely suffer 100% mortality (MMS 2009c). Overall impact to the eggs/larvae is expected to be negligible to minor. This is due to the fact that given the fecundity of fishes, the loss of eggs and larvae only represents a small fraction of equivalent adults of the species that are present and the rate egg or larval survival to adulthood is very low for many marine finfish fishes. Studies conducted in New Hampshire coastal water estimated the only one in 2,700 winter flounder survived to adulthood (MMS 2009c). These construction-related impacts are expected to be similar to impacts during de-commissioning (MMS 2009c).

5.5.2.6 Collision with Construction Equipment or Pylon/Blade

Construction equipment to station turbines and the erect turbines pose a potential collision risk to flying birds because birds are known to collide with tall stationary structures (Shire et al. 2000). Avian collision mortality associated with monopoles and stationary construction equipment has not been studied at offshore wind developments. In general, collision impacts would be anticipated to be less than of operating turbines because the potential collision area on a non-operating turbine is much smaller than an operating turbine.

5.5.2.7 Water Quality: Turbidity/Chemical Contaminants

As discussed above, seafloor preparation for foundations, including the deposition of sediment removed from the gravity foundation sites, and cable-laying activities during the construction phase will result in temporary sediment plumes, and therefore, would increase the turbidity of the water. The higher the concentration of suspended sediment in the water column, the higher the impact on aquatic organisms would be; however, the effects on aquatic organisms are more closely related to the combination of concentration and duration of exposure than concentration alone (Jensen et al. 2006).

The sensitivity of finfish/invertebrates to siltation, sedimentation, and turbidity is species-specific and highly dependent on the lifestage (egg, larvae, juvenile, and adult). Apart from these biological parameters, the degree of disturbance also depends on a number of abiotic factors: (1) density and distribution of sediment particles, (2) mineral composition, (3) adsorption and absorption capacity, and (4) prevailing temperature and oxygen (A.A. Keller et al. 2006). Demersal finfishes and invertebrates would be impacted through a decrease in water clarity potentially affecting the foraging efficiency of visual predators and filter feeders, disrupting ichthyoplankton development, clogging gills and injuring skin, and causing partial or complete burial (Newcombe and Jensen 1996; Johnson et al. 2008); however, most demersal species are highly mobile and would be able to escape the area or shed sediment accumulation. The species or lifestages (eggs/larvae) that are not able to escape the accumulation of siltation, sedimentation, and turbidity could experience physiological stress, such as decreased feeding and respiration rates, increased metabolic activity or mortality (Newcombe and Jensen 1996). Coastal pelagic fishes such as cobia (*Rachycentron canadum*), king mackerel (*Scomberomorus cavalla*) and Spanish mackerel (*S. maculates*) could alter migratory routes or temporarily disrupt feeding activity in shelf or nearshore waters (ENSR 2005). Demersal flatfish can tolerate much higher suspension concentrations than pelagic species (e.g., striped bass, Atlantic cod, and clupeids; (Keller et al. 2006).

Suspended sediment concentrations are not expected to last very long within the Study Area because of dispersal from the offshore currents and the relative size of the sediments. The larger the sediments, the faster they settle out. Sand does not remain suspended in the water column for nearly as long as silt or clay (Jensen et al. 2006).

The bottom sediments found in the Study Area consist of mostly sand with some areas of sand and gravel (see **Figure 2-15**). Sand does not retain contaminants nearly as well as silt and clay; therefore, the resuspension of sediments is not likely a source of contaminants in the water. Farther distance from the shoreline bays and rivers reduces the potential influence of land-based contaminants (Mann and Lazier 1991).

Re-suspension of sediment-bound contaminants, such as metals and pesticides, during the construction/decommissioning phase can have lethal and/or sublethal effects to fishery resources (Johnson et al. 2008). These contaminants may have accumulated in coastal sediments from past industrial activities, particularly in heavily urbanized areas. Metals may initially inhibit reproduction and development of marine organisms, but at high concentrations can directly or indirectly contaminate or kill finfish and invertebrates. The early-life stages of fish are the most susceptible to the toxic impacts associated with metals (Gould et al. 1994). The release of contaminants can reduce or eliminate the suitability water bodies as habitat for fish species and their prey. In addition, contaminants, such as copper and aluminum, can accumulate in sediments and become toxic to organisms contacting or feeding on the bottom (Johnson et al. 2008).

Sediment plumes are not likely to cause any direct impact on marine mammals, but may reduce the availability of prey, especially juvenile fish; however, the affected areas are expected to be very small compared to the total wind farm area and the duration of the plume is usually is short (Skov and Thomsen 2006).

Any activity requiring offshore vessel traffic runs the risk of degrading water quality by discharging oil or oily wastes either intentionally or by accident. All vessels used in any of the four phases of the life of a wind farm would be required to comply with all laws and regulations regarding discharges of bilge water, ballast, gray water, trash, or debris. If the requirements are followed, there would be no impact on water quality from routine vessel operations. A collision with another vessel or offshore structure could result in a release of fuel or oil.

Any type of fuel or oil spill has the potential to cause impacts to organisms and habitats in the water column, on the bottom, and on the shoreline, but it is unknown to what extent these effects are individually or cumulatively significant. The effects of a spill are dependent on the type of spill, toxicity of the substance spilled, magnitude of the spill and the movements of the spilled substance. Diesel and lighter weight oils would evaporate or degrade faster than heavier crude oil. Incidental fuel spills involving small vessels are probably common events, but these spills typically involve small amounts of material that would not cover a large area.

When bird feathers become coated with oil, they lose their ability to repel water and help with thermoregulation. Depending on the magnitude of oiling, birds may lose their ability to fly. The potential short-term impacts to birds from oil include heat loss, starvation, and drowning. Long-term impacts could include death from oil injested incidentally or from ingesting oil-contaminated food resources (MMS 2009a; Jarvis 2005).

Short-term impacts from low-level oil exposure by fish would include interference with the reproduction, development, growth, and behavior (e.g., spawning and feeding) of fishes, especially at early life-history stages (i.e., eggs and larvae are most sensitive; Gould et al. 1994).

5.5.2.7 Disturbance of Wetlands and Uplands

Because this is a discussion of general impacts associated with wind farm development in the Study Area, impacts on specific areas of wetlands or uplands are not presented and would need to be evaluated once a specific project has been proposed. That said, the cable laying from the wind farm to upland facilities would have impacts on any sensitive habitats, such as wetlands or seagrasses, it encounters. Seagrass meadows are considered EFH for several species because they provide nurseries and shelter for a variety of commercially important marine organisms (e.g., flounder, smelt, striped bass, cod, lobsters, and blue mussels). At least two species of seagrasses occur extensively in the back barrier lagoons of New Jersey; however, there are no seagrass beds within the Study Area (Macomber and Allen 1979; Green and Short 2003). Horizontal directional drilling is often used to prevent the impacts of trenching across the shoreline and beach and can be used to go under sensitive areas when going around them is not an acceptable option.[31]

Nearshore construction activities associated with the transmission line (human presence and equipment disturbance) could impact seabird nesting colonies. These impacts may result in adults abandoning nests, death of the eggs and/or young and increased predation of eggs and young due to abandonment (MMS 2009c).

5.6 OPERATIONS/MAINTENANCE PHASE

5.6.1 Description of the Operations/Maintenance Phase

Currently, most wind turbines are designed to have a 20- to 25-year lifespan. During that time, wind will turn the blades to generate electricity, which will then be transmitted via cable to a shore facility and onto the power grid. The onshore portion of operations is not addressed in this report. Offshore, the operations and maintenance phase consists of the physical presence and operation of the turbine towers and foundations, electric service platform, and transmission cables; and the vessel traffic required for routine and emergency maintenance (**Figure 5-7**).

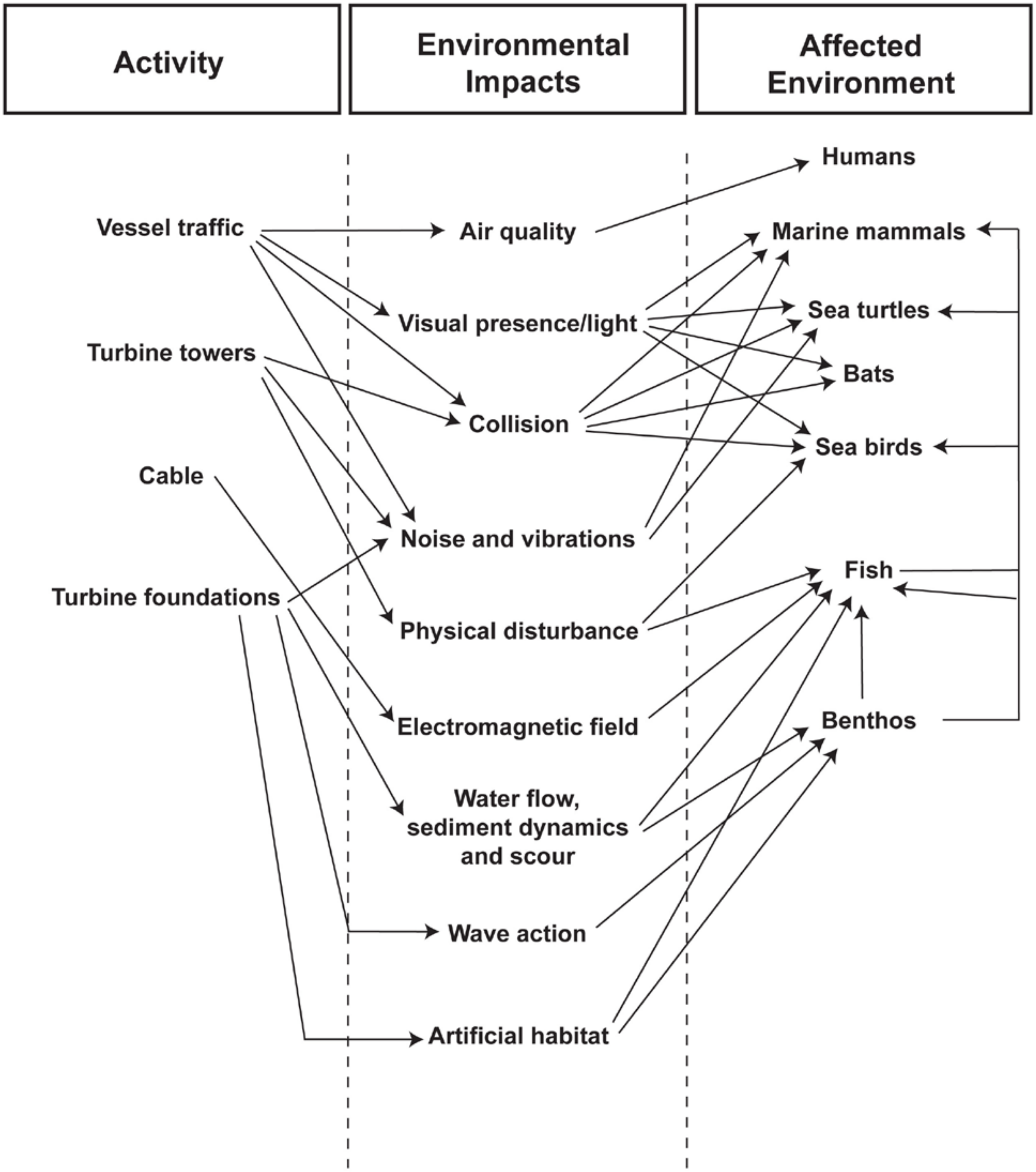

Figure 5-7. Potential impacts and targets of the operations/maintenance phase (Hiscock et al. 2002).

5.6.2 Potential Impacts of the Operations/Maintenance Phase

The potential impact-producing activities of the operations and maintenance phase of the wind farm include emissions, vessel traffic, and visual presence and lighting from the vessels used for the periodic or emergency maintenance. The visual presence, noise and vibrations, and habitat modification from the turbines and their foundations or scour protection are also potential impacts of the operation phase. EMFs produced by the cables could also have impacts on the surrounding areas. **Table 5-4** summarizes these potential impact-producing activities.

Table 5-4. Summary of potential effects of the operations/maintenance phase of offshore wind farm development. Adapted from Hiscock et al. (2002) and Nielsen (2006).

Activity	Potential Effect	Level of Effect
Physical presence of the turbine Towers	Noise Visual presence Displacement	**Local, long term** • Resultant changes in the benthic communities in the vicinity of the turbines • Disturbance of feeding birds in the vicinity • Displacement of bird flight paths, a potential barrier to flight paths or migration routes, and mortality due to bird strike • Provision of new substrata and habitats for colonization and formation of an artificial reef • Attraction of fish species to the artificial reef and their predators (seabirds, marine mammals, sea turtles, predatory fishes) • Light attraction of birds, bats, fish or their prey **Area, long term** • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast • Changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators • Provision of 'non-fishing' or 'no-take' zones
Physical presence of electric cables	Electromagnetic fields (EMF)	**Local, long term** • Potential effect of EMFs on fish migration and feeding behavior, especially in sharks and rays • Potential long-term risk of releasing heavy metals and increase in sediment temperature
Periodic maintenance	Vessel collision Visual presence	**Local, short term** • Light attraction of birds, bats, fish or their prey **Area, long term** • Potential injury or mortality of marine mammals or sea turtles

5.6.2.1 Air Quality

The operation of wind turbines themselves would not produce air emissions. Minor emissions would occur from vessel traffic related to site inspection and maintenance activities. As discussed in **Section 5.4.2.1**, vessels servicing OCS structures within 40 km (25 mi) of the shore would need to follow EPA and NJDEP requirements for emissions controls.

Normal operational activities would have no impact on air quality. Maintenance activities would involve temporary visits by vessels and minor construction repair activities. Negligible impacts are expected on birds, marine mammals, sea turtles, and fish.

5.6.2.2 Vessel Traffic

The number of vessels and trips to and from the wind farm would be considerably less during operation and maintenance than during construction. As with any vessel traffic, there is a potential for disturbance or physical harm to birds, marine mammals, and sea turtles. Crew boats carrying maintenance crews would tend to travel faster than the slow-moving construction barges, but the potential for collision or behavioral disturbance remains.

Potential impacts to birds would be the same as discussed in **Section 5.4.2.2** and **5.5.2.2**. As discussed in **Section 5.4.2.2**, the potential for injury or mortality to marine mammals from vessel collision increases with the size and speed of the vessel.

Many species of marine mammal and sea turtle, including several of those sighted during the EBS surveys, are known to react behaviorally to the presence and movement of vessels (Koski et al. 1998; Hazel et al. 2007; Smultea et al. 2008). This reaction may be in response to the noise the vessel makes or may result from a visual cue the animal receives that causes that individual to engage in reactionary behavior. Responses to vessels may include attraction, indifference, or avoidance.

As discussed in **Section 5.4.2.2**, sea turtles are likely to dive at the approach of a vessel; however, they are still at risk for injuries due to collisions with vessels. Sea turtles are more prone to collision with high-speed vessels than with vessels traveling at the slower speeds that construction barges would travel.

5.6.2.3 Navigation

Any stationary structure in the ocean presents some risk for marine navigation. The location of offshore wind farms should be selected not to interfere with designated shipping lanes and prime fishing areas. The U.S. Coast Guard (USCG) has specific requirements and guidelines for marine safety issues such as proper lighting and signage that would be taken into account during the project approval process.[32]

5.6.2.4 Structure Presence/Lighting

The presence of wind turbines may create a barrier to migrating birds. Long lines of turbines have a potential barrier effect. Shorter turbine rows could reduce this effect, allowing birds to avoid them more easily. If the area is a passageway for migrating birds, the rows of turbines could have this potential barrier effect in the migratory trajectories (OSPAR Commission 2004). At Nysted, birds detected the presence of functioning turbines and avoided them by changing their flight direction or increasing their flight height (Petersen et al. 2006). Other studies showed modified flight routes, which can add significant mileage to the migration event (Exo et al. 2003). These modifications in behavior, could have substantial effects on migratory birds; however, there are other studies that indicate the increased distance and associated energetic costs appear to be trivial (Masden et al. 2009)

How birds and bats respond to lighting is poorly understood. Night-migrating songbirds appear to be attracted to steady burning lights at communications towers and other structures, increasing the potential for large-scale fatality events (Kerlinger and Kerns 2004). Research indicates that the color of light and whether it is steady burning or flashing makes a difference in whether night-migrating birds aggregate around tall, lit structures. While red light has been blamed for bird fatalities at tall television (TV) towers, researchers concluded that white flashing lights are relatively safe; however, red flashing lights with a long dark intervals and short flash-on times are likely to be the safest lighting configuration for night-flying birds (Evans et al. 2007).

Bats are known to feed on concentrations of insects at lights; therefore, any source of lighting that attracts insects may also attract bats at a wind facility (Anderson et al. 2007). This would include the lighting on the turbine structures or other stationary structures, such as the ESP or met tower. Several species of bats, both migratory and resident, have been shown to forage out at sea (see **Appendix B**; Ahlén et al. 2009). At sea, bats feed on an abundance of prey items, such as insects, spiders, and marine crustaceans. Most migrating bats tend to fly within 10 m (33 ft) above the sea (Ahlén et al. 2009). There does not seem to be an avoidance condition with bats the way that some birds do (Ahlén et al. 2007). Although a fair amount of research has been done regarding bat fatalities and onshore wind farms, very little research has been done about bat casualties with offshore wind farms (Johnson and Arnett 2008). Baerwald et al. (2008) showed that barotraumas (tissue damage to air-containing structures [e.g., lungs] caused by rapid air pressure reductions near moving turbine blades) is the primary cause of bat mortality at onshore wind farms, and it is likely that it would be similar offshore.

As mentioned in **Section 5.5.2.3**, there is little, if any, literature discussing the interaction of marine mammals with sources of light.

Sea turtle nesting activities are seriously affected by artificial light along nesting beaches (Salmon 2003); however, since sea turtles are not known to nest on the shores of New Jersey[30], onshore lighting is not a concern. Lighted offshore structures may attract young turtles and make them more susceptible to predation (Coston-Clements and Hoss 1983).

Aviation and navigation lighting on the turbine towers and ESP would likely not be bright enough to create an attraction for fish or their prey.

5.6.2.5 Noise/Vibration Avoidance

The noise and vibration produced during the operational phase of a wind farm might have disruptive effects on the marine environment (Gerdes et al. 2005). Birds, marine mammals, and fish may be impacted by operational noise.

A study of flight behavior changes at another Danish wind park (Tuno Knob), where the turbines were on during some trials and off during others, indicated that the avoidance behavior of Common Eiders was related more to the presence of the turbine towers rather than the noise or vibrations of the turbines (Larsen and Guillemette 2007).

Wind turbine type, number of wind turbines, and sound propagation properties of the surrounding water affect the level of operational noise and resulting magnitude of impacts on residing marine species. Although emitted operational noise that has been recorded from existing wind turbines to-date has been considered to be low in comparison to construction noise levels, an addition of approximately 20 dB re 1 μPa-m (from close proximity measurements) to the background ambient noise level for the lifetime of a wind farm (20 to 30 years) makes it a permanent source of noise for many years (Nedwell et al. 2007; Tougaard et al. 2009). As yet, potential long-term cumulative effects from multiple turbines in a wind farm with respect to noise levels have not been examined in detail from sources in operation.

Underwater noise associated with operational wind farms is generated by vibrations transmitted from the machinery down through the steel tower to the foundation where it is radiated into the water column (Tougaard et al. 2009). In general, operational noise is very low (e.g., calculated source level of 151 dB re 1 μPa-m at a wind speed of 13 meters per second [m/s; 43 feet per second, ft/s] and at a frequency of 180 Hz; Tougaard et al. 2009), average sound pressure level within the wind farm was measured at 2 to 8 dB re 1 μPa-m greater than ambient noise levels measured 1.0 km (0.62 mi) outside the wind farm and limited to a few bands of frequency that are above background noise levels (Nedwell et al. 2007). In a study to assess underwater noise from three wind farms in Denmark and Sweden, only frequencies below 315 Hz to 500 Hz were detectable over background noise when measured at a distance of 14 m (46 ft) from the sound source. Additionally, wind speed did not change the frequency peak, but noise intensity did increase with wind speed (Tougaard et al. 2009). When operational noise is analyzed in terms of the sound perception of fish and marine mammals, the increase in noise level is no greater then natural variations in background level that the animals might experience due to wave action and other anthropogenic affects such as ship traffic. The small increase in noise is unlikely to cause behavioral changes (Nedwell et al. 2007); however, unlike noise impacts from construction activity, noise generated during operation of a wind turbine could affect more species over a longer period of time. Long-term studies on the potential effects of noise generated by a wind farm (whether a single unit or multiple towers) have yet to be conducted; thus, there is a possibility that over time, a slight disturbance could accumulate and 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).

