Chapter 2: Synthesis of project findings

Final Report to the Maryland Department of Natural Resources and the Maryland Energy Administration, 2015

Kathryn A. Williams[1], Iain J. Stenhouse[1], Sarah M. Johnson[1], Emily E. Connelly[1], Holly F. Goyert[2], Andrew T. Gilbert[1] and M. Wing Goodale[1]

[1]Biodiversity Research Institute, Portland, ME
[2]North Carolina State University, Department of Forestry and Environmental Resources, Raleigh, NC

Project webpage: *www.briloon.org/mabs*

Suggested citation: Williams KA, Stenhouse IJ, Johnson SM, Connelly EE, Goyert HF, Gilbert AT, Goodale MW. 2015. Synthesis of Project Findings. In: Baseline Wildlife Studies in Atlantic Waters Offshore of Maryland: Final Report to the Maryland Department of Natural Resources and the Maryland Energy Administration, 2015. Williams, KA, Connelly, EE, Johnson, SM & Stenhouse, IJ (Eds.) Report BRI 2015-17, Biodiversity Research Institute, Portland, Maine. 33 pp.

Acknowledgments: This material is based upon work supported by the Maryland Department of Natural Resources and the Maryland Energy Administration under Contract Number 14-13-1653 MEA, and by the Department of Energy under Award Number DE-EE0005362.

Disclaimers: The statements, findings, conclusions, and recommendations expressed in this report are those of the author(s) and do not necessarily reflect the views of the Maryland Department of Natural Resources or the Maryland Energy Administration. Mention of trade names or commercial products does not constitute their endorsement by the State.

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

bri NC STATE UNIVERSITY

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 as part of the Maryland and Mid-Atlantic Baseline Studies (MABS) Projects. Despite focused studies along the Atlantic coast in recent years, the MABS and Maryland Projects fill a significant information gap for a large swath of the Mid-Atlantic region, a complex ecosystem with highly variable temporal and geographic patterns that provides important habitat for a wide variety of marine wildlife over the course of the year.

The breadth of the Mid-Atlantic region was used during spring and fall migration by seabirds, landbirds, sea turtles, cetaceans, rays, and other taxa. Many of these taxa were also part-time or year-round residents in the region, using it for foraging during the breeding season, or for foraging, roosting, and other activities during non-breeding periods. Despite seasonal variation in habitat characteristics, areas near the mouths of the Chesapeake Bay and Delaware Bay remained important for many different taxa throughout the year. Boat and aerial surveys 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 were likely attractive to a wide variety of high trophic-level species, due to their consistently higher primary productivity relative to the broader region. 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 this area as part of the Maryland Project as compared to elsewhere in the MABS study area. These results are discussed in context with other recent baseline studies along the eastern seaboard, which generally found that distribution patterns of wildlife were largely driven by bathymetry, as well as other environmental and oceanographic factors.

Exposure to offshore development 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-level effects. We lack the necessary data to develop reliable risk analyses for most species in relation to offshore wind energy development, despite recent advances in Europe. However, the seasonal data on wildlife species composition, distributions, and relative abundance we present in this report are essential for providing a baseline understanding of when and where animals may be affected by anthropogenic activities, and for identifying species or taxa of particular interest for future study. We present several case studies on Northern Gannets (*Morus bassanus*), Red-throated Loons (*Gavia stellata*), scoters (*Melanitta* spp.), endangered birds, sea turtles, and cetaceans, and discuss this study’s data on exposure in the context of relevant findings from the scientific literature.

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 development and 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 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).

Since 2009, the Maryland Department of Natural Resources and the Maryland Energy Administration have been working with resource experts and user groups to compile data and information on habitats, human uses, and resources off the Atlantic coast of Maryland[1]. Using existing 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.

A number of other products and databases have been developed by other states and organizations, and are specifically designed to compile existing marine wildlife data for the western North Atlantic for use in marine spatial planning, 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[2], 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[3], Mid-Atlantic Regional Council on the Ocean, MARCO[4], and the Governors' South Atlantic Alliance, GSAA[5]). 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 also 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 visual aerial surveys and boat-based surveys to collect broad-scale data on the seasonal distribution and abundance of marine wildlife across the Atlantic Outer Continental Shelf from Florida to Maine (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 broad scale study in 2008-2009 – the Ocean/Wind Power Ecological

[1] www.dnr.state.md.us/ccs/coastal_resources/oceanplanning
[2] www.marinecadastre.gov
[3] www.northeastoceancouncil.org
[4] www.midatlanticocean.org
[5] www.gsaaportal.org

Baseline Studies – to determine the distribution of wildlife species and their use of offshore waters, and identify 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 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 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 comprehensive strategy for zoning Rhode Island's offshore waters used an ecosystem-based approach and was designed to help develop policy through both scientific research and public input (Winiarski et al., 2012). In order to plan for renewable energy development offshore of Virginia, the Virginia Aquarium and Marine Science Center and the University of North Carolina Wilmington conducted a study on whale migration off Virginia's coast between 2012 and 2013, employing visual aerial surveys and boat-based surveys for dolphins, sea turtles, and large whales (Brown-Saracino et al., 2013). A similar study is currently ongoing offshore of Maryland (S. Barco pers. comm.).

Despite these and other focused studies along the Atlantic coast in recent years, there remain several geographic holes in recent survey activities and data collection that must be filled for effective marine spatial planning efforts to occur in those areas. The Maryland Project and the companion Mid-Atlantic Baseline Studies Project, described here, fill a significant information gap for a large swath of nearshore waters in the Mid-Atlantic region between New Jersey and North Carolina (study methods are described in Chapter 1). This area (referred to as the MABS or regional study area hereafter, which includes surveys conducted for both Maryland and MABS projects) includes three federally designated Wind Energy Areas (WEAs) for which there were limited data on the distribution and relative abundance of wildlife prior to this study. The Maryland study area, as referred to elsewhere in this document, indicates a specific subset of the MABS survey area located in marine waters offshore of Maryland (Figure 2-1). Our 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 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 in the region begin to rise, and salinity in 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). Primary production decreases overall across the Outer Continental Shelf, however, 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 9). During this time, wintering seabirds departed the region to begin their migrations towards breeding grounds inland or to the north. Additionally, songbirds and shorebirds migrated through the region both along the coast and over open waters, (Chapter 11). 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, 7, and 11). Spring also marked the arrival of Bottlenose Dolphins (*Tursiops truncatus*) and a variety of sea turtle species, which were predicted to occur in highest densities offshore of Virginia (Chapter 12).

