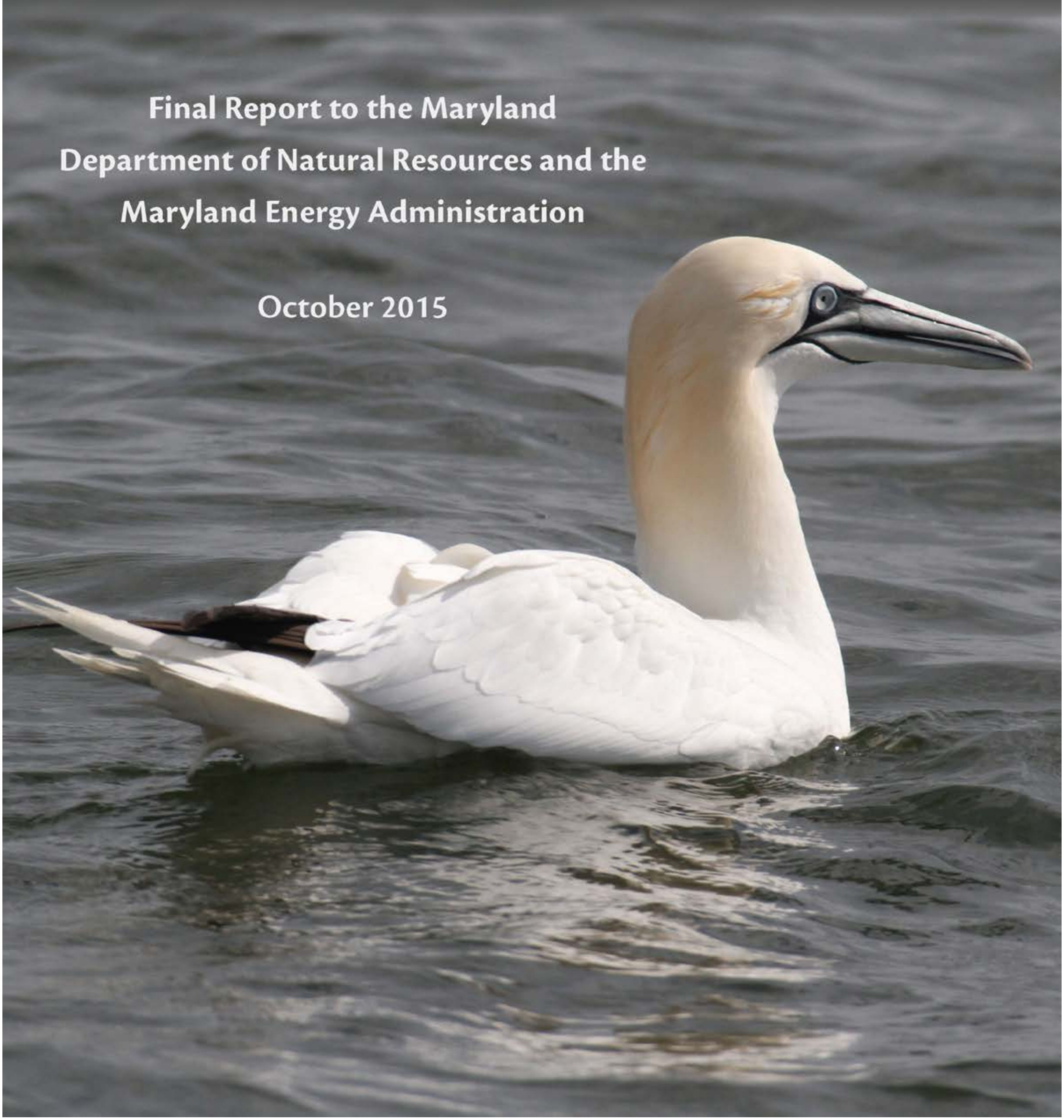
Baseline Wildlife Studies in Atlantic Waters Offshore of Maryland (2013-2014)



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

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Executive Summary

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In 2013, the Maryland Department of Natural Resources and the Maryland Energy Administration funded a study to develop baseline data on wildlife distribution and abundance offshore of Maryland, in state and federal marine waters. This study was intended to complement existing survey efforts in the region (see below), and provide detailed information on animal distributions in relation to future offshore wind energy development off Maryland's Atlantic coast.

The pre-existing Mid-Atlantic Baseline Studies (MABS) Project was a collaborative research effort to study bird, sea turtle, and marine mammal distributions, densities, and movements on the Mid-Atlantic Outer Continental Shelf between 2012 and 2014 (Williams et al. 2015a). This effort was led by the Biodiversity Research Institute (BRI) and funded by the U.S. Department of Energy (DOE) and other entities, and included collaborators from a wide variety of academic institutions, non-governmental organizations, federal agencies, foundations, and private companies. 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. The specific study area in the Mid-Atlantic was chosen because it was viewed as a likely location for future wind energy development offshore of Delaware, Maryland, and Virginia, including three federally designated Wind Energy Areas (WEAs). The study included a variety of research efforts, such as boat-based and aerial surveys in the Mid-Atlantic Outer Continental Shelf, individual tracking of several bird species, hierarchical modeling of data, and dissemination of project results to stakeholders and interested parties (Williams et al. 2015a).

In 2013, the Maryland Department of Natural Resources and the Maryland Energy Administration recognized an opportunity to significantly increase the MABS data collection effort. During the second year of the MABS study, the State provided funding to expand the existing surveys to cover a greater extent of Maryland's state and federal waters (the Maryland Project; Figure I). This expansion included three major components: the extension of existing boat surveys into Maryland state waters; the extension of high resolution digital video aerial surveys into areas west and south of the Maryland WEA (providing much greater survey coverage in these areas than was occurring previously); and the addition of an eighth annual aerial survey for Maryland waters, conducted in August 2013 (including both the WEA and the extension areas). Unless noted otherwise, data from the MABS Project and the Maryland Project were fully integrated, and survey data presented throughout this report include both the

Maryland Project transects and data from the broader MABS Project (see "Maryland study area," outlined in Figure I).

Project activities included standardized surveys to quantify bird, marine mammal, and sea turtle densities seasonally and annually throughout the study region in order to identify important habitat use or aggregation areas and examine temporal variation in these patterns. The project team also developed statistical models to help understand the drivers of these patterns and predict the combinations of environmental conditions likely to support large densities of birds, marine mammals, and turtles in the future (or in areas not included in our surveys). Such efforts have helped us to identify species that are likely to be exposed to offshore wind energy development activities in the Mid-Atlantic study area, and may also help with siting, permitting, and mitigating the effects to wildlife from these development activities.

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 the U.S. as well. This renewable resource has the potential to reduce global carbon emissions, and thus to positively affect many species, but 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 (Fox et al. 2006). Some species are negatively affected, while others show no net effect, or may even be affected positively (Bergström et al. 2014). 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 (Langston 2013). Effects from offshore wind may also be combined with other natural and anthropogenic stressors (Fox et al. 2006). 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 (Figure II). This report consists of four parts:

1. *Project overview*, which includes the executive summary (this section), a background chapter on the study area and methods (Chapter 1), a synthesis of study results, including the identification of large-scale patterns and trends (Chapter 2);

2. *Examining wildlife distributions and relative abundance from a digital video aerial survey platform* (Chapters 3-5);
3. *Examining wildlife distributions and abundance using boat-based surveys* (Chapters 6-9); and
4. *Integrating data across survey platforms* (Chapters 10-14), which incorporates data from boat and aerial survey efforts to gain a more comprehensive view of wildlife populations in the environment offshore of Maryland.

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 used 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. We also present a series of case studies to examine in detail the abundance and distributions of potentially vulnerable taxa. Observed community composition, distribution patterns, phenology, and behaviors in this study all varied somewhat from other recent baseline studies along the eastern seaboard, 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 in that 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 were coincident with areas closer to shore, though not always; Geo-Marine Inc. 2010; Paton et al. 2010). In several cases, results from these previous 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].

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 in Europe for monitoring wildlife in relation to offshore wind energy, as their higher flight speeds and much higher flight altitudes make them safer to conduct than visual aerial surveys, and also reduce or eliminate disturbance to wildlife compared to visual aerial or boat-based survey approaches. Digital approaches also produce archivable data, which allow for a robust quality assurance and audit process. There are still limitations to the digital video aerial survey method, however, including difficulties identifying some species. Digital aerial surveys avoid the distance bias common to visual methods, but to date, other forms of detection bias have not been addressed for digital aerial surveys.

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

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 and in an area west and south of the Maryland WEA, as well as a broader sawtooth transect throughout the MABS 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.

Completed analysis provided data on the number of target organisms in the video, the species or other identification category of organisms, the approximate flight height for flying birds and bats (Hatch et al., 2013; Chapter 5), and geospatial data for all objects that were used in modeling efforts (Chapter 5). Over 25,000 animals were observed within the Maryland study area over two years of digital video aerial surveys, including over 7,000 birds and 18,000 aquatic animals. The greatest numbers of animals were observed in July and September. Large groups of fishes and rays were observed in the data; if they were not individually distinguishable, they were counted as groups (e.g., shoals of fish or fevers of rays; Chapter 5), but otherwise, all animals were individually recorded and identified. The most common individually counted animals within the Maryland study area were rays, primarily Cownose Rays (*Rhinoptera bonasus*). Digital video aerial surveys proved to be particularly good at observing aquatic animals located near the water's surface, such as sea turtles and large migratory schools of rays. The most common avian group identified in video footage from the Maryland study area was gulls and terns (Laridae). Identification of animals to species proved difficult for some taxa, such as terns, alcids, and loons, 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). Species observed during aerial surveys within the Maryland study area that are listed as rare, threatened, or endangered in the state of Maryland included one Common Tern (*Sterna hirundo*), two Bald Eagles (*Haliaeetus leucocephalus*), 22 Loggerhead Sea Turtles (*Caretta caretta*), 16 Leatherback Sea Turtles (*Dermochelys coriacea*), eight Kemp's Ridley Sea Turtles (*Lepidochelys kempii*), five Green Sea Turtles (*Chelonia mydas*), one Hawksbill Sea Turtle (*Eretmochelys imbricata*), and one Humpback Whale (*Megaptera novaeangliae*; Chapter 5).

Roughly 56% of flying animals observed in the study area were estimated to be in the lowest flight altitude category (0-20 m above the water's surface); another 40% were estimated to be at altitude ranges between 20 and 200 m, which are at or near the potential rotor-sweep zone for future offshore wind energy development along the Eastern Seaboard (depending on the size and type of turbines; Chapter 5; Willmott et al., 2013).

Examining wildlife distributions and abundance using boat surveys

To accompany 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, marine mammals, and sea turtles (Chapter 6); 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 7). Over 10,000 animals were observed during surveys in the

Maryland study area, including over 9,700 birds and 300 aquatic animals, with the greatest numbers observed in February, October, and November, when large flocks of wintering birds were present in the study area (Chapter 7).

The most common species group identified during surveys in the Maryland study area was gulls and terns. Avian species observed within the Maryland study area that are listed as rare, threatened, or endangered in the state of Maryland included 235 Common Terns, 148 Royal Terns (*Thalasseus maximus*), 11 Forster's Terns (*Sterna forsteri*), eight Least Terns (*Sternula antillarum*), two Roseate Terns (*Sterna dougallii*, which are also federally endangered), one Northern Harrier (*Circus cyaneus*), and one Bald Eagle (Chapter 7). Non-avian state-listed species observed during boat surveys included 15 Loggerhead Sea Turtles, three Leatherback Sea Turtles, and one Humpback Whale (Chapter 7). While conducting 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 8).