Underwater noise from the operation of wind turbines may decrease the effective range for sound communication in fish and mask orientation signals (Wahlberg and Westerberg 2005). Atlantic salmon (*Salmo salar*) and Atlantic cod have been shown to detect offshore windmills at a maximum distance of about 0.04 to 25.0 km (0.022 to 13.5 NM) at high wind speeds (i.e., >1.3 m/s [4.27 ft/s]), and noise from turbines can lead to permanent avoidance by fish within range of about 4 m (13.1 ft; Wahlberg and Westerberg 2005; Kikuchi 2009). Hastings and Popper (2005) concluded that “the few studies on the effects of sound on eggs, larvae, and fry are insufficient to reach any conclusions with respect to the way sound wound affect survival. Moreover, most of the studies were done with seismic air guns or mechanical shock, which are stimuli that are very different than those produced by pile-driving.”

5.6.2.6 Pylon/Blade Collision

Millions of birds collide every year with man-made structures such as transmission lines, communication towers, and offshore oil platforms (Kingsley and Whittam 2005; Russell 2005). The main potential hazard is risk of bird-turbine collision (Exo et al. 2003).

Some researchers state that offshore wind farms will cause greater problems for bird conservation than those on land, because offshore areas are rich in large bird species that are generally more sensitive to disturbance, and because offshore wind turbines will be substantially taller and wind farms larger than those on land (Exo et al. 2003; Zucco et al. 2006); however, the impacts are very species- and site-specific (Exo et al. 2003; Garthe and Hüppop 2004; Kingsley and Whittam 2005; DONG Energy 2006; Zucco et al. 2006).

The collision risk at sea is expected to be higher than on land, because offshore wind turbines will be considerably taller and the rotor blades longer than onshore turbines, resulting in higher tip speeds and higher turbulence. If birds do not show avoidance behavior, there is a potential risk of collision with the turbines. Collision risk is associated with several species attributes, such as flight altitude, flight maneuverability, nocturnal flight activity, the percentage of flying time versus swimming time, and flexibility in habitat use (Garthe and Hüppop 2004). Because collision risk has been high with onshore wind farms, it is considered to be the most important hazard because of its direct effect on the death rate of birds (Exo et al. 2003).

Diving ducks are known to fly at an average height of 30 m (98 ft) above sea level (MMS 2009c). Studies at offshore European wind projects found that most loons, scoters, and gannets flew around turbine fields and had the ability to detect and fly around the wind project site at night (Christensen and Hounisen 2005; MMS 2009b). Migrant passerines e.g., (warblers, buntings, and grosbeaks) generally fly above the level of the turbine’s RSZ (Curry and Kerlinger 2007); however, migrant passerines can be forced to fly at lower altitudes during poor weather conditions (e.g., head winds, fog, and rain) and therefore have the potential for turbine collision during these conditions

At Nysted, birds detected the presence of functioning turbines and apparently avoided them by changing their flight direction or increasing their flight height (Petersen et al. 2006). Because of this, the mortality at that wind farm was very low and much less than that reported by Osborn et al. (2000). The low risk of the Nysted wind farm might be related to the fact that the area is used basically as a flight route and passageway, but not as a feeding, roosting or breeding area, which would induce lower flight heights.

At Tuno Knob in Denmark, post-construction numbers of scoters were lower than pre-construction numbers (Drewitt and Langston 2006) and at Horns Rev post-construction scoter and loon numbers were lower than expected in the wind development area. The avoidance area included the wind development site and a 2.0 to 4.0 km (1.2 to 2.5 mi) area around the wind development site (Petersen et al. 2006).

Post-construction monitoring at the Horns Rev and Nysted wind farms has shown, however, that the risk of birds colliding with the wind turbines may not be as high for offshore birds as it is for onshore birds. Of

235,000 Common Eiders (*Somateria mollissima*) passing Nysted each autumn, predicted collision rates were 0.02% (45 birds). The low figure was confirmed by the fact that no collisions were observed by infrared monitoring. Radar studies showed that approximately 80% of the birds heading for the wind farm avoided passing it and that many birds entering the wind farm re-orientated to fly down between the turbine rows rather than through the turbine blades (Nielsen 2006).

A review of the recent results of seabird studies at offshore wind farms in the North and Baltic seas concluded that some, but not all, seabirds appeared to avoid offshore wind farms, but that generalization should be limited. There has been only a relatively short period of operation and observation, and the number of collisions may be underestimated because evidence of collisions is very difficult to obtain. In addition, the impact of avoidance behavior on population dynamics is not clear; however in some species it could lead to reduced adult survival and decreased reproduction rate, creating population-level adverse impacts (Zucco et al. 2006).

Over Cape Cod, Nisbet (1963) conducted a radar study and found that migration occurred from 182.9 m to 1,828.8 m (600 ft to 6,000 ft) above ground level. In general, nocturnal flight heights for passerine migrants are reported to be above 125 m (410 ft; Mabee et al. 2004); therefore, some passerines may be flying within the turbine's rotor sweep zone, which is generally 30.48 m to 213.36 m (100 to 700 ft) above sea level, and may be at risk of colliding with turbine blades. More post-construction monitoring data is necessary to determine impacts to nocturnal passerine migrants.

Flying insects are attracted to light sources and have been seen gathering around the lights associated with offshore wind farms. Bats hunt the insects, which bring them close to wind turbines and other offshore structures (Ahlén et al. 2007). A study of bats and wind farms in Sweden showed that bats both hunted insects along their migration route and flew offshore to hunt insects and then returned to land (Ahlén et al. 2007).

5.6.2.7 Electromagnetic Fields

Transmission of electricity from offshore wind farms requires extensive lengths of cables laid along the seafloor back to land for integration into the power grid. Transmission of electricity through these cables can lead to the generation of electrical and magnetic fields (EMF). The effects of EMF on birds, marine mammals, and fish are not fully understood. In 2009, MMS launched a study into the likelihood and extent of ecological impacts from EMFs emitted by subsea power cables that is designed to help managers and engineers select, early in the planning stage, the best cables and configuration for energy transmission, environmental protection, and economic viability.[33]

Based on the Cape Wind study and similarity of bird guilds between the Cape Wind and New Jersey study areas, major effects to foraging birds or their prey are not expected during the operational phase (MMS 2009c).

A comprehensive literature review on EMF for U.K. offshore wind energy concluded that there are many EMF-sensitive species (Atlantic angel shark [*Squatina dumeril*], thresher shark [*Alopias vulpinus*], scombrids, and decapod crustaceans) occurring in the Study Area and that many are likely to experience cellular and/or behavioral responses to the EMF field generated by wind farm (Gill et al. 2005). This report also noted that EMF of a magnitude within detectable ranges of EMF-sensitive organisms would be produced by industry power cabling, even if buried to several meters, unless specific cabling configurations are capable of reducing EMF. More specific findings by (Gill et al. 2009) concluded that elasmobranchs exhibited noticeable responses to the electric (E)-field associated with energy cables, and could potentially detect E-field for several hundred meters from the source. In the past, monopolar cables were used, which created very strong EMFs. Two other technologies can now be 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 (Gerdes et al. 2005).

Marine fishes, such as elasmobranchs (sharks, rays, and skates) and anadromous fishes, utilize natural EMFs for navigation and migratory behavior (Gill et al. 2005). Magnetic fields can potentially affect the orientation of marine fish during their migrations or even redirect their migration (O. Keller et al. 2006). Studies have shown sharks and rays are capable of detecting artificial EMFs with some species having remarkable sensitivity to electric fields in seawater (Kalmijn 1982). Some species of fish found in or near the Study Area have shown sensitivity to underwater EMFs, including several species of sharks (smooth dogfish [*Mustelus canis*], blue shark [*Prionace glauca*], scalloped hammerhead [*Sphyrna lewini*], sandbar shark [*Carcharhinus plumbeus*]), skates (Kalmijn 1982; Kajiura and Holland 2002); and eels (*Anguilla* sp.), Atlantic cod, and yellowfin tuna (*Thunnus albacores*; Gill et al. 2005).

During the operational phase, contamination in relation to the underwater cabling may also pose a potential long-term risk of releasing heavy metals (copper and lead) which might become exposed and eventually leach into the sediments in which they are buried affecting benthic communities (OSPAR Commission 2008b). In addition, alterations of physio-chemical conditions in the sediment or an increase in bacterial activity are additional potential ecological impacts of heat emission from underwater cables (Meißner and Sordyl 2006; OSPAR Commission 2008b).

5.6.2.8 Fishery Modifications

The potential impacts to fisheries would result from changes in the distribution or abundance of fishery resources, losses or damages to equipment or vessels, or the exclusion of fishers from viable fishing areas.

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 non-vegetated, sandy bottom and open ocean environments (Figley 2005). Depending on the depth and average annual and seasonal water temperatures, artificial structures 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 (MMS 1999). Artificial reefs within the Study Area off New Jersey support around 150 different fish and other marine life, which are indigenous to New Jersey waters (Figley 2005). Structural features, such as shoals, ridges, ship wrecks, and reefs (artificial and natural rocks) provide prime fishing sites for anglers targeting specific species. They are also fishing hotspots popular for public fishing tournaments[34],[35]

As discovered at other previous offshore wind farms, 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 (Byrne Ó Cléirigh – EcoServe 2000). A study of the fish communities and habitats at two wind farms off the southeastern coast of Sweden, in the central Baltic Sea, determined that monopile turbines acted as both artificial reefs and fish aggregating devices (FADs), particularly for demersal and semi-pelagic fish in the area (Wilhelmsson et al. 2006). As the monopiles of the turbines can be characterized as both artificial reefs and FADs, they may increase recruitment rates not only to the structures themselves, but also to the adjacent seabed (Wilhelmsson et al. 2006).

In addition to the artificial reef effect, construction of the wind farm may exclude commercial fishing from taking place within the wind farm area for the life of the wind farm. During this period, certain fish stocks could improve without the pressures from commercial fishing. Although fishing is excluded from within the edges of many of the existing wind farms in Europe (Byrne Ó Cléirigh – EcoServe 2000; Hiscock et al. 2002; Jensen et al. 2006; Wilhelmsson et al. 2006), the proposed Cape Wind Energy Progect intends to allow “prudent fish trawling,” with certain minor restrictions for safety, as well as laying pot or trap lines. The design of the wind farm, specifically the spacing of the turbines and the proposed burial of the interconnecting cables, appear to allow these fishing activities to continue in the area (MMS 2009c). The exclusion, limitation, or permission of commercial fishing would be decided on a case-by-case basis, with safety the primary concern.

5.6.2.9 Alteration of Ocean Currents

Potential impacts of a wind farm on regional 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 4.6 to 15.2 m (15.0 to 50.0 ft). When the spacing of these structures is considered (typically 300 to 500 m [984 to 1,640 ft] apart), it is unlikely that their presence will have a strong impact on ocean currents or tidal flows (Byrne Ó Cléirigh – EcoServe 2000). These impacts would be small and limited to the immediate vicinity of the facility (MMS 2007).

Permanent changes in ocean currents (in the life time of the wind farm) result from establishment of foundations and scour protections. These construction elements will probably cause changes in the local current and wave dynamics (Jensen et al. 2006). For the Horns Rev and Nysted wind farms, modeling the hydrodynamic regime predicted that the changes in current velocity behind or between the foundations would be less than 1.5 to 2.0%. The modeling also demonstrated that changes in current velocity would be less than 15% within 5.0 m (16.4 ft) from the foundation (DONG Energy 2006). These two wind farms are 14.0 and 10.0 km (8.7 and 6.2 mi) offshore in water depths that range from 6.0 and 13.5 m (20 and 44 ft; Petersen et al. 2006). Site-specific current and wave dynamics would need to be modeled for any project within the Study Area.

5.6.2.10 Habitat Impacts

Habitat loss and changes from offshore wind development may affect the marine environment within the study site. Birds, marine mammals, and fish may be impacted by modification of the habitat.

Post construction studies of European offshore wind development sites suggest that birds (e.g., scoters and loons) avoid the sites. At Tuno Knob in Denmark, post-construction numbers of scoters were lower than pre-construction numbers (Drewitt and Langston 2006) and at Horns Rev post-construction scoter and loon numbers were lower than expected in the wind development area. The avoidance area included the wind development site and a 2.0 to 4.0 km (1.2 to 2.5 mi) area around the wind development site (Petersen et al. 2006). The results of these studies indicate some loss of habitat.

Scour control mats and the turbine monopoles themselves will provide substrate for benthic invertebrate colonization and habitat for prey fish. The entire wind development site could create an artificial reef and provide foraging habitat for gulls and terns. Post-construction studies at Nysted and Horns Rev in Europe found that most terns avoided the wind development site but increased use of the area around the wind development site. Some terns foraged at the base of boundary monopiles and some small flocks flew into the site to the second row of turbines before leaving the site (Petersen et al. 2006).

Changes in seabed substrate type would be related to the footprint of the wind farm and the nature of the existing substrate. The changes would result from the introduction of the foundations and scour protections in areas of sandy substrate. The introduction of hard bottom substrates will create an additional seabed habitat permitting the establishment of new species in the area. Sub-surface sections of turbine towers and scour protections increase the heterogeneity in an area previously consisting only of relatively uniform sand. The introduced habitats will be suitable for colonization by a variety of marine invertebrates and attached algae. The hard bottom structures may act both individually and collectively as an artificial reef (Leonhard 2006).

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 (Byrne Ó Cléirigh – EcoServe 2000). Anthropogenic structures placed into the marine environment are known to increase the biodiversity, productivity, and nutrient cycling of the area (Hiscock et al. 2002). Several studies have shown that offshore wind turbines (whether floating or constructed in the sea bed) serve as 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 and A. de Risi 2007). 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 et al. 2005). Previously, it was thought that organisms associate with artificial reefs because of increased food availability (Steimle and Ogren 1982); however, studies have found that most fish associate with Atlantic artificial reef habitats for shelter and other behavioral needs rather than a need for food (Steimle and Ogren 1982).

Both benthic and pelagic foraging fish would be attracted to this new coastal structure. Benthic-foraging fish would include the Atlantic sturgeon (proposed T&E species), spiny dogfish (*Squalus acanthias* – EFH species), northern searobin (*Prionotus carolinus*), Atlantic tomcod (*Microgadus tomcod*), cunner, grubby (*Myoxocephalus aenaeus*), and longhorn sculpin (*M. octodecemspinosus*). Pelagic foraging species would include Atlantic herring (EFH species), Atlantic menhaden (*Brevoortia tyrannus*), striped bass, American shad, alewife, Atlantic silverside (*Menidia menidia*), weakfish (*Cynosciuon regalis*), and rainbow smelt (*Osmerus mordax*; ESS Group Inc. 2006).

At the Horns Rev wind farm, the biomass produced on the introduced hard bottom structures were many times greater than biomass produced by the native benthic community, mainly due to the introduction of habitats suitable for colonization of the common mussel (*Mytilus edulis*; Leonhard 2006). More of the fish species, including the benthic species such as gobies (*Pomatoschistus* spp.), the long-spined bullhead (*Taurulus bubaris*) and the shorthorn sculpin (*Myxocephalus scorpius*), that are found at the turbine sites at Horns Rev are also typically found around wrecks in other parts of the North Sea. Very mobile species like the edible crab (*Cancer pagurus*) have also established themselves at the turbine site indicating that noise and vibrations from the turbine generators apparently have no impact on fish and other mobile organisms attracted to the hard bottom substrates for foraging, shelter and protection (Leonhard and Pedersen 2006).

5.7 DECOMMISSIONING PHASE

5.7.1 Description of the Decommissioning Phase

Decommissioning is the final stage of a wind farm's life cycle. Once the operation of the wind farm has ceased, MMS requires that the owner/operator "clear the seafloor of all obstructions created by activities on [the] lease" (30 CFR § 285.902[a][2]). Much of the activity during decommissioning is similar to construction, only in reverse. Similar vessels and equipment would be used to remove the blades, nacelles, towers, foundations, and scour protection at each turbine; the ESP and its equipment; and both the inter-turbine and onshore transmission cables. **Figure 5-8** illustrates the activities conducted in the decommissioning stage.

The lessee may petition for facilities to remain in place under 30 CFR § 285.909 and MMS would make this determination on a case-by-case basis. The most important factor would be to have a site-specific decommissioning plan developed and analyzed for potential impacts prior to project approval.

During the decommissioning phase, scour protection would be removed and disposed of onshore at an approved facility. Monopile foundations would be cut at a depth of about 5.0 m (16.4 ft) below the seafloor and removed. Gravity foundations would be lifted by crane and transported to shore (MMS 2007). Jacket or derrick-style foundations are similar to offshore oil and gas rigs. The removal of offshore oil and gas rigs often uses explosives to remove the platform structures. For structures in less than 200 m (656 ft) explosive charges are typically less than 2.27 kg (5.0 lbs; MMS 2005).

5.7.2 Potential Impacts of the Decommissioning Phase

The potential impact-producing factors of vessel traffic, vessel presence and lighting, noise and avoidance would be the same as identified under **Section 5.5.2**. The potential impacts unique to the decommissioning phase are discussed in this section and are associated with the removal of the hard surfaces provided by the structures and 20 to 25 years of habitat formation on and around the structures. **Table 5-5** summarizes the potential effects of decommissioning phase.

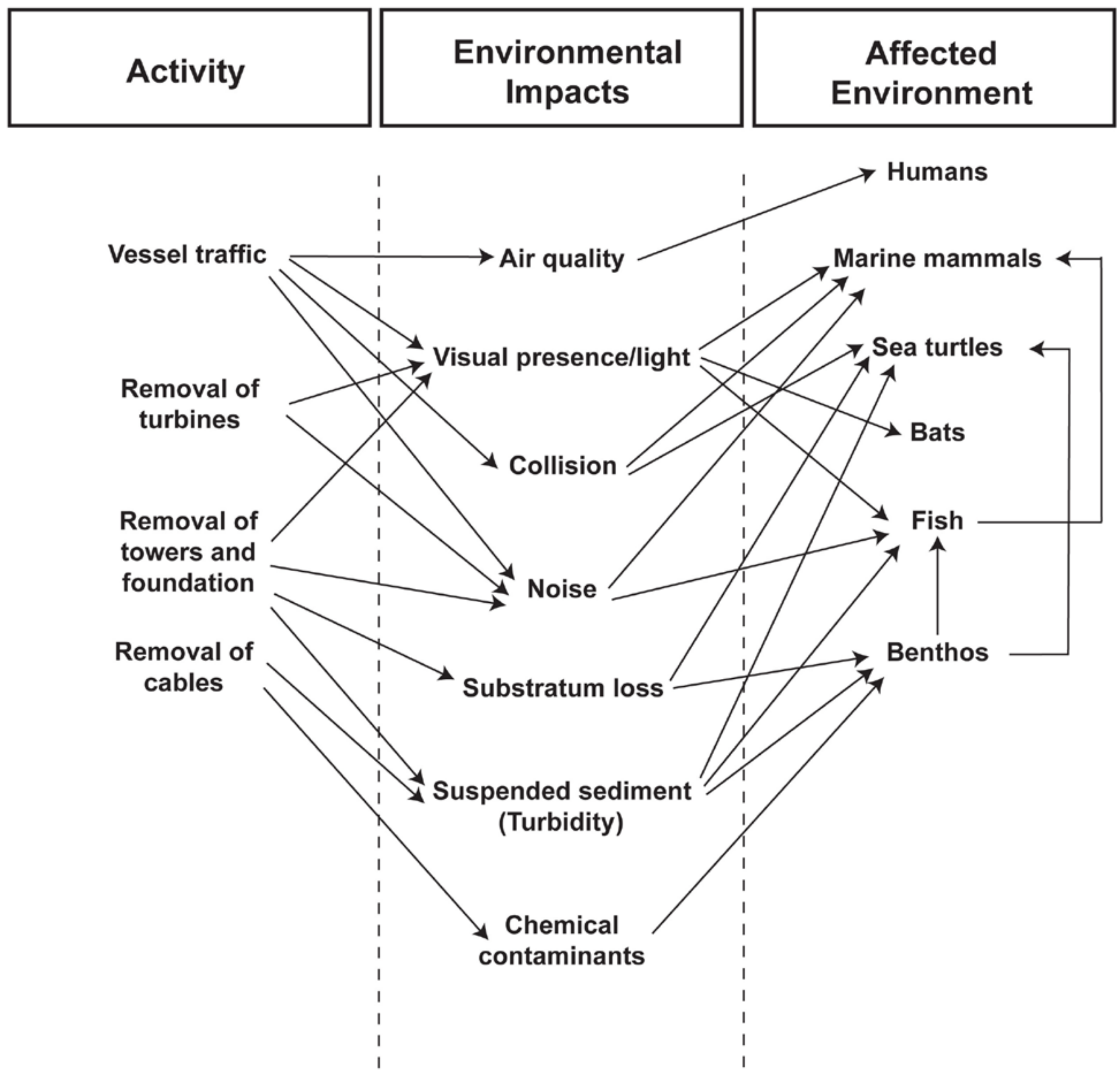

Figure 5-8. Potential impacts and targets of the decommissioning phase. Adapted from Hiscock et al. (2002).

