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).

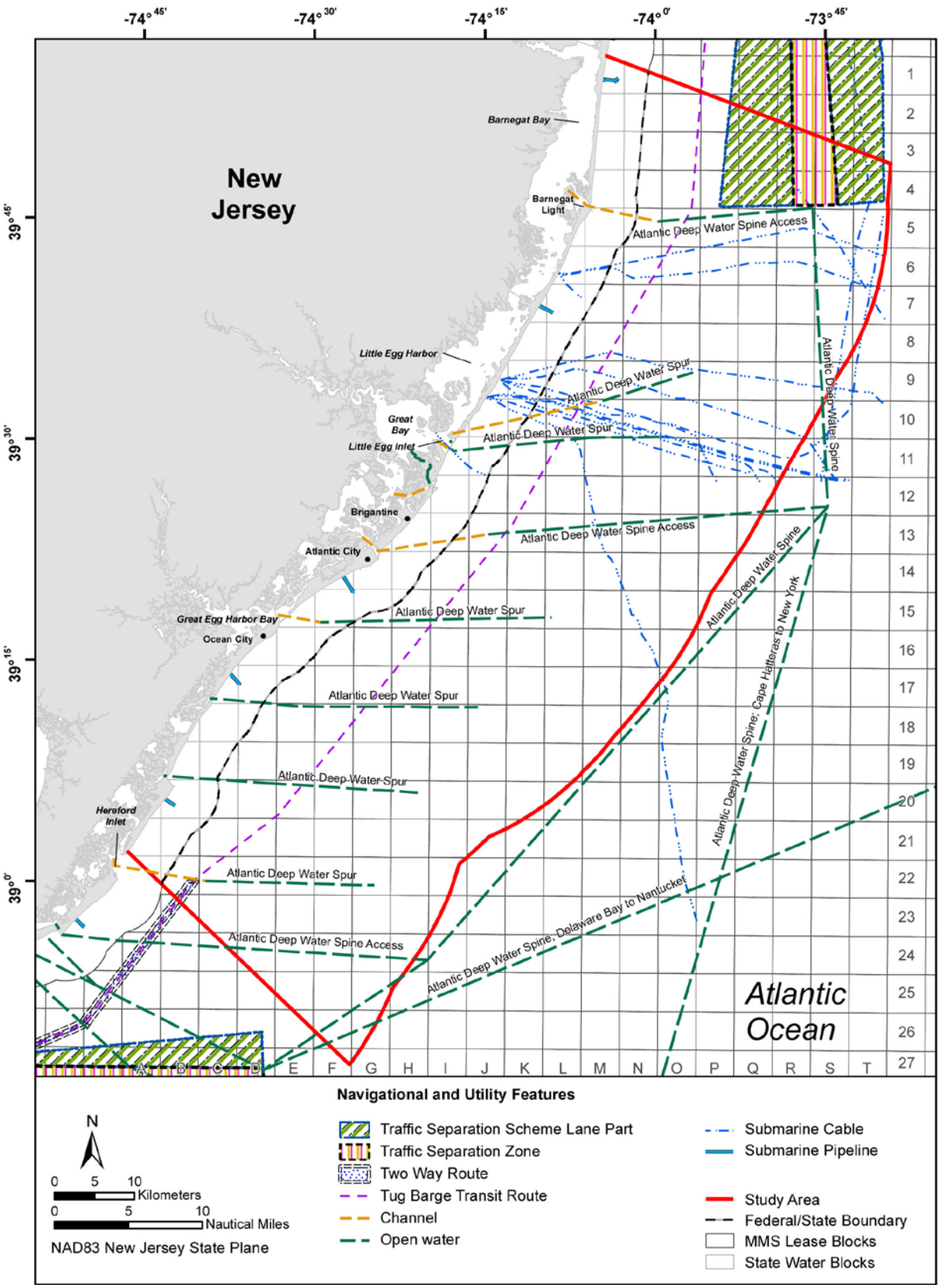

Figure 5-1. Navigational and utility features within and surrounding the Study Area. Source data: USACE (2009) and NOAA (2008a).

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

<u>Four Phases of a Wind Farm</u>

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).