Summer

During summer (June-August), the sea surface in the Mid-Atlantic warms to peak temperatures (generally ranging from 20-30˚C; Chapter 9), forming a strong thermocline (Castelao et al., 2010). In shallow waters close to shore, high temperatures may persist throughout the entire 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 the summer, chlorophyll *a* 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). Hydroacoustic surveys 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 9). Breeding seabirds were found foraging near the shore and near the mouths of the bays (Chapters 9 and 11); specifically, terns (including Common Terns, *Sterna hirundo*, and others), were predicted to be associated with nearshore habitat (Chapters 13-14). 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 continental shelf (Chapter 11). In early summer, large numbers of Cownose Rays (*Rhinoptera bonasus*) migrated through the regional study area on their way to feeding grounds in Chesapeake Bay and Delaware Bay (Chapter 5; Blaylock 1993). Sea turtles and Bottlenose Dolphins were most abundant across the regional study area in the summer, with distributions influenced by sea surface temperatures and primary productivity. Bottlenose Dolphins were predicted to occur primarily in nearshore areas (possibly because most of the individuals observed in this study were residents from coastal stocks; Kenney, 1990), while sea turtles were still more common in the southern parts of the regional study area (Chapter 12).

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, and 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 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 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 in the Maryland 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 11). Seabirds continued to be more associated with nearshore habitats as compared to winter and spring (Chapter 9). Landbirds, shorebirds, and bats were recorded flying over open waters as they migrated through the regional study area (Chapter 11; Adams et al., 2015a; Hatch et al., 2013). Alcids moved into the study region in the fall (Chapter 11). Large schools of baitfish were also observed in the regional study area, particularly on the Maryland Project transects, though they were found on the more nearshore transects all along the coast (Chapters 8 and 11). 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 region in the fall. Sea turtles remained in the regional study area and offshore of Maryland through October (Chapter 12), and were most abundant in the Maryland study area during this season. Bottlenose Dolphins remained until late fall, while Common Dolphins (*Delphinus delphis*) largely arrived in the regional study area in November (Chapters 11-12).

Winter

During winter (December-February), sea surface temperatures are at their lowest and least variable across the region, 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 region, though there was variation in distribution patterns among species (Chapters 9, 11, and 14) and individuals. Northern Gannets were the most ubiquitous seabird in the regional 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 9 and 11). Scoters were observed in large aggregations at the mouths of Chesapeake Bay and Delaware Bay (Chapter 11). Common Loons (*Gavia immer*), in contrast, were most often observed individually and were widely dispersed throughout the regional study area, generally more associated with lower sea surface temperatures (Chapter 11; Hostetter et al., 2015). Many Bonaparte's Gulls (*Chroicocephalus philadelphia*) were observed in the region in winter (Chapters 5, 7, and 11). Alcids were predicted to occur in small numbers throughout the regional study area (Chapter 14). Baleen whales were most commonly observed during this season; of the 51 large whales observed within the regional study area during surveys (2012-2014), 31 were observed between December and February (Chapters 11-12). Common Dolphins occupied habitat throughout the regional study area during the winter, predominantly in offshore areas (Chapters 11-12).

Table 2-1. Seasonal habitat use of major taxonomic groups within the Mid-Atlantic regional study area. While there is no single definition for each season, as the life history periods of specific species vary, 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. "Report chapters" refer to chapter numbers from this report, as well as citations of chapters from a companion report to the Department of Energy (Williams et al., 2015b).

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, 7, 9, 11, and 13-14 Meattey et al., 2015 Gray et al., 2015 Stenhouse et al., 2015
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, 7, 9, 11, and 13-14
Songbirds and other landbirds	Migrate through study area	Small flocks of swallows (Hirundinidae) and individuals of other landbirds observed across study area	Migrate through study area	Few individuals observed	7 and 11 Chilson et al., 2015 Desorbo et al., 2015 Adams et al., 2015
Shorebirds	Migrate through study area	Generally not present; few individuals observed throughout study area	Migrate through study area	Few individuals observed	7 and 11 Chilson et al., 2015 Adams et al., 2015
Bats	--	--	Migrate through study area	--	11, Hatch et al., 2013
Baleen whales	Migrate through study area	--	Migrate through study area	Observed throughout study area	5, 7, and 11-12
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, 7, and 11-12
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	--	10-12
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 and 10-11
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	8 and 10-11

Persistent patterns

Despite seasonal variation in habitat characteristics, areas near the mouths of Chesapeake Bay and Delaware Bay remained important for many different taxa throughout the year. Specifically, nearshore waters adjacent to and directly south of the bay mouths (roughly within 20-30 km of shore) consistently showed high species diversity and abundance of animals across all taxa observed in this study (Figure 2-1). The Maryland study area, and in particular the nearshore area in northern Maryland, also included both overall abundance and species richness hotspots. These nearshore areas were likely attractive to a wide variety of high trophic-level species, such as seabirds and marine mammals, due to greater foraging opportunities arising from consistently higher primary productivity relative to the regional study area (Chapter 1). This primary productivity forms the base of the pelagic food chain on which nearly all species observed during this study rely; thus, areas near the mouths of the bays probably provide important foraging habitat for species year-round.

While the area offshore of northern Maryland was likely a real hotspot for many species, it also may have emerged as an important habitat use area in part because this was the only region in which boat and video aerial surveys were conducted in state waters (e.g., within three nautical miles of the shoreline), as well as the only area with high density aerial survey transects in nearshore federal waters (e.g., between state waters and the WEA). Similar surveys were not conducted in nearshore or state waters elsewhere during this study. Gulls and terns, for example, both showed persistent hotspots in this area in Maryland, and this pattern was likely in large part due to the nearshore survey effort expended in this area.

Avian taxa with persistent hotspots in the Maryland study area included Red-throated Loons, primarily to the west of the Maryland WEA; Common Loons, in areas between roughly 10 and 40 km from shore (both inside and outside the WEA); storm-petrels, both inside and outside of the WEA; Northern Gannets, with persistent hotspots throughout the Maryland study area; alcids, primarily in offshore areas south of the WEA; and gulls and terns, particularly in nearshore areas in the western part of the Maryland study area (Chapter 11). Persistent hotspots of ray aggregations and delphinids occurred throughout the Maryland study area, and particularly to the west and south of the Maryland WEA (Chapter 11); the pattern of Bottlenose Dolphin distributions predicted in Chapter 12 remained fairly consistent in spring, summer, and fall, with higher densities in the western half of the study area. Hotspots of turtle persistence occurred in offshore sections of the Maryland study area, but were less consistent than hotspots in the southern half of the MABS study area, offshore of Virginia (Chapter 11); seasonal model predictions from Chapter 12 suggest that sea turtles were most common in the Maryland study area in summer and fall.

