Chapter 2: Synthesis of project findings
Final Report to the Department of Energy Wind and Water Power Technologies Office, 2015

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Abstract

This study provides baseline data on the distributions, movements, habitat use, and abundance of wildlife on the mid-Atlantic Outer Continental Shelf offshore of Delaware, Maryland, and Virginia. Despite focused studies along the Atlantic coast in recent years, the Mid-Atlantic Baseline Studies Project and Maryland Project, described here, fill a significant information gap for a large swath of the mid-Atlantic region between New Jersey and North Carolina. The mid-Atlantic study area is a complex ecosystem with highly variable temporal and geographic patterns, driven in part by the influence of the Gulf Stream to the east, and the Chesapeake Bay and Delaware Bay to the west. This area provides important habitat for a wide variety of marine wildlife over the course of the year.

In this chapter, we summarize persistent and seasonal patterns in wildlife distributions that were observed during the two years of this study, including offshore surveys, individual tracking, and methods of studying nocturnal avian migration in the offshore environment. We also present a series of case studies on specific taxa or phenomena that integrate data gained from these different methods, to examine in detail the abundance and distributions of potentially vulnerable taxa, and discuss other recent baseline studies along the eastern seaboard to provide context for this study's results. The breadth of the region is used during spring and fall migration by seabirds, landbirds, sea turtles, cetaceans, rays, and other taxa. Many of these taxa are also part-time or year-round residents of the study area, using it for foraging during the breeding season, or for foraging or roosting during non-breeding periods. Despite seasonal variation in habitat characteristics, areas near the mouths of the Chesapeake Bay and Delaware Bay remain important for many different taxa throughout the year. Boat and aerial surveys and satellite telemetry data consistently showed high species diversity, abundance, and habitat use patterns in nearshore waters adjacent to and directly south of the bay mouths (roughly within 30 km of shore). These areas are likely attractive to a wide variety of high trophic-level species, due to their consistently higher primary productivity relative to the broader study area. Areas in northern Maryland within roughly 20-30 km of shore were also consistent hotspots for biodiversity and abundance for many taxa, although this may have been partially driven by the more inshore study design implemented in the region as compared to the remainder of the study area.

Exposure to offshore development activities comprises one component of identifying risk, where risk is defined as a combination of exposure to a stressor, the hazard posed to individuals by that stressor, and the vulnerability of the population to those individual effects. Seasonal data on wildlife species composition, distributions, and relative abundance are essential for providing a baseline understanding of when and where animals have the potential to be affected by anthropogenic activities, and for identifying species or taxa of particular interest for future study. Thus, this study is an important first step towards understanding how bird, marine mammal, and sea turtle populations in the mid-Atlantic may be exposed to offshore wind energy construction and operations, as well as other anthropogenic activities. The results of this study provide insight to help address environmental permitting requirements for current and future offshore development projects, and serve as a starting point for more site-specific studies, risk analyses, and evaluation of potential measures to avoid and minimize those risks.

Background

Marine spatial planning, a priority of both international agencies (Ehler and Douvere, 2009) and the U.S. federal government (White House Council on Environmental Quality, 2010), is designed to examine the spatial and temporal distribution of activities in the marine environment and develop effective plans for the use of marine resources based on a framework of sound science. Ultimately, by improving collaboration and coordination among all coastal and ocean users and stakeholders, Marine Spatial Planning is designed to address the demand for economic development while maintaining marine ecosystem resilience (National Ocean Council, 2013).

A number of databases have been specifically designed to compile existing marine wildlife data for the western North Atlantic for use in marine spatial planning, as well as other conservation and resource management efforts. The more prominent of these include: (1) the Ocean Biogeographic Information System Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP; Halpin et al., 2009); (2) the Northwest Atlantic Seabird Catalog, formerly known as the Avian Compendium, currently managed by the U.S. Fish and Wildlife Service (USFWS; O'Connell et al., 2009); (3) the Marine Cadastre[1], a joint initiative of the Bureau of Ocean Energy Management (BOEM) and National Oceanic and Atmospheric Administration (NOAA); and (4) the data portals of the regional ocean planning councils along the east coast (Northeast Regional Ocean Council, NROC[2], Mid-Atlantic Regional Council on the Ocean, MARCO[3], and the Governors' South Atlantic Alliance, GSAA[4]). These databases have been used to assess existing data coverage and identify geographic, temporal, and taxon-specific gaps in our knowledge of wildlife along the east coast of North America (Kot et al., 2010; O'Connell et al., 2009).

A number of recent studies have been designed to address these gaps, by collecting new survey data to identify patterns in the distribution and abundance of marine wildlife in specific areas. The broadest of these is the Atlantic Marine Assessment Program for Protected Species (AMAPPS). This joint NOAA, BOEM, USFWS, and U.S. Navy project uses traditional visual aerial and boat-based surveys to collect broad-scale data on the seasonal distribution and abundance of marine wildlife across the Atlantic Outer Continental Shelf to enhance spatial modeling exercises (Northeast Fisheries Science Center and Southeast Fisheries Science Center, 2013). Several other baseline studies have occurred at the state level. The State of New Jersey carried out a two-year (2008-2009), broad scale study – the Ocean/Wind Power Ecological Baseline Studies – to determine the distribution of wildlife species and their use of offshore waters, and potential areas for offshore wind power development (Geo-Marine Inc., 2010a). The study included the marine waters of the southern half of the state out to 37 km offshore, employing a combination of traditional visual aerial and boat-based surveys, as well as radar and acoustic techniques, to inform ecological and predictive modeling exercises. Likewise, in recent years the State of Rhode Island has developed a management plan for marine waters immediately off its coast – a roughly 3,800 km^2 area, including Rhode Island Sound and Block Island Sound – known as the Ocean Special Area Management Plan (OSAMP). This is a comprehensive strategy for zoning Rhode Island's offshore waters

[1] www.marinecadastre.gov
[2] www.northeastoceancouncil.org
[3] www.midatlanticocean.org
[4] www.gsaaportal.org

using an ecosystem-based approach, and is designed to help develop policy through both scientific research and public input (Winiarski et al., 2012).

Recently, the State of Maryland[5] has been working with resource experts and user groups to compile data and information on habitats, human uses, and resources in Maryland waters. Using existing data and information, marine spatial planning tools have helped identify areas most suitable for various types of activities in order to reduce conflict among uses, facilitate compatible uses, and reduce environmental impacts to preserve crucial ecosystem services.

Despite these and other focused studies along the Atlantic coast in recent years, several geographic holes still remain in recent survey activities and data collection, which must be filled for effective marine spatial planning efforts in those areas. The Mid-Atlantic Baseline Studies Project and Maryland Project, described here, fill a significant information gap for a large swath of the mid-Atlantic region between New Jersey and North Carolina (see methods described in Chapter 1). This area includes three major wind planning areas, the federally-designated Wind Energy Areas (WEAs), for which there were limited data on the distribution and relative abundance of wildlife prior to this study. These studies provided new data for these locations, and perhaps more importantly, provided data of sufficient geographic and temporal resolution to allow for a rigorous examination of seasonal wildlife distribution patterns. The high levels of productivity in the mid-Atlantic region, and its year-round importance to a broad suite of species, mean that it is essential to understand this ecosystem in order to manage it effectively, particularly with regard to anthropogenic stressors such as offshore development.

Patterns of wildlife distributions and habitat use in the mid-Atlantic study area

Seasonal patterns

The mid-Atlantic region provides important habitat for marine wildlife over the course of the year. With each season comes a unique shift in habitat characteristics, and with it a different array of species reliant on the specific resources available (Table 2-1).

Spring

During the spring (March-May), sea surface temperatures begin to rise, and salinity across surface waters begins to decrease. As the season progresses, primary productivity begins to increase within and adjacent to the bays as nutrient rich spring runoff flows into the bays and mixes with coastal waters (Smith and Kemp 1995). Across the broader shelf within the study area, however, primary production decreases as waters begin to warm and stratify (Xu et al., 2011).

High species diversity was observed in the spring, suggesting that migratory and overwintering species dominate the region's species composition (Chapter 11). During this time, wintering seabirds departed the region to begin their migrations towards breeding grounds inland or to the north. In our study, Surf Scoters (*Melanitta perspicillata*) departed the area between January and May, Red-throated Loons (*Gavia stellata*) between March and May, and Northern Gannets (*Morus bassanus*) in between February

[5] www.dnr.state.md.us/ccs/coastal_resources/oceanplanning

and May (Chapters 20-23). During spring, songbirds and shorebirds migrated through the region both along the coast and over open waters (Chapters 17 and 27). Summer resident seabirds, such as terns, shearwaters, and storm-petrels, arrived after migrating from wintering grounds in the south or breeding grounds in the Southern Hemisphere (Chapters 5, 8, and 17). Spring also marked the arrival of Bottlenose Dolphins (*Tursiops truncatus*) and a variety of sea turtle species, which were predicted to occur in high densities offshore of Virginia (Chapter 15).