5.7.2.1 Noise

As previously discussed, birds, marine mammals, and fish may be impacted by noise. As mentioned previously decommissioning for any existing (Europe) or future (U.S.) offshore wind farm is not planned for decades. Thus, tangible noise data and related resulting impacts regarding decommissioning of offshore met towers or wind turbines are not available. Experience from the decommissioning of offshore oil and gas structures can be used to help characterize some of the potential noise sources. Removal of the tower itself is likely to be a reversal of the installation process with similar constraints on noise production (extraction activities, etc.); the minimum amount of gear likely to be required will include barges and a crane. Little noise will be transmitted below the water's surface for removal of structures that are above the sea surface. Removal of a tower foundation will create the greatest noise under water during decommissioning and is dependent upon the type of foundation used, i.e., gravity foundation, monopile, or tripod and the method of removal. (Unless the decision is made to leave a foundation in place as a natural reef for species that might have taken up residence during turbine/tower operation.) Gravity foundations are removed by crane and subsequently towed or sunk. Any of the pile foundations will require cutting at or below the surface of the seafloor (OSPAR Commission 2008a).f piles need to be removed, pile extraction using a hydraulic vibratory pile extractor or explosives could produce hazardous levels of noise. Depending on the substrate, vibratory pile extraction can exceed 160 dB re 1μPa-m, while explosives have been documented at 220 dB re 1μPa-m (Richardson et al. 1995). Larger explosives could reach much greater noise levels.

Table 5-5. Summary of potential effects of the decommissioning phase of offshore wind farm development. Adapted from Hiscock et al. (2002) and Nielsen (2006).

Activity	Potential Effect	Level of Effect
Removal of structures	Air quality Vessel traffic Visual presence Noise Seafloor disturbance Substratum loss	**Local, short term** • Noise and visual presence as above • Removal of foundations and cabling resulting in considerable sediment disturbance, substratum loss, re-suspension of sediment and turbidity, potential smothering of surrounding habitats and physical disturbance **Area, short term** • Loss of the artificial reef and associated species and habitats **Area, long-term** • Potential changes in bed-form and height and hence hydrography, water flow and changes of wave energy impinging on the coast • Changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators • Potential injury or death to marine mammals or sea turtles from vessel collisions

With the exception of explosives and the higher noise levels associated with decommissioning, noise impacts would be similar to that presented in **Section 5.5**. The larger explosive charge could injury or kill birds depending on the distance between the bird and the explosion.

Small explosives, while initially can be startling, usually only cause pinnipeds, toothed and baleen whales, sea turtles, and fish to swim away from the source area temporarily (Richardson et al. 1995). Blasts from charges that are a kilogram or larger can kill or injure any of the marine species (Nedwell et al. 2007).

Blasting in water can negatively affect fish. The sudden pressure deficit (measured indirectly as overpressure [kilopascals (kPa)]) resulting from an explosion can rupture juvenile and adult fishes with both open and closed swim bladders (Wright 1982; Keevin and Hempen 1997). In contrast, developing eggs may be damaged more from the blast by the shaking of the substrate (Wright 1982), which is typically measured as peak particle velocity. Larval fish and recently transformed, small juveniles may be less sensitive to injuries than larger juveniles and adults as suggested by (Wright 1982), but other studies have found increasing sensitivity to blasting with decreasing fish size (Yelverton 1975; Wiley et al. 1981; O'Keefe 1984). Recently, Govoni et al. (2008) reported that larval and recently transformed small juvenile spot (*Leiostomus xanthurus*) and pinfish (*Lagodon rhomboids*) are more vulnerable to underwater shock waves emanating from blasts than large juvenile and adult fishes. Based on the total number of larvae injured or killed, it would represent 2.3 to 3.2% of the total number of larvae passing through the project area.

5.7.2.2 Seafloor Disturbance

Removal of the turbine foundations, scour protection, and the cable will result in disturbance of the seabed and an increased level of suspended solids in the water column, and habitat loss. Birds and fish may be impacted.

The actions in decommissioning would not be more disruptive to the seafloor than construction activities were 20 to 25 years before. Sediment disturbance would create a temporary increase in the concentration of suspended sediments; however, as before, the affected areas would be very small compared to the total wind farm area and the duration of the impact would be short (Skov and Thomsen 2006).

Impacts on birds would be similar to that described in **Section 5.5.2.5**.

5.7.2.3 Alteration of Ocean Currents

As discussed in **Section 5.6.2.9**, the size and likely spacing of the wind turbines and foundations is not expected to create a major alteration of ocean currents or waves. Removal of the structures would not alter the ocean currents and waves either.

5.7.2.4 Habitat Impacts

Just as the construction of the wind farm introduces new hard bottom substrates into the area, decommissioning removes those substrates and the habitat they have become (Jensen et al. 2006). While immigration and succession at the new hard bottom substrate would be a fairly slow process, decommissioning is a relatively fast process that would disturb most of the fauna that have inhabited the hard bottom substrate. Many of the organisms that colonized the foundations and scour protections would be exposed to heavy predation during decommissioning, either because they cannot escape or because they cannot avoid the predators while escaping. Regeneration of the biological communities in the sandy habitats is probably much faster than the colonization of the hard bottom habitats due to the short migration distances from the surrounding sandy habitats. The complete regeneration of sandy habitat communities would be expected to take place within a few years (Jensen et al. 2006). Sea turtles that feed on benthic communities may be impacted by the removal of an established foraging area. Impacts to the benthic community of the wind farm could also be carried up the food chain to the fish, and the birds and marine mammals that feed upon the fish; however, just as the predator-prey relationship evolved with the substrate changes during and after construction, the impacts on the predator species would adapt to the removal of the wind farm (DONG Energy 2006).

The habitat disturbance resulting from foundation removal could be avoided if the colonized hard bottom substrates are left in place. The benefits of leaving the hard substrates in place as artificial reefs would need to be weighed against the hazards related to leaving structures on the seafloor. These issues would need to be addressed in a decommissioning plan evaluated and approved prior to project construction.

Post construction monitoring at Horns Rev and Nysted indicated that no bird species demonstrated enhanced use of the waters within the two Danish offshore wind farms (Petersen et al. 2006); therefore, there would not likely be any effects from removal of the turbine towers. Because there has been no decommissioning of offshore wind farms as yet, it is not clear whether the migratory birds whose avoidance response took their flight paths around the wind farm would return to their original flight paths once the structures have been removed.

5.8 IMPACT SUMMARY

Table 5-6 presents a summary of the potential impacts that could result during the four life stages of the placement and operation of a wind farm within the Study Area. Actual impacts on the biological resources and the level of severity of these impacts can only be assessed through the appropriate NEPA process and in consultation with federal and atate regulatory agencies on a site-specific basis.

5.9 CUMULATIVE IMPACTS

Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time." Cumulative impacts for an offshore wind farm in the Study Area would include combinations of offshore wind farm impacts added to

- Background levels of existing adverse impacts in the marine environment such as chemical pollution
- Impacts from other uses of the same area (e.g. fishing, vessel traffic, sand and gravel quarrying, or other obstruction)
- Impacts from multiple wind farm projects in the same area (Zucco et al. 2006).

This identification of the potential impacts that may occur as a result of the installation and operation of an offshore wind farm is specific to any development off the New Jersey coastline. As such, the area of concern in which the cumulative environment would be defined is not specific to any particular area.

In Northern Europe, where at least 25 offshore wind farms have been constructed (Breton and Moe 2009), major studies of the collective impacts of these wind farms have not been conducted. There have been some comparisons of the impacts between some of the projects, in particular the Horns Rev and Nysted offshore wind farms in Denmark (DONG Energy 2006; Nielsen 2006); however, the results just confirmed the need for more data on the presence and movement of individual species and their specific reactions to the construction and operation of offshore wind farms (Garthe and Hüppop 2004; Kingsley and Whittam 2005; Masden et al. 2009).

Although more data are needed to assess the cumulative impacts of a specific project and location, it is possible to evaluate some impacts that may produce cumulative effects in light of multiple developments within a region. These potential cumulative impacts may include:

- Potential changes in current and wave energy impinging on the coast
- Potential changes to the benthic macrofaunal communities with resultant indirect effects on fish and their predators
- Potential effects on spawning and nursery areas for fish due to habitat loss or changes in hydrography
- Potential changes to migration routes and feeding habitats for seabirds
- Potential disturbance of marine mammal communication and migration routes due to emission of low frequency sound
- Potential effect of EMF on fish migration and feeding behavior, especially in elasmobranchs (sharks and rays)
- Provision of new substrata and habitats for colonization and formation of an artificial reef
- Potential benefits of no-fishing zones on fishery population, but negative effects on the bottom trawl fishing industry if multiple areas are removed from catch areas.

The cumulative impacts of many developments distributed along the length of a species' migratory corridor could have impacts on survival and reproduction in the future. The challenge of addressing the cumulative impacts on offshore fauna is critical to the future exploitation of offshore wind resources and needs to be the subject of continuing research (DONG Energy 2006).

Table 5-6. Summary of the potential impacts that could result during the four life stages of the placement and operation of a wind farm within the Study Area.

POTENTIAL IMPACTS - PRECONSTRUCTION/EXPLORATION								
	Lighting	Vessel Disturbance	Vessel Collision	Noise	Displacement	Substrate Loss	Turbidity	Contaminants
Avian Guilds								
Scoters		X		X	X	X	X	X
Loons		X		X	X	X	X	X
Gannets				X	X	X	X	X
Gulls				X	X	X	X	X
Terns				X	X	X	X	X
Passerines	X							
Marine Mammals & Sea Turtles								
North Atlantic Right Whale		X	X	X	X		X	X
Humpback Whale		X	X	X	X		X	X
Minke Whale		X	X	X	X		X	X
Fin Whale		X	X	X	X		X	X
Bottlenose Dolphin		X	X	X	X		X	X
Short-beaked Common Dolphin		X	X	X	X		X	X
Harbor Porpoise		X	X	X	X		X	X
Harbor Seal		X	X	X	X		X	X
Leatherback Sea Turtle		X	X	X	X	X	X	X
Loggerhead Sea Turtle		X	X	X	X	X	X	X
Fisheries Groups								
Benthic Life Stages				X	X	X	X	X
Pelagic Life Stages				X	X	X	X	X

Table 5-6 (*continued*). Summary of the potential impacts that could result during the four life stages of the placement and operation of a wind farm within the Study Area.

POTENTIAL IMPACTS -CONSTRUCTION								
	Lighting	Vessel Disturbance	Vessel Collision	Noise	Displacement	Substrate Loss	Turbidity	Contaminants
Avian Guilds								
Scoters		X		X	X	X	X	X
Loons		X		X	X	X	X	X
Gannets				X	X	X	X	X
Gulls				X	X	X	X	X
Terns				X	X	X	X	X
Passerines	X				X			
Marine Mammals & Sea Turtles								
North Atlantic Right Whale		X	X	X	X		X	X
Humpback Whale		X	X	X	X		X	X
Minke Whale		X	X	X	X		X	X
Fin Whale		X	X	X	X		X	X
Bottlenose Dolphin		X	X	X	X		X	X
Short-beaked Common Dolphin		X	X	X	X		X	X
Harbor Porpoise		X	X	X	X		X	X
Harbor Seal		X	X	X	X		X	X
Leatherback Sea Turtle		X	X	X	X	X	X	X
Loggerhead Sea Turtle		X	X	X	X	X	X	X
Fisheries Groups								
Benthic Life Stages				X	X	X	X	X
Pelagic Life Stages				X	X	X	X	X

Table 5-6 (*continued*). Summary of the potential impacts that could result during the four life stages of the placement and operation of a wind farm within the Study Area.

POTENTIAL IMPACTS - OPERATIONS/MAINTENANCE									
	Lighting	Vessel Collision	Vessel Disturbance	Turbine Collision	Noise	Disturbance	EMF	Current/Wave Alteration	Artificial Habitat
Avian Guilds									
Scoters		X	X	X	X	X			
Loons		X	X	X	X	X			
Gannets				X	X	X			
Gulls				X	X	X			
Terns				X	X	X			
Passerines	X			X		X			
Marine Mammals & Sea Turtles									
North Atlantic Right Whale		X	X		X	X			X
Humpback Whale		X	X		X	X			X
Minke Whale		X	X		X	X			X
Fin Whale		X	X		X	X			X
Bottlenose Dolphin		X	X		X	X			X
Short-beaked Common Dolphin		X	X		X	X			X
Harbor Porpoise		X	X		X	X			X
Harbor Seal		X	X		X	X			X
Leatherback Sea Turtle		X	X		X	X			X
Loggerhead Sea Turtle		X	X		X	X			X
Fisheries Groups									
Benthic Life Stages					X		X	X	X
Pelagic Life Stages					X		X	X	X

Table 5-6 (*continued*). Summary of the potential impacts that could result during the four life stages of the placement and operation of a wind farm within the Study Area.

POTENTIAL IMPACTS - DECOMMISSIONING									
	Lighting	Vessel Collision	Vessel Disturbance	Noise	Disturbance	Habitat Change	Substrate Loss	Turbidity	Contaminants
Avian Guilds									
Scoters		X	X	X	X	X	X	X	X
Loons		X	X	X	X	X	X	X	X
Gannets				X	X	X	X	X	X
Gulls				X	X	X	X	X	X
Terns				X	X	X	X	X	X
Passerines	X						X	X	X
Marine Mammals & Sea Turtles									
North Atlantic Right Whale		X	X	X	X	X		X	X
Humpback Whale		X	X	X	X	X		X	X
Minke Whale		X	X	X	X	X		X	X
Fin Whale		X	X	X	X	X		X	X
Bottlenose Dolphin		X	X	X	X	X		X	X
Short-beaked Common Dolphin		X	X	X	X	X		X	X
Harbor Porpoise		X	X	X	X	X		X	X
Harbor Seal		X	X	X	X	X		X	X
Leatherback Sea Turtle		X	X	X	X	X	X	X	X
Loggerhead Sea Turtle		X	X	X	X	X	X	X	X
Fisheries Groups									
Benthic Life Stages				X	X	X	X	X	X
Pelagic Life Stages				X		X	X	X	X

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6.0 FUTURE STUDIES AND RECOMMENDATIONS

Future investigations of coastal and offshore birds, marine mammals, and sea turtles in New Jersey will be enriched by the precedent set by the NJDEP EBS. During the course of the surveys, and as a natural result of such an extensive investigation, improvements to methodologies, data collection and storage, and analysis were both identified and implemented. The finalization of this baseline report and its public circulation will mark the onset of further inquiries geared toward establishing wind-power along and off the New Jersey coast. Before-After/Control-Impact (BACI) assessments and other research and resource initiatives will no doubt be heavily reliant on the information we present in addition to addressing new issues concerning avian abundance and distribution in, and utilization of the Study Area. The following recommendations are presented as additional studies or potential improvements to the NJDEP EBS that could be implemented for future monitoring projects.

6.1 AVIAN SURVEYS

Include the Passerine Component of Nocturnal Migration – Although not especially applicable to waterbirds, recent advances in avian acoustic monitoring provide investigators with the capability of assessing the diversity and, potentially, the density of the passerine (songbird) component of nocturnal bird migration. Much is now known on the identification of species of the Eastern North American neotropical and short-distance migrant passerines (Evans and O'Brien 2002; Lanzone et al. 2009). Data collection is accomplished with a relatively simple and cost-effective system of microphone(s), data-storage units, and analysis software. The microphone can be placed to enhance radar units and also be set up in arrays over a specific area to help quantify diversity and density of migrating birds at night. Work has been to done to establish the usefulness of acoustic monitoring to correlate regional migration density data from Doppler radar (Farnsworth et al. 2004). As inexpensive acoustic monitoring methods for bats develops, those for avian monitoring should also expand, specifically when radar or other remote sensing methods are called for in BACI assessments.

Collision Mortality – Site-specific avian and bat collisions with tall structures such as radio towers and high-rise buildings are a concern similar to the potential of wind-turbine collisions. Agencies and developers may seek to enhance their knowledge of collision mortality by also studying these structures. This would help to create a regional and macro-scale picture of the current cumulative impacts, and what they might become with the development of wind power and other construction. Answering this large question would involve behavior and mortality studies involving some or all of the following: carcass searching; radar and acoustic sensing; and visual surveys during the day and night (around well-lit structures or with night-vision optics).

Coastal Fall Waterbird Migration – Localized surveying around known areas of high avian usage and/or potential development areas will now become far more important than larger scale and more randomized survey approaches. The data collected during the NJDEP EBS have greatly added to the overall knowledge of the temporal and local distribution of birdlife within the Study Area. Development that is to be proposed in the coastal zone (approximately ≤ 3 NM from shore) will greatly benefit from further investigation into the macro-phenomenon of coastal fall waterbird migration, that is, a concerted seawatch effort that was initiated in the last season of the project (fall 2009). Determination of waterbird migration density and distance from shore is of vital importance in terms of the largest potential impacts to birds.

Additional Offshore Radar Assessments – The current study provided limited radar data for offshore locations in the Study Area due to survey platforms available, water depth, and safety. Additional pre-construction met-tower or large lift barge-based radar studies and collision risk assessments are recommended to obtain better data on birds moving above, within, and below the rotor swept zone at distances beyond the reach of land-based radar units.

6.2 AVIAN SPATIAL MODELING

Foraging Behavior – The NJDEP Ecological Baseline Studies focused on measuring the spatial variability and response of avian species density to seasonality and geographic-based variables (e.g., distance to shoreline and water depth). Although the study considered flight behavior (e.g., altitude and direction) and sitting on the water as indicators of foraging behavior, it did not utilize tags and/or data loggers to analyze foraging behavior of individual birds. Such information would provide a comprehensive look into how birds make decisions on where to forage or how long they reside in particular locations. Therefore, tracking birds over lengths of time (e.g., months) may provide more insight on residence time and movement behavior within study areas.

Influence of Tidal Fluctuations – The current study did not assess fine-scale (<1 km) spatial variability of avian aggregations that may be attributed to variability in prey resources (e.g., schooling fishes) or related to dynamic tidal variability, which can change markedly along the New Jersey coastline. Such fine scale studies are necessary to understand why and where birds choose to forage and roost, and can yield important parameters to aid future modeling scenarios of avian species in regard to pre- and post construction of offshore wind energy. It is recommended that future studies incorporate tidal fluctuations in models to assess changes in avian spatial distribution.

Influence of Fisheries Resources – Emphasis should be made to better understand the spatial association between fish stocks and avian spatial distribution. There is a wealth of information from the NOAA NMFS that may be compared with avian density and spatial distribution to assess their covariation with fisheries resources. Moreover, future effort should be made to assess how birds and mammals collectively use offshore areas by conducting a comprehensive study of bird-mammal interactions at sea. Such information would increase our ability to identify and predict biologically important areas so that they can receive proper attention through ecosystem-based management plans.

Coordinate the Regional Use of Geospatial Variables – Future studies (i.e., in neighboring states) should conduct similar surveys (vessel-based and radar) using established protocols and consider using the suite of geospatial variables that were identified as important predictors of changes in avian spatial distribution and density. Such information and coordination will likely fill data gaps between states to achieve a more comprehensive view of offshore habitat use by avian species along the eastern U.S. seaboard.

6.3 MARINE MAMMAL AND SEA TURTLE SURVEYS

Increased Survey Time – Future surveys for marine mammals and sea turtles should consider allocating additional survey time in the region during seasons when rough seas are more prevalent. This will ensure that all tracklines are surveyed for the entire Study Area during monthly surveys. Rough seas are prevalent in the OCS region off New Jersey, particularly during fall, winter, and spring. The survey team experienced several delays in survey effort during these seasons. For example, only one survey day was completed during the February 2008 shipboard survey due to rough weather. The least amount of shipboard survey effort was during the spring season when we experienced relatively few days with calm seas.

Regional Surveys – Because many marine mammal and sea turtle species have large ranges of distribution, individuals may only utilize the waters of the Study Area for short periods of time as they migrate or follow prey movements. Therefore, they may not occur in the Study Area long enough to be detected during a monthly survey. To better assess shifts in distribution and abundance, that large-scale surveys are recommended that encompass a broader region, such as the entire Mid-Atlantic Bight. Shipboard and aerial surveys could cover the entire survey region. Specific changes in distribution and abundance may be more evident from these large-scale surveys. For example, this study indicates that the fall season appeared to be a transitional period for some cetacean species in the Study Area. It is likely that most bottlenose dolphins move south of the Study Area, and most short-beaked common dolphins and harbor porpoises are farther north during this time of year. However, no survey data covering these other regions during our survey period exists to verify these shifts in abundance.

