Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf (2012-2014)

Final Report to the Department of Energy Office of Energy Efficiency and Renewable Energy Wind and Water Power Technologies Office

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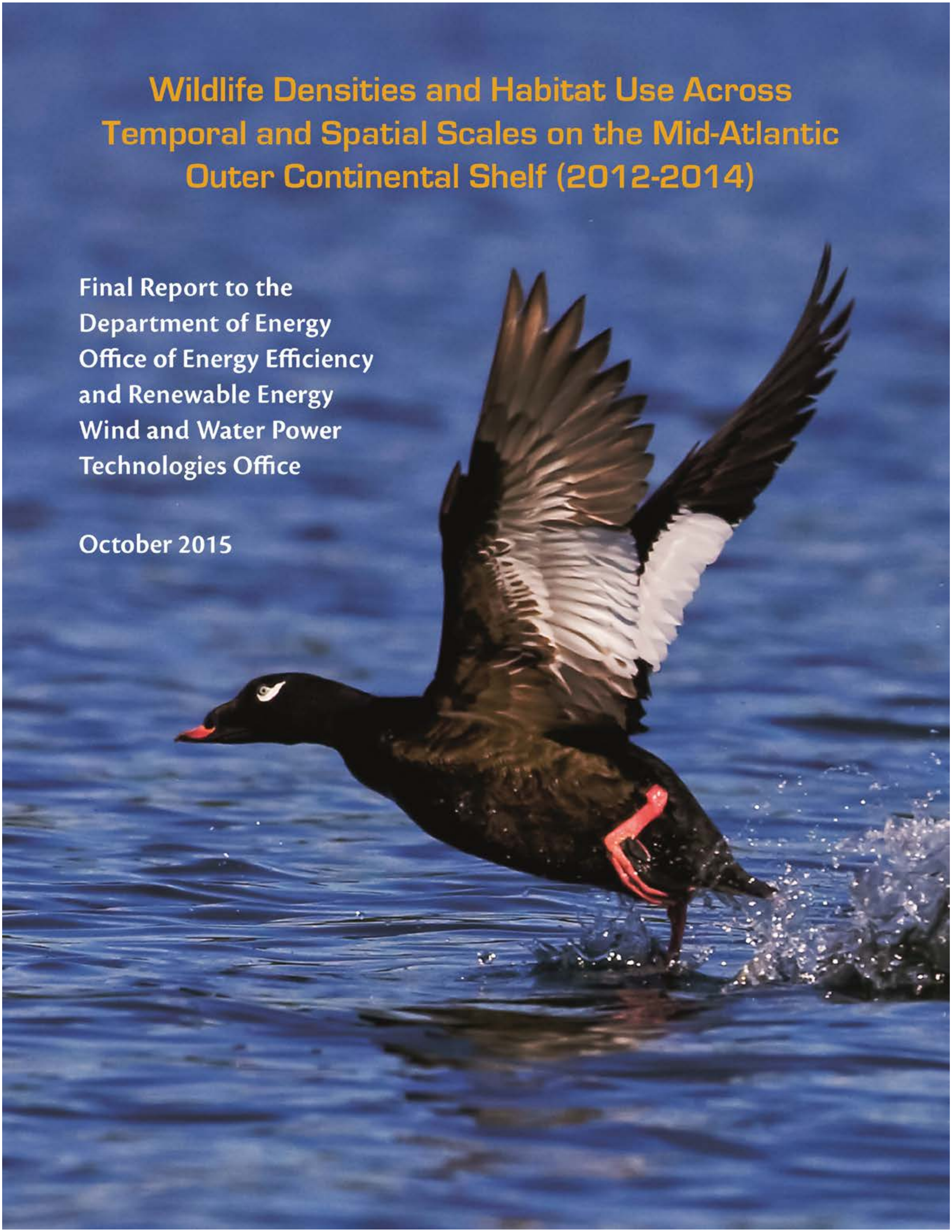

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Working Partners:

Biodiversity Research Institute, 276 Canco Rd., Portland, Maine 04103. www.briloon.org, 207-839-7600

College of Staten Island Department of Biology, 2800 Victory Blvd., Staten Island, NY 10314, and *City University of New York (CUNY) Graduate School*, 365 Fifth Avenue, New York, NY 10016

North Carolina State University Department of Forestry and Environmental Resources, 2200 Hillsborough, Raleigh, NC 27695

Duke University Marine Laboratory, 135 Pivers Island Road, Beaufort, NC 28516-9721

Oregon State University Marine Mammal Institute, Hatfield Marine Science Center, 2030 SE Marine Science Drive, Newport, Oregon 97365

University of Oklahoma School of Meteorology & Advanced Radar Research Center, 120 David L. Boren Blvd., Norman, Oklahoma 73072

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

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Executive Summary

Kathryn A. Williams, Iain J. Stenhouse, Sarah M. Johnson, and Emily E. Connelly
Biodiversity Research Institute, Portland, ME

The Mid-Atlantic Baseline Studies Project was funded by the Department of Energy's (DOE) Wind and Water Power Technologies Office in 2011, with additional support from a wide range of partners. The study was intended to help address environmental barriers to offshore wind energy development in the mid-Atlantic region and promote the incorporation of environmental data into siting and permitting processes. The study goal was to provide regulators, developers, and other stakeholders with comprehensive baseline ecological data and analyses that could help address environmental permitting requirements for current and future projects, and would serve as a starting point for more site-specific studies. In particular, we produced information that could be used to identify: 1) important wildlife areas, 2) data gaps, and 3) approaches for collecting and incorporating natural resource data into decision making. To address this goal, project funders and collaborators from a range of academic institutions, non-governmental organizations, federal agencies, foundations, and private companies came together to study bird, sea turtle, and marine mammal distributions, densities, and movements on the mid-Atlantic Outer Continental Shelf between 2012 and 2014. The specific study area in the mid-Atlantic was chosen because it was viewed as a likely region for near-term wind energy development offshore of Delaware, Maryland, and Virginia, particularly within three federally designated Wind Energy Areas (WEAs).

Specific project activities and goals included the following:

- Conduct standardized surveys to quantify bird, sea turtle, and marine mammal densities seasonally and annually throughout the study region, identify important habitat use or aggregation areas, and examine temporal variation in these patterns. Several survey approaches were employed to reach this goal.
- Develop statistical models to help understand the drivers of wildlife distribution and abundance patterns, and predict the combinations of environmental conditions likely to support large densities of birds, sea turtles, and marine mammals.
- Use individual tracking data for several focal bird species to provide information on population connectivity, individual movements, and seasonal site fidelity that is complementary to survey data.
- Identify species that are likely to be exposed to offshore wind energy development activities in the mid-Atlantic study area.
- Compare high resolution digital video aerial surveys to boat-based surveys, and publish results on the validity of high resolution digital video aerial surveys as a survey method for offshore development in U.S. waters.

- Develop U.S.-based technological resources for future monitoring efforts, and explore technological advancements and assessment methods aimed at simplifying and minimizing the cost of environmental risk assessments.
- Help meet data needs associated with National Environmental Policy Act (NEPA), Marine Mammal Protection Act, and Endangered Species Act requirements, by contributing several years of data and analysis towards future Environmental Impact Statements.
- Disseminate results to stakeholders and regulators through publicly accessible technical and summary reports, geospatial map layers, scientific manuscripts, and in-person briefings.