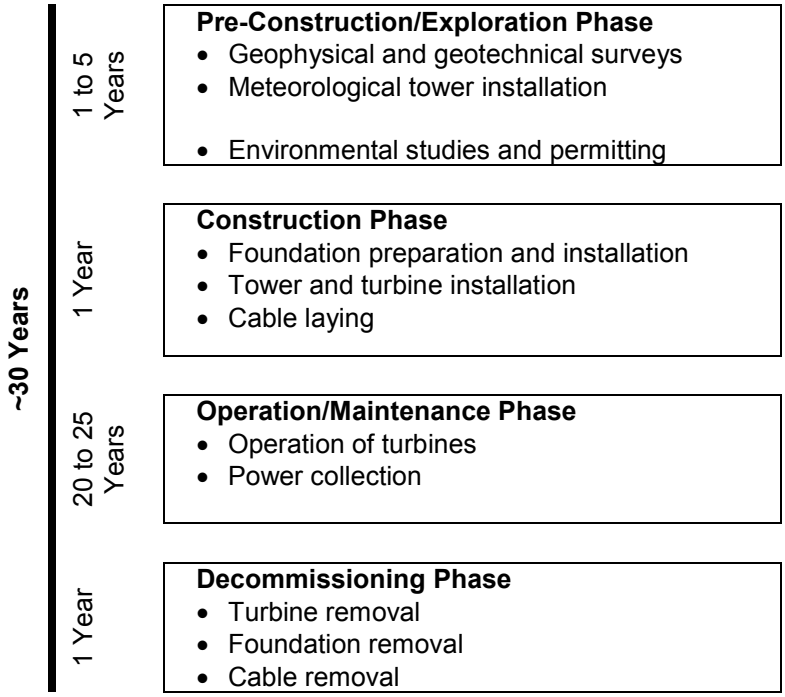

Figure 5-2. The life cycle of an offshore wind farm. Adapted from Nedwell and Howell (2004).

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).