Summer

During summer (June-August), the sea surface warms to peak temperatures (generally ranging from 20-30˚C, Chapter 12), forming a strong thermocline (Castelao et al., 2010). In shallow waters close to shore, high temperatures may persist throughout the water column (Castelao et al., 2010). Average salinity values are at their lowest in summer, with lowest salinity values at the top of the water column extending across the shelf (Castelao et al., 2010). While overall primary productivity is generally low across the shelf during summer, chlorophyll concentrations increase in shallow nearshore areas where upwelling can occur (Xu et al., 2011). Additionally, primary production within the bays is at its peak, contributing to higher productivity at the bay mouths where coastal and estuarine waters mix (Smith and Kemp 1995; Flemer 1970). Through hydroacoustic surveys, we generally observed higher levels of aquatic biomass in these regions during the summer months (Chapter 9).

In the summer, seabirds were generally more associated with nearshore habitat than they are in the spring (Chapter 12). Breeding seabirds were found foraging near the shore and near the mouths of the bays (Chapter 12 and 17); specifically, terns (including Common Terns, *Sterna hirundo*, and others), were predicted to be associated with nearshore habitat (Chapters 18-19). Non-breeding species from the southern hemisphere, such as Great Shearwaters (*Puffinus gravis*) and Wilson's Storm-Petrels (*Oceanites oceanicus*), generally occupied a wider swath of the study area (Chapter 17). In early summer, large numbers of Cownose Rays (*Rhinoptera bonasus*) migrated through the study area on their way to feeding grounds in the Chesapeake Bay and Delaware Bay (Chapter 5; Blaylock 1993). Sea turtles and Bottlenose Dolphins were most abundant across the study area in the summer, with the more inshore coastal ecotype of Bottlenose Dolphins more heavily represented than the offshore population of this species (Chapter 15; Kenney, 1990). In the summer, both Bottlenose Dolphin and sea turtle distributions were influenced by sea surface temperatures and primary productivity (Chapter 15), with Bottlenose predicted to occur primarily in nearshore areas, and sea turtles still predicted to occur primarily in the southern end of the study area (Chapter 15).

Fall

In the fall (September-November), stronger winds help initiate mixing of stratified water, leading to cooler and less variable sea surface temperatures across the region; temperatures continue to decrease as the season progresses and days become shorter (Schofield et al., 2008). The mixing of stratified water re-oxygenates the water column, setting the stage for a significant phytoplankton bloom that occurs across shallow waters in the region between late fall and early spring (Schofield et al., 2008; Xu et al., 2011). Decreased flow of fresh water from the Delaware Bay and Chesapeake Bay during the summer and fall causes salinity to rise over the course of the season, as saltier water is pushed closer to shore.

In the early fall, Cownose Rays moved out of the bays and aggregated in dense groups within the study area as they migrated south, likely prompted by changing water temperatures (Chapter 5; Goodman et al., 2011). Seabird species composition changed over the course of the fall, as summer residents migrated south to warmer climes and winter residents migrated into the region from breeding grounds farther north or inland (Chapter 17). Seabirds continued to be more associated with nearshore habitats as compared to winter and spring (Chapter 12). In our telemetry studies, tagged Surf Scoters migrated south from the breeding grounds and arrived in the wintering area between October and December, while Red-throated Loons arrived between November and December, and Northern Gannets between August and December (Chapters 20-23). As in the spring, songbirds and shorebirds were recorded flying over open waters as they migrated through the study area (Chapters 17 and 26-27). Peregrine Falcons (*Falco peregrinus anatum*) migrated over open water through the study area (Chapter 25), as did Eastern Red Bats (Chapter 17; Hatch et al., 2013). Alcids moved into the study region in the fall. Large schools of baitfish were observed in the study area in the fall, particularly offshore of Maryland where high density aerial surveys were conducted in nearshore regions, though they were found on the inshore transects all along the coast (Chapters 9 and 17). Although uncommon due to their small population sizes, baleen whales such as the Common Minke Whale (*Balaenoptera acutorostrata*) and Northern Right Whale (*Eubalaena glacialis*) were observed within the study area in the fall. Sea turtles remained widespread across the study area through October (Chapter 15). Bottlenose Dolphins also remained until late fall, while Common Dolphins (*Delphinus delphis*) arrived in the study area in November (Chapters 15 and 17).

Winter

During winter (December-February), sea surface temperatures are at their lowest and least variable across the study area, generally ranging from 5-15˚C, with the coolest temperatures found close to shore (Schofield et al., 2008). Salinity follows a similar pattern, generally increasing with distance from shore (Castelao et al., 2010). Primary productivity peaks within shallow waters (roughly to the 40 m isobath, well past the spatial extent of our study area; Xu et al. 2011; Schofield et al. 2008).

Wintering seabirds occupied habitat throughout the study area, with variation in distribution patterns among species (Chapters 12, 17, and 19) and individuals. Northern Gannets were the most ubiquitous seabird in the study area during this period, and were often observed in the bays as well as relatively far out on the shelf in search of prey (Chapters 10, 12, 17, and 22). For Northern Gannets, we found that the chances of foraging increased with the number of sea surface temperature fronts in an area, as the temperature fronts likely aggregated prey (Chapter 24). Scoters (*Melanitta* spp.) were observed in large aggregations at the mouths of the Chesapeake Bay and Delaware Bay (Chapter 17). Common Loons (*Gavia immer*), in contrast, were most often observed individually and were widely dispersed throughout the study area, generally more associated with lower sea surface temperatures (Chapters 16-17). Many Bonaparte's Gulls (*Chroicocephalus philadelphia*) were observed in the study area on both survey platforms in winter (Chapters 5 and 8). Alcids were predicted to occur in small numbers throughout the study area (Chapter 19). Baleen whales were most commonly observed during this season; of the 51 large whales observed in this study, 31 were observed between December and

February (Chapter 17). Common Dolphins occupied habitat throughout the study area during the winter, predominantly in offshore areas (Chapters 15 and 17).

Persistent patterns

Results from the weather radar study showed persistent patterns in the use of the region by nocturnal migrants, including shorebirds and songbirds, particularly during fall migration (Chapter 27). While offshore migration was most likely to occur under certain environmental conditions at different locations along the east coast, during this season there was no statistical difference in predicted levels of migratory activity in terrestrial vs. offshore locations, including locations up to 80 km offshore. In particular, the data suggested that there may be substantial offshore migration pathways that begin with "jumping off points" at certain locations along the coast (including Long Island, New York, and the Carolinas).

Primary productivity forms the base of the pelagic food chain on which nearly all species observed during this study rely. In general, primary productivity in the mid-Atlantic is higher in nearshore areas, although patterns vary seasonally (see above). Digital aerial surveys captured large numbers of schools of forage fishes in nearshore waters, with most of these recorded on the Maryland Project transects (Chapter 5), the most heavily surveyed section inshore. Bait balls were most persistently observed in high numbers in this region, in addition to nearshore regions offshore of Delaware, around the mouth of Delaware Bay (Chapter 17). In turn, despite seasonal variation in habitat characteristics, areas within about 30-40 km of shore appeared to provide important foraging habitat for a multitude of species year-round. In particular, areas near the mouths of the Chesapeake Bay and Delaware Bay consistently showed high species diversity and abundance of animals across all taxa observed in surveys during this study (Figure 2-1). Telemetry studies also highlighted these same areas around the mouths of Chesapeake Bay and Delaware Bay as high use areas for migratory seabirds in winter, even for species that were highly mobile and used a broad range of habitats, such as the Northern Gannet (Chapter 22). These areas were likely attractive to a wide variety of high trophic-level species, such as seabirds and marine mammals, due to foraging opportunities arising from consistently higher primary productivity relative to the broader study area.

Table 2-1. Seasonal habitat use within the mid-Atlantic study area for major taxonomic groups. There is no single definition for each season, as the life history periods of specific species vary, but generally speaking, for this table we consider that spring = Mar.-May, summer = Jun.-Aug., fall = Sep.-Nov., and winter = Dec.-Feb. Dashes indicate that we obtained no data for that taxon and time period. It should be noted that this table is not comprehensive; individuals of many seabird species, for example, migrate through the study area without taking up residence in summer or winter.

Species Group	Spring	Summer	Fall	Winter	Report chapters with additional information
Wintering seabirds	Depart from or migrate through study area	Few individuals observed	Arrive in or migrate through study area	Abundant; utilize habitat throughout study area, though many species concentrated in the western parts of the study area and at the bay mouths	5 8 10 12 16-24
Breeding and non-breeding summer resident seabirds	Arrive in or migrate through study area	Local breeders nest on shore and forage across the study area, concentrated near bay mouths; non-breeders are more ubiquitous across the study area	Depart from or migrate through study area	Few individuals observed	5 8 12 17-19
Songbirds and other landbirds	Migrate through study area	Small flocks of swallows (Hirundinidae) and individuals of other species observed across study area	Migrate through study area	Few individuals observed	8 17 26-27
Shorebirds	Migrate through study area.	Generally not present; few individuals observed throughout study area	Migrate through study area	Few individuals observed	8 17 26-27
Bats	--	--	Migrate through study area	--	17
Baleen whales	Migrate through study area	--	Migrate through study area	Observed throughout study area	5 8 15 17
Toothed whales (dolphins and porpoises)	Bottlenose Dolphins arrive in or migrate through study area; Common Dolphins depart from or migrate through study area	Season of highest overall abundance; Bottlenose Dolphin most commonly observed	Present across study area; Bottlenose Dolphin commonly observed; Common Dolphin arriving in or migrating through study area	Season of lowest overall abundance; Common Dolphin observed across study area	5 8 15 17
Turtles	Arrive in or migrate through study area; observed across study area, most densely in the southeast	Commonly observed across entire study area; higher densities offshore and in the southern part of the study area	All species distributed across study area as they migrate south to wintering or nesting grounds; higher densities offshore	--	5 14-15 17
Rays	Few individuals observed	Present in large numbers and broadly distributed across study area	Present in large numbers and dense aggregations during migration	Few individuals observed	5 14 17
Forage Fishes	Moderately abundant; occur throughout study area	Abundant; occur throughout study area; generally more dense closer to shore	Abundant; higher densities close to shore	Few groups visually observed, but high acoustic detection; highest densities near the mouth of Chesapeake Bay	9 14 17