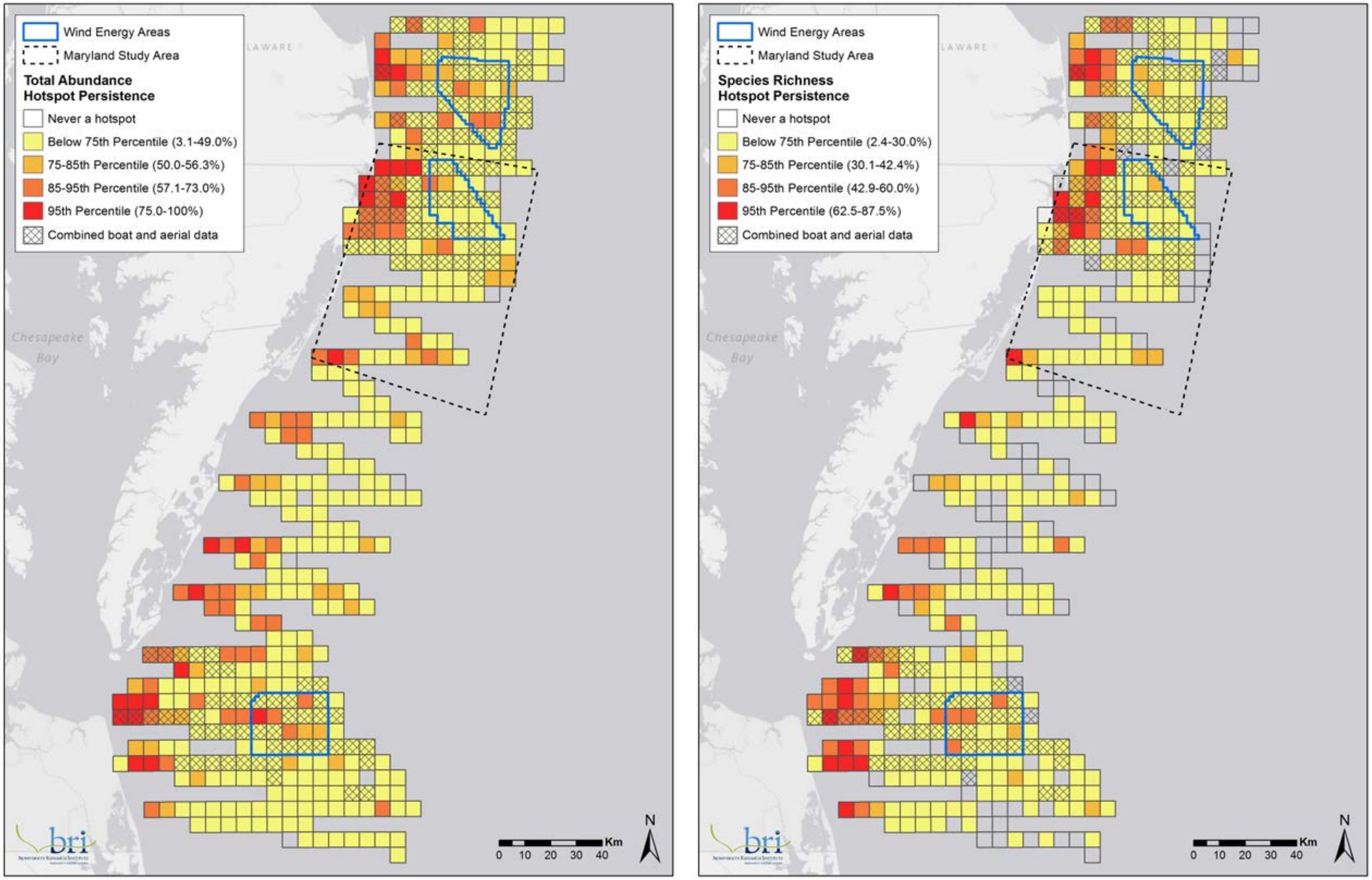

Figure 2-1. Persistent abundance hotspots across all taxa (left) and persistent species richness hotspots (right). These maps highlight areas where the greatest numbers of individuals across all taxa (left) and the greatest numbers of species (right) were consistently observed over the course of the study (Chapter 11). 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. Note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, individual grid cell persistence values should be interpreted with caution (for more information, see Chapter 11).

Interannual variation

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). Even on a shorter time scale the marine ecosystem is dynamic, 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). The Bureau of Ocean Energy Management (BOEM) suggests a minimum of two full annual cycles for offshore surveys prior to 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 (April 2012-May 2014), we found substantial variation in the community composition, distribution, and abundance of species observed (Chapters 9-10 and 13), as well as notable differences in environmental conditions. For example, we observed warmer waters in the second year of the study, possibly due to the influence of eddies from the Gulf Stream (warm core rings that meander north off of the main Gulf Stream over the Atlantic Outer Continental Shelf; Chapter 9). 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 7). Seabirds are generally patchily distributed in their environment (Fauchald, 2009), leading to some level of variation in observations between survey platforms and years. Scoters, however, also responded to their environment differently between the two years, perhaps due to warmer water temperatures in 2013 (Chapter 9), 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 9 and 13). 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 allow for more complete characterization of the expected levels of variability in these patterns. It should be noted, too, that the Maryland Project transects were only surveyed in the second year (2013-2014), which would likely influence the numbers of animals observed, particularly in the nearshore environment.

Determining and interpreting risk

The seasonal baseline data on community composition, species distributions, and relative abundance provided by this study are essential for understanding when and where animals may be affected by anthropogenic activities. 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 the exposure of animals that are present.
- *Hazards* posed to individuals that are exposed. Hazards can be direct (for example, collision mortality) or indirect (such as 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 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 effects (such as displacement) to a biologically meaningful metric (e.g., reproductive or survival impacts). 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 U.S. 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

Certain taxa are of likely regulatory concern for offshore wind energy development due to their conservation status in the U.S., or because they are known or suspected to interact with offshore wind facilities 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 in the Mid-Atlantic region based on the distribution data presented in this study.

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 U.S. (USFWS 2008), where they are abundant during non-breeding periods (Chapters 5, 7, and 9).

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 (Gilbert et al., 2015; Gray et al., 2015). These studies are still ongoing, but suggest that the greatest overlap between Red-throated Loon distributions and Mid-Atlantic WEAs may occur during migration periods, when movements were located farther offshore.

During boat and aerial surveys, 1,770 Red-throated Loons were observed in the regional study area (1% of all wildlife observations from surveys); 458 of these observations occurred within the Maryland study area (Chapters 5 and 7). This species was most common between November and May (Chapters 5, 7, and 11). In many cases, however, Red-throated Loons and Common Loons could not be distinguished in digital video aerial surveys, due to a greater overlap in 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 (Chapter 11; Hostetter et al., 2015). 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; Chapter 9). 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 flying below this range (Chapter 5).

Summary

- 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.
- In winter, Red-throated Loons were most commonly located west of the Mid-Atlantic WEAs (though recent telemetry studies suggest that they may be distributed farther offshore in the Mid-Atlantic during migration).

Northern Gannet

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, 7, and 9). 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% 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 (Gilbert et al., 2015; Stenhouse et al., 2015).