Fall Aerial Surveys – It is recommended that future aerial surveys also be conducted during the fall, particularly to collect sightings of turtle species that may be in the region.

Additional Intra-Seasonal Aerial Surveys – In addition, it is recommend more intra-seasonal aerial survey effort during the spring and summer when bottlenose dolphins concentrate in the Study Area. These surveys will help to delineate fine-scale movement patterns of bottlenose dolphins throughout the Study Area which may provide critical information on potential impacts of this species in particular sites of proposed windfarm development. Spring and summer were also the seasons in which sea turtle sightings were greatest. Additional aerial surveys during these seasons will also enable a more thorough assessment of sea turtles including abundance estimates for individual species.

Enhance Acoustic Monitoring Data – Information on the presence of vocalizing cetacean species can be obtained during bad weather conditions via passive acoustic monitoring. A large amount of passive acoustic monitoring data was collected and would have benefited from more time devoted to analyses outside of auto-detection algorithms. That is, a manual review of some of the days of data in relation to survey results for species other than North Atlantic right and fin whales may have shed light on the vocal presence of species with highly variable calls.

Further, the passive acoustic data would be nicely augmented with additional vessel surveys to assess the various species that might be present. Or, adding a towed acoustic array to the vessel surveys would dove-tail nicely with data from the passive acoustic monitoring to provide a monthly snapshot of how the vessel survey data directly compared with acoustic data from both a towed array and the passive recorders. With acoustic monitoring it is possible to collect data during times when observers are not able to survey an area (e.g., during night hours or periods of rough sea conditions or bad weather). Still, when using only passive acoustic monitoring, it is not possible to document the absence of animals because they might simply not be vocalizing. Passive acoustic monitoring is also not an appropriate tool (at least yet) to document abundance or group composition because the recorders only document those individuals who are making vocalizations, not those who are silent.

Shallow-Water Passive Acoustic Recorders – During the course of acoustic monitoring, only a few days of survey had calm seas; most of the weather experienced included a BSS of 3 or 4 or greater with recovery trips more often than not delayed while waiting for better weather. It is possible that the shallow waters of the study area facilitated an increased affect of weather and sea conditions on the particular marine autonomous recording unit (pop-up) used for data collection. That is, at the start of this project, the pop-ups were state-of-the-industry technology. Several additional models of passive acoustic recorder have become available in the last 18 months that might be better suited to the shallow-water environment off the New Jersey coast.

Two Independent Team Approach – A discussion of $g(0)$, factors affecting animal detectability, and methods of accounting for detection bias are discussed in **Volume III**. Estimates of $g(0)$ for shipboard and aerial surveys are used to calculate less biased estimates of abundance. Because $g(0)$ could not be estimated during these surveys, the abundance estimates for each species and group are considered to be underestimated. Estimates of $g(0)$ would greatly improve the accuracy of our abundance estimates. Therefore, we highly recommend the use of the two-independent team approach for future shipboard and aerial surveys. This will require a larger ship that can accommodate two observer platforms and additional observers, and it will also require a larger plane that can accommodate two teams of observers.

6.4 FISH AND FISHERIES ASSESSMENTS

In addition to recommending continued collection of ongoing fisheries monitoring, it is also recommended that the following steps be taken to improve the data available for resource assessments in marine waters:

- Update EFH/HAPC descriptions and their geographical extent. Update ecologically important commercial/recreational closure areas, the status of overfished stock assessments, and federal/state agencies' species management changes as revised or additional amendments and/or FMPs (MAFMC, NEFMC, SAFMC, NMFS, and/or ASMFC).
- Update species of concern, candidate species, proposed T&E species, DPSs, and critical habitats when they are designated by NMFS and/or USFWS.

- Provide a list of recreational fish species and associated habitat type (if available) for each of the 143 fishing hotspot locations within the Study Area.

- Use NEFSC stock assessment reports/workshops and Atlantic Coastal Cooperative Statistics Program (ACCSP) information to prepare figures showing locations of dominant commercial/recreational fisheries within potential wind farm sites.

- Analyze the ocean trawl data collected yearly in the New Jersey Ocean Stock Assessment (OSA) Program (1991 to present) and evaluate the fish/invertebrate species according to landings and economic value within potential wind farm sites.

6.5 OTHER RECOMMENDED STUDIES

6.5.1 Offshore Habitat Utilization of Bats

Aside from the offshore presence/absence assessment of bats completed during this study, very little is known concerning the distribution, abundance, and flight altitudes of bats in offshore environments. Additional studies are recommended for all potential offshore development sites to determine the distribution, abundance, and flight altitudes of bats.

6.5.2 Long-Term Monitoring

Data collected over a time frame exceeding two years would provide larger temporal datasets to more confidently assess seasonal, annual, and interannual variabilities of spatial patterns of avian and marine mammal density/abundance, avian flight migration patterns (altitude, flight direction, passage rates), and oceanographic properties (e.g., SST, surface chlorophyll). While a longer term dataset may allow for extrapolation of observed patterns and to assess whether the data gathered in this study were representative of typical or unusual conditions, the two years of seasonal data gathered during this study allowed for spatial patterns to be associated with an annual "snapshot" of environmental conditions. Although extensive, this two-year dataset does not afford the temporal range to generalize seasonal patterns given that the full effect of known fluctuations in environmental conditions such as the ENSO and the NAO occur on a time scale ranging from three to seven years. Long-term monitoring data would provide additional data to the ESI developed in this study and hence a more precise prediction of sites suitable for offshore wind farm development.

6.5.3 Influence of Natural and Human-Induced Disturbances on the Local Density and Abundance of Birds and Marine Mammals

Large, baseline datasets such as these assist regulators and managers in understanding if local density and abundance patterns of birds and marine mammals are influenced by naturally-occurring events such tropical depressions, nor'easters, changes in current patterns, and river runoff. Also, if these patterns are influenced by positive human-induced changes in the coastal zone such as coastal management and mitigation strategies (pollution cleanup, eutrophication reduction) and negative changes such as oil spills. For example, if coastal cleanup efforts were to be ramped up over a defined time period (e.g., one to two years) over a selected region of the New Jersey coastline, how would this action affect the local density and abundance of birds and marine mammals? How would this potential effect compare to (1) other portions of the coastline not subjected to the management action, (2) offshore locations in proximity of the coastline affected by the management action (i.e., onshore-offshore gradients), and (3) the same area during the years when the management action is not implemented? Although outside the scope of this work, the data collected during this study or other future, similar studies will serve as an important baseline for managers to determine if there are effects on a regional or landscape level due to natural or human-induced disturbances.

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APPENDICES

OVERVIEW, SUMMARY, AND APPLICATION

APPENDIX A

BENTHIC MAPPING

1.0 INTRODUCTION

The marine benthic mapping surveys were designed to generally characterize the ocean floor and benthic environment as part of the Ocean/Wind Power Ecological Baseline Studies project (OWPEBS) in the near shore waters of the New Jersey coast. Methods for these surveys followed those of John Madsen (Delaware Benthic Mapping Project) and Mineral Management Services (MMS) guidelines for geological, geophysical, and geotechnical site surveys for meteorological and other seafloor founded structures. The primary purpose of these general study surveys, a small subset of the study area, was to evaluate seafloor conditions in the area proposed for construction of meteorological and wind tower pylons and structures and provide baseline seafloor substrate information. The data were examined for geological variations in surface sediments and the occurrence of any unknown obstructions in the proposed wind farm construction zone. Furthermore, this baseline data will allow for future assessments of local seafloor changes resulting from natural and anthropogenic events such as offshore wind farm development.

Side scan sonar utilizes high frequency sound pulses and acoustic backscatter to provide data on the types and textures of seafloor geological features. These data makes it possible to analyze the physical and, in many cases, the biological nature of the benthic surface environment. Side scan sonar is also useful for identifying sediment transport features such as sand waves, mud deposits, ripples, ridges, fish trawling scars, and scouring patterns.

Magnetometer data is useful if the area has the potential for the presence of unmarked shipwrecks or abandoned pipes or other man made metal objects. Magnetometers are capable of detecting and aiding in the identification of ferrous, ferric, or other objects having a distinct magnetic signature.

2.0 STUDY DESIGN

2.1 SAMPLING DESIGN

This study utilized data generated by a ship-deployed magnetometer and side scan sonar to examine surface sediments, obstructions, and anomalies. Surveys began in August 2009 and ended in December 2009. The University of Delaware *R/V Hugh R. Sharp* was used as the platform for all benthic mapping surveys. Survey lines were approximately 8.0 nautical miles (NM; 14.8 kilometers [km; 9.2 miles (mi)]) off the shore of New Jersey and ran parallel to the New Jersey shoreline and were bounded north and south by the OWPEBS area (**Figure A-1**). Multiple transects, 10 NM (18.5 km [11.5 mi]) long and 0.5 NM (0.93 km [0.58 mi]) apart, were chosen to provide the highest benthic coverage possible while accommodating planned research vessel movements and ongoing marine mammal and bird surveys. The survey transects totaled 386.0 NM (714.4 km [443.9 mi]) in length and 193 square nautical miles (NM^2; 664 square kilometers [km^2]). To avoid conflicts and interference with the biological studies being conducted during the daylight hours, the benthic profiling studies were carried out from approximately 1900 to 0500 hours. Benthic surveys were conducted at ship speeds ranging from 3 to 5 knots (5.6 to 9.3 kilometers per hour [kph; 3.5 to 5.8 miles per hour (mph)]). Environmental conditions, such as sea state and thermocline, were ultimately the main factors used in determining the ship speed for each transect line.

2.2 EQUIPMENT AND PROCESSING SOFTWARE

An L-3 Communications Klein Associates, Inc. Model 3000 Towfish, equipped with a K-2 k-wing depressor and transceiver processing unit, was used for the side scan sonar surveys. The Klein 3000 is a simultaneous duel frequency 100- and 500-kilohertz (kHz) system with main beam coverage for each channel being between 20 and 70 degrees (°) below horizontal. Sonar data were reviewed and processed at 500 kHz to maximize the coverage swath being recorded during data acquisition. The sweep range varied from 13.7 to 100.0 meters (m; [45.0 to 328.0 feet (ft)]) on either side of the towfish, depending on water depth and cruising speed. Normally, the towfish is maintained at 9.1 to 18.3 m (30.0 to 60.0 ft) above the benthic surface for best coverage at the maximum sweep range. During the surveys, the shallow water typical of the outer continental shelf (OCS) of the New Jersey coast, combined with a strong thermocline and surface wave interference, limited the effective sweep coverage.

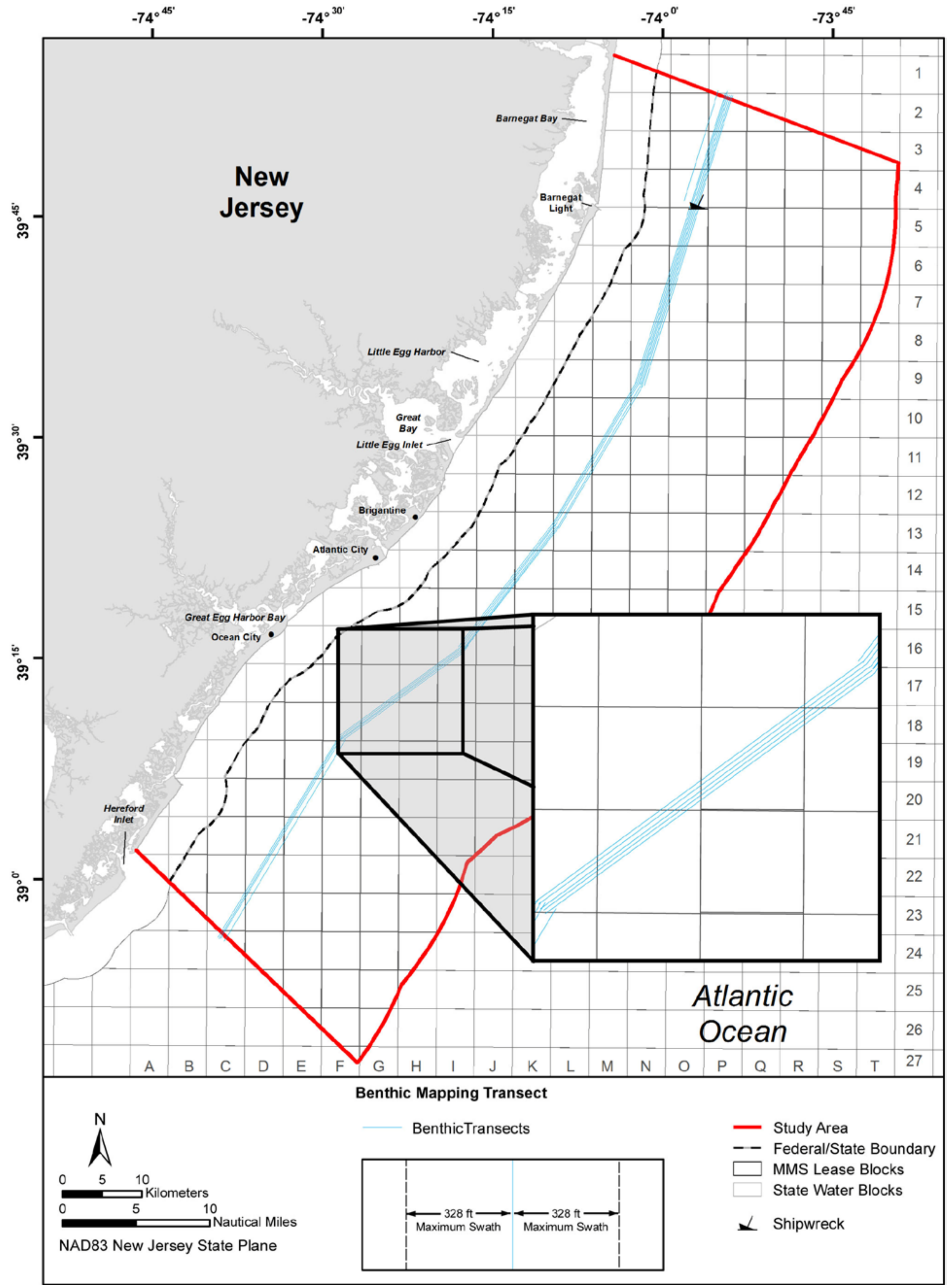

Figure A-1. Area surveyed.

A Geometrics, Inc. Model 882 magnetometer was used to detect any magnetic anomalies that might indicate shipwrecks, pipelines, cables, and other buried structures or geologic anomalies. The Geometrics 882, a cesium vapor marine magnetometer, was used during the surveys to detect and measure fluxes in the ambient background magnetic field. Magnetometer coverage was approximately 12.2 to 24.4 m (40.0 to 80.0 ft) in width for each survey transect line.

The side scan sonar and magnetometer were interfaced with a computer and the data were indexed using a differential geographic positioning system (DGPS) provided by the research vessel. The DGPS interface provided precise location data with a +/- 1 m (3.3 ft) accuracy. Side scan sonar data were reviewed and sonar mosaics were created using Chesapeake Technology SonarWizMap4 software. Magnetic data was processed and analyzed using Hypack Inc. hydrographic and data collection software. Planned survey lines were maintained using Hypack, Inc. navigation software provided by the research vessel. The survey lines were managed by the ship's captain and the survey technical leader. Side scan sonar and magnetometer data are provided in electronic format.

3.0 RESULTS AND DISCUSSION

Two complementary tools were used to examine the seafloor within the area proposed for offshore wind farm development: side scan sonar and magnetometer. Side-scan sonar mosaics of the sea floor were used to search for and identify areas of exposed rock outcrops, sea floor scarps, sedimentary textures, underwater obstacles, areas of potential biological activity, or archaeological resources.

Results of the examination and analysis of sonar imagery data, bathymetry, and backscatter made it possible to consistently identify four benthic/bottom types: sand plains, sand ripples, sand waves, and areas of mud and silt deposits.

Sand plains were observed across the Area Surveyed (**Figure A-2**). Consisting of stable sand deposits, this bottom type does not exhibit any abrupt changes in relief or elevation. Sonar characteristics of sand plains typically exhibit smooth to small changes in bathymetry with intermittent areas of sand ripples and mud deposits. Areas of transition from sand plains to other bottom types occur around major shipping lanes, areas that may be heavily fished, and/or areas in the vicinity of river outflows.

Sand ripples consist of sediment that forms regular ripples or ridges (**Figure A-3**). Ripples, and similar features such as hummocks and sand waves, are formed under high energy conditions typical of strong wave and/or currents. The observed ridges are small and uniform and generally have a north to south orientation running perpendicular to wave and sub-surface currents. There are transition areas of larger sand waves and areas of taller ripples, possibly associated with ancient deposits of mud, sand, and silt, and with changes to currents as mediated by ship traffic, and or currents altered by river outflows. Sand ripples are readily apparent and easy to discriminate on side scan sonar backscatter mosaics. Bathymetry, as also described for sand plain areas, is gently sloping or constant and has no observed abrupt changes.

Two other bottom types were observed, sand waves (**Figure A-3**) and mud/silt deposits (**Figure A-3**). Migrating sand waves occurred sporadically and seemed to be associated with changes in bathymetry and possibly with shipping lanes. Mud and silt deposits were found across the Area Surveyed and seemed to be associated with areas of high commercial fish trawling, ship lanes, and river outflow areas. While there are changes in bathymetry associated with the sand waves, the changes are very gradual. Depths ranged from 20 ft in the south to 70 ft in the north.

A number of sonar targets were detected by both side scan sonar and magnetometer analysis (**Table A-1**). Scallop fishing drag scars are frequent throughout the Area Surveyed (**Figure A-4**) and some areas have abandoned fish traps and other small areas of debris (**Figure A-5**) probably associated with commercial fishing and ship traffic. One uncharted shipwreck (**Figure A-6**) is located at 39 45.9473N and 073 56.9384W. This shipwreck appears to be the remains of a fiberglass constructed hull approximately 12.2 m (40 ft) long and 3.4 m (11 ft) wide with an altitude of 0.6 m (2 ft). Other shipwrecks (**Figures A-7** and **A-8**) were recorded but all were previously recorded on the navigational charts or associated with designated Fish Haven Areas. All magnetic anomalies detected were associated with known shipwrecks.

4.0 SUMMARY

Survey side scan sonar imaging data in the Area Surveyed (characterized by consistent backscatter patterns) revealed that the entire area is characterized by a relatively uniform sand bottom with intermittent areas of mud and silt associated with wrecks, trawling areas, and areas of heavy ship traffic. Seabed morphology in the area surveyed was found to consist of relatively flat, migrating sand waves and ripples with occasional larger sand ridges. Variable tidal and current hydraulics result in the development and migration of sand waves, dunes, and ripples through mechanisms such as scour, deposition of terrestrial origin sediments with erosion, and transport of sand and mud. Scallop fishing drag scars were frequent. Sonar targets include fish traps (abandoned and active), debris probably associated with commercial shipping traffic, ship wrecks (charted and uncharted), and possibly cement structure debris. While side scan imagery of the survey area documents considerable spatial variability in bottom types, sand plains and sand ripples were the dominant bottom type across the area surveyed.