Boat-based survey data were used to develop statistical models of seabird distributions, which also incorporated estimates of detectability and environmental covariates. Hierarchical Bayesian statistical approaches are useful for situations where distribution patterns or resource use vary with scale, and where species of interest are highly mobile and may be periodically unavailable for detection (Mordecai et al. 2011). For example, distance bias (in which observers are less likely to see animals located farther from the survey vessel) and other survey biases are well known for boat-based survey data (Buckland et al. 1993, 2001), and can be addressed within a hierarchical modeling context. These modeling methods 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 (Sollmann et al. 2015). This novel multi-species approach explicitly estimated seabird detection as well as abundance parameters (Sollmann et al. 2015). 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, Chapter 9 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. Within the Maryland study area, species with the highest predicted abundances included wintering Northern Gannets (*Morus bassanus*), Common Loons (*Gavia immer*), Razorbills (*Alca torda*), and scoters (*Melanitta* spp.), as well as Laughing Gulls (*Leucophaeus atricilla*) in fall. Overall avian abundance within the Maryland study area was predicted to be highest in winter and lowest in summer. High species density and diversity was also predicted to occur in spring and fall, suggesting that migratory and overwintering species dominated 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 species were present in the region during that time of year, including Roseate Terns, Least Terns, Common Terns, Forster's Terns, and Royal Terns. The CDS model enabled us to accommodate these relatively rare species and estimate their relationships with habitat features, improving our understanding of their distributions. This study demonstrated the importance of quantifying detection and determining the ecological drivers of a community's distribution and abundance in order to reliably predict potential exposure to offshore development activities (Chapter 9).

Integrating data across survey methods

Part IV of this report is focused on the comparison and integration of data from boat-based surveys and high resolution digital video aerial surveys. Chapter 10 contrasts results from boat-based and digital video aerial survey approaches. For some taxa, data from one survey approach were used independently to analyze wildlife distributions and relative abundance (Chapters 11-12). In other cases, digital video aerial survey data and boat survey data were used jointly (Chapters 11, 13-14) to describe distributions and abundance of animals across the study area.

In order to test the utility of high resolution digital video aerial surveys in U.S. waters and to examine how best to integrate new aerial survey data with historical data, we compared the digital video aerial data to boat-based surveys using experimentally controlled methods (Williams et al. 2015b), as well as using a more *ad hoc* approach (Chapter 10). These comparisons indicated largely complementary strengths of the two survey approaches, though they 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). Species identification rates, as well as detection rates, varied considerably between methods for some taxa (Chapter 10). In the Maryland study area, 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 (97%) compared to digital video aerial surveys (27%). In contrast, much higher counts and species diversity of sea turtles and other aquatic animals (rays, fish, sharks, etc.), were detected on the aerial surveys than on the boat surveys (Chapter 10). Gulls and terns were the most abundant avian group observed in both boat (33% of birds) and digital video aerial surveys (20% of birds) in the Maryland study area, with anatids (ducks and geese) the next most abundant group (25% boat and 19% aerial). This differed from the pattern seen in the broader MABS study area, where scoters comprised the highest percentage of birds observed.

These differences complicated the combined analysis of the two survey datasets, but also 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; Chapter 11). The bat observations from this study provided new evidence of bat movements offshore, and offered insight into their flight heights above sea level and the times of day at which such migrations may occur. Collaborators also used boat-based and aerial 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 (Chapter 11), which 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, but 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 11). 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 Maryland's northern Atlantic coast 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, and alcids.

The incorporation of environmental covariates into modeling efforts allowed for the prediction of relative densities across the study area for several taxa (Chapters 12-13), with one or the other survey dataset used to describe each population 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 12). 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 MABS study area. Bottlenose Dolphin (*Tursiops truncatus*) 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 several cases, boat-based and digital aerial survey datasets could be combined using recently developed integrated modeling frameworks. 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 (Hostetter et al., 2015; Chapter 11). In a preliminary analysis of data for four seabird groups (terns, gannets, loons, and alcids), boat and aerial models with remotely collected environmental covariate data 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 (Chapter 13). Accounting for imperfect 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 temporal variation or differences in the sampling domain or detectability.

In Chapter 14, project collaborators built off of this model comparison to develop 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 13. The combined predictions of this chapter generally supported the conclusions of Chapters 9, 11, and 13, 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.

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, which leads to a complex ecosystem where the community composition is shifting regularly, 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. To minimize the effects of such anthropogenic activities on wildlife populations, 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 the resulting analysis and presentation of wildlife distribution data. The methods that we used to examine marine wildlife distributions in the Mid-Atlantic each 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).

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, which allowed for submerged animals to more easily be detected in the upper reaches of the water column (Chapters 5 and 10; 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 7 and 10). 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.

Patterns of wildlife distribution and abundance

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 was higher in nearshore areas, although patterns varied seasonally. 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, 8, and 11). 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 11). 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 off of Maryland’s northern Atlantic coast, 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 location as compared to the remainder of the study area. High numbers of some species may have been consistently present in other nearshore areas of the Mid-Atlantic as well, but similar surveys were not conducted in state waters elsewhere during this study.

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 (Hydrobatidae), 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 Variations

There were strong seasonal variations in community composition and wildlife distributions (Chapters 9, 11, and 12). Important environmental factors influencing species distributions included distance to shore, sea surface temperature, primary productivity levels (i.e., chlorophyll *a*), salinity, seafloor slope, and sediment type, though wildlife responses to these factors varied widely by species and time of year (Chapters 9 and 12). The breadth of the 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 of the study area, using it for foraging during the breeding season or for foraging, roosting, and other activities during non-breeding periods.

During the spring (March-May), high species diversity was observed, 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 (Procellariidae), 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 and a variety of sea turtle species, which were predicted to occur in highest densities offshore of Virginia (Chapter 12).

During summer (June-August), hydroacoustic surveys generally observed higher levels of aquatic biomass in nearshore areas (Chapter 8). Seabirds were also generally more associated with nearshore habitat in the summer than in the spring (Chapter 9). Breeding seabirds, including several species of terns, were predicted to be associated with nearshore habitat and were found foraging near the shore and near the mouths of the bays (Chapters 9, 11, and 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 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 predicted to occur primarily in the southern parts of the regional study area (Chapter 12).

In the fall (September-November), Cownose Rays moved out of the bays and aggregated in dense groups in the Maryland study area as they migrated south (Chapter 5). Seabird species composition changed over the course of the fall, as summer residents migrated south and winter residents migrated into the region from breeding grounds farther north or inland (Chapter 11). Landbirds, shorebirds, and bats were recorded flying over open waters as they migrated through the regional study area (Chapter 11; Adams et al., 2015; Hatch et al., 2013). Alcids moved into the study region in the fall (Chapter 11). Large schools of forage fish were also observed in the regional study area, particularly nearshore and on the Maryland Project transects (Chapters 8 and 11). Sea turtles were widespread across 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 largely arrived in the regional study area in November (Chapters 11-12).

During winter (December-February), 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 (Chapters 9 and 11). Scoters were observed in large aggregations at the mouths of Chesapeake Bay and Delaware Bay (Chapter 11). Common Loons, 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).

Next steps

All data generated from this project will be made publically available in late 2015 via the Northwest Atlantic Seabird Catalog (formerly known as the Compendium of Avian Information), 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 expected to be incorporated into other public databases, such as the Mid-Atlantic Regional Ocean Council's (MARCO) Data Portal[2].

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

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[2] http://midatlanticocean.org/data-portal/

implications of individual-level impacts for population vulnerability (Crichton 1999, Fox et al. 2006). In this baseline study of wildlife distributions, we focused on developing a better understanding of wildlife distributions and potential 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. These baseline data may be used to inform future development or other proposed ocean activities. These results may also help to address environmental permitting requirements and inform mitigation efforts aimed at minimizing effects to wildlife. 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.

Literature cited

Adams, E., R. Lambert, E. Connelly, A. Gilbert, and K. Williams (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*.

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

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

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

Boehlert, G. W., and A. B. Gill (2010). Environmental and Ecological Effects of Ocean Renewable Energy Development: A Current Synthesis. Oceanography 23:68–81.

Breton, S. P., and G. Moe (2009). Status, plans and technologies for offshore wind turbines in Europe and North America. Renewable Energy 34:646–654.

Buckland, S. T., D. R. Anderson, K. P. Burnham, and J. L. Laake (1993). Distance sampling: estimating abundance of biological populations. Chapman and Hall, London, UK.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas (2001). Introduction to Distance Sampling: Estimating abundance of Biological Populations. Oxford University Press, Oxford, UK.

Crichton, D. (1999). The risk triangle. In Natural Disaster Management (J. Ingleton, Editor). Tudor Rose Holdings Ltd., Leicester, England, pp. 102–103.

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

Gardner, B., P. J. Sullivan, S. Epperly, and S. J. Morreale (2008). Hierarchical modeling of bycatch rates of sea turtles in the western North Atlantic. Endangered Species Research 5:279–289. doi: 10.3354/esr00105

Geo-Marine Inc. (2010). 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*.

Hatch, S. K., E. E. Connelly, T. J. Divoll, I. J. Stenhouse, and K. A. Williams (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

Hostetter, N., B. Gardner, A. Gilbert, E. Connelly, and M. Duron (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*.

Kenney, R. D. (1990). Bottlenose dolphins off the northeastern United States. In The bottlenose dolphin. Academic Press, San Diego, CA, pp. 369–386.

Kunz, T. H., E. B. Arnett, B. M. Cooper, W. P. Erickson, R. P. Larkin, T. Mabee, M. L. Morrison, M. D. Strickland, and J. M. Szewczak (2007). Assessing Impacts of Wind-Energy Development on Nocturnally Active Birds and Bats: A Guidance Document. Journal of Wildlife Management 71:2449–2486. doi: 10.2193/2007-270

Langston, R. H. W. (2013). Birds and wind projects across the pond: A UK perspective. Wildlife Society Bulletin 37:5–18. doi: 10.1002/wsb.262

Mordecai, R. S., B. J. Mattsson, C. J. Tzilkowski, and R. J. Cooper (2011). Addressing challenges when studying mobile or episodic species: hierarchical Bayes estimation of occupancy and use. Journal of Applied Ecology 48:56–66. doi: 10.1111/j.1365-2664.2010.01921.x

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*.

O'Connell, A. F., B. Gardner, A. T. Gilbert, and K. Laurent (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*.

Paton, P., K. Winiarski, C. Trocki, and S. McWilliams (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.

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.

Santora, J. A., and R. R. Veit (2013). Spatio-temporal persistence of top predator hotspots near the Antarctic Peninsula. Marine Ecology Progress Series 487:287–304. doi: 10.3354/meps10350

Sollmann, R., B. Gardner, A. Gilbert, K. Williams, and R. Veit (2015). A community distance sampling model to investigate the abundance and distribution of seabirds. *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.

Williams, K., E. Connelly, S. Johnson, and I. Stenhouse (2015a). 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 2015-11. Biodiversity Research Institute, Portland, Maine.

Williams, K., I. Stenhouse, E. Adams, E. Connelly, A. Gilbert, and M. Duron (2015b). 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*.

Willmott, J. R., G. Forcey, and A. Kent (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. J., D. L. Miller, P. W. C. Paton, and S. R. McWilliams (2013). Spatially explicit model of wintering common loons: Conservation implications. Marine Ecology Progress Series 492:273–283. doi: 10.3354/meps10492

Winiarski, K. J., D. L. Miller, P. W. C. Paton, and S. R. McWilliams (2014). A spatial conservation prioritization approach for protecting marine birds given proposed offshore wind energy development. Biological Conservation 169:79–88. doi: 10.1016/j.biocon.2013.11.004

Yoder, J. A., J. E. O’Reilly, A. H. Barnard, T. S. Moore, and C. M. Ruhsam (2001). Variability in coastal zone color scanner (CZCS) Chlorophyll imagery of ocean margin waters off the US East Coast. Continental Shelf Research 21:1191–1218. doi: 10.1016/S0278-4343(01)00009-7

Zipkin, E. F., B. Gardner, A. T. Gilbert, A. F. O’Connell, J. A. Royle, and E. D. Silverman (2010). Distribution patterns of wintering sea ducks in relation to the North Atlantic Oscillation and local environmental characteristics. Oecologia 163:893–902.