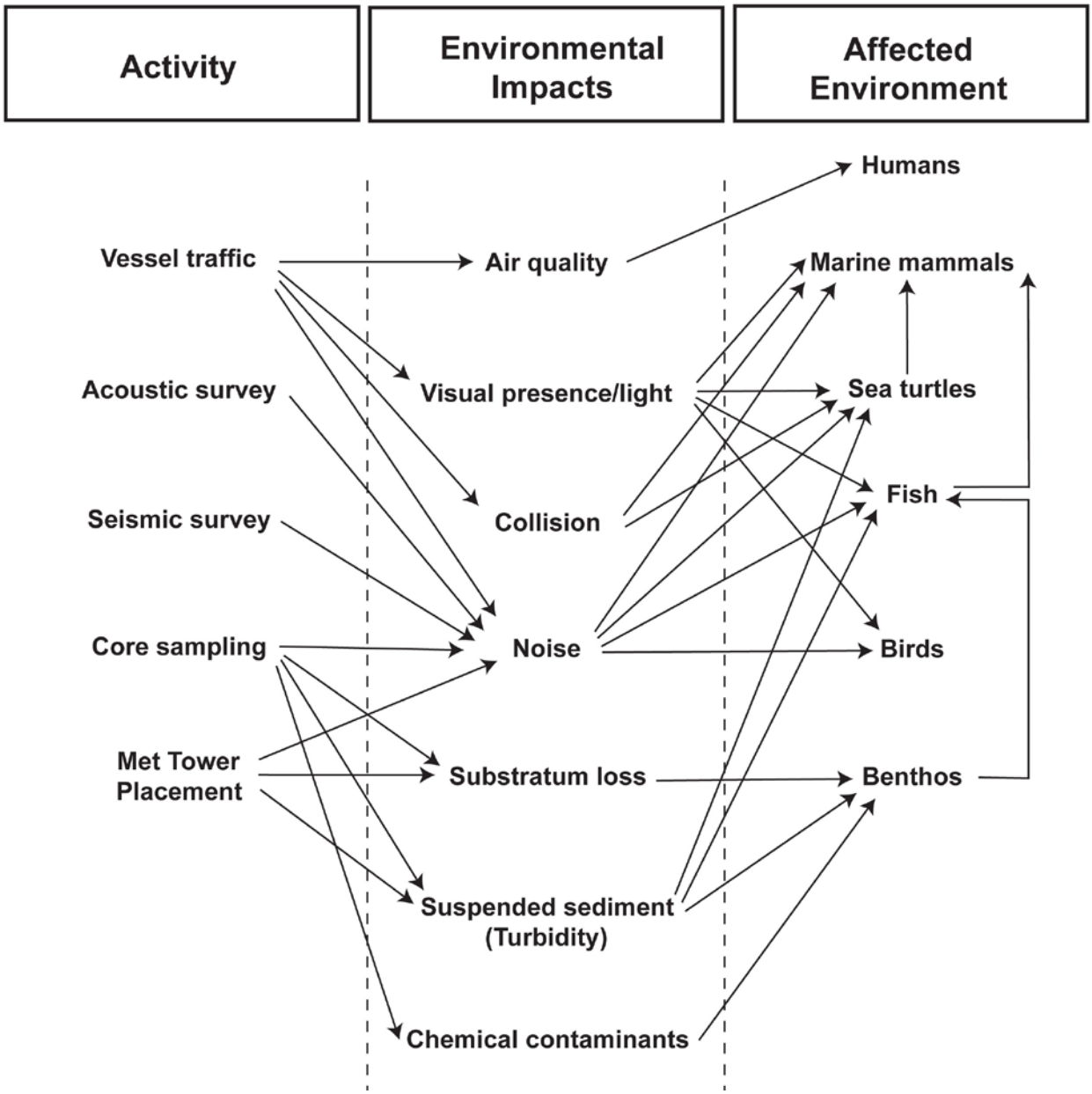

Figure 5-3. Potential impacts and targets of the preconstruction/exploration phase (Hiscock et al. 2002).