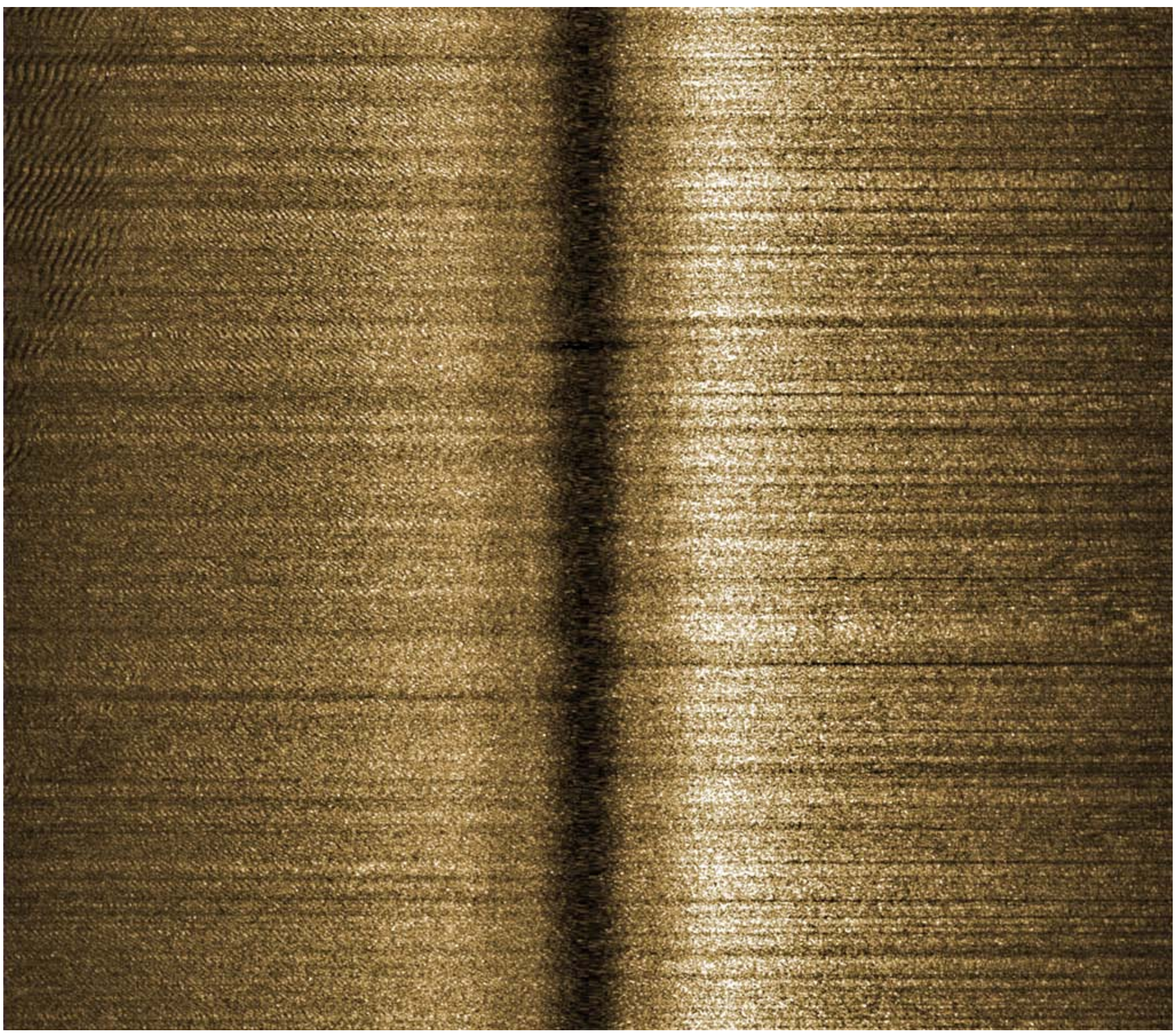

Figure A-2. Sand plains.

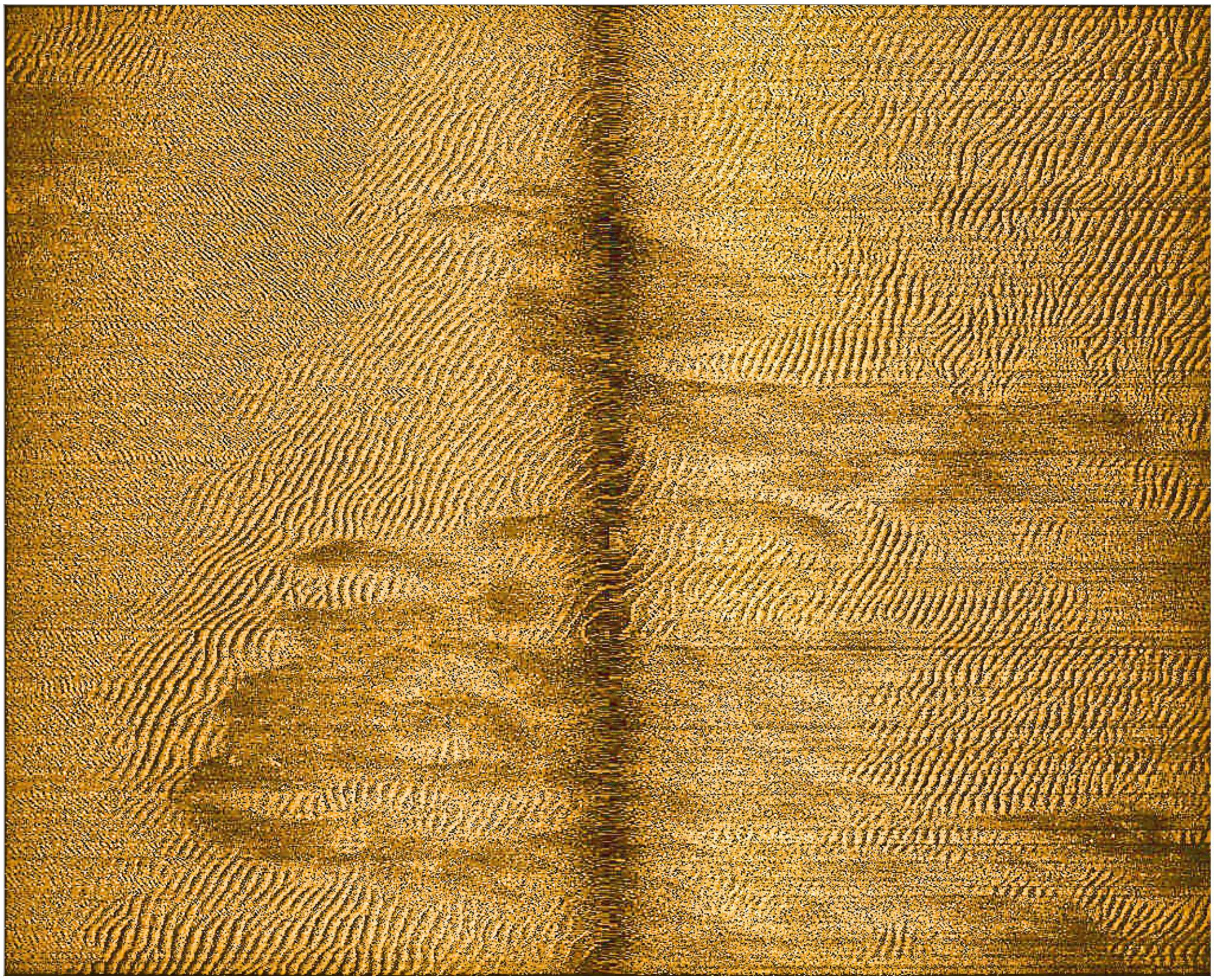

Figure A-3. Mud deposits with sand ripples transitioning to sand waves.

Table A-1. Sonar targets.

Sonar Target	Latitude	Longitude	Notes
Uncharted Shipwreck	39 45.9473N	073 56.9384W	Appears to be a fiberglass hull, 40+ feet long, 11+ feet wide, with 2 feet of altitude.
Charted Tall Wreck	39 26.3474N	074 15.8569W	Boilers can be seen in record. Line of fish traps can also be seen in close proximity to main body of wreck.
Charted Wide Wreck	39 18.1868N	074 15.8569W	
Charted Flat Wreck	39 21.2258N	074 12.8474W	Wreck is broken up and spread across the seafloor.
Charted Barge Wreck	39 37.5993N	074 01.0310W	126 feet long, 26 feet wide.
Possible concrete rubble	39 37.0474N	074 01.1875W	
Charted Wreck	39 37.8404N	074 00.9646W	
Charted Wreck	39 37.8802N	074 00.8072W	

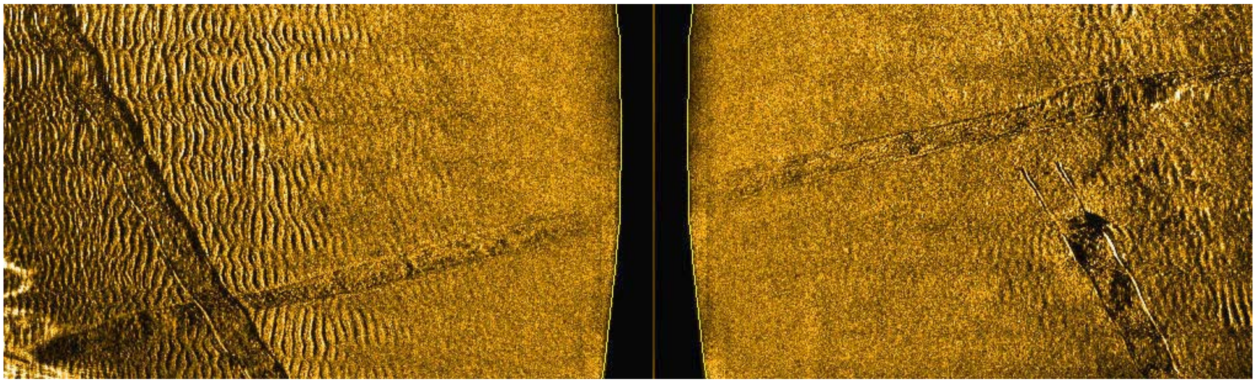

Figure A-4. Drag scars from scallop fishing.

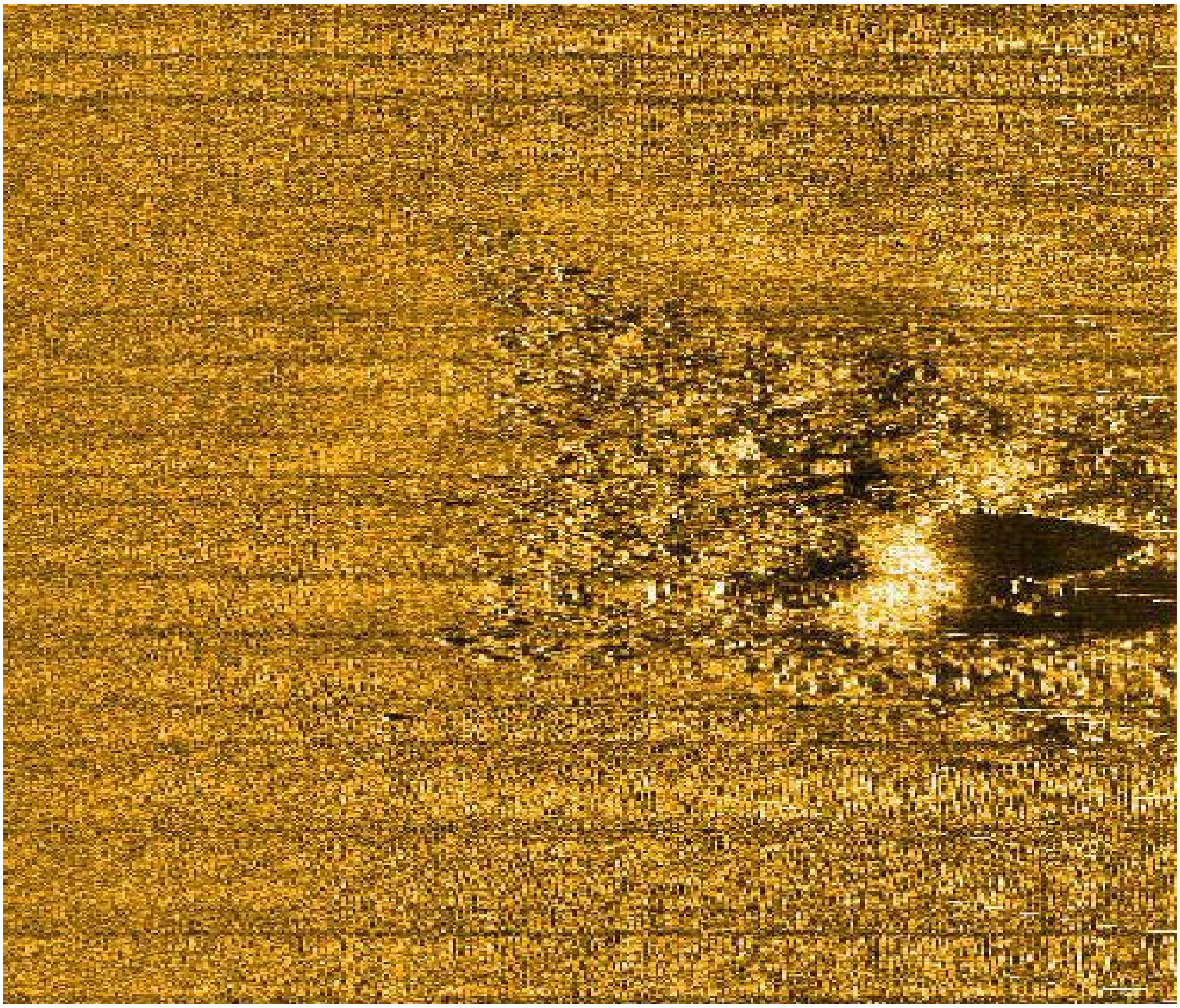

Figure A-5. Debris.

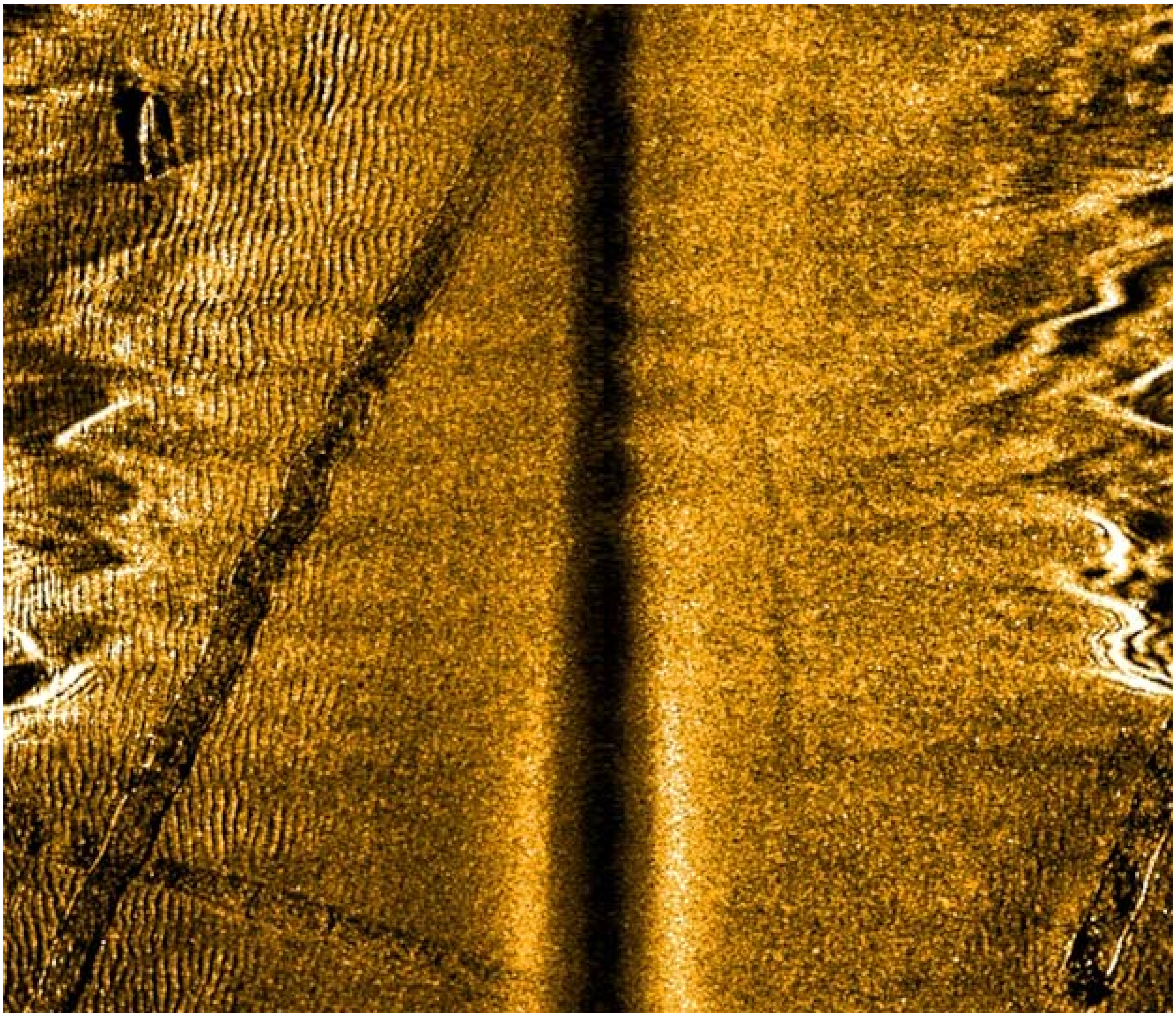

Figure A-6. Uncharted shipwreck with prominent drag scars (thermocline interference on edges).

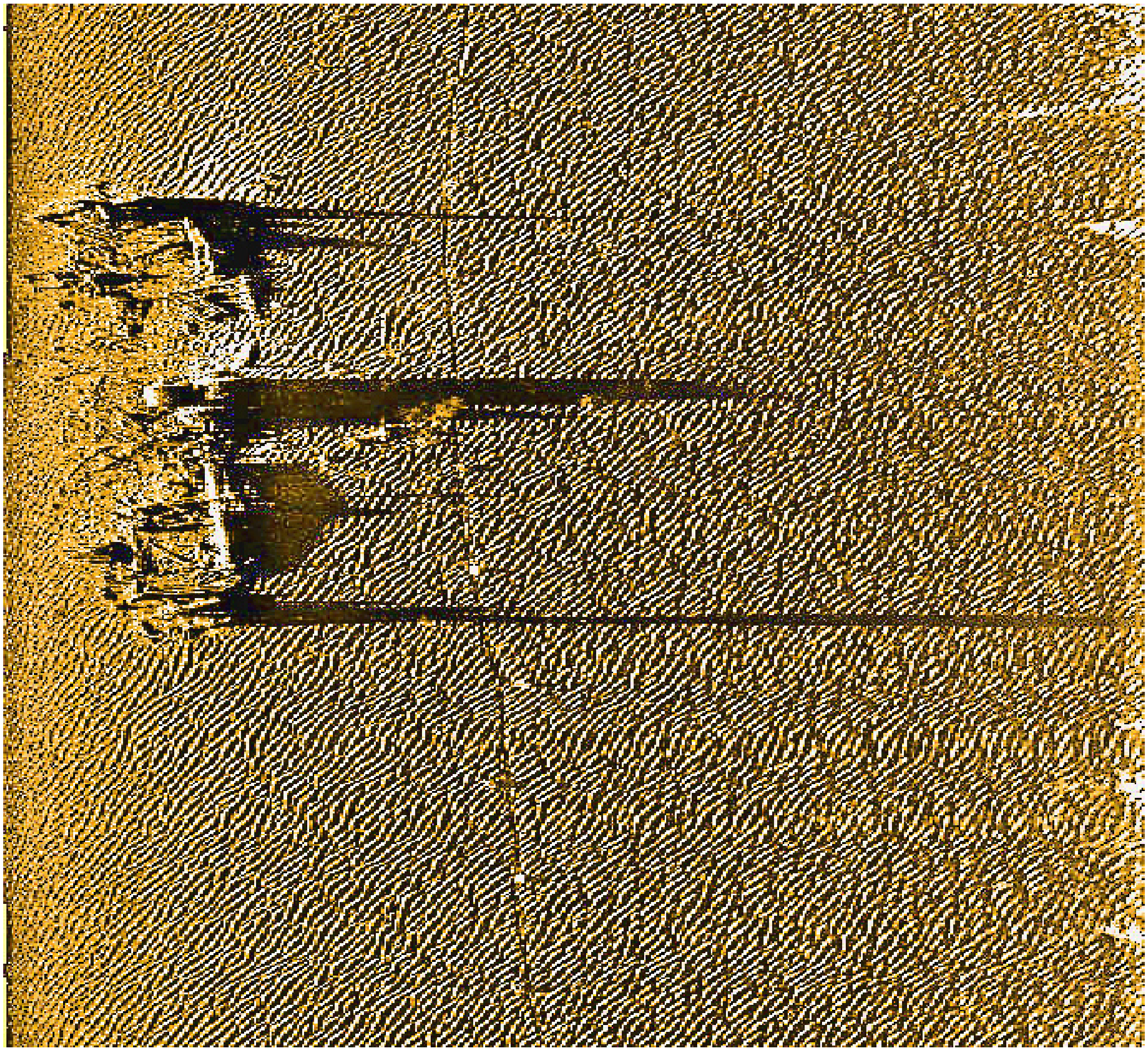

Figure A-7. Charted shipwreck and fish trap line with sand ripples and waves.