Figures

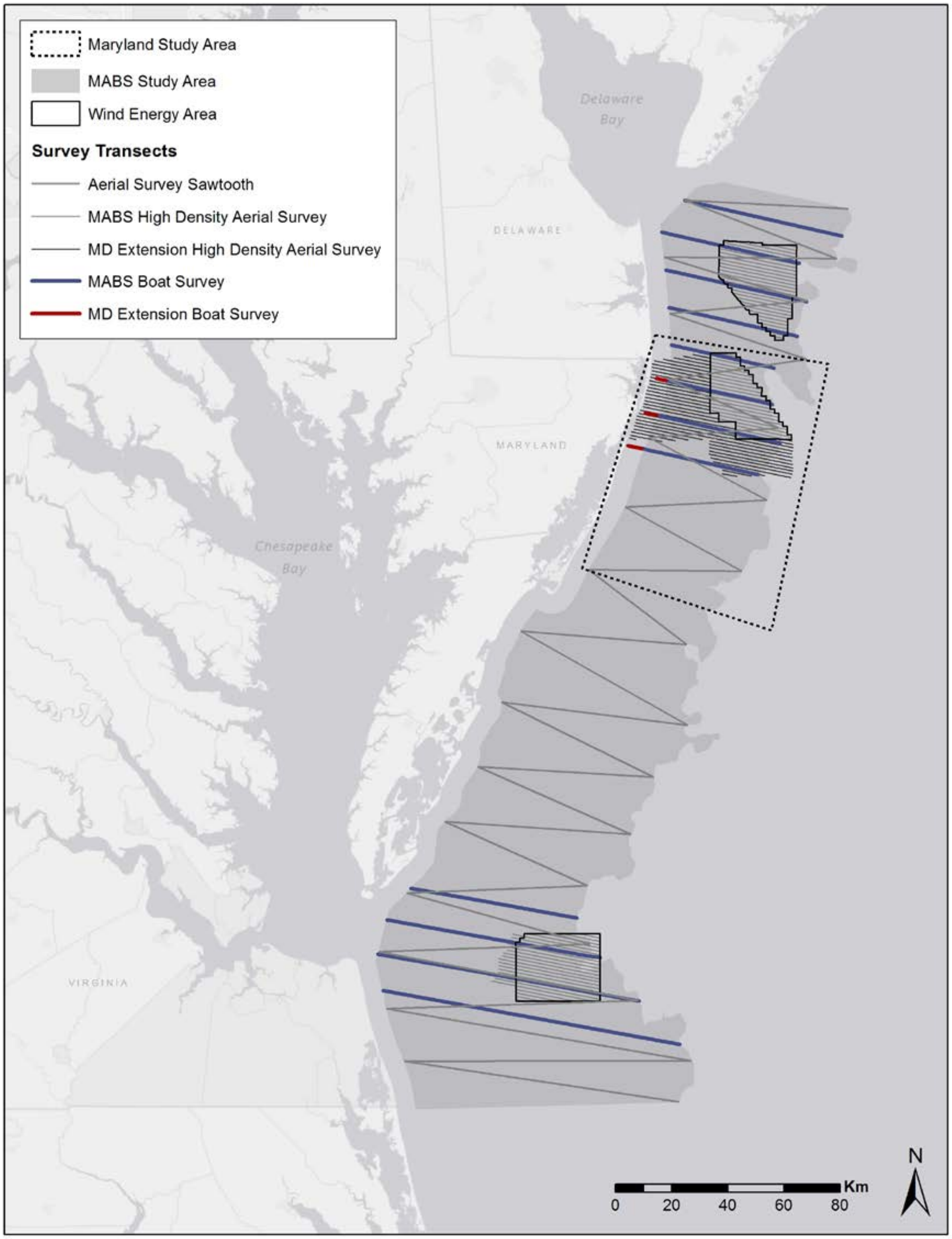

Figure I. Map of aerial and boat survey transects for the Mid-Atlantic Baseline Studies (MABS) and Maryland Projects. High resolution digital video aerial survey transects are shown in gray (MABS) and black (Maryland); boat based survey transects are shown in blue (MABS) and red (Maryland). The "Maryland Study Area," for which data are presented throughout much of this report, includes data collected under both projects.

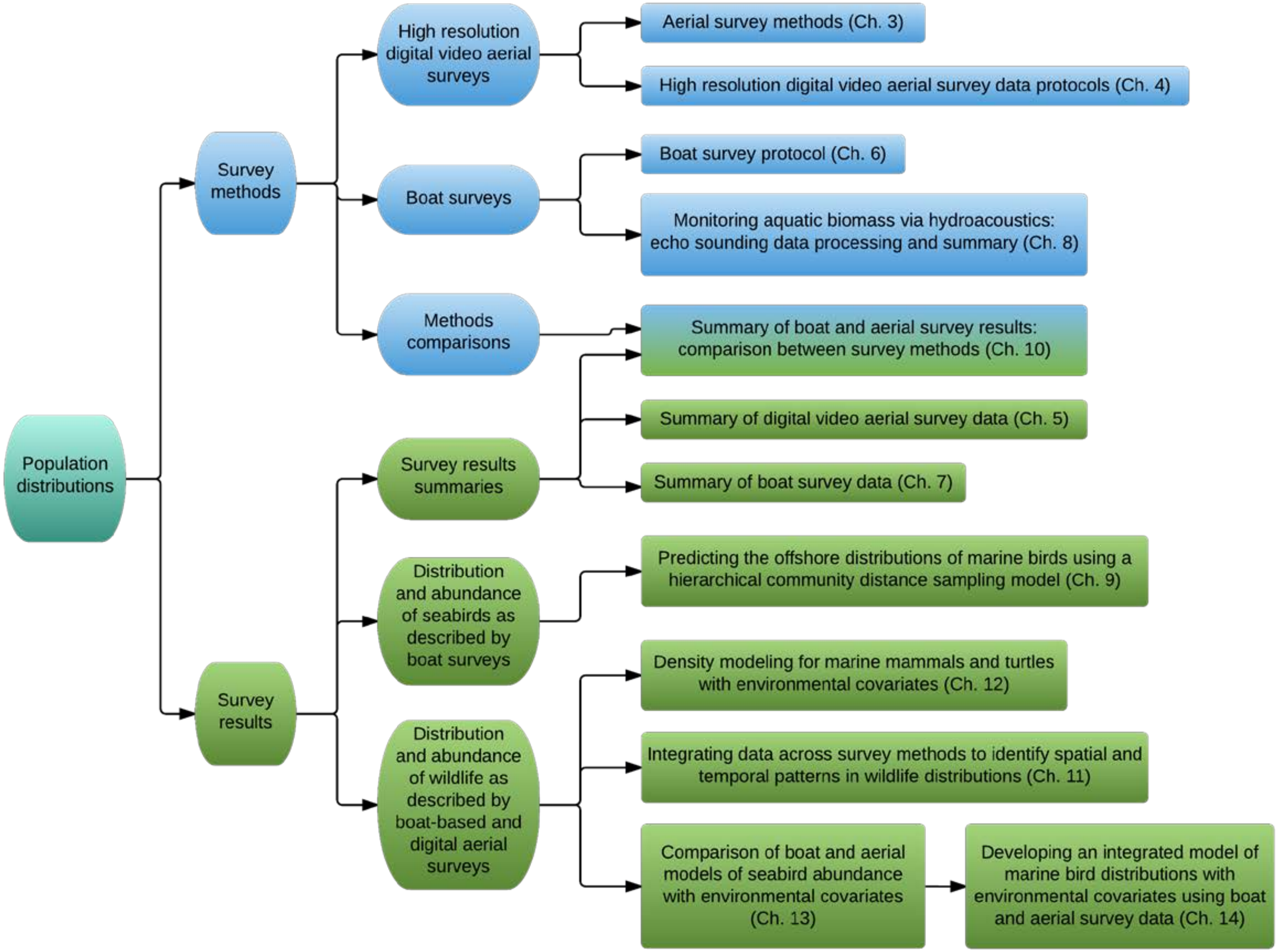

Figure II. Organization of chapters within this final report.

Chapter 1: Ecosystem background and project activities

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

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Abstract

The state of Maryland has a significant swath of oceanic waters off its eastern shore. These waters, as well as the rest of the Mid-Atlantic region, are used by a broad range of marine wildlife species across the entire annual cycle. This is due in part to relatively high levels of primary productivity, high levels of seasonal variation in environmental conditions, and the region's central location on the edge of the continent (placing it within migratory routes for many taxa). Thus, 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. The Mid-Atlantic Baseline Studies (MABS) Project and Maryland Project, described here, provide two years of intensive survey data and other information (2012-2014) to improve our understanding of this ecosystem.

The study area included waters on the Outer Continental Shelf off the coasts of Delaware, Maryland, and Virginia between the state-federal boundary (5.6 km from shore) and the 30 m isobath. Offshore of Maryland, the study area also extended westward to the shoreline to include state waters. This region is characterized by a relatively flat, gently sloping sea floor, with sandy shoals along the inner continental shelf interspersed with smaller patches of other benthic habitats. The cool Labrador Current and warmer Gulf Stream collide in the Mid-Atlantic, and the region also exhibits a strong seasonal cycle in sea surface temperatures and salinity, with large volumes of fresh water emptying onto the shelf via the Hudson Estuary, Delaware Bay, and Chesapeake Bay. Seasonal stratification on the shelf and nutrient influxes from the bays drive much of the primary productivity in the region, and are thus strong influences on the distributions of wildlife and the characteristics of this ecosystem.

Methods employed in this study included boat surveys and high resolution digital video aerial surveys. This is the first study to use high resolution digital video aerial surveys on a large scale in North America, as it is a relatively new method for collecting distribution and abundance data on animals in the marine ecosystem. Boat-based and digital video aerial surveys each showed distinct benefits in detecting different taxa. Digital aerial surveys have the added 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 surveys can provide detailed behavioral data, had generally better rates of identification of animals to species, and the analytical approaches for boat survey data are well established. Due to these respective strengths, integrating data from both survey approaches was in some cases the most effective means of filling data gaps and describing wildlife distributions in the Mid-Atlantic and Maryland study areas. Several analytical approaches were used in this study, including several approaches for integrating boat and aerial survey data, and the advantages and disadvantages of these approaches are also discussed.

Ecosystem background

The interactions among biota (e.g., organisms, populations, and communities) and abiota (i.e., the physical environment) comprise an ecosystem. The study of ecology attempts to identify these critical connections between organisms and their environment, and explain how those relationships affect, or are impacted by, the physical attributes of their habitats. Establishing baseline ecosystem function and identifying areas of important habitat and high species biodiversity is crucial to wildlife management.

For the last few decades there has been wide recognition that traditional methods of resource management, where management actions or environmental assessments target a single population, species, or issue, are extremely limiting or potentially misleading (Ehler and Douvere, 2009). Since the 1990s, management and regulatory agencies have increasingly recognized the importance of addressing research, conservation, and planning at the ecosystem scale (Christensen et al., 1996; Grumbine, 1994). Despite this fundamental shift in our collective thinking, however, few research studies are conducted at broad enough geographic or temporal scales to provide the data necessary to fully understand the complex relationships between species and their dynamic physical environments (Arkema et al., 2006; Leslie and McLeod, 2011; Ruckelshaus et al., 2008). In general, our narrow understanding of these relationships hinders the development and implementation of large-scale, ecosystem-wide management strategies, as well as the prediction of responses of species to broad environmental shifts brought about by anthropogenic activities and climatic change (Griffies, 2004; Tallis et al., 2010).

Marine ecosystems are particularly complex and dynamic assemblages that involve a variety of co-evolved species. Thus, research studies integrated across taxonomic groups and among trophic levels are critical to understanding marine ecosystem processes and mechanisms (Wiebe et al., 2009). To date, marine studies at the ecosystem scale have largely focused on the assessment and management of commercial fish stocks (Pikitch et al., 2004; Smith et al., 2007). In this study, however, we not only analyze the distributions and movements of prominent marine wildlife species across a large swath of the Mid-Atlantic coastal region, but also examine the influence of biotic and abiotic factors, such as productivity, depth, and salinity, on these distributions and movements. This ecosystem-based approach also establishes a broad baseline from which we may be able to detect and understand the impacts of future activities in this ecologically and economically important region.