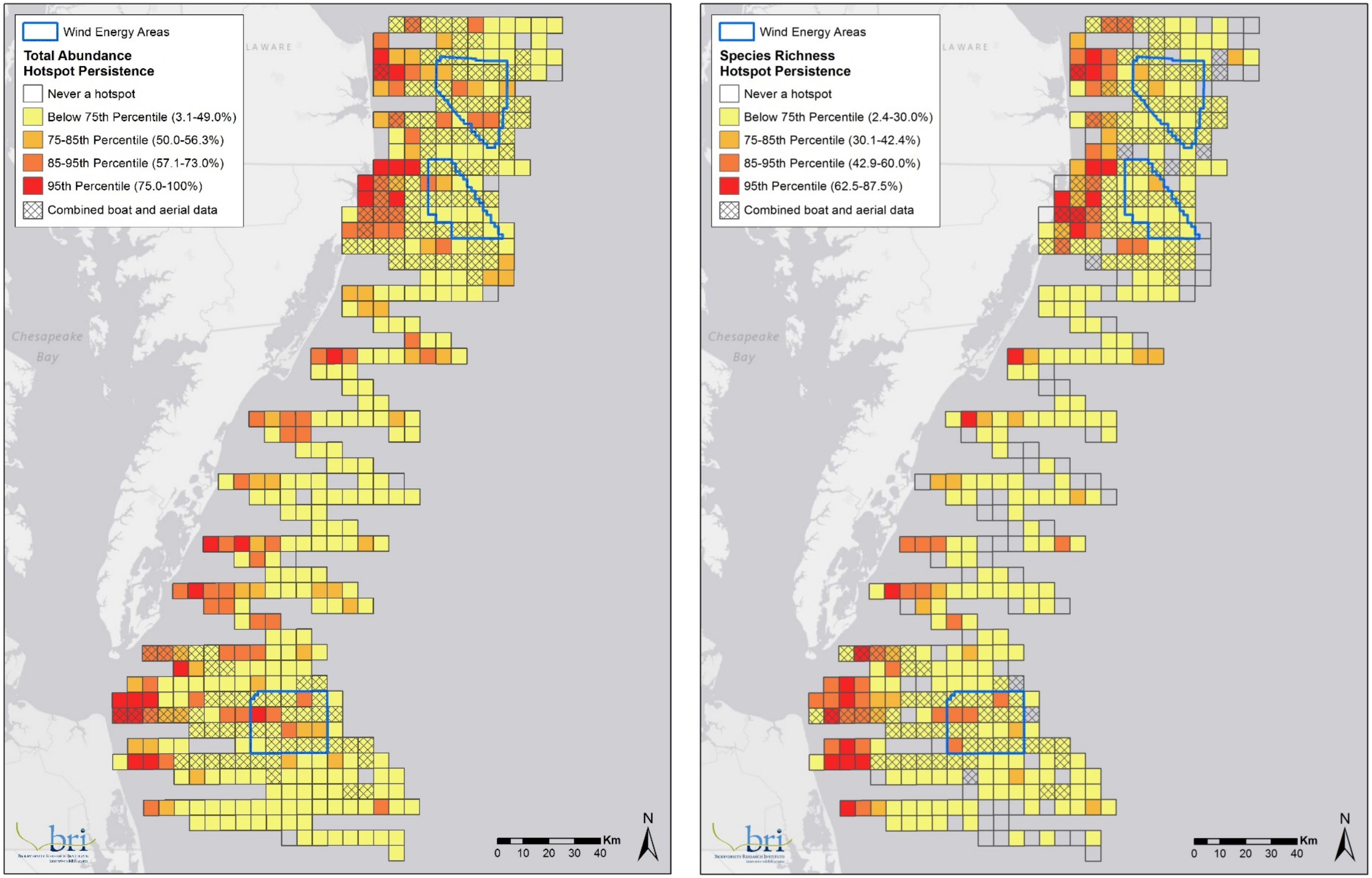

Figure 2-1. Classified persistent abundance hotspots identified across all taxa (left) and classified persistent species richness hotspots (right). These maps highlight areas where the greatest numbers of individuals across all taxa (left) and the greatest numbers of species (right) were consistently observed over the course of the study (Chapter 17). For each percentile category shown in the legends, the corresponding percentage of time a cell was a hotspot is shown parenthetically. Crosshatched cells were surveyed by and integrate data from both boat and aerial survey methods and integrate data from both approaches.

Interannual variation

The marine ecosystem is a dynamic environment, with annual changes that can influence the distributions of wildlife (Gaston et al., 2009; Schneider and Heinemann, 1996). Interannual variation is driven primarily by changes in abiotic variables, such as sea surface temperature and currents (Ballance et al., 2006). Temperature and salinity in the mid-Atlantic have changed over the past several decades (Mountain, 2003), and there have been declines in primary productivity with an increase in winter storms (Schofield et al., 2008). The Bureau of Ocean Energy Management (BOEM) suggests a minimum of two full annual cycles for offshore surveys for wind energy development (BOEM, 2013), based on a recent analysis of interannual variation in wildlife distributions that indicates that 2-3 years of surveys may be sufficient to capture shorter-term (e.g., intra-decadal) levels of variation for some taxa (Kinlan et al., 2012b).

Between the two years of data collected in this study, we found substantial variation in the community composition, distribution, and abundance of species observed (Chapters 12, 14 and 18), as well as notable differences in environmental conditions. For example, we observed warmer waters in the second year of the study, possibly due to eddies from the Gulf Stream (warm core rings that meander north off of the main Gulf Stream over the Atlantic Outer Continental Shelf; Chapter 12). Although digital video aerial surveys for this study were conducted in June and September of 2012 and July and September of 2013, large numbers of Cownose Rays were only observed in 2013. Some variation in water temperatures, ray populations, or other factors meant that very few rays were seen in 2012 (Chapter 5). Similarly, scoters were observed in high numbers each winter on the boat survey, but more than twice as many scoters were seen in January of 2013 as in January of 2014 (Chapter 8). Seabirds are generally patchily distributed in their environment (Fauchald, 2009), leading to some level of variation in observations between survey platforms and year. Scoters, however, also responded to their environment differently between the two years, perhaps due to the increase in water temperatures in 2013 (Chapter 12), or dynamic movements in response to prey. Many other seabirds also responded differently to environmental conditions in the first year vs. the second year of surveys (Chapters 12 and 18). Particularly for rarer and more patchily distributed species, more than two years of data may be required to describe the interannual variability in their distribution patterns, and conducting surveys over a longer time frame would allow for a more complete characterization of the expected levels of variability in these patterns.

Determining and interpreting risk

The seasonal baseline data on wildlife species composition, distributions, and relative abundance provided by this study are essential for understanding when and where animals have the potential to be affected by anthropogenic activities in the mid-Atlantic region. In the sections above, we have discussed the potential exposure of animals to offshore wind development in different seasons. Exposure itself, however, does not necessarily indicate that animals will suffer deleterious effects; the vulnerability of different species to development activities will also play a role. Risk to wildlife from offshore development can be thought of as an interaction of three factors (Crichton, 1999; Fox et al., 2006):

- *Exposure* of individuals to development and operation activities that have the potential to cause impacts. Species may be exposed if they are present in a potential development area during the times at which impact-producing activities occur. Specific behavioral traits may increase or decrease exposure of animals that are present.

- *Hazards* posed to individuals that are exposed. Hazards can be direct (for example, collision mortality) or indirect (displacement, or effects on habitat or prey populations).
- *Vulnerability* of populations to individual-level effects, or the potential for impacts to individuals to substantially affect the status of the population. This potential is related to a species' life history as well as its conservation status.

Published risk assessments for birds and offshore wind energy development have generally considered some combination of these factors (e.g., Desholm, 2009; Furness et al., 2013; Garthe and Hüppop, 2004; Willmott et al., 2013). For aquatic animals, risk assessments have focused primarily on acoustic disturbance (with potential for mortality/sublethal impacts as well as displacement) and habitat impacts (Bailey et al., 2014; Bergström et al., 2014). It is still unclear in most cases, however, what life history characteristics most influence risk, or how to translate some types of risk (such as displacement) to a biologically meaningful metric (e.g., reproductive or survival impacts). Nevertheless, site-specific pre- and post-construction monitoring will most likely be focused on particular species or topics, in order to prioritize limited funding and direct research towards taxa most likely to be affected (Rein et al., 2013). Assessments of relative risk, while imperfect, will be essential for directing efforts towards the taxa of greatest need.