During the boat and aerial surveys in this study, 21,345 Northern Gannets were observed across the regional study area (17% of all wildlife observations); 2,825 of these observations occurred within the Maryland study area (Chapters 5 and 7). This species was most commonly observed between October and April (Chapters 5, 7, and 11). Northern Gannets roamed widely across the region in winter; 70% of the study area was categorized as a hotspot of gannet abundance in at least one survey (Chapter 11). The most persistent abundance hotspots for this species were located in nearshore waters along the length of the regional study area, however (Chapter 11). Survey data showed that Northern Gannets in the Mid-Atlantic generally used habitats closer to shore, often characterized by highly productive waters with lower sea surface temperatures and salinities and gentle seafloor slope (Chapter 9). 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).

Summary

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

- The broad-scale distribution and 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 habitat use areas for Northern Gannets 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 more 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 (*Melanitta perspicillata*) and White-winged Scoter (*M. 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 to these species include habitat degradation, oil spills, human disturbance (such as disturbance from high-speed ferries) and commercial shellfish harvests (Anderson et al., 2015; BirdLife International, 2015). All three species use the Mid-Atlantic study area in large numbers during their nonbreeding period (Chapters 5 and 7), 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 (Schwemmer et al., 2014; Williams et al., 2015a).

Scoters were the most abundant avian genus observed over the course of the study, with 43,339 individuals observed (25% of all wildlife observations), 3,468 of which occurred within the Maryland study area (Chapters 5 and 7). This genus was most abundant in the Mid-Atlantic between October and May (Chapters 5, 7, and 11). 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. 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.

Survey data showed that scoters used habitat characterized by shallow nearshore waters with high primary productivity (Chapters 9 and 11). 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 11). In the Mid-Atlantic, scoter distributions appear to be mainly located closer to shore than most proposed offshore wind energy development (Chapters 9 and 11;

Meattey et al., 2015). 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).

Summary

- Based on European studies, scoters may be displaced from areas around offshore wind facilities for some period of years following construction.
- 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 the prey base of terns 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 video aerial surveys, so it is possible that additional individuals of these listed species were observed and were not able to be identified.

Species observed within the Maryland study area that are listed as rare, threatened, or endangered in the state of Maryland include Common Terns, Royal Terns (*Thalasseus maximus*), Forster's Terns (*Sterna forsteri*), Least Terns (*Sternula antillarum*), Roseate Terns, Northern Harriers (*Circus cyaneus*), and Bald Eagles (*Haliaeetus leucocephalus*). Bald Eagles are also federally protected under the Bald and Golden

Eagle Protection Act. The state also ranks additional species by their global and state population status[6]. In addition to federally protected species noted above, the conservation status of several of these state listed species (particularly some of the tern species, as they were most commonly observed in the Maryland study area) ensure that they are likely to be higher priorities for regulators considering proposed development in the Mid-Atlantic.

Summary

- 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.
- We had no confirmed sightings of Piping Plovers or Red Knots in the Maryland study area.

Sea Turtles

Sea turtles are long-lived animals with a world-wide oceanic distribution. Five species occur in the MABS and Maryland study areas: 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, and are state-listed in Maryland. As such, they are likely to be priority species for regulators during the environmental permitting process for offshore wind energy development. 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 5; Read, 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); 386 of these observations occurred within the Maryland study area (Chapters 5 and 7). Digital video aerial surveys proved to be more effective than boat surveys at surveying sea turtle populations (Chapters 10 and 12), likely in large part because turtles could be detected even when they were fully submerged (see also Normandeau Associates Inc. 2013). Sea turtles were most abundant from May to October, with very few individuals present in the study area in winter (Chapters 11-12). 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

[6] http://www.dnr.state.md.us/wildlife/Plants_Wildlife/rte/pdfs/rte_Animal_List.pdf

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 12). There was substantial overlap between sea turtle distributions and areas of planned offshore wind energy development, particularly in autumn and in the southern parts of the regional study area. Sea turtle abundance and species diversity was highest in the Maryland study area during this season.

Summary

- 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.
- 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. There may be species-specific differences in habitat use or movements that were not distinguishable in this study.
- 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 and state law in Maryland. 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 has been 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 in the wind facility footprint 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. Disturbance to large whales by other types of anthropogenic activities has been examined (e.g., Mccauley et al. 2000; Tyack et al. 2011), but large whales are not common in European waters where offshore wind energy 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, of which 1,423 were observed within the Maryland study area. 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 11-12). Cold-tolerant Common Dolphins were most frequently observed in offshore areas in winter and early spring (Chapters 11-12). 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 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, 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. Across the regional study area, a total of 51 observations of large cetaceans were made between boat and digital video aerial surveys, with 31 of the observations occurring in winter. In the Maryland study area, 11 large whales were observed, with seven of the observations occurring in winter (Chapters 5 and 7). Although none were observed within the Maryland study area, a total of nine North Atlantic Right Whales were observed across the regional study area, 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 (Chapter 12).

Summary

- 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.
- Relatively little is known about the migratory routes for many rare whale species in the Mid-Atlantic, although data from this study, as well as other survey efforts, 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 had a more offshore distribution, and may be particularly abundant in WEAs during winter and spring.

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

Discussion

This study provides a unique baseline dataset on the distributions, relative abundance, and habitat use of wildlife on the Mid-Atlantic Outer Continental Shelf. 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. The same is true for the Maryland study area. This study's boat and digital aerial surveys have provided 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 led to several key conclusions for the Mid-Atlantic and Maryland study regions, including:

- Boat-based surveys and digital video aerial surveys each had specific advantages and disadvantages, but are largely complementary. Digital aerial surveys may be 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 and 14).
- 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 of Maryland, 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.
- Areas off the northern Atlantic coast of Maryland represent key species richness and abundance hotspots for many taxa in this study, particularly loons, gulls, terns, rays, and dolphins. Offshore development in federal waters will still include some level of nearshore activity, including vessel traffic and laying a transmission cable to shore; these nearshore activities will need to be carefully sited and timed to minimize impacts to wildlife in the area. Several species displayed persistent hotspots of abundance in locations farther offshore on the continental shelf in the Maryland study area (including the Maryland WEA), such as gannets, alcids, and sea turtles. Species with more offshore distributions will need to be considered carefully in relation to activities conducted within the footprint of the Maryland WEA. As several of these taxa, such as sea turtles, are of conservation concern at both the state and federal level, these are likely to be key species on which to focus risk analysis efforts and improve our understanding of species vulnerability to offshore wind hazards.

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 2009-2010 (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., Fujioka et al., 2014; Halpin et al., 2009; Kenney, 2011). 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. (2012a) 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), while others used the offshore environment more broadly (e.g., Northern Gannet, large gulls), and others displayed 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, and a greater variety of more southerly species, including *Pterodroma* petrels, tropicbirds, boobies, and a greater diversity of storm-petrels (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 2009-2010 (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). 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 a similar species composition; 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 11). In our Mid-Atlantic and Maryland studies winter was the period of highest avian abundance, and winter distributions tended to be farther offshore than summer distributions (Chapter 9), 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, and shorebirds; in winter, sea ducks and loons were also commonly observed. 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 regional study area 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.

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 the regional 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 9).