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

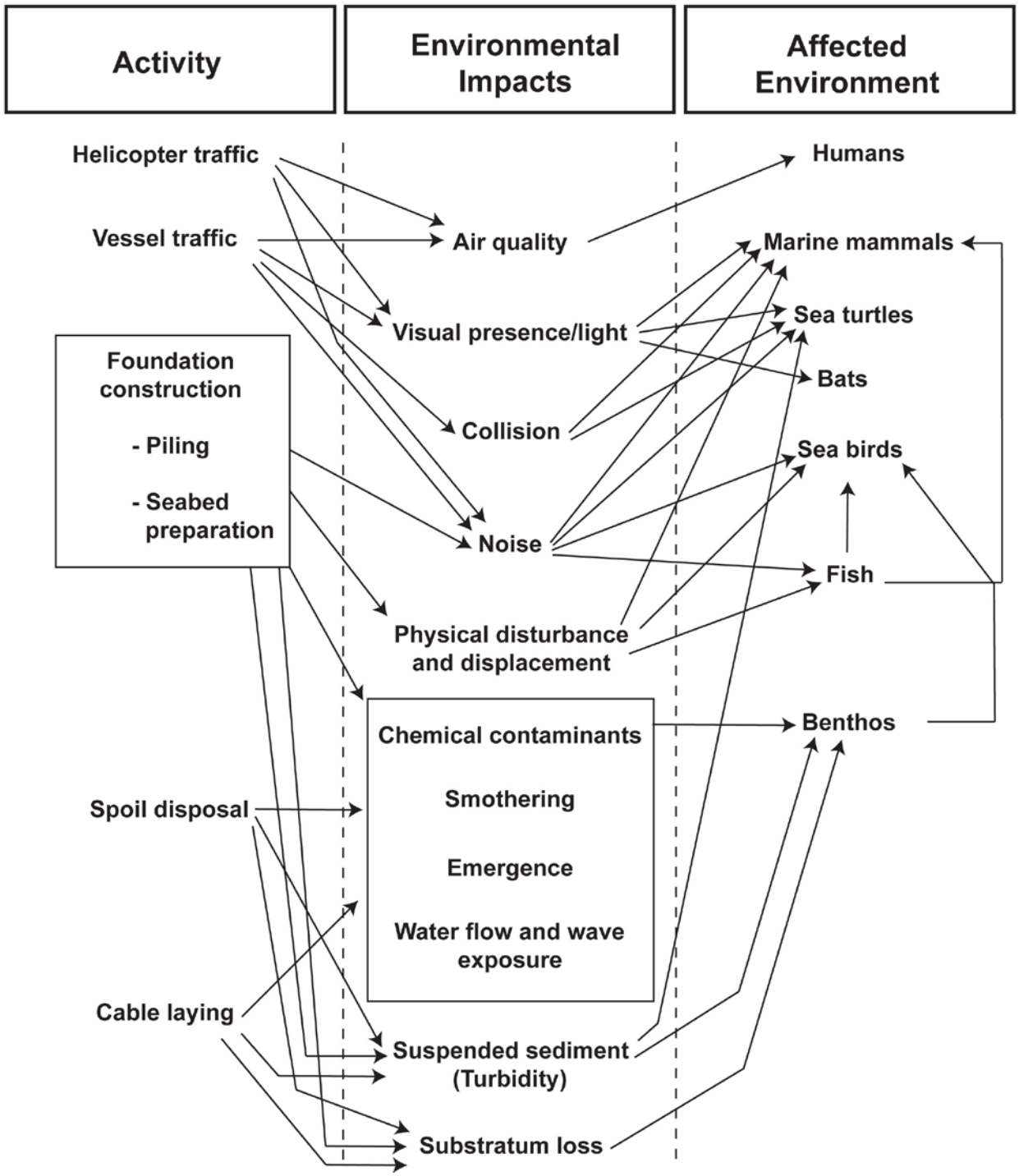

Figure 5-4. Potential impacts and targets of the construction phase (Hiscock et al. 2002).

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.