Funding by DOE was leveraged by the Biodiversity Research Institute (BRI) and other collaborators to conduct additional wildlife research in several topic areas. During the second year of survey efforts, the Maryland Department of Natural Resources (MDNR) and the Maryland Energy Administration (MEA) funded the expansion of boat and aerial surveys to cover a larger extent in Maryland's state and federal waters (the Maryland Project; Figure I). Unless noted otherwise, data from the two projects were fully integrated, and survey data presented throughout this report include the Maryland extension transects along with data funded through DOE for the Mid-Atlantic Baseline Studies Project. Seabird tracking studies for this project were also jointly funded, and conducted as part of longer-term research into seabird movements and habitat use developed and initiated by the Bureau of Ocean Energy Management (BOEM), U.S. Fish and Wildlife Service (USFWS), and Sea Duck Joint Venture (SDJV), and carried out in coordination with BRI, U.S. Geological Survey (USGS), Memorial University of Newfoundland, and other partners.

Offshore wind and wildlife

Offshore wind energy development has progressed rapidly in Europe since the first facility became operational in 1991 (Breton and Moe 2009), and it is now being pursued in other regions of the world, including the U.S. This renewable resource has the potential to reduce the impacts of climate change and ocean acidification by lowering global carbon emissions (IPCC 2014), and thus to positively affect many species. Offshore wind energy developments may also affect local wildlife more directly. Researchers are still learning about how offshore wind energy facilities affect marine ecosystems, but it seems clear that effects vary during different development phases, and that species respond in a variety of ways. Some species are negatively affected, while others show no net effect, or may even be affected positively. Possible effects to fish, marine mammals, sea turtles, birds, and bats include: mortality or injury from collisions with turbines or vessels; displacement from, or attraction to, habitat use areas; avoidance of facilities during migration or daily movements, which may necessitate increased energetic expenditures; and changes to habitat or prey populations, including artificial reef effects (Fox et al. 2006, Kunz et al. 2007, Boehlert and Gill 2010, Langston 2013, Bailey et al. 2014, Bergström et al. 2014). The scale of development is likely to be important in determining the significance of these effects. Overall, the cumulative effects to wildlife will be dependent on the size and number of wind facilities that are built, as well as local topography, climate, species ranges, and other oceanographic and biological factors. Effects from offshore wind may also be combined with other natural and anthropogenic stressors. As a result, ecological context is essential for understanding and minimizing effects of offshore development on wildlife.

Project components

The chapters in this report represent a broad range of study efforts and goals. Some chapters are purely methodological in nature, while others present a variety of analyses and results. Generally speaking, however, chapters fall into two categories: efforts focused on population distributions, and those focused on individual movements (Figure II). Part I of this report (the Executive Summary and Chapters 1-2) summarizes and synthesizes project results. The 25 subsequent chapters and their relationships to each other are shown in Figure II. An additional study effort, which explores statistical approaches for combining boat and aerial survey data to develop joint models of wildlife distributions and abundance, will be published as an addendum to this final report.

This report consists of six parts:

I. *Project overview*, which includes the executive summary (this section), a background chapter on the study area and methods (Chapter 1), and a longer synthesis that integrates findings from all project components to identify larger patterns and trends (Chapter 2);
II. *Examining wildlife distributions and relative abundance from a digital video aerial survey platform* (Chapters 3-6);
III. *Examining wildlife distributions and abundance using boat-based surveys* (Chapters 7-12);
IV. *Integrating data across survey platforms* (Chapters 13-19);
V. *Individual movements and habitat use for focal bird species* (Chapters 20-25); and
VI. *Nocturnal avian migration monitoring* (Chapters 26-27).

Project overview

The mid-Atlantic region is used by a broad suite of wide-ranging marine wildlife species across the annual cycle. This, along with the high levels of productivity in the region, mean that it is essential to understand the dynamics of this ecosystem in order to manage it effectively, particularly with regard to anthropogenic stressors, such as offshore development. In Chapter 1, we briefly discuss the ecosystem of the Mid-Atlantic Bight and describe the methods employed in the Mid-Atlantic Baseline Studies Project and Maryland Project. We discuss the relative strengths of digital video aerial surveys and other methods employed in this study, with a particular focus on comparing boat-based surveys and digital video aerial surveys. We also briefly discuss the various approaches used to present results in this report.

In Chapter 2, we summarize persistent and seasonal patterns in wildlife distributions that were observed during the two years of this study, including offshore surveys, individual tracking, and methods of studying nocturnal avian migration in the offshore environment. We present a series of case studies on specific taxa or phenomena that integrate data gained from these different methods to examine in detail the abundance and distributions of potentially vulnerable taxa. In addition, we discuss a number of similar baseline studies that have recently been conducted along the eastern seaboard. Observed community composition, distribution patterns, phenology, and behaviors in this study all varied somewhat from other recent baseline studies, as might be expected based on these studies' different latitudes, bathymetry, and other characteristics. However, at a broad scale, geographic and temporal patterns in the mid-Atlantic were consistent with findings from other recent baseline studies on the eastern seaboard (e.g., Geo-Marine Inc. 2010, Paton et al. 2010). In particular, overall abundance and species diversity were driven in large part by bathymetry, and tended to be highest in shallow water areas (which in many cases are coincident with areas closer to shore, though not always). In some cases, results from other baseline 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 (Rhode Island Coastal Resources Management Council 2013)[1]. The data developed in this study of the mid-Atlantic could be used to identify important areas for conservation as well as areas that would minimize exposure of wildlife during future development.

Examining wildlife distributions and relative abundance from a digital aerial survey platform

Fifteen aerial surveys were conducted over two years by HiDef Aerial Surveying, Ltd., using high resolution digital video. Digital aerial survey approaches have largely replaced visual aerial surveys for offshore wind energy research in Europe, as their higher flight speeds and much higher flight altitudes make them safer to conduct than visual aerial surveys, and reduce or eliminate disturbance to wildlife compared to visual aerial or boat-based survey approaches. They also produce archivable data, which allow for a robust quality assurance and audit process. There are still limitations to this method, however, including difficulties identifying some species, and a lack of defined statistical approaches for using the data for some purposes, due to the relative novelty of the survey method.

This study includes the first application of this technology on a large spatial scale in the United States. Surveys were conducted along transects with a dense spatial coverage (20% ground coverage) within WEAs, as well as a broader sawtooth transect throughout the remainder of the study area (Figure I). Four belly-mounted cameras recorded video footage during surveys, which was later analyzed to locate and identify animals (Chapter 3). Detailed video data analysis and management protocols were developed by BRI, in consultation with HiDef, including the Quality Assurance and Quality Control (QA/QC) protocol used to audit survey results (Chapter 4). Twenty percent of all video was included in blind re-reviews to ensure consistency in locating and identifying objects. Identification of animals to species proved difficult for some taxa due to variations in image quality and other factors (Chapter 5). Newer generations of camera systems currently used in Europe have greatly improved upon the identification rates obtained in this study (HiDef Aerial Surveying Ltd. unpubl. data). We make several recommendations in this report for the future use of digital aerial surveys in the Western Hemisphere, including the explicit examination of variables affecting species identifications and detection (Chapter 6).