In this baseline study of wildlife distributions and movements, we focused on developing a better understanding of exposure of wildlife to future offshore development in the mid-Atlantic. This study is a crucial first step towards understanding the implications of offshore wind energy development for bird, marine mammal, and sea turtle populations in the mid-Atlantic US. Future research to fill data gaps on hazards and vulnerability can be targeted towards habitat that supports high or low species abundance and diversity, as well as towards species with high levels of exposure, or species most likely to be impacted due to their behaviors, life history, or conservation status.

Case studies: integrating results from different project components

Here, using results from multiple study efforts, we examine certain taxa and phenomena in more depth. Taxa were chosen for inclusion because they are of likely regulatory concern due to their conservation status in the U.S., or because they are known or suspected to interact with offshore wind energy development, based on the European experience to date. As discussed above, there are several types of potential effects of offshore wind energy development on wildlife, including direct mortality or injury, behavioral effects, and indirect effects to habitat or prey populations. We reference the European literature where appropriate, and briefly discuss the most likely potential effects to each taxon based on the distribution data presented in this study. Migration is also included since it is a critical stage in the life cycle for many animals, a period when they are more mobile and physiologically stressed, making them potentially more vulnerable to additional threats.

Red-throated Loon

Loons are long-lived species with high adult survival and low annual productivity (Barr et al., 2000; Schmutz, 2014). Therefore, the loss of adult individuals or the chronic reduction of individual fitness has the potential to adversely affect populations. Fisheries are a major source of adult mortality, via bycatch of birds in nets (Barr et al., 2000). The Red-throated Loon has a global conservation status of Least Concern due to the species' broad global range and large population size, despite a population trend indicating a decline (BirdLife International, 2015). In the U.S., however, the US Fish and Wildlife Service has identified the Red-throated Loon as the highest priority open-water species for conservation in the mid-Atlantic US (USFWS 2008), where they are abundant during non-breeding periods (Chapters 5, 8, and 12).

In Europe, Red-throated Loons have exhibited long-term and possibly permanent displacement from offshore wind energy development areas, making effective habitat loss the primary concern for this species in relation to offshore development (Leonhard et al., 2013; Lindeboom et al., 2011; Percival, 2010). Thus, the Red-throated Loon has been ranked as the most vulnerable species to displacement in European studies (Furness et al., 2013; Garthe and Hüppop, 2004) and is considered to be at high risk of adverse effects from offshore wind energy development (Langston, 2010). BOEM and the USFWS have recognized the need for additional data on populations and movements of this species in the mid-Atlantic in relation to future offshore wind energy development, and have funded ongoing (2012-2016) satellite telemetry studies (of which the telemetry study in this report is a part; Chapters 21 and 23).

During boat and aerial surveys, 1,770 Red-throated Loons were observed (1% of all wildlife observations from surveys) and they were most common in the study area between November and May (Chapters 5 and 8). In many cases, however, Red-throated Loons and Common Loons could not be distinguished in video aerial surveys, due to a greater overlap in body size among North American loon populations than occurs in Europe. Red-throated Loons were most consistently observed within approximately 20 km of shore during surveys, unlike Common Loons, which were more widely distributed across the study area in winter (Chapters 16-17). Telemetry data indicated that Red-throated Loons preferentially used shallow nearshore waters with flat sandy substrates while wintering in the mid-Atlantic region, particularly around the mouth of Chesapeake Bay and south along the coast of Virginia, close to original capture locations (Chapter 21). Modeled boat survey data also indicated that proximity to shore was the strongest predictor of Red-throated Loon abundance, followed by relatively cold sea surface temperatures and primary productivity (though the predicted relationship with primary productivity varied by season, with loons associated with areas of lower productivity in spring and high productivity in winter). In the digital aerial survey video, 28% of flying loons (all species) were flying between 20 m and 200 m in altitude; the rotor-swept zone of offshore wind turbines depends on the turbine size and type, but will likely include altitudes within this range (Chapter 5; Willmott et al. 2013). Seventy percent of flying loons were estimated to be below this range (Chapter 5).

In the spring, satellite tagged Red-throated Loons left the study area between late March and early May, and largely followed the coast north to breeding grounds. Greatest offshore movements occurred during this departure from the study area. During fall migration, most individuals stopped over in Hudson Bay, and then moved either to the Gulf of St. Lawrence or to the Great Lakes before arriving in the study area between mid-November and late December.

Context

- European studies indicate that Red-throated Loons experience long-term, localized disturbance and displacement from wind energy facilities, as well as related activities such as vessel traffic.

Take home messages

- The greatest overlap between Red-throated Loon distributions and mid-Atlantic WEAs occurred during migration periods, when movements tended to be located farther offshore.
- In winter, Red-throated Loons were most commonly located west of the WEAs.

Northern Gannets

The Northern Gannet is the largest seabird to breed in the North Atlantic Ocean. In the Western Hemisphere, they breed at six colonies in southeastern Canada—three in the Gulf of St. Lawrence, Québec, and three off the eastern and southern coasts of Newfoundland (Mowbray, 2002; Nelson, 1978). On migration, Northern Gannets move widely down the east coast of North America to winter in the shelf waters of the mid-Atlantic region, the South Atlantic Bight, and the northern Gulf of Mexico (Fifield et al., 2014; Nelson, 1978), and they were one of the most commonly observed species in surveys for this study (Chapters 5, 8, and 12). The Northern Gannet has a global Conservation Status of Least Concern due to its relatively large population size and its exceptionally large range (BirdLife International 2015). The North American breeding population, which represents 27 percent of the global population, has experienced a healthy rate of growth since 1984 (4.4% per year), although that appears to have slowed in recent years (Chardine et al., 2013). The species is vulnerable to mortality from oil spills and fisheries bycatch, however, and the Northern Gannet has been identified as a possible species at risk of collision mortality from offshore wind energy development, due to its relatively poor in-air maneuverability and foraging behaviors (which include spending a large proportion of time soaring at or near an altitude that potentially places it within the rotor-sweep zone of offshore turbines; S. Garthe, Benvenuti, and Montevecchi 2000; Langston 2010). Several recent vulnerability assessments have estimated Northern Gannets to be one of the seabirds most vulnerable to collision mortality (Furness et al., 2013; Willmott et al., 2013). There is also evidence of displacement of Northern Gannets from offshore wind facilities in Europe, however (Lindeboom et al., 2011; Vanermen et al., 2015), and a further examination of Northern Gannet responses to offshore wind facilities may improve our understanding of the scope of likely hazards for this species.

In the U.S., the USFWS has identified the Northern Gannet as a high priority species for Bird Conservation Region (BCR) 30, which includes most of the mid-Atlantic study area, and has also specifically identified the importance of understanding their movements and distributions in relation to future offshore wind energy development (Atlantic Coast Joint Venture 2008); as a result, BOEM and the USFWS have funded ongoing satellite telemetry studies of the species in the mid-Atlantic (of which the telemetry study in this report is a part; Chapters 22-23).

Northern Gannet migration was highly asynchronous and widely dispersed across the continental shelf. During the boat and aerial surveys in this study, 21,345 Northern Gannets were observed (17% of all wildlife observations), most commonly between October and April (Chapters 5 and 8). Individual Northern Gannets roamed widely across the region in winter; satellite data showed that they could range up to 50 km out onto the Outer Continental Shelf (Chapter 22), and 70% of the study area was categorized as a hotspot of gannet abundance in at least one survey (Chapter 17). The general locations used by wintering Northern Gannets seemed to be somewhat consistent, however, as during surveys they were most often observed in large numbers in nearshore waters along the length of the study area (Chapter 17). Combined, telemetry and survey data showed that Northern Gannets in the mid-Atlantic generally used habitats characterized by highly productive, shallower waters, with lower sea surface salinities, especially areas closer to shore and over fine sandy substrate. Their behavioral patterns indicated that they foraged roughly 67% of the time during winter, in relatively deeper waters, and in areas with high densities of sea surface temperature fronts (e.g., boundary areas between water masses of different temperatures). The rotor-swept zone of offshore wind turbines depends on the turbine size and type, but may include altitudes between 20 m and 200 m (Willmott et al., 2013). In the digital aerial survey video, 55% of flying gannets were below this range, with 43% between 20 m and 200 m (Chapter 5).

Context

- European studies indicate a range of possible effects of offshore wind development on Northern Gannets, including collision mortality and displacement.

Take home messages

- The broad-scale distribution movements of Northern Gannets during winter may increase the likelihood that individuals would be in the vicinity of offshore wind developments repeatedly throughout the season.
- Important foraging and habitat use areas appear to be defined by a wide variety of habitat characteristics. Construction and operations of offshore wind energy facilities, including associated vessel traffic, could potentially cause localized displacement anywhere in the study area, but this is most likely within about 30-40 km of shore where Northern Gannets were most abundant.