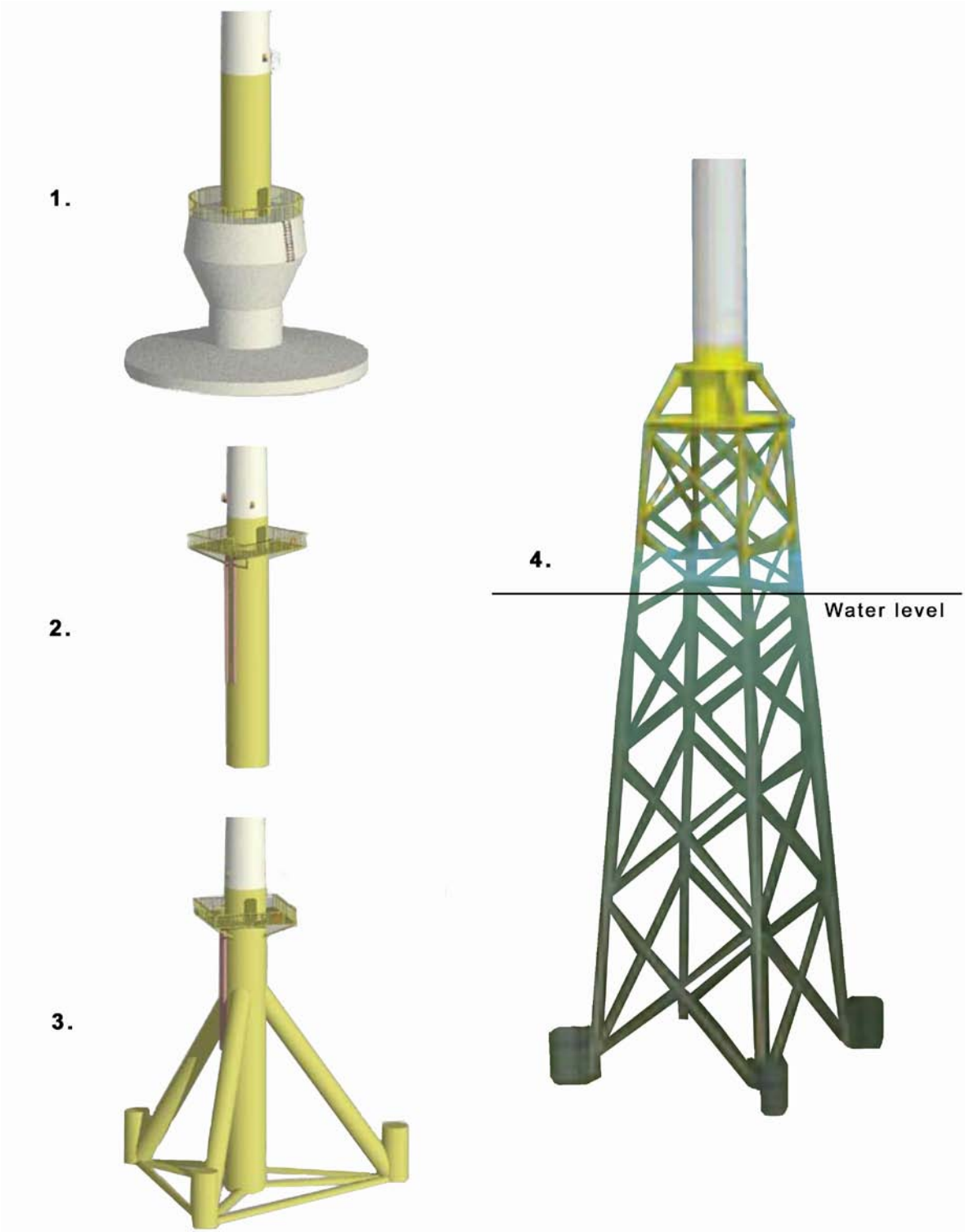

Figure 5-5. Potential styles of offshore wind turbine foundations. 1. Gravity, 2. Monopile, 3. Tripod, and 4. Jacket or Derrick. Adapted from (AWS 2009).

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.

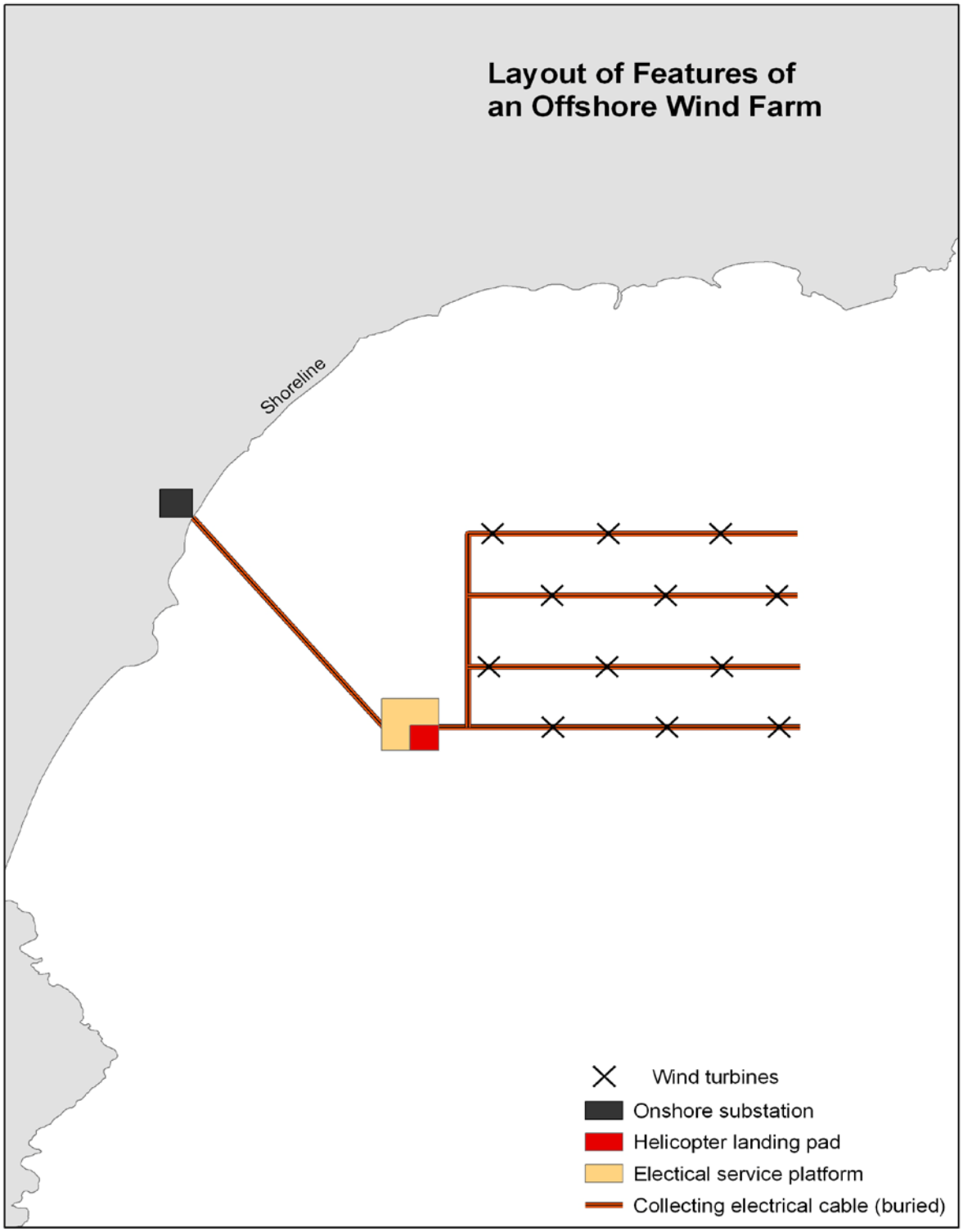

Figure 5-6. Potential layout of features of an offshore wind farm.