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 11), possibly because the species was located almost exclusively in state waters, which were only surveyed in part of the Maryland study area and in one of the two years of surveys. 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).

Paton et al. (2010) 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 than in 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).

Marine mammals and sea turtles

Existing data on marine mammals and sea turtles from the Atlantic coast of the U.S. suggest 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 11-12). Sea turtles were much more abundant in the Mid-Atlantic study area than in the New York Bight or southern New England, particularly in spring and fall, likely due to warmer ocean temperatures than in more northern latitudes (Chapters 11-12; Kenney and Vigness-Raposa, 2010; Lagueux et al., 2010). Turtle 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 11-12; 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 11-12). 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, were generally 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 regional study area in February or March, presumably during the earlier part of their northward spring migration (Chapters 11-12). Similarly, recent surveys for large whales offshore of Virginia only documented their presence between October and April. It should be noted, however, that 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 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 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 BOEM Wind Energy Areas) 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) inform the responsible 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 of future projects, as well as efforts to minimize potential effects via timing of construction

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

activities and other approaches, 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.

Literature cited

(BOEM), 2013. Guidelines for providing benthic habitat survey information for renewable energy development on the Atlantic outer continental shelf pursuant to 30 CFR Part 585.

[Atlantic Coast Joint Venture], 2008. New England/Mid-Atlantic Coast Bird Conservation Region (BCR 30) Implementation Plan, Atlantic Coast Joint Venture.

Adams, E., Lambert, R., Connelly, E., Gilbert, A., Williams, K., 2015. Passive acoustics pilot study: nocturnal avian migration in the Mid-Atlantic, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Adams, E.M., Chilson, P.B., Williams, K.A., 2015. Using WSR-88 weather radar to identify patterns of nocturnal avian migration in the offshore environment, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Anderson, E., Dickson, R., Lok, E., Palm, E., Savard, J.-P., Bordage, D., Reed, A., 2015. Surf Scoter (Melanitta perspicillata), in: Poole, A. (Ed.), The Birds of North America Online. Cornell Lab of Ornithology. Ithaca, NY. doi:10.2173/bna.363

Bailey, H., Brookes, K.L., Thompson, P.M., 2014. Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future. Aquat. Biosyst. 10, 1–13. doi:10.1186/2046-9063-10-8

Bailey, H., Rice, A., 2015. Determining Offshore Use by Marine Mammals and Ambient Noise Levels Using Passive Acoustic Monitoring: Semi-Annual Progress Report. Sponsor Grant Number 14-14-1916 BOEM. 9 pp.

Ballance, L.T., Pitman, R.L., Fiedler, P.C., 2006. Oceanographic influences on seabirds and cetaceans of the eastern tropical Pacific: A review. Prog. Oceanogr. 69, 360–390. doi:10.1016/j.pocean.2006.03.013

Barr, J.F., Eberl, C., McIntyre, J.W., 2000. Red-throated Loon (Gavia stellata), in: Poole, A. (Ed.), Birds of North America Online. Cornell Lab of Ornithology, Ithaca, NY.

Bartol, S., Ketten, D., 2006. Turtle and tuna hearing, Sea Turtle and Pelagic Fish Sensory Biology: Developing Techniques to Reduce Sea Turtle Bycatch in Longline Fisheries. NOAA Technical Memorandum NOAA-TM-NMFS-PIFSC-07. US Department of Commerce.

Bergström, L., Kautsky, L., Malm, T., Rosenberg, R., Wahlberg, M., Åstrand Capetillo, N., Wilhelmsson, D., 2014. Effects of offshore wind farms on marine wildlife—a generalized impact assessment. Environ. Res. Lett. 9, 034012. doi:10.1088/1748-9326/9/3/034012

Best, B.D., Halpin, P.N., Read, A.J., Fujioka, E., Good, C.P., LaBrecque, E. a., Schick, R.S., Roberts, J.J., Hazen, L.J., Qian, S.S., Palka, D.L., Garrison, L.P., McLellan, W. a., 2012. Online cetacean habitat modeling system for the US East Coast and Gulf of Mexico. Endanger. Species Res. 18, 1–15. doi:10.3354/esr00430

BirdLife International, 2015. IUCN Red List of Threatened Species. Version 2015.2 [WWW Document]. URL www.iucnredlist.org (accessed 7.9.15).

Birds of Conservation Concern 2008 [WWW Document], n.d. URL http://www.fws.gov/migratorybirds/newreportspublications/specialtopics/bcc2008/bcc2008.pdf (accessed 4.1.15).

Blaylock, R.A., 1993. Distribution and Abundance of the Cownose Ray, Rhinoptera bonasus, in Lower Chesapeake Bay. Estuaries 16, 255–263. doi:10.1071/MF05227

Brown-Saracino, J., Smith, C., Gilman, P., 2013. Final Report for Mid- Atlantic Marine Wildlife Surveys, Modeling, and Data: Workshop to Establish Coordination & Communication, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Wind and Water Power Technologies Office. Silver Spring, Maryland.

Burger, J., Gordon, C., Lawrence, J., Newman, J., Forcey, G., Vlietstra, L., 2011. Risk evaluation for federally listed (roseate tern, piping plover) or candidate (red knot) bird species in offshore waters: A first step for managing the potential impacts of wind facility development on the Atlantic Outer Continental Shelf. Renew. Energy 36, 338–351. doi:10.1016/j.renene.2010.06.048

Castelao, R., Glenn, S., Schofield, O., 2010. Temperature, salinity, and density variability in the central Middle Atlantic Bight. J. Geophys. Res. Ocean. 115, 1–14. doi:10.1029/2009JC006082

Chardine, J., Rail, J.-F., Wilhelm, S.I., 2013. Population dynamics of Northern Gannets in North America, 1984-2009. J. F. Ornithol. 84, 187–192. doi:10.1111/jofo.12017

Crichton, D., 1999. The risk triangle. Nat. Disaster Manag.

Desholm, M., 2009. Avian sensitivity to mortality: Prioritising migratory bird species for assessment at proposed wind farms. J. Environ. Manage. 90, 2672–2679. doi:10.1016/j.jenvman.2009.02.005

Desorbo, C., Gray, R., Tash, J., Gray, C., Williams, K., Riordan, D., 2015. Offshore migration of Peregrine Falcons (Falco peregrinus) along the Atlantic Flyway, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Dilorio, L., Clark, C., 2010. Exposure to seismic survey alters blue whale acoustic communication. Biol. Lett. 6, 51–54. doi:10.1098/rsbl.2009.0651

Dow Piniak, W.E., Eckert, S.A., Harms, C.A., Stringer, E.M., 2012. Underwater hearing sensitivity of the leatherback sea turtle (Dermochelys coriacea): Assessing the potential effect of anthropogenic noise, OCS Study BOEM 2012-01156. U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs.

Ehler, C., Douvere, F., 2009. Marine Spatial Planning: a step-by-step approach toward ecosystem-based management, IOC Manual and Guides No. 53, ICAM Dossier No. 6. Intergovernmental Oceanographic Commission and Man and the Biosphere Programme, Paris: UNESCO.