Completed analysis provided data on the number of target organisms in the video, the species or other identification category of organisms (Chapter 5), the approximate flight height for flying birds and bats (Hatch et al. 2013), and geospatial data for all objects that may be used in modeling efforts. Over 100,000 animals were observed within the study area over two years of digital video aerial surveys, including over 46,000 birds and 60,000 aquatic animals. Digital video aerial surveys proved to be particularly good at detecting aquatic animals located near the water's surface, such as sea turtles and large migratory schools of rays. In fact, rays (Batoidea) were the most abundant animal observed in aerial surveys, representing over 44% of all observations. Scoters (*Melanitta* spp.) were the most abundant

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

avian species observed in the aerial surveys (20% of all observations; Chapter 5). Flight heights were estimated for 5,299 birds and bats (of the >7,000 animals observed in flight). Roughly 60% of flying animals were estimated to be in the lowest flight altitude category (0-20 m above the water's surface). Another 37% were estimated to be at altitude ranges between 20 and 200 m, which are in or near the potential rotor-sweep zone for future offshore wind energy development along the Eastern Seaboard (Willmott et al. 2013), depending on the size and type of turbines (Chapter 5).

Examining wildlife distributions and abundance using boat surveys

To accompany (and compare with) data from digital aerial surveys, 16 boat surveys were conducted over two years (Figure I). Standardized boat-based surveys with distance estimation are a widely used method of obtaining density data for birds, sea turtles, and marine mammals (Chapter 7); the study design was particularly optimized for avian species, and detected a wide variety of seabird species as well as raptors, passerines, and other taxa (Chapter 8). A total of 64,642 animals were observed on the survey, including over 62,000 birds and 1,500 aquatic animals, with the greatest numbers observed in December and January, when large flocks of wintering birds were present in the study area (Chapter 8). Scoters were the most abundant animal observed in boat surveys, constituting 34% of all observations.

While conducting these surveys, we also collected environmental covariate data in order to assess fine-scale patterns of these environmental variables in relation to wildlife densities. In particular, fisheries sonar (a scientific echo sounder) was used to estimate relative prey biomass in the same areas as boat survey observations (Chapter 9). We observed high levels of spatial and temporal variation in prey biomass across the study area and between surveys, although mean depth of biomass in the water column did not vary significantly between seasons. Total biomass, summed across all water depths, was higher in nearshore areas in the summer and fall and in the southern end of the study area during winter surveys.

These data were used to examine spatial associations between feeding seabirds and acoustically detected prey (Chapter 10). There were statistically significant associations between seabirds and patches of prey biomass for bird species that feed largely or entirely near the water's surface (Northern Gannets [*Morus bassanus*], Laughing Gulls [*Larus atricilla*], Common Terns [*Sterna hirundo*], and Royal Terns [*Thalasseus elegans*]), but not for deep-diving species such as loons and sea ducks. Identifying the spatial and temporal associations and lags between aquatic biomass and seabird behavior is helpful for understanding how these birds make decisions in the marine environment, and in turn may help managers to determine the behaviors or environmental conditions that present the highest risk of interactions between seabirds and offshore wind energy development.

A broader geographic and temporal scale of analysis is required to develop products appropriate for use in siting future development projects, and to fully assess exposure to wildlife from proposed projects. These goals also require correction of certain biases associated with boat survey data, such as distance bias, in which observers are less likely to see animals located farther from the survey vessel. Hierarchical Bayesian statistical approaches, as applied to survey data in Chapters 11-12, allow distribution models to be chosen to fit the observed data (Gardner et al. 2008, Zipkin et al. 2010), and incorporate distance estimation and environmental covariates into the model structure in order to predict animal distributions and abundance on a broad geographic scale. Project collaborators first focused on the development of a community distance sampling (CDS) model for seabirds using data from the first boat survey in April 2012 (Chapter 11). This novel multi-species approach for estimating seabird abundance and distributions explicitly estimated detection as well as abundance parameters. By sharing information across species, this community model allowed us to make inferences about abundance, distribution, and response to environmental variables of rare species for which there would not be enough data to run individual models.

Building on the CDS model in Chapter 11, Chapter 12 examined survey data from 15 boat surveys and incorporated remotely collected environmental covariate data into the hierarchical modeling structure. This approach accounted for imperfect detection to estimate "true" abundance, and predicted seabird distributions by season to help identify important habitat use areas and patterns. Seabird distributions were spatially, seasonally, and taxonomically variable; winter was the period of highest predicted abundance and species diversity, particularly during the second year of surveys. High species density and diversity was also predicted to occur in spring and fall, suggesting that migratory and overwintering species dominate the region's species composition. Distributions for some species, such as Common Terns and Red-throated Loons (*Gavia stellata*), were concentrated farther offshore in spring (during the pre-breeding migratory period). While summer was the period of lowest overall predicted abundance, several federally- and state-listed *Threatened* or *Endangered* species were present in the region during that time of year, including include Roseate Terns (*Sterna dougallii*), Least Terns (*Sternula antillarum*), Common Terns, Forster's Terns (*Sterna forsteri*), and Royal Terns. The community distance sampling model enabled us to accommodate these relatively rare species and estimate their relationships with habitat features, improving our understanding of their distributions.

Integrating data across survey platforms

Several chapters in this report focus on contrasting boat-based and digital video aerial survey approaches (Chapters 13-14 and 18). In some cases, data from one survey approach were used independently to analyze wildlife distributions and relative abundance (e.g., in the case of sea turtles, Chapters 15 and 17, or Bottlenose Dolphins [*Tursiops truncatus*], Chapter 15). In other cases, digital video aerial survey data and boat survey data were used jointly (Chapters 16-17 and 19) to describe distributions and abundance of animals across the study area.

In order to test the utility of high resolution digital video aerial surveys on the Atlantic coast, and to integrate new aerial survey data with historical data, we compared the digital aerial data to boat-based surveys using experimentally controlled methods (Chapter 13). This comparison indicated largely complementary strengths of the two survey approaches, though it also highlighted their respective weaknesses (namely, the need for additional analytical development for digital survey data, and the issue of disturbance to wildlife populations caused by the vessel during boat-based surveys). The two survey methods found similar distribution patterns for scoters, but were poorly correlated for highly mobile Northern Gannets, which at the density of transects in the comparison study were not adequately surveyed by the plane's relatively narrow transect strip width. In addition to this formal comparison of methods, project collaborators also pursued other approaches for comparing and contrasting the two full survey datasets. Species identification rates, as well as detection rates, varied considerably between methods for some taxa (Chapter 14). More birds per unit effort, and more bird species, were observed in the boat surveys, and birds made up a higher proportion of boat observations (98%) compared to digital video aerial surveys (43%). In contrast, much higher counts and species diversity of sea turtles and other aquatic animals (sharks, rays, fish, etc.), were detected on the aerial surveys than on the boat surveys (Chapter 14). Gulls and terns (Laridae), loons (Gaviidae), and auks (Alcidae) all had much higher identification rates to the species level from the boat surveys than in aerial video (Chapter 14). The limitation of many aerial identifications to the family or genus level was likely due in part to video image quality, but was also a result of the exhaustive quality assurance and audit protocol followed by aerial video reviewers, and characteristics inherent to the video review process itself (such as the use of multiple levels of "certainty" criteria in identifications). However, aerial video observers were better at identifying the most common avian family, Anatidae (scoters, ducks, and geese), to species than were boat observers, perhaps due in part to disturbance to this taxon from the survey vessel (Chapter 13). Identification rates of toothed whales (Odontoceti) were higher on boat surveys, but baleen whales (Mysticeti) had higher rates of identification from aerial surveys.