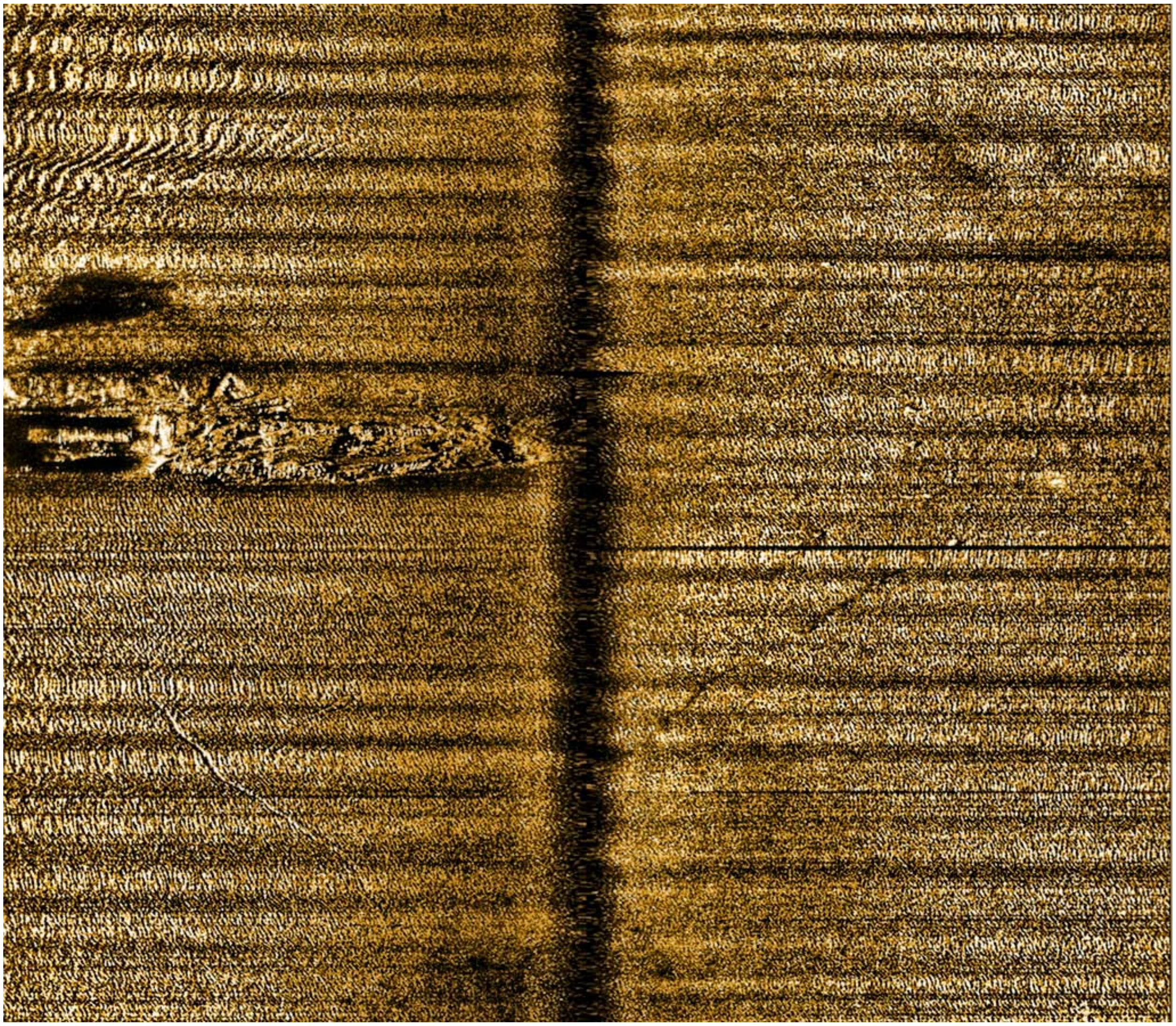

Figure A-8. Charted shipwreck.

APPENDIX B

BATS

1.0 BAT DETECTION SURVEY EFFORT

During the March, April, May, June, August, September, and October 2009 shipboard surveys, a bat survey was conducted with Anabat II detectors as part of a research project conducted by a graduate student, Angela Sjollema, of the University of Maryland Center for Environmental Science. The goal of the research project was to conduct preliminary offshore wind turbine pre-construction surveys for bat activity along the Delmarva Peninsula. Research funding came from the Maryland Department of Natural Resources Power Plant Research Program. All bat data results are considered preliminary.

2.0 SURVEY AND ANALYSIS METHODS

Anabat II detectors were deployed to record the presence of offshore bats within the Study Area. Two detectors were used to prevent instances of no data collection in the event of equipment failure. One recording setup was attached to the port and one to the starboard sides of the *R/V Hugh R. Sharp* on the upward deck, approximately 6.1 to 7.6 meters (m; 20 to 25 feet [ft]) above sea level. Each setup consisted of an Anabat II bat detector, a ZCAIM (Zero Crossings Analysis Interface Modules; Titley Electronics, Ballina, New South Wales, Australia), and an external 12-Volt (V; 12 A h) battery. Anabat units are designed to detect ultrasonic frequencies up to 120 kilohertz (kHz); the information is recorded with a time and date stamp by the ZCAIM and recorded to a 256 megabyte (MB) compact flash (CF) card. The sensitivity was calibrated to the maximum detection distance of 30 m (98.4 ft). Monitors, ZCAIMs, and batteries were housed and kept in a waterproof fiberglass box (27.7×22.3×13.3 centimeter [cm; 10.9x8.8x5.2 inches (in.)]). Polyvinyl chloride (PVC) pipe arched from the top of the box with a microphone (Titley Black Low Energy Mic) inside pointing towards a 20.32x20.32 cm (8x8 in.) Plexiglas sheet angled at 45 degrees (°). The fiberglass boxes were attached to conduit which was then fastened to the ship's railings with hoseclamps. The systems turned on and off automatically and were programmed to monitor from 1800 to 0800 in March and April, and from 1900 to 0700 in May, June, August, September, and October 2009.

After downloading the information from the CF card, extraneous sound files were deleted. Bat calls were identified by using visual comparisons from the region and a bat call identification key. Depending on the quality of the calls, a minimum of three individual call pulses were required. If less than three call pulses occurred the call was automatically categorized as no identification (NOID). Calls were analyzed to species whenever possible. Otherwise, they were categorized into groups (e.g., Myotis species [MYSP] and *E. fuscus/Lasionycteris noctivagans* [EPFU/LANO]). A northeastern bat call library and a call identification key specific to northeastern bats were used to visually identify the bat calls (Amelon 2005). In order to find the coordinates of the bat calls, the time and date of each call were compared to global positioning system (GPS) data (**Table B-1**).

Table B-1. Bat species recorded within the Study Area by Anabat II detectors aboard ship offshore surveys in May, August, September, and October 2009.

Date	Time	Species	Latitude	Longitude
5/2/2009	23:24:52	EPFU/LANO	39.357912	-74.289357
8/1/2009	6:13:36	EPFU/LANO	38.8198	-75.046805
8/2/2009	22:06:48	NOID	39.902725	-74.03907
8/3/2009	0:05:20	LABO	39.908871	-74.02126
8/3/2009	22:24:15	LABO	39.699296	-74.0832866
8/3/2009	22:46:57	LABO	39.703073	-74.0786866
8/3/2009	23:07:08	LABO	39.70685	-74.07438
8/3/2009	23:45:59	LABO	39.712208	-74.067515
8/3/2009	23:46:14	LABO	39.712241	-74.06746
8/3/2009	0:14:52	NOID	39.9122316	-74.02126
8/3/2009	23:15:24	NOID	39.708038	-74.072888

Table B-1 (*continued*). Bat species recorded within the Study Area by Anabat II detectors aboard ship offshore surveys in May, August, September, and October 2009.

Date	Time	Species	Latitude	Longitude
8/4/2009	0:36:20	EPFU/LANO	39.71497	-74.0635683
8/4/2009	2:26:10	EPFU/LANO	39.665868	-74.08599
8/4/2009	0:17:24	LABO	39.7152083	-74.062656
8/4/2009	0:33:29	LABO	39.717453	-74.061705
8/4/2009	3:19:46	LABO	39.669888	-74.079396
8/4/2009	0:23:53	LACI	39.7156416	-74.0617
8/30/2009	21:09:27	LABO	39.29252	-74.31913
8/30/2009	21:19:03	LABO	39.291501	-74.31757
8/30/2009	22:22:51	LABO	39.273665	-74.284103
8/30/2009	21:21:18	NOID	39.29118	-74.317156
8/31/2009	5:06:24	EPFU/LANO	39.23229	-74.26682
8/31/2009	3:01:42	LABO	39.207816	-74.381316
8/31/2009	3:05:18	LABO	39.209398	-74.378081
8/31/2009	3:29:49	LABO	39.22086	-74.358861
8/31/2009	23:27:06	LABO	39.47686	-74.10793
8/31/2009	23:51:25	LABO	39.450551	-74.128063
8/31/2009	3:33:52	MYSP	39.22292	-74.35515
8/31/2009	0:15:31	NOID	39.190826	-74.428455
8/31/2009	3:05:33	NOID	39.209473	-74.37791
8/31/2009	3:05:42	NOID	39.20973	-74.37791
8/31/2009	3:06:03	NOID	39.20977	-74.377341
8/31/2009	3:06:16	NOID	39.20977	-74.377341
8/31/2009	3:06:29	NOID	39.20977	-74.377341
8/31/2009	3:08:06	NOID	39.210576	-74.37574
8/31/2009	3:08:21	NOID	39.210576	-74.37574
8/31/2009	3:29:21	NOID	39.22086	-74.358861
8/31/2009	3:44:48	NOID	39.22837	-74.34373
8/31/2009	4:55:47	NOID	39.2474	-74.27777
9/30/2009	23:17:53	EPFU/LANO	39.627555	-74.016275
9/30/2009	23:59:37	MYSP	39.746381	-73.965431
9/30/2009	22:15:46	NOID	39.627555	-74.016275
9/30/2009	22:19:41	NOID	39.627555	-74.016275
9/30/2009	22:19:58	NOID	39.627555	-74.016275
9/30/2009	22:20:10	NOID	39.627555	-74.016275
9/30/2009	23:43:06	NOID	39.76822	-73.953931
9/30/2009	23:59:45	NOID	39.746381	-73.965431
10/1/2009	0:40:20	LABO	39.68844	-73.989225
10/1/2009	0:04:26	LABO	39.73964	-73.968515
10/1/2009	0:06:57	MYSP	39.73608	-73.96978
10/1/2009	0:33:32	NOID	39.69824	-73.98535
10/1/2009	1:34:12	NOID	39.61145	-74.02057
10/1/2009	6:29:21	NOID	39.88717	-73.89198
10/1/2009	21:57:26	NOID	39.45579	-74.121545

EPFU/LANO = *Eptesicus fuscus/Lasionycteris noctivagans*, LABO = *Lasiurus borealis*, LACI = *Lasiurus cinereus*, MYSP = Myotis sp., NOID = No identification (unknown)

3.0 RESULTS

Bats were not recorded on the surveys in March, April, and June 2009. On 2 May 2009 one big brown/silver-haired bat (*Eptesicus fuscus/ Lasionycteris noctivagans*) was recorded offshore (**Tables B-1** and **B-2**). Bats were recorded on eight different nights in August, September, and October 2009 (**Table B-1**). A total of 54 calls were archived: 25 unidentifiable, 19 Eastern red bats, six big brown/silver-haired bats, three Myotis species (*Myotis* sp.), and one hoary bat (**Table B-2**). The farthest a bat was recorded from shore was 19.2 km (10.4 NM) and the mean distance was 10.6 km (5.2 NM; **Figure B-1**).

Table B-2. Bat species recorded in the Study Area by Anabat II detectors during shipboard offshore surveys in May, August, September, and October 2009.

Bat species		Date				Total
Common name	**Scientific name**	**2 to 6 May**	**1-5 Aug**	**30 Aug to 3 Sep**	**28 Sep to 2 Oct**	
Big brown/ silver haired bat	*Eptesicus fuscus/ Lasionycteris noctivagans*	1	3	1	1	**6**
Eastern red bat	*Lasiurus borealis*		9	8	2	**19**
Hoary bat	*Lasiurus cinereus*		1			**1**
Myotis sp.	*Myotis* sp.			1	2	**3**
Unknown			3	12	10	**25**
Total		**1**	**16**	**22**	**15**	

4.0 LITERATURE CITED

Amelon, S. 2005. Preliminary key to the qualitative identification of calls with the Anabat system. Bat Conservation International acoustic monitoring workshop. Barree, Pennsylvania, 8-13 August 2005.

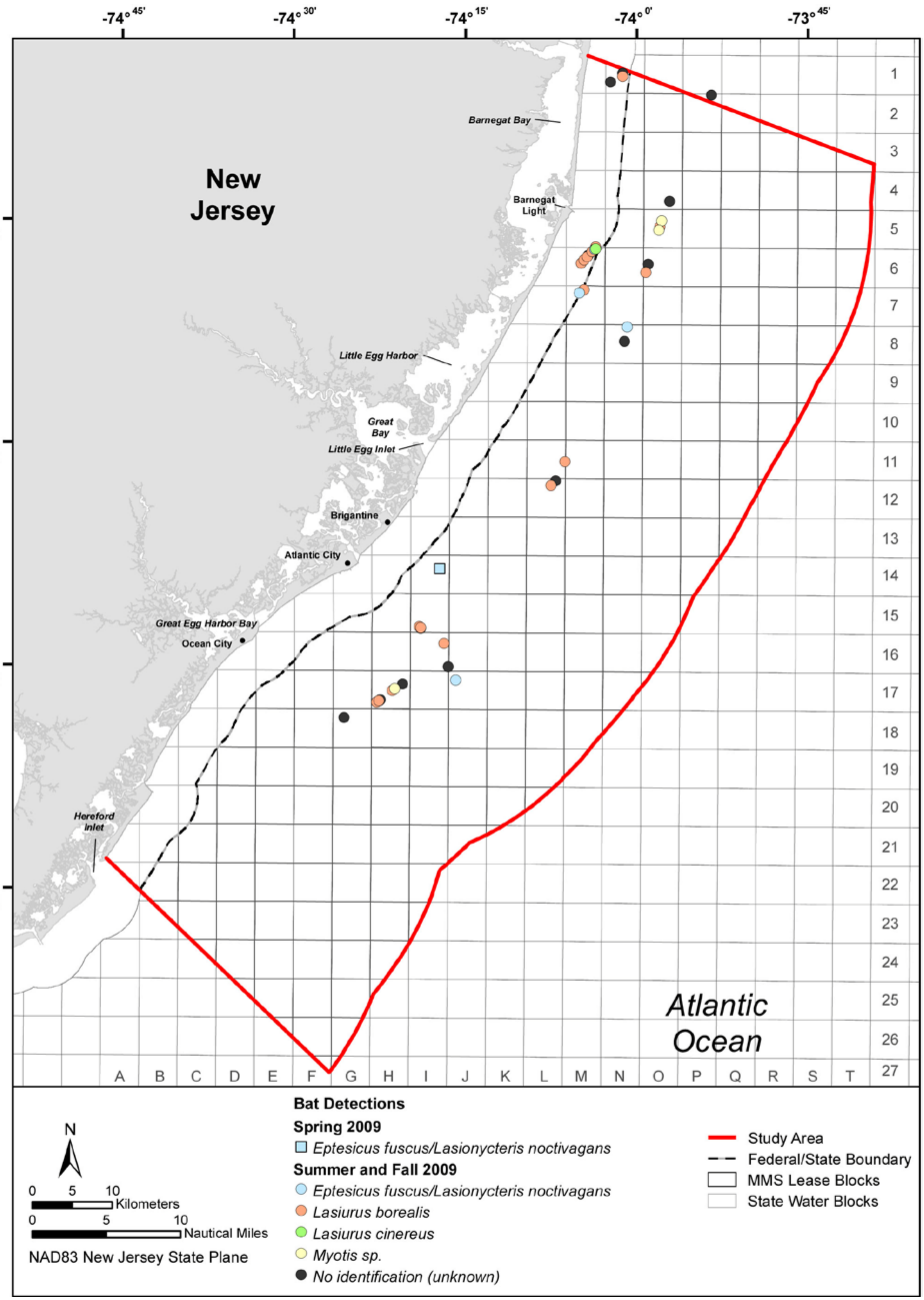

Figure B-1. Bat echolocations in the Study Area. Bats were located by Anabat II detectors during ship offshore surveys in May and August through October 2009.

APPENDIX C

ENVIRONMENTAL SENSITIVITY INDEX

Table C-1. Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
A	20	X	X		X	X			X		X				X				X								
A	21	X	X	X	X	X			X		X	X			X			X	X		X						
A	22	X	X	X		X		X	X		X	X			X		X		X				X				
B	18		X	X	X	X				X	X				X			X	X								
B	19	X	X	X	X	X			X	X	X	X		X	X			X	X		X		X		X		
B	20	X	X	X	X	X		X	X	X	X	X			X			X	X		X	X					
B	21	X	X	X		X		X	X			X			X		X	X	X	X	X				X		
B	22	X	X	X		X		X	X			X			X		X	X	X	X			X	X	X	X	
B	23	X				X		X	X			X	X		X		X		X	X				X		X	
C	16		X		X					X	X				X												
C	17	X	X	X	X	X			X	X	X	X			X			X				X	X				
C	18	X	X	X	X	X		X	X	X	X	X			X		X	X	X								
C	19	X	X	X		X		X	X	X		X			X		X	X	X	X			X				
C	20	X	X	X		X		X	X			X			X			X	X	X			X		X		
C	21	X	X	X		X		X	X			X			X		X		X	X					X	X	
C	22	X	X	X		X	X	X	X			X	X		X		X	X	X	X			X		X	X	
C	23	X	X			X	X	X	X			X	X		X		X	X	X	X							
C	24	X	X				X	X				X	X		X	X	X	X	X	X			X				
D	16	X	X	X	X	X			X	X	X	X	X		X												
D	17	X	X	X	X	X		X	X	X		X	X		X			X				X	X				
D	18	X	X			X		X	X			X			X		X	X	X	X			X				
D	19	X	X	X		X		X	X			X			X		X	X	X	X					X		
D	20	X	X			X		X	X			X			X		X	X	X	X	X		X		X	X	
D	21	X	X			X	X	X	X			X			X		X	X	X	X						X	
D	22	X	X			X	X	X				X	X		X	X	X	X	X	X			X				
D	23	X	X				X	X				X	X		X	X	X	X	X	X	X						
D	24	X	X				X	X				X	X		X	X	X	X	X	X			X				
D	25	X					X	X				X	X			X		X	X	X							
E	15	X	X	X	X	X			X	X	X	X			X			X	X				X				
E	16		X	X	X	X		X	X	X		X	X		X				X		X				X		
E	17	X	X	X		X		X	X			X	X		X				X	X					X		
E	18	X	X	X		X	X	X	X			X			X		X	X	X	X			X				
E	19	X	X	X		X	X	X	X			X			X		X	X	X	X					X	X	

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
E	20	X	X	X		X	X	X	X			X			X	X	X	X	X	X	X		X		X	X	
E	21	X	X			X	X	X	X			X	X		X	X	X	X	X	X							
E	22	X	X				X	X				X	X		X	X	X	X	X	X			X		X		
E	23	X	X				X	X	X			X	X			X	X	X	X	X	X						
E	24	X	X	X			X	X	X			X	X			X		X	X	X			X		X		
E	25	X	X	X			X	X	X				X			X		X	X	X							
E	26	X	X				X		X				X			X	X		X	X							
F	14	X	X	X	X	X			X		X			X	X			X	X			X			X		
F	15	X	X	X	X	X		X	X			X	X	X	X			X	X		X	X	X		X		
F	16	X	X	X		X		X	X			X	X	X	X				X		X						
F	17	X	X			X		X	X			X	X		X				X	X					X		
F	18	X	X			X	X	X	X			X	X		X		X	X	X	X			X		X	X	
F	19	X	X				X	X	X			X			X	X	X	X	X	X						X	
F	20	X					X	X	X			X			X	X	X	X	X	X			X				
F	21	X					X	X	X			X				X		X	X	X	X						
F	22	X	X				X	X	X	X		X	X			X		X	X	X			X				
F	23	X	X				X	X	X			X	X			X	X	X	X	X							
F	24	X	X				X		X	X		X	X			X			X	X			X				
F	25	X	X	X			X		X	X			X			X	X	X	X	X							
F	26	X	X	X			X		X	X			X			X	X	X	X	X			X				
F	27	X					X			X		X	X			X				X							
G	13	X	X	X	X			X	X		X				X			X					X				
G	14	X	X	X	X	X		X	X		X	X	X	X	X			X	X		X				X		
G	15	X	X	X		X		X	X			X	X	X	X			X	X		X	X	X		X		
G	16	X	X			X		X	X			X	X	X	X				X						X		
G	17	X	X			X		X	X			X	X	X	X				X	X	X				X	X	
G	18	X	X			X	X	X	X			X	X		X			X	X	X			X			X	
G	19	X	X				X	X	X			X			X	X		X	X	X	X						
G	20	X	X				X		X	X		X				X	X	X	X	X			X				
G	21	X					X	X	X	X		X	X			X		X	X	X							
G	22	X					X	X	X	X		X	X			X	X	X	X	X			X				
G	23	X					X		X	X		X	X			X	X	X		X							
G	24	X					X		X	X		X	X			X				X			X				