Scoters

Scoters are medium-sized sea ducks that breed near lakes or slow-moving rivers on the Arctic tundra from Labrador to Alaska. The Surf Scoter and White-winged Scoter (*Melanitta fusca*) both have a global Conservation Status of Least Concern, due to their large population sizes and broad ranges, despite the fact that the population trends for both species indicate a decline (BirdLife International 2015). The Black Scoter (*M. americana*) is listed as Near Threatened due to suspected recent population declines (BirdLife International 2015). Threats include hunting, particularly along the east coast of North America, as well as possible habitat degradation and increased harvest of mussels for human consumption (Bordage and Savard, 2011; Savard et al., 1998). All three species use the mid-Atlantic study area in large numbers during their nonbreeding period (Chapters 5 and 8), and they are listed in several state wildlife action plans in the region (Atlantic Coast Joint Venture 2008). The USFWS has identified them as high priority species, and specifically identified the importance of understanding their movements and distributions in relation to future offshore wind energy development (Atlantic Coast Joint Venture 2008). Common Scoters (*M. nigra*) in Europe have been displaced from feeding or roosting grounds for several kilometers surrounding offshore wind energy development, resulting in short-term effective habitat loss

(Langston 2013; Leonhard et al. 2013). The species returned to a facility footprint at a project in Denmark three years after construction, although whether this was a result of habituation or changes in prey distributions, or both, remains unclear (Petersen and Fox, 2007). Vessel traffic is also known to disturb scoters, though the degree of this disturbance varies by species (Chapter 13; Schwemmer et al. 2014).

Scoters were the most abundant avian genus observed over the course of the study, with 43,339 individuals observed (25% of all wildlife observations) and were most abundant in the mid-Atlantic between October and May (Chapters 5, 8 and 17). The majority of scoter observations were not identified to species, but observations included at least 30% Black Scoters, 9% Surf Scoters, and 0.001% White-winged Scoters. Satellite tagged Surf Scoters spent an average of 133 days in the region during winter, generally arriving in the study area between mid-October and mid-December. They departed the study area between early January and mid-May, and followed the coastline north to breeding and molting areas in northern Canada. This route was reversed during fall migration as birds returned to wintering areas in or near the mid-Atlantic. In the digital aerial survey video, 77% of flying scoters (all species) were flying below 20 m in altitude; 19% were between 20 m and 200 m.

Satellite tagged Surf Scoters spent >50% of their time in the study area within or at the mouths of the bays (Chapter 20). Core use areas of Surf Scoters identified by satellite telemetry may have been heavily influenced by capture locations, but survey and telemetry data both showed that scoters use habitat characterized by shallow nearshore waters with high primary productivity (Chapters 12, 17, and 20). Large aggregations of scoters were most consistently observed during surveys at the mouth of Chesapeake Bay and just south of the mouth of Delaware Bay, within roughly 20 km of shore (Chapter 17). In the mid-Atlantic, scoter distributions appear to be mainly located closer to shore than most proposed offshore wind energy development (Chapters 12, 17, and 20). They could experience considerable disturbance from development activities in nearshore areas, however, as well as vessel activity related to projects located in WEAs or other offshore areas (particularly if vessel activity occurred near the mouths of Chesapeake Bay and Delaware Bay).

Context

- Based on European studies, scoters may be displaced from areas around offshore wind facilities for some period of years following construction.

Take home messages

- Telemetry and survey data for scoters indicated strong nearshore distribution patterns, which held true across species and were largely driven by water depth and food resources.
- In the mid-Atlantic, construction and operation of offshore wind energy facilities (and associated vessel traffic) are most likely to cause localized displacement of scoters from high-quality feeding areas if these activities occur within about 20 km from shore.

Endangered birds

Three federally endangered bird species could interact with offshore wind energy facilities in the mid-Atlantic, based on their respective ranges: the Piping Plover (*Charadrius melodus*), Roseate Tern (*Sterna dougallii*), and the American subspecies of the Red Knot (*Calidris canutus rufa*). Due to their conservation status and protection under the Endangered Species Act, all three species are likely to be priorities for regulators during the offshore wind permitting process in the mid-Atlantic, as indeed has been the case for the Cape Wind project off the coast of Massachusetts (Normandeau Associates Inc., 2011). The primary hazard posed to terns and shorebirds from offshore wind energy development would appear to be collision mortality (Everaert and Stienen, 2007; Furness et al., 2013; Willmott et al., 2013), although impacts of construction activities on terns' prey base have also been noted at one wind facility in the UK (Perrow et al., 2011). Except in the case of a wind facility constructed on a jetty directly adjacent to a tern colony in Belgium (e.g., Everaert and Stienen 2007), however, limited evidence exists for mortalities. Development of wind facilities in locations between tern colonies and major offshore foraging grounds could pose a potential hazard, as adults would have to navigate past turbines multiple times daily (Henderson et al., 1996), and there may also be some limited exposure of Red Knots during migration; however, for wind energy facilities located farther offshore, there is likely to be limited or no interactions with Piping Plovers, which are thought to mainly migrate along the coast (Burger et al., 2011). We can provide little evidence of exposure in this study; three Roseate Terns were observed during boat surveys off of Delaware and Maryland (all observed in May or June, within about 20 m of shore), but no other confirmed observations of these species were made, likely due in part to these species' rarity. It should be noted that species identification rates for terns and shorebirds were relatively poor in the digital aerial surveys, so it is possible that additional individuals of these listed species were observed and were not able to be identified.

In addition to federally endangered bird species, state-listed species in Delaware, Maryland, and Virginia include Least Tern (*Sterna antillarum*), Peregrine Falcon, Common Tern, Forster's Tern (*S. forsteri*), Royal Tern (*Thalasseus maximus*), and Wilson's Plover (*Charadrius wilsonia*). Each of the states also lists additional bird species in various ways (as state threatened, included in state Wildlife Action Plans, in various conservation "tiers," etc.[6]). Due to their conservation status in the region, these species are also likely to be higher priority for regulators considering proposed development in the mid-Atlantic. With the exception of Common Terns, all of these species were rare, if they were seen at all, on the boat and digital aerial surveys (Chapters 5 and 8). However, telemetry data for Peregrine Falcons indicates considerable use of offshore areas during fall migration (Chapter 25; see 'Migration' section below).

Take home messages

- Several state- and federally-listed bird species were observed during offshore surveys, including Roseate Terns, Least Terns, Common Terns, Forster's Terns, and Royal Terns, all of which were observed most commonly in the spring, summer, and fall within roughly 20 km of shore.
- Telemetry data indicate that a large number of Peregrine Falcons may also use the mid-Atlantic study area during fall migration along the Atlantic Flyway.
- We had no confirmed sightings of Piping Plovers or Red Knots in the study area.

[6] http://www.dgif.virginia.gov/wildlife/virginiatescspecies.pdf, http://www.dnrec.delaware.gov/fw/dwap/Documents/B%20and%20C%20-%20SGCN%20and%20Species-Habitat%20Associations.pdf, http://www.dnr.state.md.us/wildlife/Plants_Wildlife/rte/pdfs/rte_Animal_List.pdf

Sea Turtles

Sea turtles are long-lived animals with a world-wide oceanic distribution. Five species occur in our study area: the Loggerhead Sea Turtle (*Caretta caretta*), Leatherback Sea Turtle (*Dermochelys coriacea*), Kemp's Ridley Sea Turtle (Lepidochelys kempii), Hawksbill Sea Turtle (*Eretmochelys imbricata*), and Green Sea Turtle (*Chelonia mydas*). All are listed as threatened or endangered under the Endangered Species Act. As such, they are likely to be priority species for regulators during the environmental permitting process for offshore wind energy development. The mid-Atlantic region has large populations of a high diversity of turtles, but existing threats that could cause population declines (Wallace et al., 2011) include mortality from bycatch in fishing nets (Murray and Orphanides, 2013), collisions with vessels, especially those traveling at high speeds (Hazel et al., 2007), loss of nesting habitat to coastal development, and disturbance or destruction of nests by humans or other animals (Wallace et al., 2011).

Sea turtles are uncommon in European waters, so no information is available about their interactions with offshore wind facilities. Construction of offshore wind facilities has been identified as the period with the most potential risks for sea turtles, due to noise from pile driving and other activities, though the potential for injury or behavioral impacts remains largely unknown (Chapter 15; Michel, 2013). Green Turtles and Kemp's Ridley Turtles (Bartol and Ketten, 2006), Loggerhead Turtles (Martin et al., 2012), and Leatherback Turtles (Dow Piniak et al., 2012) all hear a relatively narrow range of low frequencies, with a maximum sensitivity in the range of ~100-500 Hz, which overlaps with the sounds produced by many human activities, including seismic studies, drilling, low-frequency sonar, shipping, pile driving, and operating wind turbines.

There were 1,862 sea turtles observed in total in boat and aerial surveys (1.5% of all wildlife observations). Digital video aerial surveys proved to be more effective than boat surveys at surveying sea turtle populations (Chapters 14-15; see also Normandeau Associates Inc. 2013), likely in large part because turtles could be detected even when they were fully submerged. Sea turtles were most abundant from May to October, with very few individuals present in the study area in winter (Chapters 15 and 17). Models predicted highest turtle densities in areas far from shore off of Virginia in spring, in areas with warmer sea surface temperatures; in summer, sea turtles were predicted to be distributed across a broader range, as females moved to shore to lay eggs on sandy beaches. Sea turtles were most widely distributed across the study area in fall, predominantly in offshore areas. In addition to water temperature, primary productivity and distance from shore were important influences on sea turtle densities (Chapter 15). There was substantial overlap between sea turtle distributions and areas of planned offshore wind energy development, particularly in the southern parts of the study area.

Context

- The effects of offshore wind development on sea turtles remain poorly understood, most notably in relation to noise and the potential for collisions with vessels.

Take home messages

- There may be species-specific differences in habitat use or movements that were not distinguishable in this study.