In a preliminary analysis of data for four seabird groups (terns, gannets, loons, and alcids), remotely-collected environmental data were incorporated into boat and aerial models (Chapter 18). Results were compared to determine if the two sampling methods detected similar patterns in seabird abundance, with the goal of determining how best to combine boat and digital aerial survey data for an integrated analysis. Accounting for detection resulted in higher abundance for the boat-based than the aerial models. Similar species-habitat relationships were estimated between the two survey types for gannets, terns, and loons, but alcids were less consistent between the survey types and years. These results suggested that a model combining both data types could be powerful for understanding seabird distributions, but that caution may be required for species like alcids where different patterns were observed between surveys, possibly due to differences in the sampling domain, detectability, or temporal variation.

Thus, the integration and combined analysis of the two survey datasets provided an opportunity to create higher-quality end products by incorporating complementary data streams. On a small scale, this led to the publication of a scientific paper on Eastern Red Bat (*Lasiurus borealis*) migration in the offshore environment of the mid-Atlantic (Hatch et al. 2013). Surveys were not designed to detect bats and other terrestrial species (due to their small body size, and because many of these species are thought to migrate exclusively at night). Despite this limitation, 17 bats were observed altogether, including two during boat surveys and 15 in video aerial surveys. Weather conditions were good at the time of these observations, suggesting that these bats were deliberately migrating offshore rather than driven offshore by high winds or other severe weather (Hatch et al. 2013). Despite their generally nocturnal behavioral patterns, bats were observed during morning daylight hours. Observations occurred between approximately 16 and 70 km from shore, and all bats with estimable flight heights in the aerial survey video were estimated to be >200 m above sea level, above the rotor swept zone of current offshore wind turbine models. Little is known about the migration and movements of tree bat species in North America, but anecdotal observations of bats migrating over the Atlantic Ocean (particularly during fall migration periods) have been reported since at least the 1890s (Hatch et al. 2013). Despite the relatively small sample size, the observations from this study provide further evidence of bat movements well offshore, and offer insight into their flight heights above sea level and the times of day at which such migrations may occur.

Collaborators also used the two datasets to identify temporal and spatial patterns of species presence and relative abundance in the study area, including the identification of “hotspots,” or geographic areas with consistently high numbers of animals through time (adapted from Santora and Veit 2013). Persistent hotspots likely provided important habitat for foraging, roosting, or other activities (Santora and Veit 2013). The presence and relative abundance of different species varied widely by time of year, with late fall to early spring identified as a time with high effort-corrected counts of animals in the study area, though many aquatic animals peaked in abundance in the summer. For many taxa, hotspots were most consistently observed in areas within 30-40 km from shore, particularly offshore of the mouths of Chesapeake Bay and Delaware Bay (Chapter 17). These areas consistently showed high species diversity and abundance of animals across all taxa observed in this study, and may have been attractive to many animals due to environmental gradients in salinity, water temperature, and other factors that created reliable foraging habitat in these locations. Areas offshore of northern Maryland also showed high diversity and abundance, although this may have been partially due to the high survey effort in nearshore waters in this region. Species that were consistently observed farther offshore on the Outer Continental Shelf included sea turtles, Common Dolphins (*Delphinus delphis*), Common Loons (*Gavia immer*), and alcids.

The incorporation of environmental covariates into modeling efforts allowed for the prediction of relative densities across the study area for many taxa (Chapters 12, 15, and 18-19), with one or both survey datasets used to describe populations of interest. In some cases, one survey method was significantly better than the other for surveying a particular taxon. For example, sea turtles were much more frequently observed in digital aerial surveys than in boat surveys, likely in large part because the turtles could be detected even when they were fully submerged. Because of these high detection rates, we used only the aerial survey results to develop predictive models of sea turtle distributions (Chapter 15). Sea turtles were most abundant from May to October, and their densities were correlated with warmer water temperatures and greater distances from shore. There was substantial overlap between sea turtle distributions and WEAs, particularly in the southern part of the study area. Bottlenose Dolphin distributions were modeled using boat data, and they were predicted to use primarily more nearshore areas with high levels of primary productivity and higher sea surface temperatures in spring, summer, and fall. There were few observations of the species during cooler months.

In other cases, boat and digital aerial survey datasets could be combined using recently developed integrated modeling frameworks (as with several seabird groups; Chapter 19). Common Loons and Red-throated Loons, which proved difficult to distinguish in aerial video, provided a test case for using boat-based species identifications to inform aerial models and develop spatially explicit species-specific estimates of relative abundance (Chapters 16-17). In Chapter 19, project collaborators developed an integrated modeling approach in which predictions of marine bird abundance and distribution were jointly informed by aerial surveys (which encompassed a large geographic area), and boat surveys (which allowed for estimation of detection probability). Integrated models were developed for the same four taxa examined in Chapter 18 (terns, alcids, loons, and gannets). The combined predictions of this chapter generally supported the conclusions of Chapters 12 and 17-18, which found that the distribution of marine birds was often patchy, species- and survey-specific, and correlated with habitat covariates. The integrated models had noticeable improvements in predicting local hotspots and marine bird distributions relative to models that only included boat-based data. The greater spatial span of aerial surveys may have assisted in the detection of latitudinal gradients and hotspots, especially those occurring outside of areas surveyed by the boat. The integrated models, however, often had lower predictive power than boat-only models for describing observations from other surveys conducted in the same season, which was likely a consequence of dynamic relationships between boat and aerial surveys and changing habitat covariates (Winiarski et al. 2013, 2014). While additional exploration and model development is needed, these results indicate that joint modeling approaches may be a fruitful avenue of continued research.

Individual movements and habitat use for focal bird species

We investigated the spatial and temporal patterns of offshore bird migration and winter habitat use through the use of satellite telemetry, and incorporated remotely collected covariate information into models to determine how birds' use of space covaried with environmental conditions. We tracked the movements of 149 individuals from three focal avian taxa: seabirds (Red-throated Loon and Northern Gannet); sea ducks (Surf Scoter, *Melanitta perspicillata*); and raptors (Peregrine Falcon, *Falco peregrinus*). Wintering movements and habitat use in the mid-Atlantic study area were the main focus of telemetry studies for seabirds. Kernel-based utilization distributions and resource selection functions, used to examine scoter habitat use in a previous study (Loring et al. 2014), allowed for the identification of important habitat use areas for Surf Scoters (Chapter 20). Scoters are likely to use more geographically stable prey resources than are Red-throated Loons or Northern Gannets (Chapter 18, Appendix A), and modifications to this approach using different resource selection methods and temporally variable environmental covariates were applied to Red-throated Loons (Chapter 21) and Northern Gannets (Chapter 22). Surf Scoters in core-use areas used shallow (<40 m) areas within 4.5 km from shore. Red-throated Loons also tended to use nearshore areas, and in our sample the greatest chance for interaction between Red-throated Loons and WEAs generally occurred during the spring migration period (late March to early May). In contrast, Northern Gannets ranged widely over the Outer Continental Shelf during winter (Chapter 22). Though core habitat of tagged Northern Gannets within the study area included the protected inshore waters of the major bays and bay mouths, individual birds displayed extensive movements up and down the eastern seaboard between the core use areas, increasing the likelihood that they would encounter offshore wind developments in the region repeatedly throughout the winter.