The Mid-Atlantic and Maryland study areas

Politically, the coastal Mid-Atlantic region includes the states of Virginia, Maryland, Delaware, New Jersey, and New York. Oceanographically, however, the waters off the East Coast of the U.S. are divided into three large geographic zones (the Gulf of Maine/Bay of Fundy, the Mid-Atlantic Bight, and the South Atlantic Bight). The central sector, the Mid-Atlantic Bight, spans an area from Cape Cod south to Cape Hatteras. This central region of the Outer Continental Shelf is characterized by a broad expanse of gently-sloping, sandy-bottomed continental shelf that extends up to 150 km to the shelf edge, where the waters reach about 200 m deep. On the seafloor, the continental shelf features a series of linear sandy ridges that run roughly parallel to shore (Field, 1980).These sand shoals provide important spawning habitat for a variety of benthic and epipelagic fishes, and support a diverse epifauna (Diaz et al., 2004). Beyond the shelf edge, the continental slope descends rapidly to around 3,000 m. Much of the coastal region is bathed in cool Arctic waters, brought south by the Labrador Current as it travels down the east coast. At the southern end of this region, around Cape Hatteras, these cool waters collide with the warmer water of the Gulf Stream (Townsend et al., 2006). The region also exhibits a strong seasonal cycle in sea surface temperatures (spanning approximately 3-30 °C), and in salinity, with large volumes of fresh water emptying onto the shelf via the Hudson Estuary, Delaware Bay, and Chesapeake Bay.

While the marine environment of Maryland is dominated by the massive and highly productive Chesapeake Bay, Maryland also has a significant swath of oceanic waters off its eastern shore. These waters are dominated by linear shoals along the inner continental shelf, as is true in many other areas along the east coast between New York and Florida (Conkwright et al., 2000). These shallow, sandy shoals are comprised of significantly different sediments than surrounding finer, often peaty bottom sediments, and can either be attached to the shore (e.g., near barrier islands) or detached from the shoreline, as is the case for many shoals offshore of Maryland (Conkwright et al., 2000). These shoals are important resources for many species of marine wildlife (Diaz et al., 2004), but are also areas of interest for various types of offshore development, including sand mining for beach replenishment (Conkwright et al., 2000).

The Maryland Wind Energy Area (WEA), like other benthic habitats off Maryland's eastern shore, is flat and gently sloping towards the Continental Shelf, and is dominated by sandy habitats, though there are patches of fine-grained mud and gravel-cobble habitats as well, each of which support slightly different benthic faunas (Guida et al., 2015). Although most of the Mid-Atlantic Bight is soft-bottomed and devoid of major structure, patches of hard bottom exist off of Maryland and Delaware, and these natural rocky areas support substantial stands of the sea whip (*Leptogorgia virgulata*) in waters as shallow as eight meters and <16 km from shore (Packer and Dorfman, 2012). These nearshore patches of corals provide rare habitat for structure-loving fish species such as black sea bass (*Centropristis striata*) in this otherwise open, sandy region (Packer and Dorfman, 2012). Few such patches appear to be present within the Maryland WEA, however (Guida et al., 2015).

Seasonal stratification drives overall annual primary productivity across the Mid-Atlantic Outer Continental Shelf, with the largest and most persistent phytoplankton blooms in the late fall and winter (Schofield et al., 2008; Yoder et al., 2001). Areas near the mouths of Delaware Bay and Chesapeake Bay, however, typically have the highest levels of chlorophyll *a* in the Mid-Atlantic study area, due to their proximity to these highly productive estuarine ecosystems. The influxes of fresh water from the bays deliver nutrients such as nitrogen and phosphorus, and year-round mixing of saline and fresh waters through estuarine circulation, in combination with strong tidal currents, boosts primary productivity in these areas. As water flows from the bays into the coastal area, nutrient- and phytoplankton-rich waters are swept southwards by the Labrador Current into other nearshore areas. In these shallow coastal waters, sunlight is able to penetrate a relatively high proportion of the water column (Schofield et al., 2008; Xu et al., 2011), further fueling photosynthetic activity and growth of phytoplankton where nutrients are available. Downstream of Delaware Bay, the productivity in Maryland coastal waters is boosted from this infusion of nutrients.

Phytoplankton blooms are followed by a pulse in secondary productivity – zooplankton species foraging on the phytoplankton – which in turn become food for larger predators, such as small fishes. The Mid-Atlantic Bight is generally rich in these small, schooling epipelagic fishes, known as 'forage fish' due to their critical importance for many piscivorous predators, and their pivotal role in driving ecosystems worldwide (Pikitch et al., 2014). In the Mid-Atlantic region, key forage fish species include Atlantic menhaden (*Brevoortia tyrranus*), Atlantic mackerel (*Scomber scombrus*), butterfish (*Peprilus triacanthus*), sand lance (*Ammodytes americanus* and *A. dubius*), anchovies (including *Anchoa mitchelli*, *A. hepsetus*, and *Engraulis eurystole*), and 'river herring', including the alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*; Clay et al., 2014; Kenney et al., 1997; Safina et al., 1990). Two large invertebrate species, the longfin inshore squid (*Loligo paeleii*) and the northern shortfin squid (*Illex illecebrosus*), are also important prey items for a broad range of predators in the region (Dawe et al., 2007; Hendrickson, 2004). In Maryland, species of commercial importance off the eastern shore include Atlantic menhaden, black sea bass, bluefish (*Pomatomus saltatrix*), summer flounder (*Paralichthys dentatus*), and weakfish (*Cynoscion regalis*), among others (Vogt et al., 2015). Many of these species serve as forage fish for higher trophic level predators, such as seabirds and marine mammals, but most are also predators themselves, feeding on smaller forage species, such as anchovies, menhaden, and herring. In this study, we observed numerous schools of small fish across the region, most commonly from May to October (Chapter 11). The persistence and number of these schools was particularly notable within about 30 km of Maryland's northern shoreline (Chapter 11). The presence of these forage fish populations indicate the high levels of productivity in the area, and is likely responsible, in part, for the relatively large numbers of predators that use the area (Veit, 2015).

These relatively high levels of productivity, as compared to many other areas in the western North Atlantic (Yoder et al., 2001), ensure that the Mid-Atlantic region is used by a broad range of marine wildlife species across the entire annual cycle. 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). This results in a complex ecosystem where the community composition shifts regularly, and temporal and geographic patterns are highly variable. The Mid-Atlantic supports large populations of marine wildlife in the summer, some of which breed in the area, such as coastal birds and some sea turtles. Other summer residents are visiting from the Southern Hemisphere (where they breed during the austral summer), such as shearwaters (Procellaridae) and storm-petrels (Hydrobatidae). In the fall, many of the summer residents leave the area and migrate south, but are replaced by species that breed further north and winter in the Mid-Atlantic, such as Northern Gannets (*Morus bassanus*). Many marine species also make annual migrations up and down the eastern seaboard, taking them directly through the Mid-Atlantic region in spring and fall. Many migrant terrestrial species, such as landbirds and bats, may follow the coastline on their annual trips, or choose more direct flight routes over expanses of open water. These seasonal variations in wildlife communities are explored in further detail in Chapter 2.

The Mid-Atlantic Baseline Studies and Maryland projects fill 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 is a focus due to its ecological significance and relative lack of data on wildlife distributions. In addition, 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, with an annual average predicted offshore wind speed of 7-9 m/s (16-20 mph), 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.

In this overview of project methods, we discuss the range of study approaches used to examine the distributions, abundance, and habitat use of sea turtles, marine mammals, birds, and other wildlife. Within this report, we present survey results in a variety of ways, and a brief overview of the advantages and disadvantages of each analytical approach are also discussed.

Methods used in the Mid-Atlantic Baseline Studies Project and Maryland Project

The Mid-Atlantic Baseline Studies (MABS; 2012-2015) and Maryland (2013-2015) projects fill significant information gaps for wildlife in a large swath of the Mid-Atlantic region between New Jersey and North Carolina. The MABS project study area included waters from the state-federal boundary (5.6 km from shore) east to the 30 m isobath (roughly 40-90 km from shore) on the Outer Continental Shelf off the coasts of Delaware, Maryland, and Virginia (Figure 1-1). This study provided two years of high-density survey data and other information to improve our understanding of this ecosystem. Study methods included both boat surveys and high resolution digital video aerial surveys. The Maryland Project expanded the MABS survey effort in 2013-2014, in order to develop more detailed data on wildlife distributions, abundance, and habitat use offshore of the state. This included the extension of boat-based surveys into Maryland state waters and the expansion of high density digital video aerial surveys south and west of the Maryland WEA (Figure 1-1). This Maryland project also included a partial 15th aerial survey, conducted in August 2013. All Maryland Project survey efforts, as well as data management and quality assurance processes, were conducted in conjunction with MABS surveys, and the two datasets were combined prior to analysis.

This was the first use of digital aerial surveys on a large scale in North America, and the safety and speed with which surveys can be conducted make this approach attractive in the offshore environment. Boat-based surveys, on the other hand, provide detailed behavioral data, and the analytical approaches for boat survey data are well established. Often, approaches for studying wildlife must balance geographic vs. temporal coverage; focusing on abundance (or relative abundance) vs. obtaining detailed species identifications; and gathering data on behavior and movements vs. population-wide distributions. By using a complimentary suite of methods, we aimed to minimize knowledge gaps and develop a comprehensive understanding of the Mid-Atlantic marine ecosystem. We present results from these surveys in a variety of ways, ranging from raw observation data (for rare species such as large whales) to fully effort-corrected and bias-corrected predictive models of animal distributions and abundance. Throughout the report, data are presented for either (1) the Maryland study area (Figure 1-1), which includes Maryland Project transects as well as MABS data from transects located in federal waters offshore of Maryland, or (2) the entire MABS regional study area (including all data from both projects).