- Digital aerial surveys seem to have higher detection rates of sea turtles than other survey approaches, but application of newer technologies with improved species differentiation is needed.
- Construction of offshore wind energy facilities in mid-Atlantic WEAs is likely to occur in warmer months and sea turtles will be present during these periods.

Cetaceans

All cetaceans are protected under the Marine Mammal Protection Act, and most are also protected under the Endangered Species Act. The conservation status of marine mammals, and particularly baleen whale populations, has the potential to make them a priority regardless of their exposure or the risk of individual hazards. Acoustic disturbance from a variety of human activities is viewed as a high potential risk for all marine mammals (Bergström et al., 2014), and is known to increase physiological stress (Rolland et al., 2012), disrupt communications (Dilorio and Clark, 2010; Parks et al., 2007), cause significant avoidance behavior (Tougaard et al., 2009), and is associated with mass strandings (Frantzis, 1998). European studies have indicated that Harbor Porpoises (*Phocoena phocoena*) can hear pile driving noise from offshore wind construction over 80 km from the source, and the species showed displacement up to 20 km away during construction (Thomsen et al. 2006; Teilmann and Carstensen 2012). Results of operational displacement studies in Denmark and the Netherlands have varied (Scheidat et al. 2011; Teilmann and Carstensen 2012). There has been little or no detectable avoidance during operations at some facilities, while in at least one instance, porpoise acoustic activity levels were at only 29% of pre-construction levels nine years after construction had been completed (Teilmann and Carstensen 2012). Prey availability may be an important factor affecting porpoise behavior around operational wind facilities (Teilmann and Carstensen 2012), but more information is needed. Data on disturbance to large whales by other types of anthropogenic activities have also been examined (e.g., Mccauley et al. 2000; Tyack et al. 2011), but large whales are not common in European waters where development has occurred, so no information is available about their interactions with offshore wind facilities.

We observed 3,289 marine mammals in boat and aerial surveys. The majority (99%) were dolphins and porpoises, from at least five species. Bottlenose Dolphins were the most abundant delphinid in surveys, and were observed primarily in spring, summer, and fall (Chapters 15 and 17). Cold-tolerant Common Dolphins were most frequently observed in offshore areas in winter and early spring (Chapters 15 and 17). Distance from shore, primary productivity, and sea surface temperature were important predictors of Bottlenose Dolphin distributions. This is possibly because of their use of areas of high productivity for feeding, particularly in and around the mouths of the Chesapeake Bay and Delaware Bay, and their temperature-related migratory behaviors. Many of the Bottlenose Dolphins observed in this study may have been residents from coastal stocks, leading to the nearshore distribution patterns we observed. A more robust density gradient from west to east was observed in summer, possibly due to an influx of transient populations during the warmer period.

Migratory routes for many large whale species are poorly defined, though several are known to migrate through the mid-Atlantic between their wintering and breeding grounds (Firestone et al., 2008). North Atlantic Right Whales (*Eubalaena glacialis*), the most critically endangered of these species along the east coast of North America, have already spurred the development of additional mitigation measures to minimize the potential for adverse effects from offshore wind energy development in the mid-Atlantic[7]. We can provide limited information about potential exposure from this study, though our observations may be useful in combination with data from other studies. A total of 51 observations of large cetaceans were made between boat and digital aerial surveys, with 31 of the observations occurring in winter. We observed a total of nine North Atlantic Right Whales, all of which were observed in February and March, which is an important contribution to our knowledge for this species given their small population size and our lack of data on their movements and habitat use in the mid-Atlantic. We also observed endangered Humpback Whales and Fin Whales, as well as several other whale species.

Context

- Offshore wind energy facilities present significant increases in underwater noise during construction, which may affect all marine mammals. Our current lack of understanding of the hazards posed to baleen whales by offshore wind energy development make these species a particular concern for regulators in the U.S.

Take home messages

- Relatively little is known about migratory routes for many rare whale species in the mid-Atlantic, although data from this and other studies are beginning to fill this gap.
- Bottlenose Dolphins may be most likely to be exposed to development activities during summer and in the northern end of the study area, as well as in western areas of the mid-Atlantic WEAs in spring and fall. Common Dolphins have a more offshore distribution and may be particularly and spring.

Migration

Migration is a difficult phenomenon to study, particularly in offshore areas, but our study captured a number of migratory events through the mid-Atlantic study area. Over the course of this project, we employed several methods that documented the timing and routes of animal migrations through the mid-Atlantic region, including our analysis of weather radar (NEXRAD) data, the use of avian passive acoustic recorders, satellite telemetry, and boat and aerial surveys. If we are to fully understand the potential effects of offshore activities on wildlife populations, we need to determine when and where migration occurs, and what migratory species are likely to be exposed to offshore wind energy development in the region.

Rays

The Cownose Ray is a species of eagle ray that primarily eats mollusks and shellfish, and has a global conservation status of Near Threatened due to overfishing in regions of Central and South America (Barker, 2006), though it is not listed in the U.S. Many elasmobranchs can detect electromagnetic fields (EMF), which are produced by offshore wind power transmission cables (Gill et al., 2009; Normandeau Associates Inc. et al., 2011). Cownose Rays use electroreception to detect their prey, however their ability to detect and tendency to react to EMFs from sub-sea cables have not yet been determined (Boehlert and Gill, 2010; Smith and Merriner, 1985). In large groups, called "fevers", these rays migrate

[7] http://docs.nrdc.org/oceans/files/oce_12121101a.pdf

north and into inland bays, such as Chesapeake, to breed during the summer (Goodman et al., 2011). While their breeding habits are reasonably well known, the migratory period is poorly understood. However, digital video aerial surveys recorded immense migratory schools near the water's surface in the mid-Atlantic up to 75 km from shore; we observed almost 48,000 rays in the summer and fall (Chapter 5). The unexpected detection of these massive migrations is a reminder of how little we truly know about the migratory lives of many ocean creatures.

Bats

Bat fatalities have been regularly documented at terrestrial wind facilities in the U.S. (Arnett et al., 2008; Kunz et al., 2007), particularly for migratory tree-roosting species such as Eastern Red Bats (*Lasiurus borealis*). Bats are not commonly thought of as migrating offshore, but there is substantial anecdotal evidence for offshore movements in this taxon, particularly among migratory tree bats (Hatch et al., 2013), and fatalities have been documented at offshore wind facilities in Europe (European Environmental Agency, 2009). Seventeen Eastern Red Bats, were detected up to 70 km from shore in this study during both boat and aerial surveys (Chapter 17; Hatch et al., 2013). Of these, fourteen were seen on a single day of aerial surveys. They were observed flying during the day, and those that had estimable flight heights were estimated to be flying higher than 200 m above sea level (Chapter 17; Hatch et al., 2013), both unexpected behaviors for this taxon in the offshore environment.

Songbirds

The movements of individual songbirds can be difficult to track because of their small body size. They also migrate at night, making the study of their migrations particularly difficult. Weather radar can detect migratory activity in the atmosphere, which allowed us to document broad-scale geographic and temporal patterns of nocturnal migrants in the offshore environment (Chapter 27). Nocturnal acoustic sensors deployed on the survey boat also allowed us to identify some of the species making these flights (Chapter 26). In this study, nocturnal migrants, including songbirds and shorebirds, regularly flew over open water, and this was particularly true in the fall, when offshore migratory activity was often higher than over land. For many songbirds, expansive areas of open water on the Outer Continental Shelf may not be the barrier to movement that we previously thought which increases the concern for effects of offshore development on these species during critical migration periods.

Falcons

The Peregrine Falcon is the world's fastest animal, and their aerial dexterity allows them to catch small birds on the wing. This ability, coupled with physical stamina, allows them to migrate over large expanses of the Atlantic Ocean. Our satellite telemetry data indicated that though Peregrine Falcons often migrated relatively close to shore, individuals were capable of flying hundreds of kilometers offshore (Chapter 25) and staying in those areas for weeks. They are able to fly for several consecutive days over open water, soar and forage at night, and often roost on offshore structures and vessels (Cochran, 1975; Desorbo et al., 2012; Johnson et al., 2011; Voous, 1961). During migration, Peregrine Falcons primarily prey on other migrating birds, like songbirds and shorebirds (White et al., 2002). It is possible that falcon migratory routes in offshore areas are dictated by the migratory paths of their prey.

Context

- The consequences of interactions between migratory wildlife and offshore wind facilities are unclear. Some species may have increased collision risk. Others may have increased energetic expenditures from avoidance during migratory movements, although these effects will depend on the scale and number of offshore wind facilities along a migration route.

Take home messages

- Our research suggests that a wide variety of animals migrate through areas that have been proposed for offshore wind energy development in the mid-Atlantic region. Additional research on migrant populations may be warranted for sites proposed for development or other offshore activities.

Discussion

This study provides a unique baseline dataset on the distributions, movements, habitat use, and relative abundance of wildlife on the mid-Atlantic Outer Continental Shelf, between about 5 and 85 km from shore. The mid-Atlantic study area is a complex ecosystem with highly variable temporal and geographic patterns, driven in part by the influence of the Gulf Stream to the east, and the Chesapeake Bay and Delaware Bay to the west. This study's boat and digital aerial surveys, individual tracking studies, and nocturnal avian migration studies provide the most comprehensive view to date of offshore wildlife populations in this region. The complexity of resulting datasets, as well as the differing and often complementary information provided by different study methodologies, have necessitated the development of a suite of analytical approaches for comparing and integrating data for use in decision making.