Chapters 20-22 explored spatial patterns and movements of three target species using fairly traditional methods, which collapse the temporal component of movement data into a single period for analysis. Time-variant kernel density analysis allowed for a more explicit understanding of habitat use through time (Keating and Cherry 2009; Chapter 23). This is an effective tool for showing fine-scale temporal variation in use of the study area, especially in and around WEAs (Chapter 23). The tracking results are preliminary, however, as data were drawn from the first two years of an extended (four year) satellite tracking project.

As well as movements and general habitat use, satellite telemetry can also provide detailed information on specific behaviors. Northern Gannet interactions with offshore wind energy development are hypothesized to largely occur as a result of their foraging behaviors, which include a large proportion of time spent soaring at or near the altitude of the rotor-swept zone for offshore wind turbines (Garthe et al. 2000, Langston 2010). Being able to differentiate between foraging and other behaviors in telemetry data allows us to better determine areas of potential conflict between offshore wind energy development and gannet habitat use. In Chapter 24, we used Northern Gannet positional data in a behavioral state switching state-space model (SSSM) in a Bayesian modeling framework (Jonsen et al. 2007) to analyze telemetry data from the nonbreeding period and examine the habitat characteristics at locations that were used by Northern Gannets for foraging. Weekly sea surface temperature front density was a very strong predictor of foraging activity, indicating that Northern Gannets responded dynamically to either the change in water temperature itself, or to the increase in prey availability that is likely occurring in areas with high front density (Chapter 24).

Unlike these seabird species, Peregrine Falcons migrate through the project study area but seldom winter in or near the mid-Atlantic. Peregrines are probably the most commonly encountered non-piscivorous raptor in marine settings, and they are commonly observed foraging or perching far from shore at offshore islands, oil drilling platforms, and large offshore vessels (Voous 1961, Cochran 1975, 1985; Russell 2005, Johnson et al. 2011, DeSorbo et al. 2012). We used satellite telemetry to document falcon movements and use of space within the project study area during fall migration (Chapter 25). Data were analyzed using a dynamic Brownian Bridge Movement Model, which improves upon traditional (i.e., fixed kernel) approaches used in Chapters 20-22 by accounting for the order in which locations were fixed, the time interval between them, and location error, and thus generating space use estimations that more accurately depict high and low use areas and movement corridors. During this study, Peregrine Falcons regularly used habitat hundreds of kilometers offshore along the Atlantic coast, including within and east of the mid-Atlantic study area. Twelve of the 13 tracked falcons that continued their fall migration beyond the mid-Atlantic coast initiated a significant transoceanic flight from coastal North Carolina to the Caribbean or South America. Birds tracked in this study were all captured on offshore islands, and it remains unclear what proportion of the Peregrine Falcon population ventures offshore. However, findings from this study are consistent with observations elsewhere (Cochran 1975, Fuller et al. 1998, Desorbo et al. 2012) and suggest that this species commonly uses offshore habitats along the Atlantic flyway.

Nocturnal migration monitoring

Limited information is available on nocturnal avian migrants in the offshore environment. The project team investigated the species composition, general spatial patterns, and weather-dependent and seasonal variation in offshore bird migration through a combination of acoustic and radar data collection. Both the nocturnal passive acoustic avian monitoring from the boat (Chapter 26) and the analysis of WSR-88 radar data, also known as NEXt generation RADar (NEXRAD, Chapter 27) were undertaken to determine the utility of these approaches for examining avian migration in the offshore environment, and to improve our understanding of migratory patterns in the offshore environment on the Atlantic coast of the U.S. Many bird species can be identified by their vocalizations, so nocturnal acoustic monitoring stations can provide species-specific presence-absence data and indices of activity for birds that vocalize during migration ("migratory flight calls"). When the boat stayed overnight on the water (seven total occasions over two years, located 25-46 km from shore), we detected migratory flight calls from at least 15 species, including both passerines and shorebirds. Migrant passerines were not detected on the majority of the seven survey nights, but during one survey occasion 40 km off the coast, we detected 123 individual calls in one night. This is consistent with other studies of nocturnal avian migration over the ocean (as well as over land), which have found that migratory activity is highly episodic and appear to be largely driven by variations in weather (Hill et al. 2014). This pilot study suggests that a diverse range of landbirds may migrate over the mid-Atlantic Outer Continental Shelf at low altitudes, though a more extensive effort is warranted before drawing broader conclusions about the frequency of such occurrences.

Developed as a tool to monitor meteorological phenomena, weather surveillance radars regularly detect flying animals in the atmosphere at night (Bridge et al. 2011, Chilson et al. 2012), including passerines, shorebirds, waterfowl, bats, insects, and other nocturnal migrants. We used WSR-88D (NEXRAD) weather radar to study nocturnal migration off the mid-Atlantic coast of the U.S. from New York to North Carolina (Chapter 27). We compared migratory activity at sites over land and up to 80 km out to sea, controlling for variables that could affect measured levels of migratory activity, and we identified the environmental variables correlated with offshore activity. The high level of altitudinal overlap between our measurements and turbine heights suggests that our predictions of bioscatter levels in the offshore environment are highly relevant to migration occurring at rotor-sweep heights. After controlling for biases in measured levels of migratory activity (including varying distances of sampling sites from the radar units), we found that in fall, there was no significant difference in migratory activity at offshore vs. terrestrial sites across the mid-Atlantic region. This suggests that migration over open water areas may be quite common during this season. There is a strong weather-related component to offshore fall migration, however, as discussed above; there were high levels of daily variation in activity at our study sites, and offshore activity was particularly high under west winds. Responses also varied by topographic location along the coast, and some offshore areas had consistently higher predicted activity levels, most notably the New York Bight (south of Long Island) and offshore of North Carolina. In spring, there was still substantial offshore activity around North Carolina, but predicted levels of nocturnal offshore migration were fairly minimal in other locations.

These data suggest that while birds are less likely to migrate offshore in spring, during the fall there appear to be multiple "jumping off points" along the coast for tailwind-aided overwater migrations. Trans-oceanic migrations, once thought to be extreme events only undertaken by few individuals or species with extreme physiological adaptations (DeLuca et al. 2015), are perhaps more commonplace than previously thought in this region. While additional research will be required to determine the degree to which certain taxa use the offshore environment, the levels of migratory activity predicted in offshore locations suggest that regulators for offshore wind energy development may want to consider potential impacts to migrants, including terrestrial species (passerines, shorebirds, bats, etc.), in offshore wind development scenarios. This may be particularly important in locations with consistently higher levels of migratory activity, such as the New York Bight, and areas offshore of North Carolina. Predicted levels of activity in many other parts of the study area were also intermittently high, however, suggesting that offshore migration is a widespread phenomenon, and should be regarded as such during planning activities.