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**).

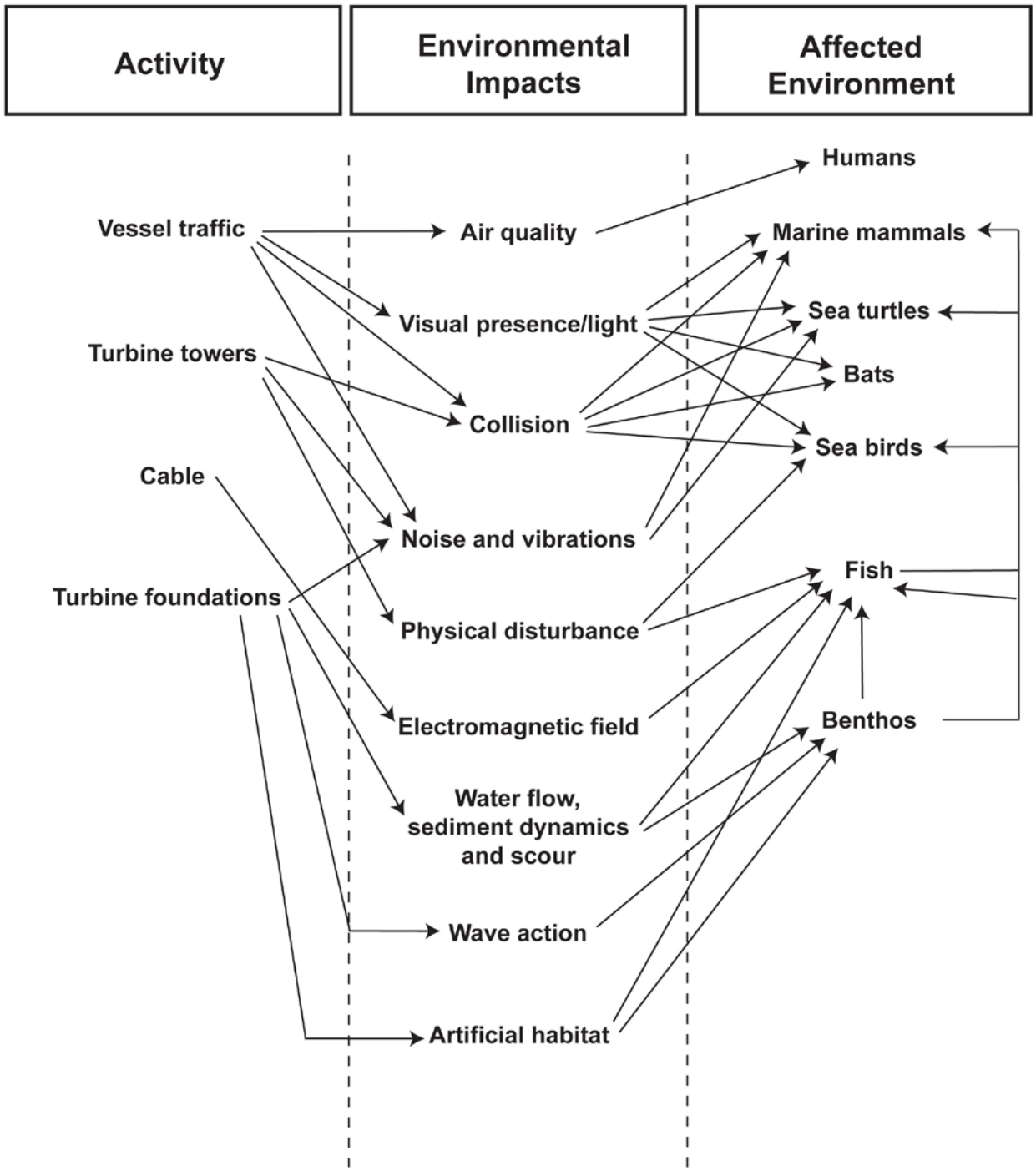

Figure 5-7. Potential impacts and targets of the operations/maintenance phase (Hiscock et al. 2002).