These varied approaches have led to several key conclusions for the mid-Atlantic study region, including:

- Boat-based surveys and digital aerial surveys each have specific advantages and disadvantages, but are largely complementary. Digital aerial surveys are particularly useful for covering offshore areas at broad scales, where general distributions of taxonomic groups are a priority; boat surveys can provide more detailed data on species identities and behaviors, but are more limited in geographic scope due to their slower survey pace (Chapters 1, 6, 13 and 19).
- Habitat gradients/fronts located in nearshore waters (near the mouths of Chesapeake Bay and Delaware Bay) are important influences on productivity and patterns of species distributions and abundance. Areas offshore of the mouths of these bays, as well as to the south of Delaware Bay along the coast, were consistent hotspots for relative abundance of many taxa, regardless of survey methodology or analytical approach.
- There is considerable variation in species composition and spatial patterns by season. As well as being a focus for wintering and breeding seabirds, the location of the study area (the central sector of the eastern seaboard) makes it a key migratory corridor. Dynamic environmental conditions also contribute to wide variation in community composition and seasonal patterns of wildlife in the region.

Regional context

Several assessments of wildlife distributions along the Atlantic coast of the United States have contributed to ecosystem-based marine spatial planning efforts in recent years, and provide context for our findings in the mid-Atlantic. In particular, baseline studies offshore of New Jersey in 2008-2009 (Geo-Marine Inc., 2010a, 2010b) and Rhode Island in 2009-2012 (Paton et al., 2010; Winiarski et al., 2012) have provided comparable datasets to the contribution that we make in this study for areas offshore of Delaware, Maryland and Virginia. Additional efforts are currently ongoing for cetaceans offshore of Maryland (S. Barco, pers. comm.) and along the entire eastern seaboard (Northeast Fisheries Science Center and Southeast Fisheries Science Center, 2013).

Assessments of historical data have also occurred in recent years; the Northwest Atlantic Seabird Catalog (formerly known as the Compendium of Avian Information) includes most of the data collected on seabird and shorebird distributions on the Atlantic Outer Continental Shelf over the past 40+ years (O'Connell et al., 2011, 2009). The Catalog includes data for other taxa as well, and similar datasets are also available for cetaceans and sea turtles (e.g., Kenney, 2011). The Ocean Biogeographic Information System-Spatial Ecological Analysis of Megavertebrate Populations (OBIS-SEAMAP) is another large compendium of data, which includes distribution, abundance, and telemetry data for marine mammals, seabirds, and sea turtles over multiple decades (Fujioka et al., 2014; Halpin et al., 2009). These databases have been used in Rhode Island (Kenney and Vigness-Raposa, 2010), New York (Kinlan et al., 2012a; Lagueux et al., 2010), and the South Atlantic Bight, offshore of the Carolinas, Georgia, and Florida (Michel, 2013), among other locations (Best et al., 2012), to assess wildlife distributions and abundance and identify data gaps.

Seabirds

Based on a subset of the Northwest Atlantic Seabird Catalog data, primarily from the 1980s, Kinlan et al. (2012) found distributions of marine birds offshore in the New York Bight to be broadly similar to this study, with some species groups showing strong nearshore distributions (e.g., sea ducks, terns, small gulls), some using the offshore environment more broadly (e.g., Northern Gannet, large gulls), and others displaying consistently offshore distributions (e.g., alcids, jaegers, and storm-petrels). Catalog data for the mid-Atlantic also indicate similar patterns to those derived from our more recent boat and aerial survey data. In Catalog datasets, Red-throated Loons and scoters were observed nearshore and primarily in the winter, for example, while Northern Gannets were seen in high densities in the fall, winter, and spring throughout much of the study area (O'Connell et al., 2009). The species of seabirds observed, along with the timing of their peak abundances and the inshore vs. offshore patterns of their distributions, were largely similar to our findings, though we saw fewer shearwaters and Wilson's Storm-Petrels than would be indicated based on the data in the Catalog. It is important to note when examining these Catalog data, however, that they cover a very broad time range, and seabird distributions could have changed since the 1970s (O'Connell et al., 2009).

Based on a review of existing data, similar species composition and distributions have also been reported for the South Atlantic Bight. Common Loons are more abundant than Red-throated Loons in the region, for example, with the latter having a more inshore distribution (Jodice et al., 2013). Data from this region include fewer alcids than the mid-Atlantic, however, and a greater variety of more southerly species, including *Pterodroma* petrels, a greater diversity of storm-petrels, tropicbirds, and boobies (Jodice et al., 2013). In general it appears that marine bird abundance may be lower in the South Atlantic Bight, likely because oceanographic features tend to not create consistent or predictable areas of increased productivity, and bathymetric features that do exist are farther offshore (Jodice et al., 2013). Regular pelagic surveys have not been conducted in this study area, which may also be a factor (Jodice et al., 2013).

Perhaps the most similar recent avian study efforts to our mid-Atlantic Baseline Studies are the New Jersey Department of Environmental Protection's boat and visual aerial surveys offshore of New Jersey in 2008-2009 (Geo-Marine Inc., 2010a) and the Rhode Island Ocean Special Area Management Plan's boat and visual aerial surveys in 2009-2012 (Paton et al., 2010; Winiarski et al., 2012). Both studies obtained some data on avian flight heights in the offshore environment, although these data were derived from visual observations during boat surveys rather than using parallax in digital video aerial surveys (Hatch et al., 2013), and thus are likely biased towards somewhat lower altitude bands than the aerial data from our study. The New Jersey study defined the potential rotor-sweep zone for offshore turbines as 31-213m (100-700 ft), and found that 4.8% of observed individuals recorded during shipboard surveys occurred in this range (Geo-Marine Inc., 2010a). Rhode Island surveys suggested 6% of observations occurred at 25-125m in altitude and <1% at >125m, although these percentages included birds on the water's surface as well (22% of all observations; Paton et al., 2010). In contrast, our aerial survey data for the mid-Atlantic suggested that 38% of flying birds occurred between 20 and 200 m in altitude, a rotor-sweep zone range that was used in one recent study to cover a variety of possible turbine types and tidal effects (Willmott et al., 2013). In all three studies, however, the highest percentage of bird observations occurred below the potential range of rotor-sweep zone heights.

The New Jersey study indicated that avian densities were highest in nearshore regions during all seasons, although the pattern was more pronounced in winter than in summer, due to differences in community composition between seasons. Winter avifauna was dominated by inshore-foraging species (e.g., scoters and Laughing Gulls, *Leucophaeus atricilla*), while the summer community included more offshore foraging species, with predictive models indicating distributions that were farther offshore and in deeper waters (Geo-Marine Inc., 2010a). This is a different pattern than observed south of New Jersey in our study, despite similar species compositions noted in both studies; Common Terns, for example, were considered to be "offshore foragers" during summer in the New Jersey study, while breeding Common Terns clearly were foraging in relatively nearshore areas in our study as compared to many other species (Chapter 17). In our mid-Atlantic study, winter was the period of highest avian abundance, and winter distributions tended to be farther offshore than summer distributions (Chapter 12), although these patterns varied substantially between years.

The Rhode Island study found that nearshore, shallow waters were important to a broad range of species (though it should be noted that in addition to offshore survey data, this dataset relied heavily on land-based seawatches, which by their nature will suggest higher abundance near the coast). Nearshore waters were important in summer for terns, gulls, shorebirds; in winter, sea ducks and loons were also commonly observed during surveys. Species that relied on the ocean for food year-round (such as shearwaters, storm-petrels, and Northern Gannets) tended to be distributed farther offshore than species that only used the ocean during part of their annual cycle (including loons, grebes, and waterfowl; Paton et al., 2010). In general, species guilds and seasonal distribution patterns were similar between Rhode Island and our mid-Atlantic study area. Fewer species were detected in Rhode Island boat surveys than in our mid-Atlantic boat surveys, however, and species composition was slightly different, as would be expected based on the two studies' different latitudes and bathymetry. For example, Black-legged Kittiwakes (*Rissa tridactyla*) were much more common in offshore areas of Rhode Island in winter than they were anywhere within our mid-Atlantic study area. This is likely in part because kittiwakes were mostly observed in >50 m water depths in Rhode Island, while our maximum water depths in the mid-Atlantic were <40 m. Fewer species and guilds were observed in Rhode Island aerial surveys as compared to our mid-Atlantic aerial surveys, as well, though species compositions were broadly similar, with the exception of Common Eiders, a common species in New England that is largely absent from the mid-Atlantic.

In Rhode Island boat surveys, 94% of avian observations were identified to species, as compared to 72% in our study (Chapter 14). Large flocks of Black Scoters and Surf Scoters greatly reduced this identification rate in the mid-Atlantic, which otherwise was 97% for boat surveys. Visual aerial surveys in 2009-2010 in Rhode Island had a species identification rate of 62% (Paton et al., 2010), as compared to 45% in digital video aerial surveys, a rate that was likely influenced by a range of factors (Chapters 1 and 14).