Synthesis: Advancements in the state of our knowledge

The mid-Atlantic ecosystem

The mid-Atlantic region is used by a broad range of marine wildlife species across the entire annual cycle, due in part to a relatively high level of productivity, as compared to many other areas in the western North Atlantic (Yoder et al. 2001). The importance of the region to wildlife is also partially due to the region's central location on the eastern edge of the continent (a major migratory corridor for many species). As a result, the mid-Atlantic supports large populations of marine wildlife during breeding, nonbreeding, and migratory periods, and this results in a complex ecosystem where the community composition is constantly shifting, and temporal and geographic patterns are highly variable.

The Mid-Atlantic Baseline Studies Project and Maryland Project have filled a significant information gap for wildlife in a large swath of the mid-Atlantic region between New Jersey and North Carolina. In part, this area was a focus due to its ecological significance and relative lack of data on wildlife distributions. Additionally, this region has great economic importance, including commercial fisheries, shipping, and the potential for offshore renewable energy development. The mid-Atlantic region has a relatively high wind energy potential, and is also located near large energy markets on the U.S. Atlantic coast (Baker 2011). Thus, the region has been a focus for offshore wind developers and regulators in recent years, and several of the first federally designated WEAs are located off the mid-Atlantic coast. To minimize the effects of development activities on wildlife populations, however, the complexities of this ecosystem require that a range of study methods be used to obtain a comprehensive view of ecosystem structure and configuration.

Study methods and comparisons

Field study methods have a substantial influence on resulting analysis and presentation of wildlife distribution data. Often, study methods involve tradeoffs between geographic vs. temporal coverage, information on animal abundance (or relative abundance) vs. accurate species identifications, and detailed behavior or movement data vs. information on population distributions (Chapter 1). Each of the methods that we used to examine marine wildlife distributions and movements in the mid-Atlantic had inherent strengths and weaknesses. Our evaluation of the utility of each survey method in documenting different types of data is necessarily subjective in many cases, and is dependent upon the specific study design implemented for this project (i.e., the study area, available technology, sample size, and other factors).

Compared to the other study methods used in this project, boat and aerial surveys provided relatively comprehensive information on wildlife populations in the offshore environment (Chapter 1). Each showed distinct benefits in detecting different taxa. High resolution digital video aerial surveys provided better detection rates for aquatic animals, likely due to a combination of reduced disturbance, reduced glare, and a unique field of view compared to boat-based and visual aerial surveys, allowing for submerged animals to more easily be detected in the upper reaches of the water column (Chapters 5 and 14; Normandeau Associates Inc., 2012). Boat surveys provided better detection rates for many birds, however, which is probably due to a combination of availability bias, detection bias, and identification issues in digital video aerial surveys (Chapters 5 and 13-14). Digital aerial surveys have the advantage of being auditable and archivable, and include an extensive quality assurance process, which may lead to a greater degree of reliability in species identifications. The safety and speed with which digital aerial surveys can be conducted also make this approach attractive in the offshore environment, and the capabilities of digital aerial surveys will likely continue to improve with technological advances in the field. Boat-based surveys can provide detailed behavioral data, however, and had generally better rates of identification of animals to species. The analytical approaches for boat survey data are also well established, while additional technological advances and analytical developments for digital aerial surveys would strengthen this approach for understanding wildlife distributions in the offshore environment of North America (Chapter 6).

Patterns of wildlife distribution and abundance

Distribution and relative abundance of wildlife in the mid-Atlantic is largely driven by environmental variables, including weather, habitat characteristics, prey distributions, and the topography of the coastline. Important environmental factors influencing species distributions included distance to shore, sea surface temperature, primary productivity levels (e.g., chlorophyll *a*), salinity, seafloor slope, and sediment type, though wildlife responses to these factors varied widely by species and time of year (Chapters 12, 15, and 20-22). There are strong seasonal variations in community composition and wildlife distributions. The breadth of the region is used during spring and fall migration by seabirds, landbirds, sea turtles, cetaceans, rays, and other taxa. Many of these taxa are also part-time or year-round residents of the study area, using it for foraging during the breeding season, or for foraging, roosting, and other activities during non-breeding periods.

Spring

During the spring (March-May), sea surface temperatures begin to rise, and salinity across surface waters begins to decrease. As the season progresses, primary productivity begins to increase within and adjacent to the bays as nutrient rich spring runoff flows into the bays and mixes with coastal waters (Smith and Kemp 1995). High species diversity was observed in the spring, suggesting that migratory and overwintering species dominate the region's species composition (Chapter 12). During this time, wintering seabirds departed the region to begin their migrations towards breeding grounds inland or to the north. In our study, Surf Scoters departed the area between January and May, Red-throated Loons between March and May, and Northern Gannets between February and May (Chapters 20-23). During spring, songbirds and shorebirds migrated through the region both along the coast and over open waters (Chapters 17 and 27). Summer resident seabirds, such as terns, shearwaters (Procellaridae), and storm-petrels (Hydrobatidae), arrived after migrating from wintering grounds in the south or breeding grounds in the Southern Hemisphere (Chapters 5, 8, and 17). Spring also marked the arrival of

Bottlenose Dolphins and a variety of sea turtle species, which were predicted to occur in high densities offshore of Virginia during this period (Chapter 15).

Summer

During summer (June-August), overall primary productivity is generally low across the Outer Continental Shelf, but chlorophyll concentrations increase in shallow nearshore areas where upwelling can occur (Xu et al. 2011). Additionally, primary production within the bays is at its peak, contributing to higher productivity at the bay mouths where coastal and estuarine waters mix (Smith and Kemp 1995; Flemer 1970). Through hydroacoustic surveys, we generally observed higher levels of aquatic biomass in these regions during the summer (Chapter 9). Seabirds were generally more associated with nearshore habitat in summer than they were in the spring (Chapter 12). Breeding seabirds were found foraging near the shore and near the mouths of the bays (Chapter 12 and 17); specifically, terns (including Common Terns, and others), were predicted to be associated with nearshore habitat (Chapters 18 and 19). Non-breeding species from the southern hemisphere, such as Great Shearwaters (*Puffinus gravis*) and Wilson's Storm-Petrels (*Oceanites oceanicus*), generally occupied a wider swath of the study area (Chapter 17). In early summer, large numbers of Cownose Rays (*Rhinoptera bonasus*) migrated through the study area on their way to feeding grounds in the Chesapeake Bay and Delaware Bay (Chapter 5; Blaylock 1993). Sea turtles and Bottlenose Dolphins were most abundant across the study area in the summer, with the more inshore coastal ecotype of Bottlenose Dolphins more heavily represented than the offshore population of this species (Chapter 15; Kenney, 1990). In the summer, both Bottlenose Dolphin and sea turtle distributions were influenced by sea surface temperatures and primary productivity (Chapter 15), with Bottlenose Dolphins predicted to occur primarily in nearshore areas, and sea turtles still predicted to occur primarily in the southern end of the study area (Chapter 15).