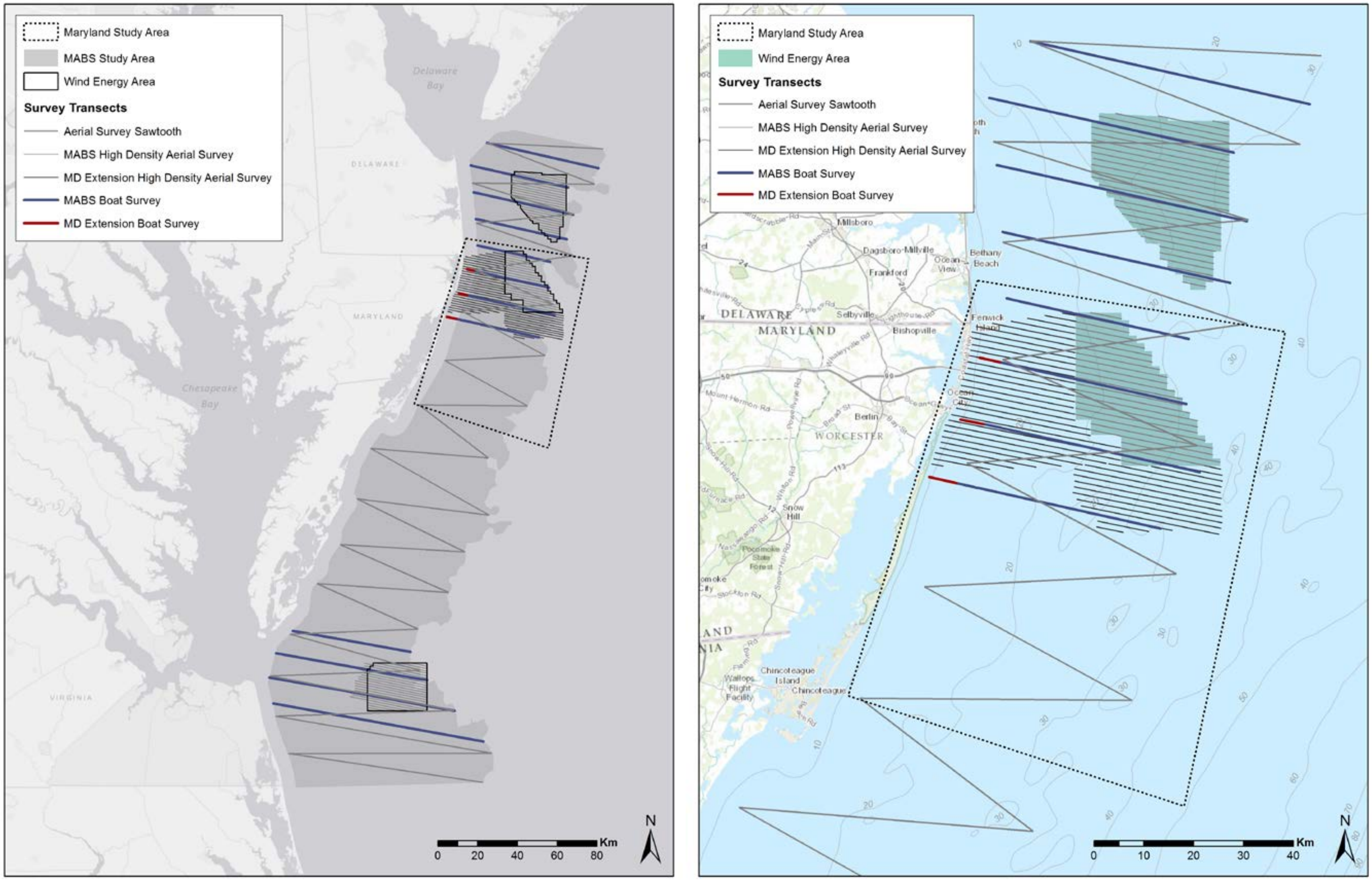

Figure 1-1. Maps of aerial and boat survey transects for the Mid-Atlantic Baseline Studies Project (left) and Maryland Project (right). High resolution digital video aerial survey transects are shown in gray (MABS) and black (Maryland); boat-based survey transects are shown in blue (MABS) and red (Maryland). The “Maryland study area” for which data are presented throughout much of this report includes data collected during both projects.

Boat surveys

Boat-based surveys are a widely-used method to monitor offshore wildlife. Due to the relatively slow speed of survey vessels, observers have time to collect data on species presence and abundance and can often record information on observed behaviors, such as an animal's interactions with conspecifics or other marine fauna (e.g., while in multi-species feeding aggregations; Chapters 6-7). Observers can also collect *in-situ* environmental and biological data, such as wind speed, wave height, sea surface temperature, salinity, and biomass densities (Chapters 6 and 8). Relating these directly to sightings can help explain the drivers of wildlife distributions, as well as variation in detection rates for different species (Ainley et al., 2005).

Detection of animals in boat surveys is not perfect, although there are methods to account for missed animals on the survey transects (Hedley and Buckland, 2004; Royle et al., 2004; Spear et al., 2004). An observer's ability to detect or identify an animal correctly decreases with increased distance between the observer and the animal, and can be further limited by deteriorating weather conditions (Royle et al., 2004). Mammal-focused surveys have particularly strict limitations on the wave height in which accurate data can be collected (Evans and Hammond 2004). The quality of the data collected, including species identifications and distance data used for developing abundance estimates, is also dependent on the skills of the observer, which can be variable (Spear et al., 2004). When observers are unable to identify individuals to species, they are trained to record the genus or family, so as to avoid misidentification. Uncertainty in these species identifications is difficult to measure, however, and is generally under-recognized or ignored in boat-based surveys, with potential implications for abundance estimation (Conn et al., 2013; Hobbs and Waite, 2010). The simultaneous use of independent observers can provide information on observer biases (Nichols et al., 2000; Ronconi and Burger, 2009), but without any permanent record of observations, it is difficult to verify identifications on boat surveys.

The movement of the survey vessel through the environment can also alter animal behaviors, whether through disturbance or attraction (Bodey et al., 2014; Schwemmer et al., 2014; Spear et al., 2004; Williams et al., 2015). Some marine birds, such as scoters (*Melanitta* spp.), auks (Alcidae), and loons (*Gavia* spp.), will flush or dive when approached by a boat, even from several hundred meters away (Henkel et al., 2007; Schwemmer et al., 2014). Other seabirds that scavenge from fishing boats, such as Northern Gannets, are attracted to slow-moving vessels from several kilometers away (Spear et al., 2004; Votier et al., 2013). Marine mammals and sea turtles also react to the presence of vessels, with responses varying depending on the size/type of vessel, vessel speed, and the species involved (Mattson et al., 2005; Normandeau Associates Inc., 2013).

Data collected from boat-based surveys present "snapshots" at given points in time. Although boat-based surveys provide an excellent opportunity for collecting behavioral and population-level data across a broad spatial extent (e.g., seasonally), they do not easily allow for understanding of individual movements and use of the study area. Survey speed is also much lower than for aerial surveys, limiting spatial coverage. While surveying more of the study area provides greater statistical power, as more information on species distributions can be collected over a broader range of environmental features, the time required to do so leads to greater turnover of animals in the study region and results in the potential for double counting of individuals or groups as they move around the area (Spear et al., 2004). In addition, boat surveys are conducted during daylight hours in fair weather conditions, which limits our understanding of nocturnal behaviors and animal behaviors in harsher weather conditions.

High resolution digital video aerial surveys

High resolution digital video aerial surveys are a relatively new method for collecting distribution and abundance data on animals in the marine ecosystem (Thaxter and Burton, 2009). Though digital video aerial surveys have become common practice for offshore wind energy planning and monitoring in Europe (Buckland et al., 2012), this study was the first to apply these methods on a broad spatial scale in the United States. Digital aerial surveys have a high cost efficiency on broad spatial scales, and are expected to largely replace traditional visual surveys, by boat or aircraft, in the offshore environment in Europe (Buckland et al., 2012). High resolution video surveys collect information on abundance for most species and the width of the survey transect is predetermined by the camera's field of view, allowing for easy calculation of the size of the surveyed area. Given the altitude at which surveys can be flown (>600 m), there is minimal disturbance to marine wildlife, unlike with boat-based surveys (Buckland et al., 2012; Williams et al., 2015). This high altitude is considerably safer than low-level visual aerial surveys, which are flown at 60-180 m, and allows for the collection of survey data pre- and post-construction at offshore wind facilities. High resolution digital video aerial surveys also allow for the estimation of flight heights for flying animals using parallax, or the movement of animals relative to the ocean background (Chapter 5; Hatch et al., 2013), data which are sometimes used in assessments of potential collision risk for animals flying through a project site (Band, 2012). Digital aerial surveys also appear to be excellent for collecting data on aquatic animals such as marine mammals and sea turtles (Chapters 10 and 12; Normandeau Associates Inc., 2013). As with boat surveys, digital aerial surveys provide a "snapshot" of animal distributions at a given point in time, and are only flown in daylight hours under fair weather, which limits our understanding of animal behaviors at night and in harsh weather conditions.

Importantly, the data collected using digital video aerial surveys are recorded, allowing for species verifications, the application of rigorous audit protocols, and archived footage for later review (Chapters 3 and 4). This is a distinct advantage over visual survey approaches. The survey transects are relatively narrow, however, which in this study may have led to problems of availability for highly mobile animals (Williams et al., 2015). Researchers continue to develop solutions to correct for many of the detection biases described above for boat-based surveys (e.g., Sollmann et al., 2015; Chapter 9). Digital aerial surveys avoid the distance bias common to visual methods, but, to date, other forms of detection bias have not been addressed for digital aerial surveys (Williams et al., 2015).

In this study, rates of identification to species for most taxa in digital video were lower than identification rates for boat surveys (Chapter 10). Recent technological advancements in camera designs and image quality have improved identification rates beyond those seen in this study (HiDef Aerial Surveying, unpubl. data), but it is likely that some taxonomic groups may remain easier to identify from a vessel (Chapter 10). The high speed of the digital aerial survey aircraft, while beneficial for cost-effective completion of surveys in large or remote study areas, means that digital surveys provide only basic information on behavior, such as "flying" or "sitting," because the footage of each animal is brief (<1 second), and more complex behaviors can rarely be discerned. Identifications can be audited, however, and the extensive quality assurance processes afforded by the recording of video may ensure more reliable, repeatable results.

Comparing and integrating methods

By using the above survey methods to collect a broad range of data, we aimed to develop a more complete picture of the Mid-Atlantic study region. Together, boat-based and digital video aerial surveys provided relatively comprehensive information on wildlife populations in the offshore environment. Each showed distinct benefits in detecting different taxa (Figure 1-2). 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 better field of view than is provided by either boat or visual aerial surveys, allowing for submerged animals to more easily be detected in the upper reaches of the water column (Chapters 5 and 10; Normandeau Associates Inc., 2013). Boat surveys provided better detection rates for many birds, however (Figure 1-2), which is probably due to a combination of availability bias, detection bias, and identification issues in digital video aerial surveys (Chapters 5 and 10; Williams et al., 2015). Digital aerial surveys have the advantage of being auditable and archivable, however, 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 continue to improve with technological advances in the field. Boat 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.

Though each methodology has clear limitations, survey data allowed us to determine the distributions and relative abundance of taxa of interest throughout the study areas, and to develop analytical products that will be useful for marine spatial planning and decision making regarding offshore development activities. By using complementary methods, we aimed to minimize knowledge gaps and develop a more comprehensive understanding of the Mid-Atlantic marine ecosystem.