Everaert, J., Stienen, E.W.M., 2007. Impact of wind turbines on birds in Zeebrugge (Belgium): Significant effect on breeding tern colony due to collisions. Biodivers. Conserv. 16, 3345–3359. doi:10.1007/s10531-006-9082-1

Fauchald, P., 2009. Spatial interaction between seabirds and prey: review and synthesis. Mar. Ecol. Prog. Ser. 391, 139–151.

Fifield, D.A., Montevecchi, W.A., Garthe, S., Robertson, G.J., Kubetzki, U., Rail, J.F., 2014. Migratory tactics and wintering areas of Northern Gannets (Morus bassanus) in North America. Ornithol. Monogr. 79, 1–63.

Firestone, J., Lyons, S.B., Wang, C., Corbett, J.J., 2008. Statistical modeling of North Atlantic right whale migration along the mid-Atlantic region of the eastern seaboard of the United States. Biol. Conserv. 141, 221–232. doi:10.1016/j.biocon.2007.09.024

Flemer, D., 1970. Primary production in the Chesapeake Bay. Chesap. Sci. 11, 117–129.

Fox, A.D., Desholm, M., Kahlert, J., Christensen, T.K., Krag Petersen, I., 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis (Lond. 1859). 148, 129–144. doi:10.1111/j.1474-919X.2006.00510.x

Frantzis, A., 1998. Does acoustic testing strand whales? Nature 392, 29.

Fujioka, E., Kot, C.Y., Wallace, B.P., Best, B.D., Moxley, J., Cleary, J., Donnelly, B., Halpin, P.N., 2014. Data integration for conservation: Leveraging multiple data types to advance ecological assessments and habitat modeling for marine megavertebrates using OBIS-SEAMAP. Ecol. Inform. 20, 13–26. doi:10.1016/j.ecoinf.2014.01.003

Furness, R.W., Wade, H.M., Masden, E.A., 2013. Assessing vulnerability of marine bird populations to offshore wind farms. J. Environ. Manage. 119, 56–66. doi:10.1016/j.jenvman.2013.01.025

Garthe, S., Benvenuti, S., Montevecchi, W.A., 2000. Pursuit-plunging by gannets. Proc. R. Soc. London Ser. B - Biol. Sci. 267, 1717–1722.

Garthe, S., Hüppop, O., 2004. Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. J. Appl. Ecol. 41, 724–734. doi:10.1111/j.0021-8901.2004.00918.x

Gaston, A.J., Bertram, D.F., Boyne, A.W., Chardine, J.W., Davoren, G., Diamond, A.W., Hedd, A., Montevecchi, W.A., Hipfner, J.M., Lemon, M.J.F., Mallory, M.L., Rail, J.-F., Robertson, G.J., 2009. Changes in Canadian seabird populations and ecology since 1970 in relation to changes in oceanography and food webs. Environ. Rev. 17, 267–286. doi:10.1139/A09-013

Geo-Marine Inc., 2010a. Ocean Wind Power Ecological Baseline Studies Final Report - Volume 2: Avian Studies, Report by Geo-Marine Inc and New Jersey Department of Environmental Protection Office of Science.

Geo-Marine Inc., 2010b. Ocean Wind Power Ecological Baseline Studies Final Report - Volume 1: Overview, Summary, and Application, Report by Geo-Marine Inc and New Jersey Department of Environmental Protection Office of Science.

Geo-Marine Inc., 2010c. Ocean Wind Power Ecological Baseline Studies Final Report - Volume 1: Overview, Summary, and Application, Report by Geo-Marine Inc and New Jersey Department of Environmental Protection Office of Science.

Gilbert, A., Adams, E., Anderson, C., Berlin, A., Bowman, T., Connelly, E., Gilliland, S., Gray, C., Lepage, C., Meattey, D., Montevecchi, W., Osenkowsi, J., Savoy, L., Spiegel, C., Stenhouse, I., Williams, K., 2015. Incorporating temporal variation in seabird telemetry data: time variant kernel density models, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Goodman, M.A., Conn, P.B., Fitzpatrick, E., 2011. Seasonal Occurrence of Cownose Rays (Rhinoptera bonasus) in North Carolina’s Estuarine and Coastal Waters. Estuaries and Coasts 34, 640–652.

Gray, C., Gilbert, A., Tash, J., Anderson, C., 2015. Wintering movements and habitat use of Red-throated Loons (Gavia stellata) in the mid-Atlantic U.S., Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Halpin, P.N., Read, A.J., Fujioka, E., Best, B.D., Donnelly, B., Hazen, L.J., Kot, C., Urian, K., LaBrecque, E., DiMatteo, A., Cleary, J., Good, C., Crowder, L.B., Hyrenbach, K.D., 2009. OBIS-SEAMAP: The World Data Center for Marine Mammal, Sea Bird, and Sea Turtle Distributions. Oceanography 22, 104–115. doi:10.5670/oceanog.2009.42.

Hatch, S.K., Connelly, E.E., Divoll, T.J., Stenhouse, I.J., Williams, K.A., 2013. Offshore observations of eastern red bats (Lasiurus borealis) in the mid-Atlantic United States using multiple survey methods. PLoS One 8, 1–8. doi:10.1371/journal.pone.0083803

Hazel, J., Lawler, I.R., Marsh, H., Robson, S., 2007. Vessel speed increases collision risk for the green turtle Chelonia mydas. Endanger. Species Res. 3, 105–113.

Henderson, I.G., Langston, R.H.W., Clark, N.A., 1996. The response of common terns Sterna hirundo to power lines: An assessment of risk in relation to breeding commitment, age and wind speed. Biol. Conserv. 77, 185–192.

Hostetter, N., Gardner, B., Gilbert, A., Connelly, E., Duron, M., 2015. Modeling species assignment in strip transect surveys with uncertain species identification, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Jodice, P.G., Tavano, J., Mackin, W., 2013. Chapter 8: Marine and coastal birds and bats, South Atlantic Information Resources: Data Search and Literature Synthesis, OCS Study BOEM 2013-01157. US Department of the Interior, Bureau of Ocean Energy Management, New Orleans, LA.

Kenney, R.D., 2011. The North Atlantic right whale consortium database: a guide for users and contributors. 2011-01., North Atlantic Right Whale Consortium Reference Document. Narragansett, RI, Narragansett (RI): University of Rhode Island Graduate School of Oceanography, North Atlantic Right Whale Consortium.

Kenney, R.D., 1990. Bottlenose dolphins off the northeastern United States, in: The Bottlenose Dolphin. Academic Press, San Diego, CA, pp. 369–386.

Kenney, R.D., Vigness-Raposa, K.J., 2010. Chapter 10: Marine Mammals and Sea Turtles of Narragansett Bay, Block Island Sound, Rhode Island Sound, and Nearby Waters: An Analysis of Existing Data for the Rhode Island Ocean Special Area Management Plan, in: Rhode Island Ocean Special Area Management Plan (Ocean SAMP) Volume 2. p. 337.