Fall

In the fall (September-November), the mixing of stratified water re-oxygenates the water column, setting the stage for a significant phytoplankton bloom that occurs across shallow waters in the region between late fall and early spring (Schofield et al. 2008, Xu et al. 2011). Decreased flow of fresh water from the Delaware Bay and Chesapeake Bay during the summer and fall causes salinity to rise over the course of the season, as saltier water is pushed closer to shore. In the early fall, Cownose Rays moved out of the bays and aggregated in dense groups within the study area as they migrated south (Chapter 5). Seabird species composition changed over the course of the fall, as summer residents migrated south to more suitable climes and winter residents migrated into the region from breeding grounds farther north or inland (Chapter 17). Seabirds continued to be more associated with nearshore habitats as compared to winter and spring (Chapter 12). In our telemetry studies, tagged Surf Scoters arrived in the wintering area between October and December, while Red-throated Loons arrived between November and December, and Northern Gannets between August and December (Chapters 20-23). As in the spring, songbirds and shorebirds were recorded flying over open waters as they migrated through the study area (Chapters 17 and 26-27). Nocturnal migratory activity was higher at many offshore locations than along the coast, particularly south of Long Island and offshore of the Carolinas (Chapter 27). Additionally, Peregrine Falcons and Eastern Red Bats migrated over open water through the study area (Chapters 17 and 25; Hatch et al., 2013). Large schools of forage fish were observed in the study area, particularly in nearshore regions (Chapters 9 and 17). Sea turtles remained widespread across the study area through October (Chapter 15). Bottlenose Dolphins also remained until late fall, while Common Dolphins arrived in the study area in November (Chapter 15 and 17).

Winter
During winter (December-February), sea surface temperatures are at their lowest and least variable across the study area (Schofield et al. 2008). Wintering seabirds occupied habitat throughout the study area, with variation in distribution patterns among species (Chapters 12, 17 and 19) and individuals. Northern Gannets were the most ubiquitous seabird in the study area during this period, and were often observed in the bays as well as relatively far out on the shelf in search of prey (Chapters 10, 12, 17, and 22). For Northern Gannets, we found that the chances of foraging increased with the number of sea surface temperature fronts in an area, as the temperature fronts likely aggregated prey (Chapter 24). Scoters were observed in large aggregations at the mouths of the Chesapeake Bay and Delaware Bay (Chapter 17). Common Loons, in contrast, were most often observed individually and were widely dispersed throughout the study area, generally more associated with lower sea surface temperatures (Chapters 16 and 17). Many Bonaparte's Gulls (*Chroicocephalus philadelphia*) were observed in the study area on both survey platforms in winter (Chapters 5 and 8). Alcids were predicted to occur in small numbers throughout the study area (Chapter 19). Baleen whales were most commonly observed during this season. Of the 51 large whales observed in this study, 31 were observed between December and February (Chapter 17). Common Dolphins occupied habitat throughout the study area during the winter, predominantly in offshore areas (Chapters 15 and 17).

Persistent patterns
Primary productivity forms the base of the pelagic food chain on which nearly all species observed during this study rely. In general, primary productivity in the mid-Atlantic is higher in nearshore areas, although patterns vary seasonally (see above). Schools of forage fishes were most commonly observed in nearshore waters, particularly offshore of northern Delaware and Maryland, around the mouth of Delaware Bay (Chapters 5 and 17). In turn, despite seasonal variation in habitat characteristics, areas within about 30-40 km of shore appeared to provide important foraging habitat for a wide range of species year-round. In particular, analyses of survey data indicated that areas near the mouths of the Chesapeake Bay and Delaware Bay were consistent hotspots of species diversity and abundance during this study (Chapter 17). Telemetry studies also highlighted these as high use areas for migratory seabirds in winter, even for species that were highly mobile and used a broad range of habitats, such as the Northern Gannet (Chapter 22). These areas were likely attractive to a wide variety of high trophic-level species, such as seabirds and marine mammals, due to foraging opportunities arising from gradients in salinity, water temperature, and other factors offshore of the mouths of the bays, and the consistently higher primary productivity relative to the broader study area. Areas in northern Maryland within roughly 20-30 km of shore were also consistent hotspots for biodiversity and abundance for many taxa, although this may have been partially driven by the more inshore study design implemented in the region as compared to the remainder of the study area.

Inter-annual variation was substantial, and with only two years of data included in this study, the distribution, abundance, and movement patterns that we present in this report may not be representative of longer-term (e.g., inter-decadal) patterns. In particular, the importance of certain environmental variables, such as sea surface temperature, in predicting animal distributions indicates that these species may well respond to future environmental shifts brought about by anthropogenic effects and climatic change (Griffies 2004, Tallis et al. 2010). This study is an important first step, however, 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.

Next steps

Several project activities will continue after the project end date, including development of additional joint modeling approaches for integrating boat and digital video aerial survey datasets. All data generated from this project will also be made publically available in late 2015 via the Northwest Atlantic Seabird Catalog (formerly the Compendium of Avian Information)[2], a relational database hosted by the U.S. Fish and Wildlife Service that contains decades of survey data on seabirds, marine mammals, sea turtles, and other wildlife across a broad spatial scale in the northwest Atlantic (O'Connell et al. 2009). Data are also hosted and available for download on the project web page (www.briloon.org/MABS), and certain analytical products are also expected to be incorporated into other public databases, such as the Mid-Atlantic Regional Ocean Council's (MARCO) Data Portal (http://midatlanticocean.org/data-portal/).

Effects to wildlife from offshore development can be thought of as a combination of exposure to development and operation activities; hazards posed to individuals that are exposed; and the implications of individual-level impacts for population vulnerability (Crichton 1999, Fox et al. 2006). In this baseline study of wildlife distributions and movements, we focused on developing a better understanding of wildlife exposure to future offshore development in the mid-Atlantic. While exposure to offshore development does not necessarily indicate that exposed animals will suffer deleterious effects, or that any impacts that do occur will translate to population-level impacts, 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 United States. The siting and permitting of future projects, as well as efforts to minimize potential effects by considering the timing of construction activities and other approaches, will rely on baseline data such as these. As planning and development move forward, however, it will be important to take steps beyond this baseline assessment in order to focus on species most likely to be impacted due to their conservation status or other factors.