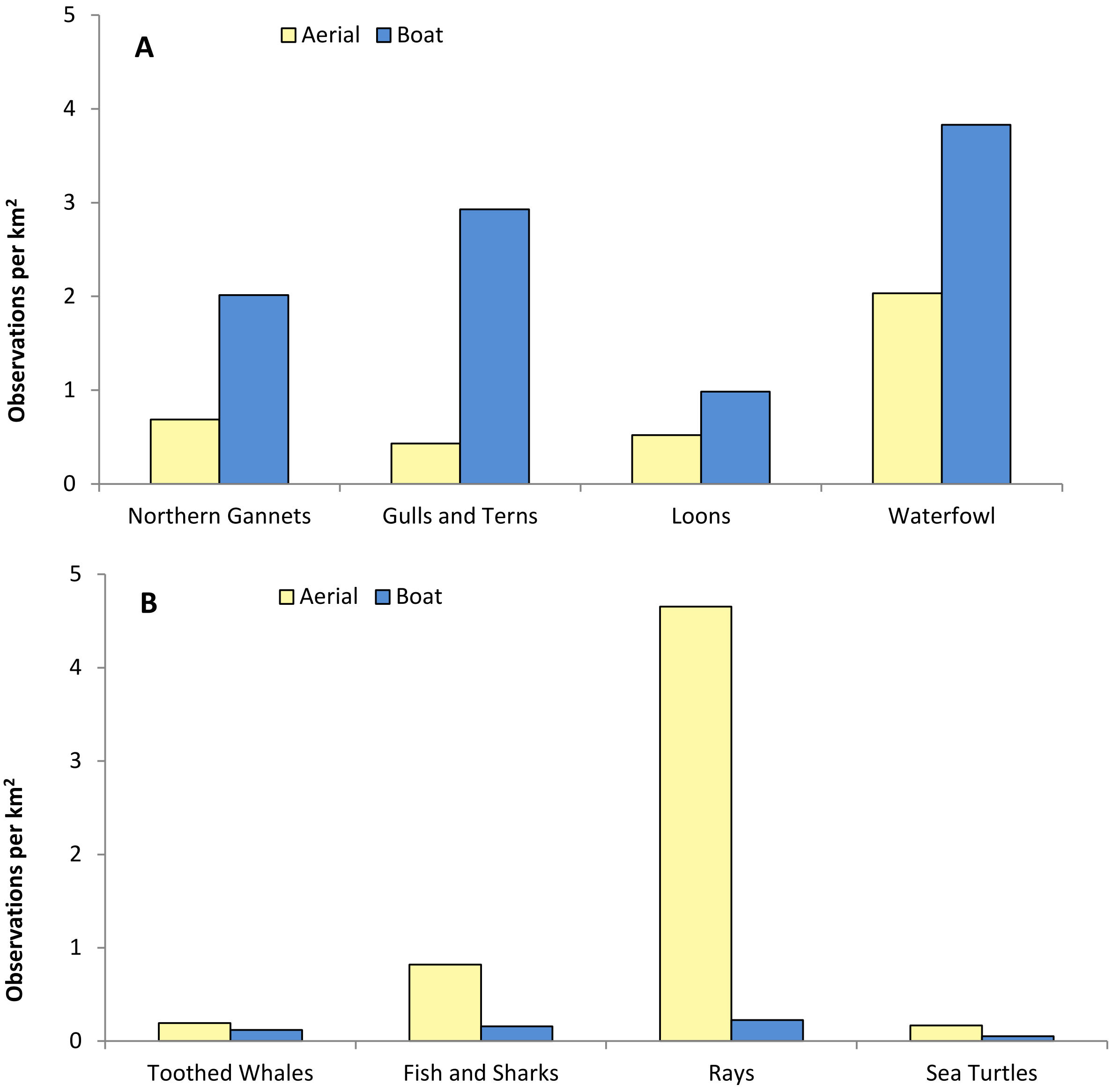

Figure 1-2. Comparison of total effort-corrected boat and aerial survey counts by taxon for all surveys (2012-2014). Aerial densities were calculated using transect strip widths (either 200 or 300m); boat densities were estimated as described below. A) Effective boat transect strip widths were estimated using distance data for each avian family (Chapter 10). B) There were insufficient data from boat surveys to develop reliable distance curves for many aquatic taxa, so estimated boat transect widths for this figure were based on the median distance of observations from the boat across all surveys (Odontoceti = 300m; Fish/Sharks = 50m; Batoidea = 7.5m; Testudines = 100m). Observations of groups that were not individually counted or identified (e.g., bait balls, ray schools) are excluded from this figure (see Chapter 4).

Interpretation and analysis of survey data

Analysis and presentation of data collected via the above study methods can take many forms. In this report, we adopted a variety of approaches for presenting spatially and temporally explicit results, and it is essential to understand their limitations in order to use resulting products appropriately. Simply mapping raw survey data, while intuitively straightforward, has several severe limitations; for example, mapping raw data precludes prediction of animal distributions, so that the only locations where estimations about animal distribution or abundance can be made are directly where surveys were conducted (Table 1-1). In addition, there are several known sources of bias associated with survey data that prevent consistency across a spatial extent (see above), making it hard to compare values between different locations without first controlling for those biases (Burnham and Anderson, 1984; Spear et al., 2004; Wintle et al., 2004).

Analysis of survey data often includes a variety of analytical corrections to account for bias and more accurately estimate how many (and which) animals are present. For example, sea state and the distance of animals from the boat transect are common factors that affect detection of animals (Chapter 9; Evans and Hammond, 2004; Hedley and Buckland, 2004; Royle et al., 2004; Spear et al., 2004; Williams et al., 2015). We would expect lower detectability of animals that are further away, especially during high sea states, so by including these two factors in a model of animal abundance, we estimated the proportion of animals that observers may have missed (Chapter 9). Survey effort is another factor that greatly influences observations made in a given location. If survey effort varies across a region (as both our boat and aerial survey efforts varied across the MABS and Maryland study areas), then areas surveyed more intensely are going to appear to support more animals. Thus, in addition to correcting for sources of bias in survey datasets, it is also important to correct for the amount of survey effort expended in different areas in order to develop maps of distribution or abundance that show real biological patterns (Chapter 11; Table 1-1). Biotic and abiotic factors, including weather, habitat characteristics, prey distributions, hydrography, drive the distribution and abundance of marine wildlife (Ainley et al., 2005). Environmental factors, or covariates, that we believe to be important for predicting animal distributions or abundance can be incorporated into a single modeling framework with effort and bias corrections (Chapters 9 and 12-14). This allows us to identify correlations between these covariates, and to understand the factors influencing animal distributions. These relationships can also be used to predict distributions for locations or time periods in which surveys were not conducted, given environmental covariate data at an appropriate spatial or temporal scale. Maps showing a continuous prediction surface across a large spatial scale are generally based on model predictions, rather than observed data; the data are used to determine relationships with environmental factors, and those relationships are mapped across the scale of the environmental factors.

Table 1-1. General approaches for presenting spatial data from offshore surveys. The distance between animals and the transect line, observer abilities, environmental conditions, and survey effort all can affect detection of animals, causing biases in observed data that must be corrected in order to use survey data to estimate wildlife densities or abundance.

Data Presentation	Advantages	Disadvantages	Example (map from this report)
Raw observation data	No assumptions—presents what was observed and where	Does not incorporate known sources of observer bias. Does not allow for predictions of wildlife distribution/abundance in areas that were not surveyed, or to predict future distributions in surveyed areas.	Figure 11-29 (large whales observed during boat and aerial surveys)
Bias-corrected and effort-corrected data	Uses known sources of observation bias to correct raw data and improve estimates of where animals are present, and in what numbers. Uses information about where animals were not seen during surveys in order to correct counts for variation in survey effort between locations.	Does not allow for predictions of wildlife distribution/abundance in areas or time periods that were not surveyed.	Figure 5-15 (maps of relative ray densities, corrected for effort, across areas surveyed by plane)
Model-predicted abundance or relative abundance estimates	Uses other environmental or habitat data to find correlations with effort- and bias-corrected observation data. Allows researchers to attempt to identify WHY animals are there, not just where they are. Allows for predictions of wildlife distribution/abundance in areas or time periods that were not surveyed.	Predictions include several implicit assumptions (e.g., consistency of species-habitat relationships across unsampled time/space) and require habitat data from unsampled locations that have similar levels of variation as the sampled habitat.	Figure 9-3 (predicted abundance of scoter flocks during the nonbreeding season, throughout the study area)

There are several types of modeling frameworks that can incorporate these different objectives. In this study we have focused on generalized additive models (GAMs) and generalized linear models (GLMs) using a hierarchical Bayesian framework (for a review of the use of GAMs and GLMs in ecology, see Guisan et al. 2002). Hierarchical approaches in a Bayesian framework (Chapters 9 and 13-14) can be useful for situations where distribution patterns or resource use vary with scale, and where species of interest are highly mobile and may be periodically unavailable for detection (Mordecai et al., 2011). They can provide an easily interpretable measure of uncertainty in predicted results, and allow for better fit of the model to observed data (Gardner et al., 2008; Zipkin et al., 2010). Generalized additive models (Chapter 12) are semi-parametric extensions of GLMs that use smoothing functions for predictor variables to improve model fit, and can be particularly useful for situations with highly non-linear and non-monotonic relationships between predictor and response variables (Guisan et al., 2002; Hastie and Tibshirani, 1990). This highly tailored model fit, however, can make it somewhat more difficult to interpret or generalize results to other locations or time periods (Guisan et al., 2002). Both modeling frameworks discussed in this report incorporate environmental covariates, effort corrections, and observation bias corrections into their structure for the purposes of estimating absolute abundance (as opposed to relative abundance).

Due to limitations inherent in raw data (e.g., detection bias), we generally avoided mapping raw counts, except in cases where we had insufficient data to conduct more reliable analyses (for example, with large cetaceans; Chapters 11-12). The ray distribution maps presented in Chapter 5 (Figure 5-15) are an example of effort-corrected data; all observations and survey effort were aggregated into 4.8x4.8 km lease blocks, so that we could compare the number of observations made per lease block area (regardless of how much surveying was actually conducted in each block). This correction did not include the incorporation of observation biases or environmental covariates, however, and resulting estimates of ray observations per unit area represent relative, rather than absolute, ray abundance for each lease block. Fully effort-corrected and bias-corrected predictive models, which allow for an understanding of the mechanisms driving animal distributions and the estimation of true abundance, are presented in several other chapters in this report (Chapters 9 and 13-14).

Environmental conditions are not static, and developing the capability to predict where animals will be (both in the future, and in areas that were not surveyed) based on environmental factors is essential to understanding potential changes in future distributions and abundance (Guisan and Thuiller, 2005; Zipkin et al., 2010). Due to the inherent variability in marine systems, however, it is unclear how useful descriptions of past distributions (particularly with relatively few years of data, as with this study) will be for predicting future distributions, especially over the longer term. Predictive models involve several implicit assumptions, such as consistent species-habitat relationships across unsampled time and space (Guisan et al., 2002), and it is important to understand the limitations of these and other analytical approaches so that results can be correctly interpreted.

Combining data from different sources

Regulators and resource managers are often required to make decisions about wildlife resources using imperfect information. Wildlife data are also collected in a variety of approaches and circumstances, which can make them difficult to use collectively in decision-making. As the survey data for this study were collected from both boat-based and digital video aerial platforms, there were analytical challenges involved in combining those data to develop integrated products to aid in assessing and managing wildlife resources.

Data gathered using boat and digital video aerial methods may not be directly comparable, due to differences in transect design and study area coverage, as well as the detection and availability of taxa of interest. Boat survey data require distance correction, where effective strip widths vary by taxon, making it more difficult to calculate effort data; digital video aerial data have a defined strip width and are not distance-biased, but lack a defined analytical framework for incorporating other potential sources of detection and availability bias. Each method appears to be more efficient at surveying some taxa than others (Chapter 10). We also identified several different species-habitat relationships from boat survey data than from digital aerial data (Chapter 13). As a result of this variability, our approaches for integrating datasets varied by taxon and analytical goal. In some cases (sea turtles in Chapter 12, for example), one survey dataset alone provided the best available picture of animal distributions, and combining the datasets was not effective using approaches developed to date. In other cases, we evaluated potential exposure of the marine bird community to offshore development by developing a preliminary model to integrate data from the two survey platforms, and producing a single prediction of abundance, distributions, and local hotspots (Chapter 14). Initial efforts at integrating data included the following approaches:

- Using species identifications from the boat survey to inform species proportions in the digital video aerial dataset (Hostetter et al., 2015).
- Using effort-corrected relative abundance ratios of taxa in boat vs. video aerial surveys to weight each dataset in combined maps of persistent hotspots of relative abundance (Chapter 11).
- Comparing datasets, particularly in relation to environmental covariates, to understand when and how integration is warranted (Chapter 13).
- Developing predictions of marine bird abundance and distribution that are jointly informed by aerial surveys, which encompass a large geographic area, and boat surveys, which allow for estimation of detection probability (Chapter 14).

The results of these efforts are summarized in Chapter 2 of this report, *Synthesis of Project Findings*.

Literature cited

Ainley, D.G., Spear, L.B., Tynan, C.T., Barth, J.A., Pierce, S.D., Glenn Ford, R., Cowles, T.J., 2005. Physical and biological variables affecting seabird distributions during the upwelling season of the northern California Current. Deep Sea Res. Part II Top. Stud. Oceanogr. 52, 123–143. doi:10.1016/j.dsr2.2004.08.016

Arkema, K.K., Abramson, S.C., Dewsbury, B.M., 2006. Marine ecosystem-based management: From characterization to implementation. Front. Ecol. Environ. 4, 525–532. doi:10.1890/1540-9295(2006)4[525:MEMFCT]2.0.CO;2

Baker, S., 2011. The Atlantic Offshore Wind Power Potential in PJM: A Regional Offshore Wind Power Resource Assessment. University of Delaware, Newark, DE, U.S.A.

Band, B., 2012. Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Wind Farms. The Crown Estate Strategic Ornithological Support Services.