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.

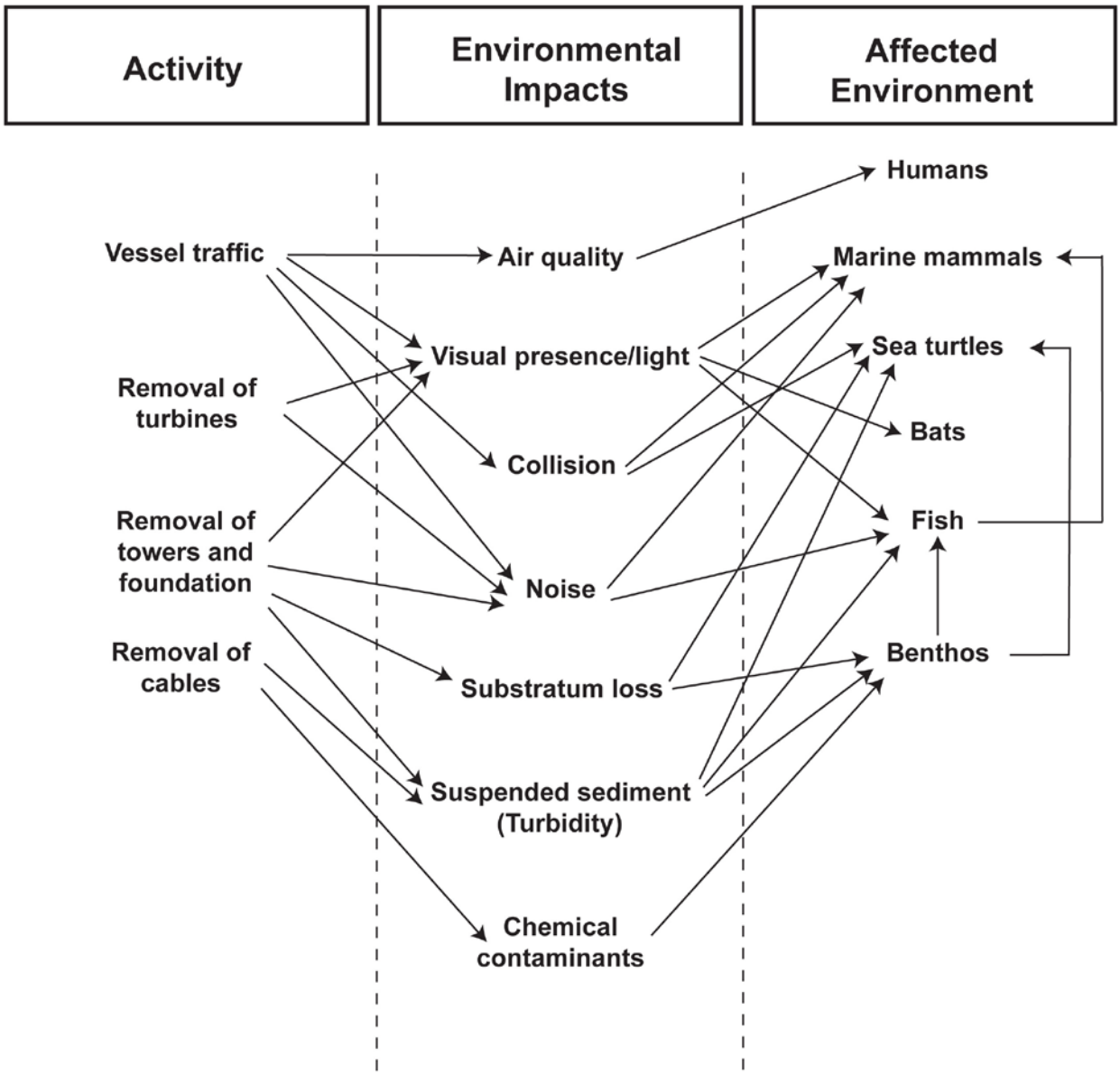

Figure 5-8. Potential impacts and targets of the decommissioning phase. Adapted from Hiscock et al. (2002).

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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