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
G	25	X					X			X		X	X			X				X			X		X		
G	26	X					X			X		X	X			X				X			X				
G	27	X					X			X		X	X			X				X							
H	12	X	X		X	X		X			X				X			X	X	X	X				X		
H	13		X	X	X	X		X	X		X	X			X			X	X	X	X		X				
H	14	X	X	X	X	X		X			X	X	X	X	X			X	X		X				X		
H	15	X	X	X		X		X				X	X	X	X		X	X	X		X		X		X	X	
H	16	X	X			X		X	X			X	X		X		X	X	X						X	X	
H	17	X	X	X		X		X	X			X	X	X	X			X	X	X	X				X	X	
H	18	X	X	X		X	X	X	X			X			X	X	X	X	X	X			X				
H	19	X	X				X	X	X	X		X			X	X			X	X							
H	20	X					X		X	X		X				X	X	X	X	X	X		X				
H	21	X					X			X	X	X				X			X	X	X						
H	22	X					X		X	X	X	X	X			X		X	X	X	X						
H	23	X					X		X	X	X	X	X			X		X		X							
H	24	X					X			X	X	X	X			X		X		X			X				
H	25	X					X			X		X				X				X			X				
I	10			X	X			X	X		X				X			X	X	X			X				
I	11	X	X	X	X			X	X		X	X			X			X	X	X	X		X		X		X
I	12	X	X	X	X	X		X			X	X	X		X			X	X	X	X				X		
I	13	X	X	X		X		X			X	X	X	X	X		X	X	X	X			X		X		
I	14	X	X			X		X	X			X	X	X	X			X	X		X				X	X	
I	15	X	X			X		X	X			X	X	X	X			X	X		X		X		X	X	
I	16	X	X			X		X				X	X	X	X				X								
I	17	X	X			X	X	X				X	X		X			X	X		X						
I	18	X				X	X	X	X			X	X		X	X	X	X	X				X				
I	19	X					X	X	X	X		X	X			X			X								
I	20	X					X			X	X	X				X	X		X								
I	21	X	X				X			X	X	X				X	X		X								
I	22	X	X				X			X	X					X			X								
I	23	X					X			X	X					X		X									
I	24	X					X			X	X					X											
J	9		X	X	X	X		X			X	X	X		X			X	X								X

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
J	10	X	X	X	X	X		X	X		X	X	X		X			X	X	X	X		X		X		X
J	11	X	X	X	X	X		X	X		X	X	X		X			X	X	X	X		X				X
J	12	X	X	X	X	X		X	X			X	X		X		X	X	X	X	X				X		X
J	13	X	X	X		X		X	X			X	X		X		X	X	X	X	X		X		X	X	
J	14	X	X			X		X	X			X	X	X	X				X		X				X	X	
J	15	X	X			X		X	X			X	X	X	X				X				X		X		
J	16	X	X			X	X	X				X	X		X				X								
J	17	X				X	X	X				X	X		X			X	X		X						
J	18	X					X	X	X	X		X	X		X	X	X	X	X				X				
J	19	X					X		X	X		X	X			X	X		X								
J	20	X					X			X	X	X				X	X		X								
J	21	X					X			X	X	X				X			X								
K	7		X	X	X	X			X			X	X		X			X	X			X					
K	8	X	X	X	X	X		X	X		X	X	X		X			X	X		X				X		
K	9	X	X	X	X	X		X				X	X	X	X			X	X		X						X
K	10	X	X	X		X		X					X	X	X			X	X	X	X		X				X
K	11	X	X			X		X	X				X	X	X				X	X	X		X			X	
K	12	X	X	X		X		X	X				X		X			X	X		X				X	X	
K	13	X	X	X		X		X	X				X		X			X	X		X		X			X	
K	14	X	X			X		X	X				X		X			X	X						X		
K	15	X	X			X	X	X	X			X	X		X			X	X				X		X		
K	16	X				X	X	X	X			X	X		X			X	X								
K	17	X					X	X	X			X	X		X	X		X	X						X		
K	18	X					X	X	X	X		X	X		X	X		X	X								
K	19	X					X		X	X	X	X	X			X	X	X	X								
K	20	X					X			X	X	X				X	X		X								
K	21	X					X			X		X				X			X								
L	5		X	X	X	X			X			X			X				X		X						
L	6		X	X	X	X			X		X	X	X		X			X	X		X				X		X
L	7	X	X	X	X	X			X		X	X	X		X		X	X	X			X					X
L	8	X	X	X		X		X	X			X	X	X	X				X						X		X
L	9	X	X	X		X		X					X	X	X			X	X						X	X	X
L	10	X	X			X		X					X	X				X	X		X		X			X	X

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
L	11	X	X			X		X	X				X	X	X			X	X		X		X		X	X	X
L	12	X	X			X		X	X			X	X	X	X			X	X						X		
L	13	X	X	X		X		X	X			X	X		X				X				X		X		
L	14	X	X			X	X		X				X		X				X								
L	15	X				X	X	X	X			X	X		X			X	X				X				
L	16	X					X	X	X			X	X		X	X		X	X						X		
L	17	X					X		X			X	X		X	X		X	X								
L	18	X					X		X	X		X	X			X		X	X								
L	19	X					X		X	X	X	X				X			X								
L	20	X					X			X		X				X			X								
M	1	X	X	X	X	X			X		X	X				X		X	X		X	X					
M	2		X	X	X	X			X		X	X				X		X	X						X		
M	3	X	X	X	X	X			X		X	X			X	X		X	X								
M	4	X	X	X	X	X			X		X	X			X			X	X		X		X		X		
M	5	X	X	X	X	X			X		X	X	X		X			X	X		X		X		X		
M	6	X	X	X		X			X			X	X		X		X	X	X						X		X
M	7	X	X			X		X	X			X	X	X	X		X	X	X		X				X		
M	8	X				X		X	X			X	X	X	X			X	X		X					X	X
M	9	X				X		X	X				X	X				X	X				X		X	X	X
M	10	X	X			X		X	X				X	X				X	X		X		X				X
M	11	X	X			X		X	X				X	X	X				X				X				X
M	12	X	X			X			X			X	X	X	X				X								X
M	13	X				X			X			X	X		X				X				X				X
M	14	X				X	X		X				X		X				X								X
M	15	X				X	X		X			X	X		X	X		X	X								
M	16	X	X				X		X			X	X		X	X		X	X								
M	17	X					X		X	X		X	X			X		X	X								
M	18	X					X		X	X	X	X	X			X			X								
M	19	X					X			X	X	X				X			X								
N	1	X	X	X		X	X	X	X			X				X		X	X								
N	2	X	X	X		X	X	X	X			X				X		X	X						X		
N	3	X	X	X		X		X	X			X			X	X		X	X		X						
N	4	X	X	X		X		X	X			X			X			X	X		X				X		

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
N	5	X	X	X		X		X	X			X			X			X	X		X		X		X		
N	6	X	X			X		X	X			X	X		X				X		X				X	X	X
N	7	X	X			X		X	X			X	X	X	X			X	X		X				X	X	
N	8	X	X			X		X	X			X	X	X				X	X							X	X
N	9	X	X			X		X	X				X	X				X	X				X				X
N	10	X	X			X		X	X			X	X	X					X				X				X
N	11	X				X		X	X			X	X	X	X				X						X		X
N	12	X				X		X	X			X	X	X	X				X								
N	13	X	X			X	X	X	X			X	X		X				X				X				
N	14	X				X	X		X			X	X		X				X								X
N	15	X				X	X		X		X	X	X		X	X		X	X								X
N	16	X					X		X	X	X	X	X		X	X		X	X								X
N	17	X					X		X	X		X				X		X	X								X
N	18	X					X			X		X				X			X								
O	1	X				X	X	X	X			X	X			X		X	X						X	X	
O	2	X	X			X	X	X	X			X	X		X	X		X	X						X	X	
O	3	X	X			X	X		X			X	X		X	X	X	X	X							X	
O	4	X	X			X			X			X	X		X		X	X	X		X				X	X	
O	5	X	X			X		X	X			X	X		X			X	X				X		X	X	
O	6	X	X			X		X	X			X	X		X			X	X		X					X	X
O	7	X				X		X	X			X	X	X	X				X						X		
O	8	X				X		X	X			X	X	X					X								
O	9	X	X			X			X			X	X	X					X				X				X
O	10	X	X			X		X	X			X	X	X					X								X
O	11	X				X		X				X	X	X	X				X								X
O	12	X				X		X				X	X		X				X								
O	13	X				X		X	X			X			X				X				X				
O	14	X				X	X		X	X		X			X				X								
O	15	X				X	X		X	X	X	X			X			X	X								
O	16	X					X		X	X	X	X			X	X		X	X								
O	17	X					X			X		X				X		X	X								X
P	1	X					X		X				X			X			X							X	
P	2	X	X				X		X				X		X	X			X					X		X	

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
P	3	X	X			X	X		X				X		X		X		X					X	X		
P	4	X	X			X	X		X				X		X			X	X					X	X		
P	5	X	X			X		X	X				X		X				X				X				X
P	6	X	X			X		X	X				X		X				X								X
P	7	X				X			X			X	X	X	X				X						X		
P	8	X				X			X	X		X		X	X			X	X								
P	9	X	X			X			X	X		X		X					X								X
P	10	X	X			X		X	X	X		X		X					X								X
P	11	X				X	X	X	X		X	X		X	X				X								X
P	12	X				X	X	X	X		X	X		X	X				X				X				X
P	13	X				X	X	X	X	X	X	X			X				X				X				
P	14	X				X	X		X	X	X	X			X				X								
P	15	X					X			X	X	X			X			X	X								
Q	2	X	X			X	X		X	X		X	X		X			X	X					X			
Q	3	X	X			X	X		X	X		X	X		X		X	X	X					X	X		
Q	4	X	X			X	X		X				X		X		X		X					X			
Q	5	X	X			X	X	X	X				X		X	X			X				X				X
Q	6	X				X		X	X				X		X				X								X
Q	7	X				X		X	X	X		X	X		X			X	X								
Q	8	X				X			X	X		X		X	X			X	X								
Q	9	X				X	X		X	X	X	X		X				X	X								X
Q	10	X				X			X	X	X	X		X					X								X
Q	11	X				X	X		X	X	X	X		X					X								X
Q	12	X				X	X		X	X	X			X	X				X				X				X
Q	13	X				X			X	X	X			X	X				X								
Q	14	X				X				X	X				X				X								
R	2	X					X			X		X			X			X	X					X			X
R	3	X				X	X		X	X		X	X		X		X	X	X				X	X			X
R	4	X	X			X	X		X	X		X	X		X	X		X	X				X	X			X
R	5	X	X	X		X	X		X	X			X		X	X	X	X	X				X				X
R	6	X	X	X		X			X	X			X		X	X	X	X	X				X				X
R	7	X				X			X	X		X	X		X	X	X	X	X								
R	8	X				X			X	X		X	X	X	X			X	X								

Table C-1 (*continued*). Physical and biological features found within each grid cell in the environmental sensitivity index.

Column	Row	Avian Density Rank 2	Avian Density Rank 4	Avian Density Rank 6	Essential Fish Habitat Rank 1	Essential Fish Habitat Rank 2	Essential Fish Habitat Rank 3	MM Density (Non T&E) Rank 1	MM Density (Non T&E) Rank 2	MM Density (Non T&E) Rank 3	MM Density (T&E) Rank 1	MM Density (T&E) Rank 2	MM Density (T&E) Rank 3	Sea Turtle SPUE Rank 1	Sea Turtle SPUE Rank 2	Sea Turtle SPUE Rank 3	Shoals Rank 1	Recreational Fishing Rank 1	Commercial Fisheries Rank 1	MPA Rank 1	Obstructions No Build	Pipelines No Build	Shipping Lanes No Build	Traffic Separation Zone No Build	Shipwrecks No Build	Tug Barge Transit Route No Build	Utility Cables No Build
R	9	X				X	X		X	X	X	X		X	X			X	X								X
R	10	X				X				X	X	X		X				X	X								X
R	11	X				X				X	X			X					X								X
R	12	X				X	X			X	X			X					X								X
S	3	X					X			X	X	X			X			X	X					X			
S	4	X					X			X		X	X		X	X		X	X					X			
S	5	X	X	X		X	X			X		X	X			X	X	X	X								X
S	6	X	X	X		X			X	X			X			X			X				X				X
S	7	X				X	X		X	X			X		X	X		X	X				X				X
S	8	X				X			X	X	X	X	X		X				X				X				X
S	9	X				X				X		X		X	X				X				X				X
S	10	X				X				X		X		X	X				X				X				
T	3	X					X			X	X	X			X			X	X					X			X
T	4	X					X			X	X	X			X	X		X	X					X			X
T	5	X				X	X			X		X	X		X	X		X	X								X
T	6	X	X			X	X			X	X	X	X			X			X								X
T	7	X	X			X				X		X	X		X	X			X								X
T	8	X				X				X	X	X	X		X	X			X								X

APPENDIX D

GLOSSARY TERMS

Abiotic—refers to nonliving

Acoustic scanning—see side-scan sonar

Acoustic wave log—a technique based on he fact that the reservoir rock and fluid filled pores constitute an elastic system. It is primarily used for identification of porosity, cement evaluation, mechanical properties, and formation velocities for seismic studies of the sea floor. Also referred to as the sonic log

Advection—the differential motion within a fluid; changes in properties (e.g., temperature, salinity) that take place in the presence of horizontal or vertical flows of seawater (i.e., currents) represent advective changes

Air gun—a device that releases compressed air into the water column, creating an acoustical energy pulse with the purpose of penetrating the sea floor

Alternative energy—energy derived from other than what are generally considered conventional sources of energy (e.g., fossil fuels). Possible alternative energy sources include, wind, solar, biomass, wave, ocean current, hydrogen, and tidal energy

Altitude—the vertical elevation of an object above a surface (as sea level or land) of a planet or natural satellite

Ambient noise—environmental background noise composed of contributions from various sources at both near and far distances

Amphibious—capable of living on land or in water

Anthropogenic—describing a phenomenon or condition created, directly or indirectly, as a result of effects, processes, objects, or materials that are derived from human activities, as opposed to those occurring in natural environments without human influences

Anti-cyclonic—clockwise circulation in the Northern Hemisphere and counterclockwise circulation in the Southern Hemisphere; in oceanography, synonymous with warm-core ring

Artificial reef—a human-made, reef habitat (sunken ships, trains, tanks, concrete igloos, rubble) created in the navigable waters of the U.S. or in waters overlying the continental shelf to attract aquatic life

Auditory brain stem (ABR) response—an electrical signal evoked from the brainstem of a human or other mammal by the presentation of a sound such as a click

Auditory threshold—the lowest intensity at which a sound may be heard

Autonomous recording unit—a self-contained audio recording device that is deployed in marine or terrestrial environments for sound monitoring. It typically consists of several components: a microphone or hydrophone, an amplifier and associated digital electronics, and a software digital storage device

Avian—of, relating to, or derived from birds

Avifauna—the birds or the kinds of birds of a region

Avoidance response—a form of escape behavior present in animals in which the subject evades an aversive event

Baleen whale—any whale of the suborder Mysticeti; characterized by presence of baleen in the upper jaw

Barometric pressure—the pressure of the atmosphere usually expressed in terms of the height of a column of mercury

Barrier effect—the disruption of migration by a condition (such as a wind farm) that causes the migrating animal to divert from its normal route to avoid the condition

Barrier islands—long, broad, sandy islands lying parallel to a shore that is built up by the action of waves, currents, and winds and that protects the shore from the effects of the ocean

Bathymetry—refers to the topography of the ocean floor; study and mapping of the ocean depths

Bedform—a depositional feature on the bed of an river or other body of flowing water that is formed by the movement of the bed material due to the flow

Benthic—in, on, or near the ocean floor; the term is used irrespective of whether the sea is shallow or deep

Benthos—the collection of organisms that are found in, on, or are attached to the ocean bottom substrate (e.g., invertebrates, bivalves)

"Bigeye" binocular—25x150 power Fujinon binocular mounted on the port and starboard sides of the vessel during line transect shipboard surveys for marine mammals and sea turtles

Biomass—the amount of living matter per unit of water surface or water volume

Biotic—pertaining to life or living organisms

Cable-tool drilling—uses rigs that raise and drop a drill string with a heavy carbide-tipped drilling bit that chisels through the rock by finely pulverizing the subsurface materials

Cetacean—an individual of the order Cetacea, which includes whales, dolphins, and porpoises

Cichlids—are fishes from the family Cichlidae in the order Perciformes

Cochlea—the organ of the inner ear that converts mechanical vibrations into electrical impulses for the purpose of hearing

Conspecific—refers to a member of the same species, and in many cases, the same age or even sex

Coral reef—is a massive, wave-resistant structure built largely by colonial, stony coral via deposition of calcium carbonate; forms habitat for a variety of marine animals; only formed under specific environmental conditions and locations

Craton—a stable relatively immobile area of the earth's crust that forms the nuclear mass of a continent or the central basin of an ocean

Cretaceous—of, relating to, or being the last period of the Mesozoic era (142 to 65 million years ago) characterized by continued dominance of reptiles, emergent dominance of angiosperms, diversification of mammals, and the extinction of many types of organisms at the close of the period

Criteria pollutants—a group of common air pollutants whose presence in the environment is regulated by the U.S. Environmental Protection Agency (EPA) on the basis of health and/or environmental effects

Crustacean—any chiefly aquatic arthropod of the class Crustacea, typically having the body covered with a hard shell or crust, including the lobsters, shrimps, crabs, and barnacles

Cumulative impacts—Impacts on the environment that result from the incremental effect of an action when added to other past, present, and reasonably foreseeable future actions regardless of by whom the action is undertaken

Cyclonic—refers to the counterclockwise circulation in the Northern Hemisphere or clockwise in the Southern Hemisphere; in oceanography, synonymous with cold-core ring

Decibel (dB)—a logarithmic measure of sound strength; it is a ratio of intensity (pressure) at a reference range compared with a reference level; in air, the reference pressure is 20 μPa and the reference range is 1 m, while for underwater sound, the reference is 1 μPa and the reference range is also at 1 m

Deltaic deposits—sedimentary deposits in a river delta

Demersal—refers to fish that live close to or on the seafloor, such as cod and hake

Deposition—an act or process of depositing

Detection thresholds—the lowest level at which a stimulus (sound) can be detected

Detritus—loose material (as rock fragments or organic particles) that results directly from disintegration

Displacement—to move something from its natural environment

Diurnal tides (daily tides)—one high water and one low water in each lunar day (tidal period of about 24.8 hours)

Double saw-tooth pattern—refers to survey design; describes the zig-zag pattern of randomly-generated tracklines designed to maximize coverage of the Study Area

Downwelling—downward movement or sinking of surface water towards the ocean bottom; may be caused by convergent currents or density differences

Dredging—an excavation activity or operation with the purpose of gathering bottom sediments or scraping and removing solids from the seafloor. This method is used for harvesting bivalve mollusks such as oysters, clams, and scallops from the seabed

Duty cycle—the relationship between the active (operating) time and the inactive (resting) time of an equipment or machine

Ebb-tidal delta—ebb tide: refers to outgoing or a falling tide

Eiders—large sea ducks in the genus *Somateria* much valued for the fine, soft down of the females

El Niño—refers to the wind-driven reversal of the Pacific equatorial currents resulting in the movement of warm water towards the coasts of the Americas, considered a natural cyclical atmospheric/oceanic phenomenon; El Niño is often referred to as a warm phase or El Niño-Southern Oscillation, or "ENSO"

El Niño-Southern Oscillation (ENSO)—see "El Niño (warm phase) events"

Elasmobranch—fishes of the class Chondrichthyes characterized by having a cartilaginous skeleton; includes sharks, skates, and rays

Electrical service platform (ESP)—a stationary structure located approximately in the center of a wind farm. It is the common electrical interconnection point for all of the turbines in the array. The ESP provides electrical protection and voltage step-up transformers

Electromagnetic fields (EMF)—the field of energy resulting from the movement of alternating electrical current along the path of a conductor, composed of both electrical and magnetic components and existing in the immediate vicinity of, and surrounding, the electrical conductor. EMF exists in both high-voltage electrical transmission power lines and in low-voltage electric conductors in homes and appliances