Winter surveys in Rhode Island detected fewer species and lower abundance than summer or fall (though Northern Gannet and Common Loon detections were highest in winter). Fall was the period of highest species diversity in the mid-Atlantic boat surveys, but winter was the period of highest abundance in our study area. Northern Gannets, while a common migrant in Rhode Island waters in spring and fall, appeared to be a much more common winter resident in mid-Atlantic waters. Sea ducks were commonly observed in Rhode Island surveys, but at nowhere near the relative abundance we observed in the mid-Atlantic, where scoters were much more abundant than any other avian taxon in both boat and aerial datasets. In both studies, however, there were large amounts of interannual variation in abundance for sea ducks, and they were consistently observed foraging in areas <25 m deep.

Both studies found Common Loons and Red-throated Loons to be common in winter; offshore of Rhode Island, most loons were observed in nearshore waters <35 m deep, but, as this was essentially the same depth range as our entire study area, we cannot determine whether loon distributions dropped off in deeper waters in the mid-Atlantic (although Red-throated Loon distributions in our study area, at least, were distinctly skewed towards nearshore and shallow waters). The same six species of alcids were observed by both studies in winter; spatial segregation between species was observed in Rhode Island, with Razorbills (*Alca torda*) specializing in shallower areas closer to land, Common Murres (*Uria aalge*) in central latitudes, and Dovekies (*Alle alle*) appearing to be offshore specialists. The alcid data in the mid-Atlantic was more difficult to parse to species, particularly the digital aerial survey data, but there was some indication that Dovekies were distributed farther offshore than Razorbills (Chapter 12).

Herring Gulls (*Larus argentatus smithsonianus*) were the most common species observed offshore of Rhode Island, particularly near summer breeding colonies and dispersed offshore in fall. Observations of this species in the mid-Atlantic were less common relative to scoters and other taxa, and seldom occurred in summer (Chapter 17), possibly because the species was located almost exclusively in state waters west of the survey area. Terns were commonly observed in summer in nearshore areas in both studies, though most terns in Rhode Island were observed by land-based observers rather than on boat or aerial surveys. Roseate Terns were almost exclusively detected in land-based point counts in Rhode Island, despite targeted boat surveys for this species in late summer, and although >100 individuals were regularly observed on Block Island in August, suggesting regular passage across Block Island Sound (Paton et al., 2010).

Bathymetry was an important driver of distributions in the Rhode Island study area. Many more sea ducks were observed in Nantucket Sound in the mid-2000's (as cited in Paton et al. 2010) than in the Rhode Island surveys in 2009-2010, and the authors suggest that this is because Nantucket Sound is mostly <20 m deep. In contrast, many species that were observed and used deeper waters in Rhode Island were not observed at all in Nantucket Sound (Paton et al., 2010). Study authors concluded that bathymetry drove patterns in water temperatures, circulation, productivity, and other variables offshore of Rhode Island, and that water depth was an important driver of distribution, abundance, and species composition of seabirds as a result. Despite the much greater numbers of sea ducks observed in the mid-Atlantic compared to Rhode Island, we suspect that bathymetry is a similarly important driver of avian distributions in our study area, with sea ducks common in shallow (nearshore) areas, and offshore specialists more common in deeper waters. Water depth and distance to shore are highly collinear in the mid-Atlantic study area, and in many cases in this report we refer to "nearshore" areas being important for many species. However, Rhode Island distribution data suggest that it is bathymetry, rather than distance to shore, that is actually driving these distributions for many species. The exception is likely to be birds breeding on the shoreline west of the study area in summer, whose foraging ranges are limited by distance from their breeding locations.

Avian migration patterns

Thirty four species of landbirds and passerines were detected in land based seawatches during the Rhode Island study; many fewer species were seen from boat, with the most common being Tree Swallows (*Tachycineta bicolor*). Swallows, including Purple Martins (*Progne subis*) were also the most common of the 29 passerine, raptor, and other landbird species observed in mid-Atlantic boat surveys (Chapter 8). A slightly different species composition was detected during passive acoustic monitoring from the survey vessel at night, where migratory flight calls were mostly identified as finches, thrushes, and warblers (Chapter 26).

NEXRAD studies in New Jersey indicated that nocturnal avian migratory activity over the ocean was higher in the fall than in the spring (Geo-Marine Inc., 2010c), which was also clearly evident on our study (Chapter 27). The New Jersey study also indicated that nearshore bird densities were higher than offshore bird densities in both spring and in fall, however. Our mid-Atlantic study, which corrected for biases in measured reflectivity caused by distance from the radar unit, predicted offshore migratory activity in fall to be as high or higher than levels of migratory activity at many onshore locations.

Marine mammals and sea turtles

Existing data on marine mammals and sea turtles from the Atlantic coast of the U.S. suggests largely similar patterns to what was observed during our study, although community composition differs between locations, in large part in relation to water temperature and bathymetry. Data from the South Atlantic Bight, for example, include the same five sea turtle species observed in our mid-Atlantic study area, and Loggerhead Sea Turtles were also the most abundant species in the South Atlantic (Read, 2013). Loggerheads are present in the region year-round, however, which appears not to be the case in the mid-Atlantic (Chapters 15 and 17). Sea turtles were much more abundant in the mid-Atlantic study area than in the New York Bight or southern New England, however, particularly in spring and fall, likely due to warmer ocean temperatures than in more northern latitudes (Chapters 15 and 17; Kenney and Vigness-Raposa, 2010; Lagueux et al., 2010). Species diversity may likewise be higher in the mid-Atlantic during these months, based on existing data for New England and New Jersey (Geo-Marine Inc., 2010b; Kenney and Vigness-Raposa, 2010), although none of these other recent efforts used digital aerial survey approaches, and their results for sea turtles are thus not directly comparable to those presented in this report.

As in the mid-Atlantic, the highest abundances of Bottlenose Dolphins offshore of New Jersey were predicted in spring and summer, and Common Dolphins in winter and spring (Chapters 15 and 17; Geo-Marine Inc., 2010b). Interestingly, the New Jersey study observed lower abundance of Bottlenose Dolphins during the fall months, speculating that observed coastal populations moved south of New Jersey during this time. Our study provides some corroboration for this idea, as we observed sustained abundance of Bottlenose Dolphins during this season, with highest encounter rates predicted in nearshore regions (Chapters 15 and 17). An online cetacean habitat modeling systems for the US east coast, based on ship-based and visual aerial survey data from OBIS-SEAMAP, predicted similar cetacean species in the mid-Atlantic study area to what we observed, with inshore Bottlenose Dolphin distributions being driven by water depth and specific SST ranges in the spring (Best et al., 2012).

Rare large whale species, including the North Atlantic Right Whale, Humpback Whale, and Fin Whale, are observed in southern New England primarily in spring, summer and fall, while in our study the majority of animals were seen in winter (Kenney and Vigness-Raposa, 2010). All Right Whales, for example, were observed in the mid-Atlantic study area February or March, presumably during the earlier part of their northward spring migration (Chapters 15 and 17). It should be noted, however, that studies that include passive acoustic surveys for whales (e.g., Geo-Marine Inc., 2010a; Rice et al., 2014) have found these species present year-round within their study areas, and an ongoing passive acoustic study offshore of Maryland may confirm that the same is true in the mid-Atlantic (Bailey and Rice, 2015).

As in more northerly survey locations, cetacean species that tend to occur at or beyond the continental shelf break (such as beaked whales, some types of sperm and pilot whales, and several species of dolphin) are probably most likely to be found to the east of our study area, though they may be exposed to underwater noise from development activities within the study area (Kenney and Vigness-Raposa, 2010). Cetacean abundance was predicted to be higher near the shelf break and offshore of the Outer Continental Shelf than in nearshore areas in the New York Bight (Lagueux et al., 2010), and the same may well be true in the mid-Atlantic.

Using data from this project in permitting and decision making

Baseline studies along the U.S. Atlantic coast have generally found that, with the possible exception of marine mammals (above), overall abundance and species diversity tends to be highest in shallow water areas (which in many cases are coincident with areas closer to shore, though not always). Results from these studies have been used to identify areas of high biodiversity and priorities for conservation, ultimately influencing the choice of lease sites for offshore wind development. For example, the Rhode Island Coastal Resources Management Council identified *Areas Designated for Preservation*, and prohibited large-scale offshore developments and other activities (including, but not limited to, offshore wind) in areas of 20 m or less in water depth, specifically to preserve foraging habitat for sea ducks (Rhode Island Coastal Resources Management Council, 2013). In other locations along the east coast, the specific areas offered for offshore wind energy development leases (e.g., included in WEAs) have also been determined in part via the use of wildlife distribution and abundance data[8].

Results from this project represent a baseline that can be used for comparison with compatible future surveys, and to assess changes in offshore populations due to development or other causes. This study is an important first step towards understanding the implications of offshore wind energy development for bird, marine mammal, and sea turtle populations in the mid-Atlantic. These data on the geographic distributions and relative abundance of wildlife in the mid-Atlantic are expected to be useful for minimizing impacts to wildlife populations from offshore wind energy development in that they can be used to (1) help inform the siting of future projects, (2) address the environmental permitting requirements for current and future projects, and (3) inform the development of mitigation approaches aimed at minimizing potential effects. Exposure to offshore development does not necessarily indicate that exposed animals will suffer deleterious effects, however, or that effects will translate to population-level impacts. Siting and permitting future projects, as well as other efforts to minimize potential effects, will rely on the baseline data collected in this study, but must move beyond these initial steps to focus on species most likely to be impacted due to their conservation status or other factors.

[8] www.boem.gov/BOEM-Newsroom/Press-Releases/2012/press05302012.aspx

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