Kinlan, B.P., Menza, C., Huettmann, F., 2012a. Chapter 6: Predictive Modeling of Seabird Distribution Patterns in the New York Bight, in: Menza, C., Kinlan, B.P., Dorfman, D.S., Poti, M., Caldow, C. (Eds.), A Biogeographic Assessment of Seabirds, Deep Sea Corals and Ocean Habitats of the New York Bight: : Science to Support Offshore Spatial Planning. NOAA Technical Memorandum NOS NCCOS 141. Silver Spring, MD, pp. 87–224.

Kinlan, B.P., Zipkin, E.F., O'Connell, A.F., Caldow, C., 2012b. Statistical analyses to support guidelines for marine avian sampling: final report., U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon, VA. OCS Study BOEM 2012-101. NOAA Technical Memorandum NOS NCCOS.

Kot, C.Y., Fujioka, E., Hazen, L.J., Best, B.D., Read, A.J., Halpin, P.N., 2010. Spatio-Temporal Gap Analysis of OBIS-SEAMAP Project Data: Assessment and Way Forward. PLoS One 5, e12990. doi:10.1371/journal.pone.0012990

Lagueux, K., Wikgren, B., Kenney, R.D., 2010. Technical Report for the Spatial Characterization of Marine Turtles, Mammals, and Large Pelagic Fish to Support Coastal and Marine Spatial Planning in New York, Prepared for Stone Environmental, Inc., and the State of New York's Ocean Planning and Coastal Management Program.

Langston, R.H.W., 2013. Birds and wind projects across the pond: A UK perspective. Wildl. Soc. Bull. 37, 5–18. doi:10.1002/wsb.262

Langston, R.H.W., 2010. Offshore wind farms and birds: Round 3 zones, extensions to Round 1 & Round 2 sites & Scottish Territorial Waters (No. 39). Bedfordshire, UK.

Leonhard, S.B., Pedersen, J., Grøn, P.N., Skov, H., Jansen, J., Topping, C.J., Petersen, I.K., 2013. Wind farms affect Common Scoter and Red-throated Diver behaviour, in: Danish Offshore Wind: Key Environmental Issues – A Follow-Up. The Environment Group: The Danish Energy Agency, The Danish Nature Agency, DONG Energy and Vattenfall, pp. 70–93.

Lindeboom, H.J., Kouwenhoven, H.J., Bergman, M.J.N., Bouma, S., Brasseur, S., Daan, R., Fijn, R.C., de Haan, D., Dirksen, S., van Hal, R., Hille Ris Lambers, R., ter Hofstede, R., Krijgsveld, K.L., Leopold, M., Scheidat, M., 2011. Short-term ecological effects of an offshore wind farm in the Dutch coastal zone; a compilation. Environ. Res. Lett. 6, 035101. doi:10.1088/1748-9326/6/3/035101

Martin, K., Alessi, S., Gaspard, J., Tucker, A., Bauer, G., Mann, D., 2012. Underwater hearing in the Loggerhead Turtle (Caretta caretta): a comparison of behavioral and auditory evoked potential audiograms. J. Exp. Biol. 215, 3001–3009.

McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.-N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J., McCabe, K., 2000. Marine Seismic Surveys - A study of environmental implications. APPEA J. 40, 692–708.

Meattey, D., Savoy, L., Gilbert, A., Tash, J., Gray, C., Berlin, A., Lepage, C., Gilliland, S., Bowman, T., Osenkowsi, J., Spiegel, C., 2015. Wintering movements and habitat use of Surf Scoter (Melanitta perspicillata) in the mid-Atlantic U.S., Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Michel, J. (Ed.), 2013. South Atlantic Information Resources: Data Search and Literature Synthesis, OCS Study BOEM 2013-01157. US Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region., New Orleans, LA.

Mountain, D.G., 2003. Variability in the properties of Shelf Water in the Middle Atlantic Bight, 1977–1999. J. Geophys. Res. 108, 1–11. doi:10.1029/2001JC001044

Mowbray, T.B., 2002. Northern Gannet (Morus bassanus), in: Poole, A., Gill, F. (Eds.), The Birds of North America, No. 693. The Birds of North America Inc., Philadelphia, PA.

Murray, K.T., Orphanides, C.D., 2013. Estimating the risk of loggerhead turtle Caretta caretta bycatch in the US mid-Atlantic using fishery-independent and -dependent data. Mar. Ecol. Prog. Ser. 477, 259–270. doi:10.3354/meps10173

National Ocean Council, 2013. National Ocean Policy Implementation Plan. National Ocean Council, Washington, D.C.

Nelson, J.B., 1978. The Gannet. Berkhamsted, UK.

Normandeau Associates Inc., 2013. High-resolution Aerial Imaging Surveys of Marine Birds, Mammals, and Turtles on the US Atlantic Outer Continental Shelf—Utility Assessment, Methodology Recommendations, and Implementation Tools, Report prepared under BOEM Contract #M10PC00099. U.S. Department of the Interior, Bureau of Ocean Energy Management Headquarters, Herndon, VA.

Normandeau Associates Inc., 2011. New Insights and New Tools Regarding Risk to Roseate Terns, Piping Plovers, and Red Knots from Wind Facility Operations on the Atlantic Outer Continental Shelf, Report No. BOEMRE 048-2001. Contract No. M08PC20060. U.S. Department of the Interior, Bureau of Ocean Energy Management, Gainesville, FL.

Northeast Fisheries Science Center and Southeast Fisheries Science Center, 2013. Annual Report of a Comprehensive Assessment of Marine Mammal, Marine Turtle, and Seabird Abundance and Spatial Distribution in US Waters of the Western North Atlantic Ocean,. Annu. Rep. to Inter-Agency Agreem. M10PG00075/0001 204.

O'Connell, A., Spiegel, C.S., Johnson, S., 2011. Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the United States: Final Report (Database Selection – Shorebirds), Prepared by the U.S. Fish and Wildlife Service, Hadley, MD for the USGS Patuxent Wildlife Research Center, Beltsville, MD. U.S. Department of the Interior, Geological

Survey, and Bureau of Ocean Energy Managaement Headquarters, OCS Study BOEM 2012-076. BOEMRE, Beltsville, MD.

O'Connell, A.F., Gardner, B., Gilbert, A.T., Laurent, K., 2009. Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the United States, Final Report (Database Selection – Seabirds), U.S. Department of the Interior, Geological Survey, and Bureau of Ocean Energy Management Headquarters, OCS Study BOEM 2012-076. Prepared by the USGS Patuxent Wildlife Research Center, Beltsville, MD.

Parks, S., Clark, C., Tyack, P., 2007. Short- and long-term changes in right whale calling behavior: the potential effects of noise on acoustic communication. J. Acoust. Soc. Am. 122, 3725–3731.