Bodey, T.W., Jessopp, M.J., Votier, S.C., Gerritsen, H.D., Cleasby, I.R., Hamer, K.C., Patrick, S.C., Wakefield, E.D., Bearhop, S., 2014. Seabird movement reveals the ecological footprint of fishing vessels. Curr. Biol. 24, R514–R515. doi:10.1016/j.cub.2014.04.041

Buckland, S.T., Burt, M.L., Rexstad, E.A., Mellor, M., Williams, A.E., Woodward, R., 2012. Aerial surveys of seabirds: The advent of digital methods. J. Appl. Ecol. 49, 960–967. doi:10.1111/j.1365-2664.2012.02150.x

Burnham, K.P., Anderson, D.R., 1984. The Need for Distance Data in Transect Counts. J. Wildl. Manage. 48, 1248–1254.

Christensen, N.L., Bartuska, A.M., Brown, J.H., Carpenter, S., Antonio, C.D., Francis, R., Franklin, J.F., Macmahon, J.A., Noss, R.F., Parsons, J., Peterson, C.H., Turner, M.G., Woodmansee, R.G., 1996. The Report of the Ecological Society of America Committee on the Scientific Basis for Ecosystem Management. Ecol. Appl. 6, 665–691.

Clay, P.M., DePiper, G., Gaichas, S., Hare, J., Houde, E., Seagraves, R., 2014. Managing forage fishes in the mid-Atlantic Region, A white paper to inform the Mid-Atlantic Fishery Management Council. 40 pp.

Conkwright, R.D., Williams, C.P., Christiansen, L.B., 2000. Offshore Sand Resources in Northern Maryland Shoal Fields. Coastal and Estuarine Geology File Report No. 00-2. Department of Natural Resources, Maryland Geological Survey. Report to the Minerals Management Service, Contract # 14-35-0001-30769. 96 pp.

Conn, P.B., McClintock, B.T., Cameron, M.F., Johnson, D.S., Moreland, E.E., Boveng, P.L., 2013. Accommodating species identification errors in transect surveys. Ecology 94, 2607–2618. doi:10.1890/12-2124.1

Dawe, E.G., Hendrickson, L.C., Colbourne, E.B., Drinkwater, K.F., Showell, M.A., 2007. Ocean climate effects on the relative abundance of short-finned (Illex illecebrosus) and long-finned (Loligo pealeii) squid in the northwest Atlantic Ocean. Fish. Oceanogr. 16, 303–316. doi:10.1111/j.1365-2419.2006.00431.x

Diaz, R., Cutter, G., Hobbs, C., 2004. Potential impacts of sand mining offshore of Maryland and Delaware: Part 2-Biological considerations. J. Coast. Res. 20, 61–69.

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.

Evans, P.G.H., Hammond, P.S., 2004. Monitoring cetaceans in European waters. Mamm. Rev. 34, 131–156. doi:10.1046/j.0305-1838.2003.00027.x

Field, M.E., 1980. Sand bodies on coastal plain shelves: Holocene record of the U.S. Atlantic inner shelf off Maryland. J. Sediment. Res. 50, 505–528.

Gardner, B., Sullivan, P.J., Epperly, S., Morreale, S.J., 2008. Hierarchical modeling of bycatch rates of sea turtles in the western North Atlantic. Endanger. Species Res. 5, 279–289. doi:10.3354/esr00105

Griffies, S.M., 2004. Fundamentals of ocean climate models. Princeton University Press, Princeton, NJ.

Grumbine, R.E., 1994. What Is Ecosystem Management? Conserv. Biol. 8, 27–38. doi:10.1046/j.1523-1739.1994.08010027.x

Guida, V., Drohan, A., Johnson, D., Pessutti, J., Fromm, S., Mchenry, J., Gallager, S., Stokesbury, K., Drucker, J.R., Burns, K., Bethoney, N., 2015. January 2015 NOAA / NEFSC / MD Interim Report Report on Benthic Habitats in the Maryland Wind. Rep. to U.S. Dep. Inter. Bur. Ocean Energy Manag. under Interag. Agreem. M13PG00019/02 86.

Guisan, A., Edwards Jr, T.C., Hastie, T., 2002. Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecol. Modell. 157, 89–100.

Guisan, A., Thuiller, W., 2005. Predicting species distribution: Offering more than simple habitat models. Ecol. Lett. 8, 993–1009. doi:10.1111/j.1461-0248.2005.00792.x

Hastie, T.J., Tibshirani, R., 1990. Generalized additive models. Stat. Sci. 1, 297–318. doi:10.1016/j.csda.2010.05.004

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

Hedley, S.L., Buckland, S.T., 2004. Spatial models for line transect sampling. J. Agric. Biol. Environ. Stat. 9, 181–199. doi:10.1198/1085711043578

Hendrickson, L.C., 2004. Population biology of northern shortfin squid (Illex illecebrosus) in the Northwest Atlantic Ocean and initial documentation of a spawning area. ICES J. Mar. Sci. 61, 252–266. doi:10.1016/j.icesjms.2003.10.010

Henkel, L.A., Ford, R.G., Tyler, W.B., Davis, J.N., 2007. Comparison of Aerial and Boat-based Survey Methods for Marbled Murrelets Brachyramphus Marmoratus and Other Marine Birds. Mar. Ornithol. 35, 145–151.

Hobbs, R.C., Waite, J.M., 2010. Abundance of harbor porpoise (Phocoena phocoena) in three Alaskan regions, corrected for observer errors due to perception bias and species misidentification, and corrected for animals submerged from view. Fish. Bull. 108, 251–267.

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.

Kenney, R.D., Scott, G.P., Thompson, T.J., Winn, H.E., 1997. Estimates of prey consumption and trophic impacts of cetaceans in the USA northeast continental shelf ecosystem. J. Northwest Atl. Fish. Sci. 22, 155–171. doi:10.2960/J.v22.a13

Leslie, H.M., McLeod, K.L., 2011. Confronting the challenges of implementing marine ecosystem-based management. Front. Ecol. Environ. 5, 540–548. doi:10.1890/060093

Mattson, M.C., Thomas, J.A., St. Aubin, D., 2005. Effects of Boat Activity on the Behavior of Bottlenose Dolphins (Tursiops truncatus) in Waters Surrounding Hilton Head Island, South Carolina. Aquat. Mamm. 31, 133–140. doi:10.1578/AM.31.1.2005.133

Mordecai, R.S., Mattsson, B.J., Tzilkowski, C.J., Cooper, R.J., 2011. Addressing challenges when studying mobile or episodic species: hierarchical Bayes estimation of occupancy and use. J. Appl. Ecol. 48, 56–66. doi:10.1111/j.1365-2664.2010.01921.x

Nichols, J., Hines, J.E., Sauer, J.R., Fallon, F.W., Fallon, J.E., Heglund, P.J., 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117, 393–408.

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.

Packer, D., Dorfman, D., 2012. Chapter 5: Deep Sea Corals, in: 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, Maryland, pp. 69–85.

Pikitch, E.K., Rountos, K.J., Essington, T.E., Santora, C., Pauly, D., Watson, R., Sumaila, U.R., Boersma, P.D., Boyd, I.L., Conover, D.O., Cury, P., Heppell, S.S., Houde, E.D., Mangel, M., Plagányi, É., Sainsbury, K., Steneck, R.S., Geers, T.M., Gownaris, N., Munch, S.B., 2014. The global contribution of forage fish to marine fisheries and ecosystems. Fish Fish. 15, 43–64. doi:10.1111/faf.12004

Pikitch, E.K., Santora, C., Babcock, E.A., Bakun, A., Bonfil, R., Conover, D.O., Dayton, P., Doukakis, P., Fluharty, D., Heneman, B., Houde, E.D., Link, J., Livingston, P., Mangel, M., McAllister, M., Pope, J., Sainsbury, K., 2004. Ecosystem-based Fishery Management. Science (80-.). 305, 346–347.

Ronconi, R.A., Burger, A.E., 2009. Estimating seabird densities from vessel transects: distance sampling and implications for strip transects. Aquat. Biol. 4, 297–309.

Royle, J.A., Dawson, D.K., Bates, S., 2004. Modeling Abundance Effects in Distance Sampling. Ecology 85, 1591–1597.

Ruckelshaus, M., Klinger, T., Knowlton, N., DeMaster, D.P., 2008. Marine Ecosystem-based Management in Practice: Scientific and Governance Challenges. Bioscience 58, 53. doi:10.1641/B580110

Safina, C., Wagner, R.H., Witting, D.A., Smith, K.J., 1990. Prey delivered to Roseate and Common Tern chicks; composition and temporal variability. J. F. Ornithol. 61, 331–338.

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, A.D.M., Fulton, E.J., Hobday, A.J., Smith, D.C., Shoulder, P., 2007. Scientific tools to support practical implementation of ecosystem based fisheries management. ICES J. Mar. Sci. 64, 633–639.

Sollmann, R., Gardner, B., Gilbert, A., Williams, K., Veit, R., 2015. A community distance sampling model to investigate the abundance and distribution of seabirds, 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.

Spear, L.B., Ainley, D.G., Hardesty, B.D., Howell, S.N.G., Webb, S.W., 2004. Reducing biases affecting at-sea surveys of seabirds: Use of multiple observer teams. Mar. Ornithol. 32, 147–157.

Tallis, H., Levin, P.S., Ruckelshaus, M., Lester, S.E., McLeod, K.L., Fluharty, D.L., Halpern, B.S., 2010. The many faces of ecosystem-based management: Making the process work today in real places. Mar. Policy 34, 340–348. doi:10.1016/j.marpol.2009.08.003

Thaxter, C.B., Burton, N.H.K., 2009. High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols, Report commissioned by COWRIE Ltd.

Townsend, D.W., Thomas, A.C., Mayer, L.M., Thomas, M.A., Quinlan, J.A., 2006. Oceanography of the Northwest Atlantic Continental Shelf, in: Robinson, A.R., Brink, K.H. (Eds.), The Sea, Vol. 14A. Harvard University Press, Cambridge, pp. 119–168.

Veit, R., 2015. Spatial association between seabirds and prey on the mid-Atlantic Outer Continental Shelf, 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.

Vogt, B., Franke, E., Cummins, J., Fabrizio, M., Frye, J., Gary, M., Grist, J., Havens, K., Holzer, J., Ihde, T., King, B., Lukens, R., Ogburn, M., Poukish, C., Price, J., Smith, G., Tango, P., Uphoff, J., 2015. Forage Fish Outcome: Management Strategy (Draft for public review, March 16, 2015), Chesapeake Bay Management Strategy: Forage Fish. Chesapeake Bay Program. Annapolis, Maryland.

Votier, S.C., Bicknell, A., Cox, S.L., Scales, K.L., Patrick, S.C., 2013. A Bird's Eye View of Discard Reforms: Bird-Borne Cameras Reveal Seabird/Fishery Interactions. PLoS One 8. doi:10.1371/journal.pone.0057376

Wiebe, P.H., Harris, R.P., Werner, F.E., Young, B. De, 2009. BASIN: Basin-scale Analysis, Synthesis, and Integration. Science Plan and Implementation Strategy, GLOBEC Report 27. Plymouth, UK.

Williams, K., Stenhouse, I., Adams, E., Connelly, E., Gilbert, A., Duron, M., 2015. 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.

Wintle, B.A., McCarthy, M.A., Parris, K.M., Burgman, M.A., 2004. Precision and bias of methods for estimating point survey detection probabilities. Ecol. Appl. 14, 703–712. doi:10.1890/02-5166

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

Yoder, J.A., O'Reilly, J.E., Barnard, A.H., Moore, T.S., Ruhsam, C.M., 2001. Variability in coastal zone color scanner (CZCS) Chlorophyll imagery of ocean margin waters off the US East Coast. Cont. Shelf Res. 21, 1191–1218. doi:10.1016/S0278-4343(01)00009-7

Zipkin, E.F., Gardner, B., Gilbert, A.T., O'Connell, A.F., Royle, J.A., Silverman, E.D., 2010. Distribution patterns of wintering sea ducks in relation to the North Atlantic Oscillation and local environmental characteristics. Oecologia 163, 893–902.

