Ocean/Wind Power Ecological Baseline Studies

January 2008 – December 2009

FINAL REPORT

Volume I: Overview, Summary, and Application

NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION
OFFICE OF SCIENCE

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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?

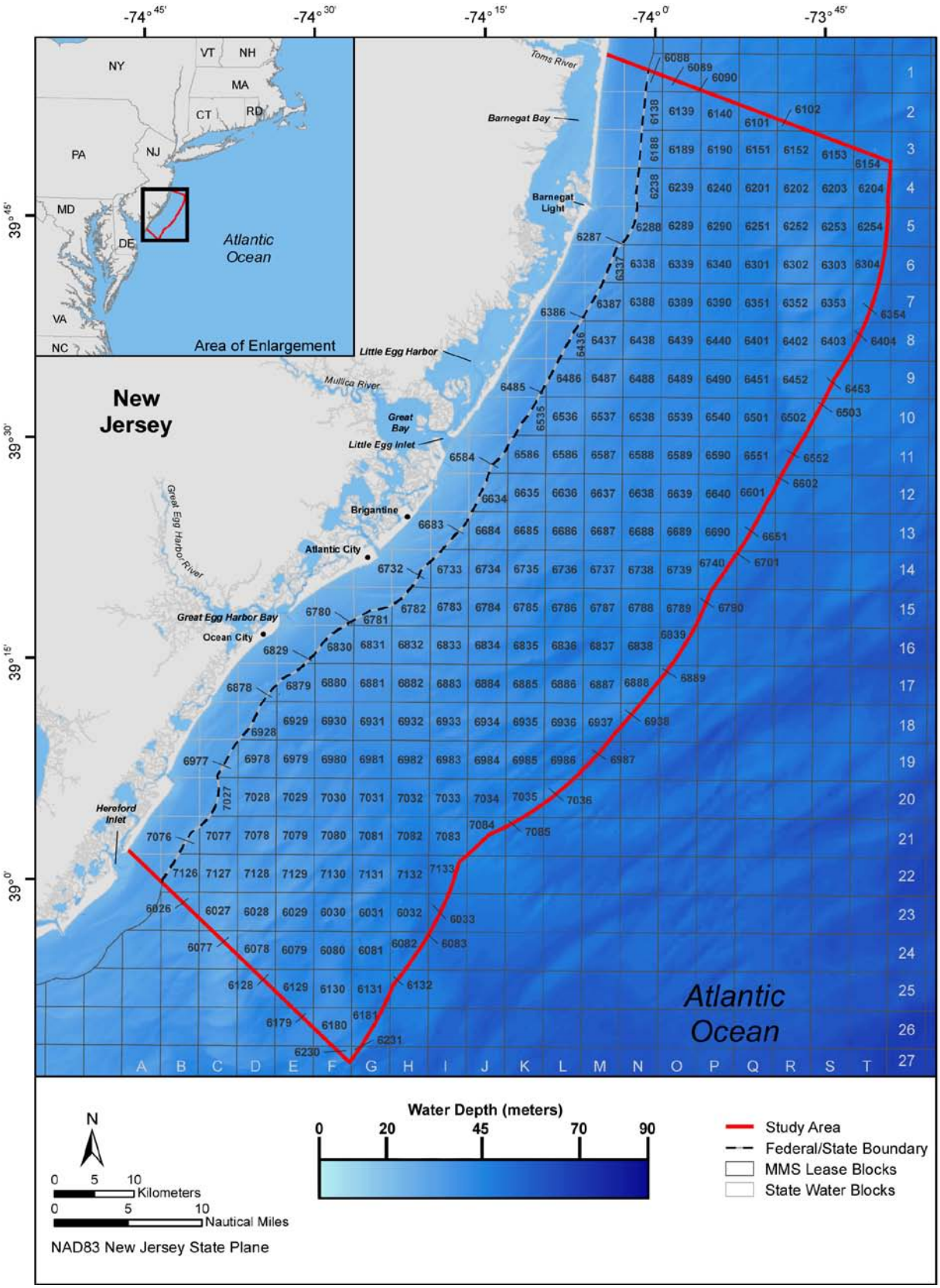

Figure 1-1. Location of the Study Area (0 to 20 NM [0 to 23 mi] offshore).

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.