Paton, P., Winiarski, K., Trocki, C., McWilliams, S., 2010. Spatial Distribution, Abundance and Flight Ecology of Birds in Nearshore and Offshore Waters in Rhode Island, in: Rhode Island Ocean Special Area Management Plan (Ocean SAMP), Volume II. Kingston, RI, p. 304.

Percival, S.M., 2010. Kentish Flats Offshore Wind Farm: Diver Surveys 2009-10. Durham, UK.

Perrow, M.R., Gilroy, J.J., Skeate, E.R., Tomlinson, M.L., 2011. Effects of the construction of Scroby Sands offshore wind farm on the prey base of Little tern Sternula albifrons at its most important UK colony. Mar. Pollut. Bull. 62, 1661–70. doi:10.1016/j.marpolbul.2011.06.010

Petersen, I., Fox, A., 2007. Changes in bird habitat utilization around Horns Rev 1 offshore wind farm, with particular emphasis on Common Scoter, Report commissioned by Vattenfall A/S. National Environmental Research Institute.

Read, A., 2013. Chapter 9: Sea Turtles, South Atlantic Information Resources: Data Search and Literature Synthesis, OCS Study BOEM 2013-01157. US Department of the Interior, Bureau of Ocean Energy Management, New Orleans, LA.

Rhode Island Coastal Resources Management Council, 2013. Chapter 11 : The Policies of the Ocean SAMP, in: Rhode Island Ocean Special Area Management Plan (Ocean SAMP), Volume 1. Wakefield, Rhode Island, p. 73.

Rice, A.N., Morano, J.L., Hodge, K.B., Salisbury, D.P., Muirhead, C.A., Frankel, A.S., Feinblatt, M., Nield, J., Clark, C.W., 2014. Baseline Bioacoustic Characterization for Offshore Renewable Energy Development in the North Carolina and Georgia Wind Planning Areas, OCS Study BOEM 2015-026. US Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region. New Orleans, LA.

Rolland, R., Parks, S., Hunt, K., Castellote, M., Corkeron, P., Nowacek, D., Wasser, S., Kraus, S., 2012. Evidence that ship noise increases stress in right whales. Proc. R. Soc. B 279, 2363–2368. doi:10.1098/rspb.2011.2429

Schmutz, J.A., 2014. Survival of adult Red-throated Loons (Gavia stellata) may be linked to marine conditions. Waterbirds 37, 118–124.

Schneider, D.C., Heinemann, D.W., 1996. State of Marine bird populations from Cape Hatteras to the Gulf of Maine, in: Sherman, K., Jaworski, N.A., Smayda, T.J. (Eds.), The Northeast Shelf Ecosystem: Assessment, Sustainability, and Management. pp. 197–216.

Schofield, O., Chant, R., Cahill, B., Castelao, R., Gong, D., Kahl, A., Kohut, J., Montes-Hugo, M., Ramadurai, R., Ramey, P., Yi, X., Glenn, S., 2008. The Decadal View of the Mid-Atlantic Bight from the COOLroom: Is Our Coastal System Changing? Oceanography 21, 108–117.

Schwemmer, P., Mendel, B., Sonntag, N., Dierschke, V., Garthe, S., 2014. Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. Ecol. Appl. 21, 1851–1860.

Smith, E.M., Kemp, W.M., 1995. Seasonal and regional variations in plankton community production and respiration for Chesapeake Bay. Mar. Ecol. Prog. Ser. 116, 217–232. doi:10.3354/meps116217

Stenhouse, I., Gray, C., Gilbert, A., Montevecchi, W., 2015. Wintering movements and habitat use of Northern Gannets (Morus bassanus) in the mid-Atlantic U.S., Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Tougaard, J., Carstensen, J., Teilmann, J., Skov, H., Rasmussen, P., 2009. Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (Phocoena phocoena (L.)). J. Acoust. Soc. Am. 126, 11–14. doi:10.1121/1.3132523

Tyack, P.L., Zimmer, W.M.X., Moretti, D., Southall, B.L., Claridge, D.E., Durban, J.W., Clark, C.W., D'Amico, A., DiMarzio, N., Jarvis, S., McCarthy, E., Morrissey, R., Ward, J., Boyd, I.L., 2011. Beaked whales respond to simulated and actual navy sonar. PLoS One 6, e17009. doi:10.1371/journal.pone.0017009

Vanermen, N., Onkelinx, T., Courtens, W., Van de Walle, M., Verstraete, H., Stienen, E.W.M., 2015. Seabird avoidance and attraction at an offshore wind farm in the Belgian part of the North Sea. Hydrobiologia 756, 51–61. doi:10.1007/s10750-014-2088-x

Wallace, B.P., DiMatteo, A.D., Bolten, A.B., Chaloupka, M.Y., Hutchinson, B.J., Abreu-Grobois, F.A., Mortimer, J.A., Seminoff, J.A., Amorocho, D., Bjorndal, K.A., Bourjea, J., Bowen, B.W., Dueñas, R., Casale, P., Choudhury, B.C., Costa, A., Dutton, P.H., Fallabrino, A., Finkbeiner, E.M., Girard, A., Girondot, M., Hamann, M., Hurley, B.J., López-Mendilaharsu, M., Marcovaldi, M.A., Musick, J.A., Nel, R., Pilcher, N.J., Troëng, S., Witherington, B., Mast, R.B., 2011. Global conservation priorities for Marine turtles. PLoS One 6, 1–14. doi:10.1371/journal.pone.0024510

White House Council on Environmental Quality, 2010. Final Recommendations of the Interagency Ocean Policy Task Force.

Williams, K., Stenhouse, I., Adams, E., Connelly, E., Gilbert, A., Duron, M., 2015a. Integrating novel and historical survey methods: a comparison of standardized boat-based and digital video aerial surveys for marine wildlife in the United States, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Williams, K., Stenhouse, I., Johnson, S., Connelly, E., Goyert, H., Gilbert, A., Goodale, M., 2015b. Synthesis of project findings, Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind

& Water Power Technologies Office, Award Number: DE-EE0005362. Report BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Willmott, J.R., Forcey, G., Kent, A., 2013. The Relative Vulnerability of Migratory Bird Species to Offshore Wind Energy Projects on the Atlantic Outer Continental Shelf: An Assessment Method and Database., Final Report to the U.S. Department of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs. OCS Study BOEM 2013-207.

Winiarski, K., Paton, P., McWilliams, S., Miller, D., 2012. Rhode Island Ocean Special Area Management Plan: Studies Investigating the Spatial Distribution and Abundance of Marine Birds in Nearshore and Offshore Waters of Rhode Island (No. 26). University of Rhode Island.

Xu, Y., Chant, R., Gong, D., Castelao, R., Glenn, S., Schofield, O., 2011. Seasonal variability of chlorophyll a in the Mid-Atlantic Bight. Cont. Shelf Res. 31, 1640–1650. doi:10.1016/j.csr.2011.05.019