[2] For more information, contact: Kaycee Coleman, Database Manager, Division of Migratory Birds, U.S. Fish and Wildlife Service, Laurel, MD 20708. Phone: 301-497-5998, email: kaycee_coleman@fws.gov

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Figures

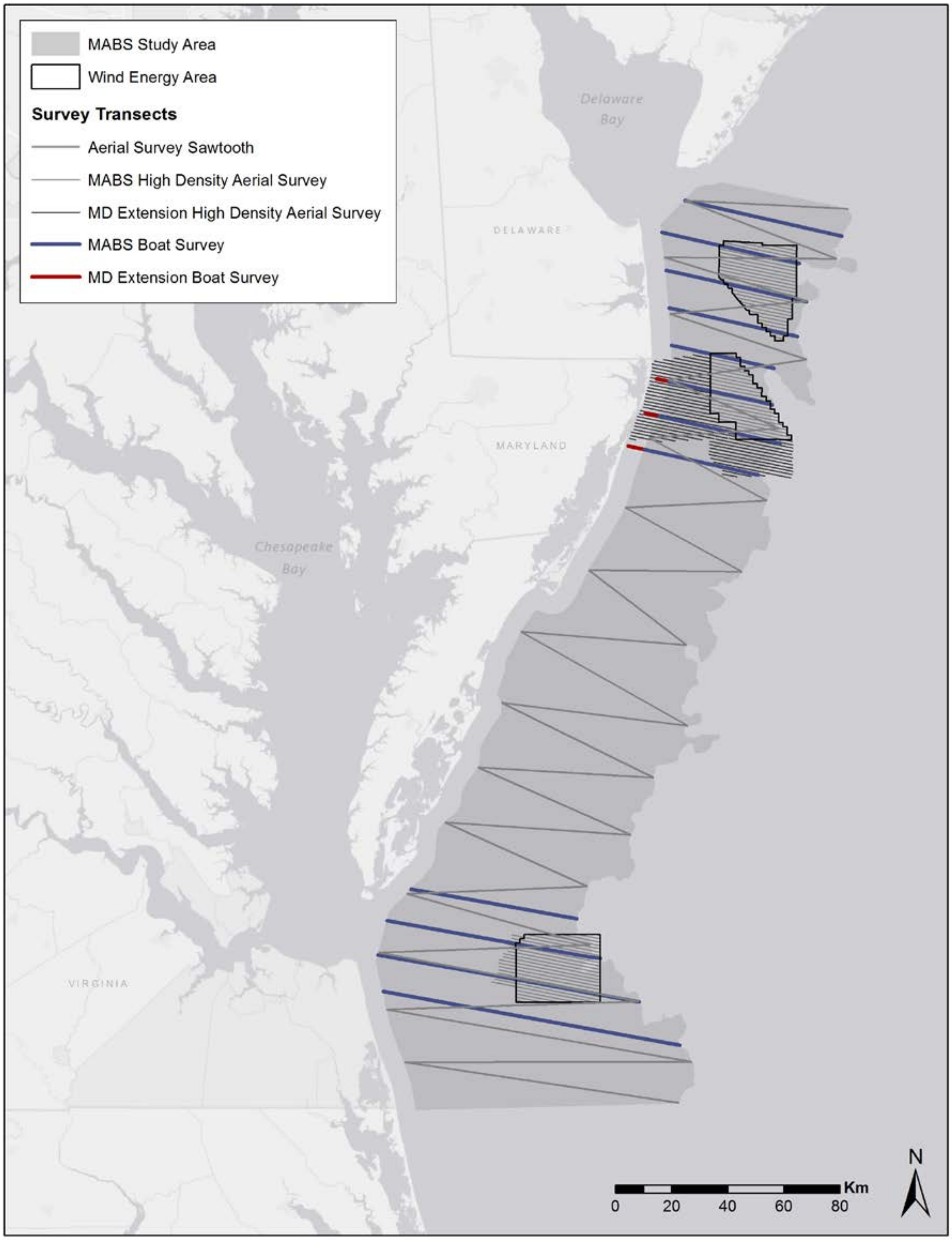

Figure I. Map of aerial and boat survey transects for the Mid-Atlantic Baseline Studies and Maryland Projects. High resolution digital video aerial survey transects are shown in gray and black and boat based survey transects are shown in red and blue.

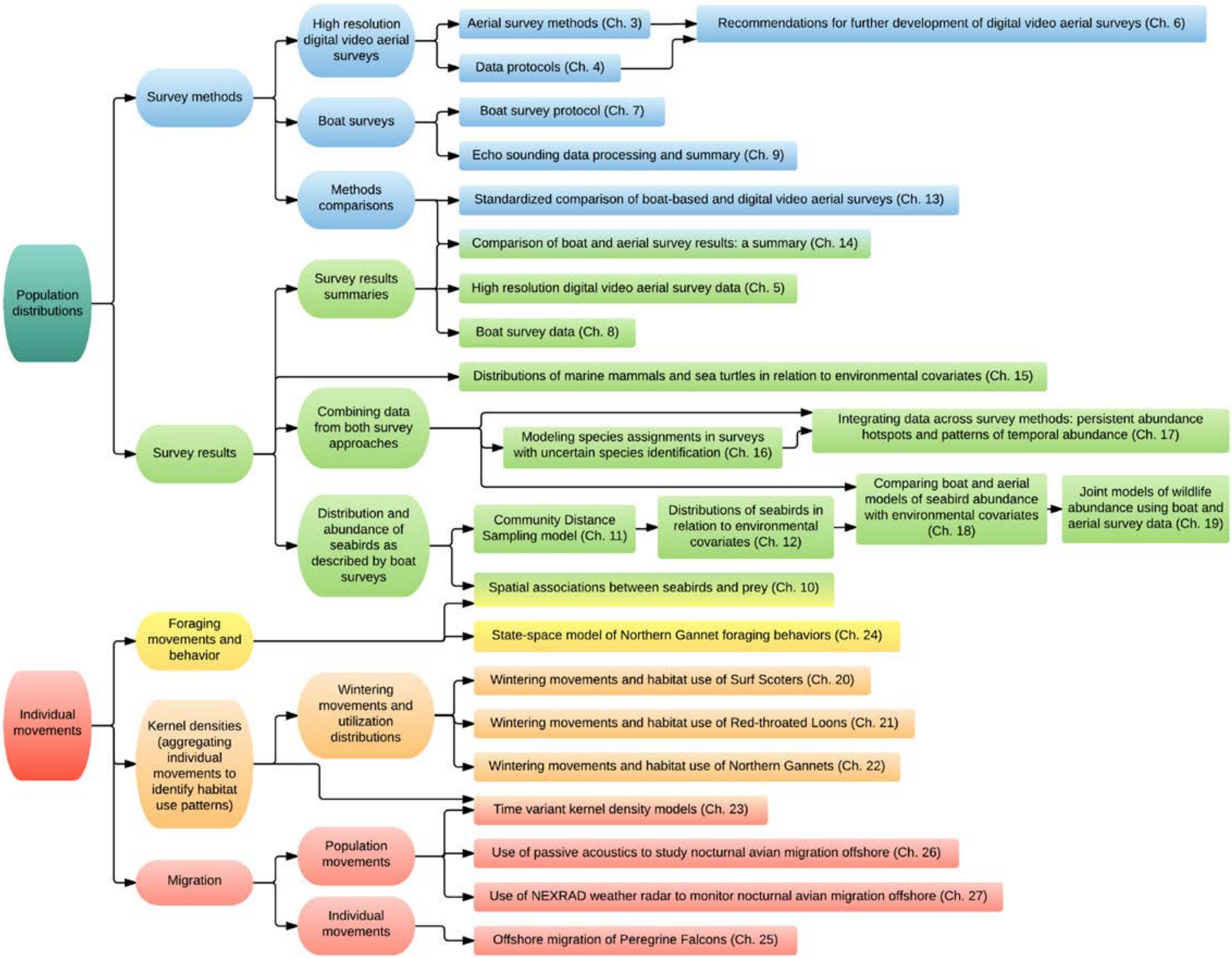

Figure II. Organization of chapters within this final report.