Entrained—incidental trapping of fish and other aquatic organisms (i.e., zooplankton) in the water

Eocene—of, relating to, or being an epoch of the Tertiary between the Paleocene and the Oligocene (56 to 34 million years ago) or the corresponding series of rocks

Epifauna—refers to animals living on the surface of the ocean floor; any encrusting fauna

Essential Fish Habitat (EFH)—those habitats necessary to fish for spawning, breeding, feeding, or growth to maturity, designated by the NMFS or fishery management councils, as authorized by the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA) and amended by the Sustainable Fisheries Act (SFA)

Eustatic—relating to or characterized by worldwide change of sea level

Exclusive Economic Zone (EEZ)—all waters from the low-tide line outwards to 200 NM (except for those that are close together, i.e., Mediterranean countries) in which the inner boundary of that zone is a line coterminous with the seaward boundary of each of the coastal states; the country has the power to manage all natural resources

Extratropical storm—A synoptic scale low pressure system whose primary energy source is baroclinic (i.e., nor'easters)

Facies—accrual of deposits that demonstrate specific characteristics and grades laterally into other sedimentary accumulations that formed concurrently but exhibit different characteristics; can range in size from a few millimeters to hundreds of meters thick

Fauna—animals of a given region

Feldspar—any of a group of crystalline minerals that consist of aluminum silicates with either potassium, sodium, calcium, or barium and that are an essential constituent of nearly all crystalline rocks

Fish Aggregating Device (FAD)—single or multiple floating structures that are connected to the ocean floor by ballast or anchors; device used to attract fish

Flora—the plant species of a given region

Fluvial—produced by the action of a stream

Forebulge—uplift at the front edge of a glacier caused by flexing of the crust

Frequency—cycles per second; the number of cycles completed per unit of time of a wave/oscillation. Sound is measured in cycles per second or frequency, called Hertz

Freshet—a great rise or overflowing of a stream caused by heavy rains or melted snow

Front—a boundary between two water or air masses that have different densities; water density differences are caused by differences in temperature or salinity

Geologic—pertaining to, or based on the scientific study of the earth's structure (geology)

Geostrophic circulation—a type of thermohaline circulation. See "Thermohaline circulation"

Glacial maximum—the point of an ice cap's maximum advance

Glacial rebound—the rise or fall of land masses that were depressed by the huge weight of ice sheets during the last glacial period

Glacial—of, relating to, or being any of those parts of geologic time from Precambrian onward when a much larger portion of the earth was covered by glaciers than at present

Glacioeustasy—changes in sea level due to the storage or release of water from glacier ice

Glauconite—a mineral consisting of a dull green earthy iron potassium silicate occurring in greensand

Gravity foundation—a flat base used to support a turbine tower. It is usually made of concrete or a steel case filed with heavy-weight material such as stones, boulders, and rocks to hold the base in place

Ground truth—refers to information that is collected "on location." In remote sensing, this is especially important in order to relate image data to real features and materials on the ground. The collection of ground-truth data enables calibration of remote-sensing data, and aids in the interpretation and analysis of what is being sensed

Guild—a group of organisms that use the same ecological resource in a similar way

Gulf Stream—warm current in North Atlantic flowing from Gulf of Mexico NE along United States coast to Nantucket & thence eastward

Gust—a sudden brief rush of wind

Habitat—is the area where an organism is found temporarily or permanently; it provides the essentials for survival: sustenance, food, water, shelter, and space

Hard bottom—area of the seafloor, usually on the continental shelf, associated with hard substrate such as outcroppings of limestone or sandstone that may serve as attachment locations for organisms such as corals, sponges, and other invertebrates or algae

Hertz—the unit of frequency measurement, representing cycles per second

Heterogeneity—the quality of being diverse and not comparable in kind

Highstand—relatively high sea level

Hinge line—boundary between a stable region and one undergoing relative vertical movement

Holocene—of, relating to, or being the present or post-Pleistocene geologic epoch; began approximately 12,000 years ago

Holocentrids—ray-finned fish, belonging to the order Beryciformes, typically known as squirrelfish

Homogeneity—the quality of being similar or comparable in kind or nature

Horizontal directional drilling—is a steerable, trenchless method of installing underground pipes, conduits and cables in a shallow arc along a prescribed bore path with minimal surface impact

Hudson apron—a plateau-like feature between the Hudson and Toms canyons

Hurricane—A tropical cyclone in which the maximum 1-minute sustained surface wind is 64 knots (74 mph) or greater

Hurricane return period—the frequency at which a certain intensity or category of hurricane can be expected within 75 nm (86 statute miles) of a given location. Example: a return period of 20 years for a Category 3 or greater hurricane means that on average during the previous 100 years, a Category 3 or greater hurricane passed within 75 nm (86 miles) of that location about five times

Hydraulic vibratory pile extractor—a vibratory hammer used to extract a pile; extraction is commonly used to recover steel "H" piles used in temporary foundation shoring. Hydraulic fluid is supplied to the driver by a diesel engine powered pump mounted in a trailer or van and connected to the driver head through a set of long hoses

Hydrodynamic regime—the pattern of water movement around an object

Hydrography—the science of measuring and describing the surface waters

Hydrophone—a transducer used for detecting underwater sound pressures; an underwater microphone

Hypoxic—waters with a low oxygen concentration, usually less than two parts per million; hypoxic waters are considered oxygen-depleted

Ichthyofauna—refers to fish species found in a particular geographical area

Ichthyoplankton—fish eggs and larvae

Infauna—invertebrates found within the sediment of the seafloor

Infrasonic—sound at frequencies too low to be audible to humans, generally below 20 Hz

Inlet—a narrow body of water between islands or leading inland from a larger body of water, often leading to an enclosed body of water, such as a sound, bay, lagoon or marsh; a connection between a bay and the ocean

Intense (major hurricanes)—those reaching category three or higher

Interglacial—a warm period between glacial epochs

Isobath—refers to the bathymetric contour of equal depth; usually shown as a line linking points of the same depth

Isostasy—equilibrium of lithospheric rock units

Isotherm—refers to the contour of equal temperature; usually shown as a line linking points of the same temperature

Jack-up barge—a floating barge with long support legs that can be raised or lowered. It is towed (or self propelled) to a location with its legs up and the barge section floating on the water. Upon arrival, the legs are jacked down onto the seafloor. The jacking system is then used to raise the entire barge above the water so that wave, tidal and current loading acts only on the legs and not on the barge hull

Kilohertz—1,000 Hertz; see Hertz

La Niña—is an oceanographic event when ocean temperatures in the eastern equatorial Pacific are unusually cold; it is essentially the opposite of the El Niño phenomenon; La Niña sometimes is referred to as the cold phase of an El Niño Southern Oscillation event (ENSO)

Liquefaction—loss of strength of loosely-packed, waterlogged sediments in response to strong shaking

Lithofacies—the rock record of any particular sedimentary environment, including both physical and organic characteristics

Lowstand—relatively low sea level

Macrofauna—refers to small to moderate sized invertebrates found on or in bottom sediments; visible with the naked eye

Magnetometer surveys—a type of geophysical survey that measures the irregularities in the magnetic field of a given area

Masking—an acoustic term that pertains to noise that cancels out a sound of interest; e.g., vessel engine noise can mask the calls of some whales because they are produced in the same frequency range

Meridional shift—a shift of the winds to parallel a line of longitude

Meroplankton—portion of the zooplankton spends only part of its life as plankton; include the eggs, larval and juvenile stages of many organisms that spend most of their lives as either free swimmers (such as fish) or bottom dwellers (such as crabs and starfish)

Mesoscale—of intermediate size relating to a meteorological phenomenon approximately 10 to 1,000 kilometers in horizontal extent

Meteorological—the atmospheric phenomena and weather of a region

Microfauna—minute animals; especially those invisible to the naked eye

Migration—a periodic movement between one habitat and one or more other habitats involving either the entire or significant component of an animal population; this adaptation allows an animal to monopolize areas where favorable environmental conditions exist for feeding, breeding, and/or other phases of the animals' life history

Mixed tides—have characteristics of both diurnal and semi-diurnal tides with successive high and/or low tides (with significantly different heights) along with diurnal periods for a few days per month

Monopile—a long, steel tube driven into the seafloor 10 to 20 meters (33 to 66 feet) to support a wind turbine

Mysticeti—suborder of cetaceans comprised of the baleen whales

Nacelle—the housing of a wind turbine that protects the major components (e.g., generator and gear box)

Nautical mile (NM)—a distance unit used in the marine environment that is equal to one minute of latitude or 1.85 km

Neap tides—occurs when the sun and moon are nearest to 90° to each other giving the resultant force a minimum value

Neutral years—occur when the SST index is not more than 0.5°C above or below average

Nocturnal—applied to events that occur during nighttime hours

Non-frontal—weather events not associated with a front. See "Front"

North Atlantic Oscillation (NAO)—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

North Atlantic Oscillation (NAO) index—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

Northeasterlies (nor'easters)—prevailing winds moving from the northeast to the southwest

Northwesterlies—prevailing winds moving from the northwest to the southeast

Odontoceti—suborder of cetaceans comprised of toothed whales (e.g., beaked whales, dolphins, porpoises, sperm whale)

Onshore breezes ("sea breezes")—small scale wind pattern events that form perpendicular to the coast and directly influence temperatures experienced. Onshore breezes are caused by warm continental air rising and moving offshore while cooler oceanic air moves onshore

Outer Continental Shelf (OCS)—the farthest of 200 nautical miles seaward of the baseline or, if the continental shelf that can be shown to exceed 200 nautical miles, a distance not greater than a line 100 nautical miles from the 2,500-meter isobath or a line 350 nautical miles from the baseline

Paleochannel—deposits of unconsolidated sediments or semi-consolidated sedimentary rocks deposited in ancient, currently inactive river and stream channel systems

Passive Acoustic Monitoring (PAM)—an acoustic tool where a hydrophone or microphone is used to capture sounds from various sources in a given environment

Passive margin—a continental margin that is not affected by rifting, subduction, transform faulting, or other large-scale tectonic processes, but instead forms a shelf that accumulated sediments

Peak particle velocity—maximum instantaneous velocity experienced by the particles of a medium when set into transient vibratory motion. This can be derived as the magnitude of the vector sum of three orthogonal components and is measured in cm/s

Pelagic—the open ocean; the primary division or zone in the open ocean that encompasses the entire water column and is subdivided into the neritic (shallow) and oceanic (deep) zones

Permanent threshold shift—an increase in the threshold of hearing that results in permanent damage to an individual's hearing capability. This may occur as a result of long-term or extremely loud exposure to noise

Phytoplankton—single-celled organisms, at the base of the marine food chain, similar to plants in that use sunlight and chlorophyll to photosynthesize

Pile driving—the act of forcing piles, either via impact hammering or vibration, into soil to provide foundation support for buildings or other structures

Pinniped—member of the suborder Pinnipedia; includes seals, sea lions, fur seals, and walruses

Pleistocene—of, relating to, or being the earlier epoch of the Quaternary (2.588 million to 12,000 years ago) or the corresponding series of rocks

Pliocene—of, relating to, or being the latest epoch of the Tertiary (5.332 million to 2.588 million years ago) or the corresponding series of rocks

Population-level effects—impacts that affect the survival of a group of individuals of the same species occupying the same area

Prey—an animal that is hunted, pursued, and caught for food (diet)

Primary production—organic matter synthesized by organisms from inorganic substances

Procellariiformes—an order of seabirds that comprises four families: the albatrosses, procellariids, storm-petrels and diving petrels

Progradation—seaward buildup of a beach, delta, or fan by nearshore deposition of sediments either transported by a river or by accumulation of sediment through wave motion or longshore drift

Pycnocline—refers to a zone of marked water density gradient that is usually associated with depth

Quaternary—of, relating to, or being the geological period from the end of the Tertiary (2.588 ± 0.005 million years ago) to the present time or the corresponding system of rocks

Ravinement—erosional surface that tends to occur wherever the landward edge of the sea rises over an underlying sedimentary surface

Reflector (seismic)—a subsurface cross-section that is constructed by seismic data showing a distinctive type of sediment geometry produced by sea level variations; used to evaluate stratigraphic sequences

Rotor swept zone—area of the circle “swept” by the blades of a wind farm in square meters or square feet

Saffir/Simpson Hurricane Scale (SSHS)—A scale on a 1-5 rating based on the hurricane's present intensity. 1) 64-82 kt (74-95 mph); 2) 83-95 kt (96-110 mph); 3) 96-113 kt (111-130 mph); 4) 114-135 kt (131-155 mph); 5) greater than 135 kt (155 mph)

Salmonids—soft-finned fishes of cold and temperate waters including salmon and trout

Sciaenids—a family of fish commonly called drums, croakers, or hardheads for the repetitive throbbing or drumming sounds they make

Scour—the rapid erosion of sediment caused by the movement of water

Sea level transgression—a geologic event during which sea level rises relative to the land and the shoreline moves toward higher ground, resulting in flooding. Transgressions can be caused either by the land sinking or the ocean basins filling with water (or decreasing in capacity)

Sea surface temperature (SST)—refers to the temperature of the uppermost layer of seawater (approximately 0.5 m deep). Measured over large spatial scales by remote sensing satellite-based detectors and at point locations by moored buoys or ships

Sediment—materials that sink to the bottom of a body of water after being deposited by wind, water, or glaciers

Seismic surveys—a geophysical exploration method whereby subsurface sediment layers can be mapped and analyzed based on the time taken for energy reflected from these layers to return to surface

Seismogram—a record of the ground motion at a measuring station as a function of time. Seismograms typically record motions in three cartesian axes (x, y, and z), with the z axis perpendicular to the Earth's surface and the x- and y- axes parallel to the surface. The energy measured in a seismogram may result from an earthquake or from some other source, such as an explosion

Semi-diurnal tides (twice daily)—two high and two low waters in the same interval (tidal period of about 12.4 hours)

Sessile—is terminology used to describe an animal that is attached to something rather than freely moving

Shelf break (continental)—refers to the region where the slope of the seabed rapidly changes from gently sloping on the continental shelf to steeply sloping on the continental slope; the world-wide average water depth at the shelf break is 155 m, and on average, the shelf break usually occurs between 100 to 200 m

Shoal—a sandbank or sandbar that makes the water shallow

Shoreface sand ridge—shelf sand bars created by longshore currents carrying sand along the shoreface and depositing it in submerged bars parallel to the shore

Shoreface-attached sand ridge—the initial development of a sand ridge field; probably developed as sand is deposited in ebb tide deltas of barrier systems. The inlets open, migrate and then close with ebb tidal deltas acting as point sources for sand

Shoreface-detached sand ridge—ridge formed in response to storm-generated currents and barrier islands. They slowly migrate offshore and down coast in the prevailing direction of storm flow and the eroding shoreface retreats out from under them. As they have detached from the shoreface they continued to evolve in response to storm wave surge and water drift currents

Side-scan sonar—a geophysical instrument that uses sound waves reflected off the seafloor to image the areal extent of different bottom types

Sirenia—the order of marine mammals that consists of manatees and the dugong

Sound exposure level—standardized measure of a single sound event, expressed in A-weighted decibels, that takes into account all sound above a specified threshold set at least 10 decibels below the maximum level. All sound energy in the event is integrated over one second

Sound pressure level—the ratio of the absolute sound pressure over a reference pressure and implies a decibel measure

Sound propagation—sound is a mechanical vibration that travels through matter as a waveform. Sound propagation is the movement of these waves through air, water, or other materials

Southern Oscillation—the atmospheric component of El Niño. It is an oscillation in air pressure between the tropical eastern and the western Pacific Ocean waters

Southern Oscillation Index (SOI)—The SOI measures the strength of the Southern Oscillation. The SOI is computed from fluctuations in the surface air pressure difference between Tahiti and Darwin, Australia. El Niño episodes are associated with negative values of the SOI, meaning that the pressure at Tahiti is relatively low compared to Darwin

Spawn—the release of eggs and sperm during mating

Spring tides—occurs when the forces due to the sun and moon come into phase on the same side of the earth or both on opposite sides

Storm surges—the result of the frictional stress of strong winds blowing toward land and pushing up the water against the land

Strandplain—a broad stretch of sand along a shoreline with a surface displaying distinct parallel sand ridges alternating with shallow swales

Strata—parallel layers of sedimentary rock

Stratigraphy—the geographic and chronologic arrangement of strata; incorporates thickness, characteristics, sequence, age, and correlation of rocks

Strip transect method—"single saw-tooth" sample design was implemented for the small boat coastal survey. The starting location for each survey was randomly determined among two starting points (north end and south end) by the toss of a coin.

Submerged aquatic vegetation—plants that have adapted to living in aquatic environments

Subsidence—the sudden or gradual downward motion of the Earth's surface with little or no horizontal displacement

Substrate—the material to which an organism is attached or in which it grows and lives; also, the underlying layer or substance

Subtropical cyclone—A non-frontal low pressure system that has characteristics of both tropical and extratropical cyclones. This system is typically an upper-level cold low with circulation extending to the surface layer and maximum sustained winds generally occurring at a radius of about 100 miles or more from the center. In comparison to tropical cyclones, such systems have a relatively broad zone of maximum winds that is located farther from the center, and typically have a less symmetric wind field and distribution of convection

Subtropical depression—A subtropical cyclone in which the maximum 1-minute sustained surface wind is 33 knots (38 mph) or less

Subtropical storm—A subtropical cyclone in which the maximum 1-minute sustained surface wind is 34 knots (39 mph) or more

Surficial—of or relating to a surface

Temporal—of or relating to time as distinguished from space

Temporary threshold shift—an increase in the threshold of hearing that results in temporary damage to an individual's hearing capability; return to normal hearing ability is attained after a period of time

Terrigenous—shallow marine sediments consisting of material derived from the land surface

Tertiary—of, relating to, or being the first period of the Cenozoic era (65 million to 2.588 million years ago) or the corresponding system of rocks marked by the formation of high mountains (as the Alps, Caucasus, and Himalayas) and the dominance of mammals on land

Thalweg—the deepest continuous line along a channel

Thermocline—refers to a relatively narrow boundary layer of water where temperature decreases rapidly with depth; little water or solute exchange occurs across the thermocline which is maintained by solar heating of the upper water layers

Thermohaline circulation—the part of the large-scale ocean circulation that is driven by global density gradients created by surface heat and freshwater fluxes

Triassic—of, relating to, or being the earliest period of the Mesozoic era (about 250 to 200 million years ago) or the corresponding system of rocks marked by the first appearance of the dinosaurs

Tripod foundation—a steel frame with three to four legs driven 10 to 20 meters (33 to 66 feet) into the seafloor to support a turbine tower

Trophic level—refers to a step in the transfer of food or energy within a chain; an ecological term

Tropical cyclone—A warm-core, non-frontal synoptic-scale cyclone, originating over tropical or subtropical waters with organized deep convection and a closed surface wind circulation about a well-defined center

Tropical depression—A tropical cyclone in which the maximum 1-minute sustained surface wind is 33 knots (38 mph) or less

Tropical storm—A tropical cyclone in which the maximum 1-minute sustained surface wind ranges from 34 to 63 knots (39 to 73 mph) inclusive

Turbidity—a cloudy condition in water due to suspended silt or organic matter

Turbine—a device in which a stream of water or gas turns a bladed wheel, converting the kinetic energy of the flow into mechanical energy available from the turbine shaft. Turbines are considered the most economical means of turning large electrical generators. They are generally driven by steam, fuel vapor, water, or wind

United Nations Convention on the Law of the Sea—the international agreement that defines the rights and responsibilities of nations in their use of the world's oceans, establishing guidelines for businesses, the environment, and the management of marine natural resources. Although the United States helped shape the Convention and its subsequent revisions, and though it signed the 1994 Agreement on Implementation, it has not ratified the Convention

Upwelling—movement of dense, cold, nutrient-rich water up from ocean depths to the surface

Vibracore—a coring technique which involves pushing a vibrating pipe into sediment and removing it with a core sample intact inside the pipe

Vibratory—vibratory hammer that propels a core barrel into the sub-bottom materials

Vocalization—a sound produced through an animal’s respiratory system, which is emitted for auditory communication

Westerlies—wind currents blowing from the southwest between 30°N and 60°N in the northern hemisphere and from the northwest between 30°S and 60°S in the southern hemisphere

Wind farm—a group of wind turbines in the same location used for production of electric power (renewable/alternative energy)

Wisconsinan stage—a period of geologic time during the last glacial maximum (about 35,000 to 15,000 years before present)

Zooplankton—diverse group of non-photosynthesizing organisms that drift freely in the water or its surface; zooplankton are composed of a wide range of invertebrates, including larval forms of fish and shellfish