Chapter 2: Synthesis of project findings

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

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Abstract

This study provides baseline data on the distributions, movements, habitat use, and abundance of wildlife on the Mid-Atlantic Outer Continental Shelf offshore of Delaware, Maryland, and Virginia 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

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[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.

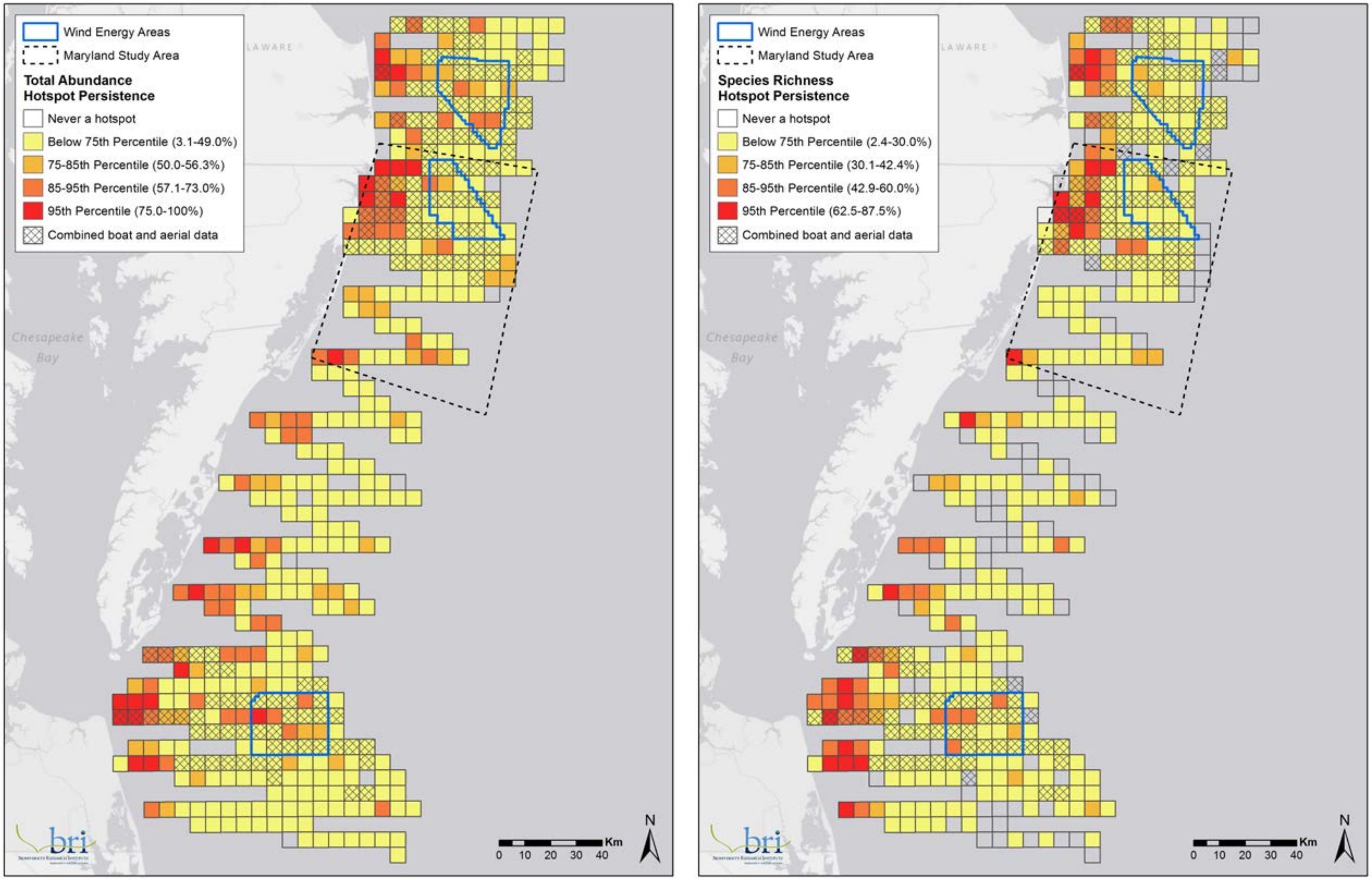

Figure 2-1. Persistent abundance hotspots across all taxa (left) and persistent species richness hotspots (right). These maps highlight areas where the greatest numbers of individuals across all taxa (left) and the greatest numbers of species (right) were consistently observed over the course of the 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

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[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.

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[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

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[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

Introduction to Part II

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

Report structure

The chapters in this report represent a broad range of study efforts focused on understanding wildlife population distributions in Atlantic waters offshore of Maryland (and elsewhere in the Mid-Atlantic United States). Some chapters are purely methodological in nature, while others present a variety of analyses and results (Figure I). Part I of this report (the Executive Summary and Chapters 1-2) summarizes and synthesizes project results. The 12 subsequent chapters and their relationships to each other are shown in Figure I. In Parts II (Chapters 3-5) and III (Chapters 6-9), we describe methods and results for high resolution digital video aerial surveys and boat-based surveys, respectively. Part IV of this report (Chapters 10-14) combines data from both survey approaches to develop a comprehensive understanding of marine wildlife populations that use the Mid-Atlantic study area.

Part II: Examining wildlife distributions and relative abundance from a digital video aerial survey platform

High resolution digital video aerial surveys are a relatively new method for collecting distribution and abundance data on animals (Thaxter and Burton 2009, Buckland et al. 2012), and ours was the first study to use this method on a broad scale in the U.S. The technology used in this study, one of several different digital aerial survey methodologies, was developed by HiDef Aerial Surveying, Ltd., in the UK. 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 reduces or eliminates disturbance to wildlife compared to visual aerial or boat 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 utilizing the data for some purposes, due to the relative novelty of the survey method.

There are three chapters in Part II of this report, focused on the use of digital video aerial surveys to examine wildlife distributions and relative abundance:

Chapter 3. High resolution digital video aerial survey methods.

Chapter 4. Data management, video analysis, and audit protocols for digital video aerial surveys.

Chapter 5. Summary of high resolution digital video aerial survey data.

Methods and protocols

Chapter 3 briefly describes the survey methods employed for high resolution digital video aerial surveys, which are referenced throughout the following chapters. Surveys were flown in twin-engine Cessnas at 250 km/hr and an altitude of approximately 610 m (Figure II), which is much higher than traditional visual aerial surveys. While analysis and management of video require substantial personnel time, the resulting data are quality-controlled and audited much more intensively than is possible with visual observation data (Chapter 4).

Results from Mid-Atlantic digital video aerial surveys

Surveys detected a wide variety of taxa, including marine mammals, sea turtles, rays, sharks, fish, bats, seabirds, shorebirds, and raptors (Chapter 5). Some taxa were notable for their unexpected abundance within the survey dataset (e.g., Cownose Rays, *Rhinoptera bonasus*, and sea turtles). Other taxa were not expected to be observed in surveys at all (e.g., bats; Chapter 5; Hatch et al. 2013). Flight heights of flying animals could be estimated from the aerial video using parallax, or the movement of animals relative to the ocean background (Chapter 5; Hatch et al. 2013). This information may be helpful in understanding the potential for interactions between flying animals and offshore wind turbines. For example, 56% of all birds with estimable flight heights in the Maryland study area were observed within 0 and 20 meters above sea level, which is below rotor height for most turbine designs. This type of flight height data is often used alongside information on avoidance behaviors, turbine specifications, and other data in models that attempt to estimate avian collision risk for offshore wind energy projects in Europe (e.g., Band 2012), although there is still debate in the European literature regarding the factors that best predict this risk (e.g., Cook et al. 2012, Douglas et al. 2012, Langston 2013, Furness et al. 2013).

Identification of animals to species in the video aerial survey data was variable by survey, season, and taxon (Chapter 5). In part, this is likely due to variations in image quality and other factors, some of which are being addressed through technological advances in the field; the current generation of cameras being used in Europe have much higher resolution and color rendition than the cameras used in this study, with better identification rates as a result (95% for all seabirds, on average; A. Webb pers. comm.). Unlike observations made from video, however, observational data from boat or visual aerial surveys are not replicable, and species identifications made by observers in the moment can seldom be verified after the fact. The exhaustive quality assurance and audit protocol followed by aerial video reviewers, as well as characteristics inherent to the video review process itself (such as the use of multiple levels of “certainty” criteria in identifications), ultimately lead to fewer definitive identifications than observational approaches (Chapter 10). However, this also recognizes the inherent uncertainty in the identification process, which can be difficult to account for in unrecorded visual surveys. This uncertainty is generally under-recognized or ignored, as it can be difficult to measure, but in some cases species misclassification in visual surveys may actually lead to less reliable density estimates than classifying animals as “unknown” (Conn et al. 2013).

Implications and uses of digital video aerial survey data elsewhere in this report

In addition to the three chapters in this section, the digital video aerial survey data are used in analytical efforts in Chapters 10-14. Several chapters focus on contrasting the two survey approaches (Chapters 10 and 13). In some cases, digital aerial survey data are used independently to analyze wildlife distributions and relative abundance (e.g., in the case of sea turtles, which were much more easily detected in video than from boat surveys; Chapters 11 and 12). In other cases, digital video aerial survey data and boat survey data are used jointly (Chapters 11 and 14) to describe distributions and abundance of animals across the study area.

Our application of these methods in the Mid-Atlantic is expected to be useful for understanding wildlife populations and minimizing impacts to those populations from anthropogenic activities in the offshore environment in several ways:

- First, this study has developed U.S.-based technological resources for future wildlife monitoring efforts, and explored technological advancements and assessment methods that could simplify or minimize the cost of environmental risk assessments.
- Second, we identify species that are likely to be exposed to development activities in the Maryland study area, along with their important habitat use or aggregation areas and temporal variation in distribution patterns. This information can be helpful for:
    - Informing the siting of future projects, by incorporating wildlife patterns into marine spatial planning and decision making, and by using exposure data as a first step towards defining relative risk by location;
    - Informing the permitting process for development projects, by contributing data towards National Environmental Protection Act (NEPA) and other regulatory requirements, and by helping to define target taxa or research priorities on which to focus on during site-specific pre- and post-construction monitoring studies; and
    - Informing mitigation efforts, by presenting temporal data on community composition, distributions, and abundance that can be used to time certain activities to coincide with reduced potential for exposure of key taxa.

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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.

Literature cited

Band, B. (2012). Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Wind Farms.

Buckland, S. T., M. L. Burt, E. A. Rexstad, M. Mellor, A. E. Williams, and R. Woodward (2012). Aerial surveys of seabirds: the advent of digital methods. Journal of Applied Ecology 49:960–967. doi: 10.1111/j.1365-2664.2012.02150.x

Conn, P. B., B. T. McClintock, M. F. Cameron, D. S. Johnson, E. E. Moreland, and P. L. Boveng (2013). Accommodating species identification errors in transect surveys. Ecology 94:2607–2618. doi: 10.1890/12-2124.1

Cook, A. S. C. P., A. Johnston, L. J. Wright, and N. H. K. Burton (2012). A Review of Flight Heights and Avoidance Rates of Birds in Relation to Offshore Wind Farms. *Report prepared on behalf of The Crown Estate*.

Douglas, D. J. T., A. Follestad, R. H. W. Langston, and J. W. Pearce-Higgins (2012). Modelled sensitivity of avian collision rate at wind turbines varies with number of hours of flight activity input data. Ibis 154:858–861.

Furness, R. W., H. M. Wade, and E. A. Masden (2013). Assessing vulnerability of marine bird populations to offshore wind farms. Journal of Environmental Management 119:56–66. doi: 10.1016/j.jenvman.2013.01.025

Hatch, S. K., E. E. Connelly, T. J. Divoll, I. J. Stenhouse, and K. A. Williams (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

Langston, R. H. W. (2013). Birds and wind projects across the pond: A UK perspective. Wildlife Society Bulletin 37:5–18. doi: 10.1002/wsb.262

Thaxter, C. B., and N. H. K. Burton (2009). High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols. *Report commissioned by COWRIE Ltd*.

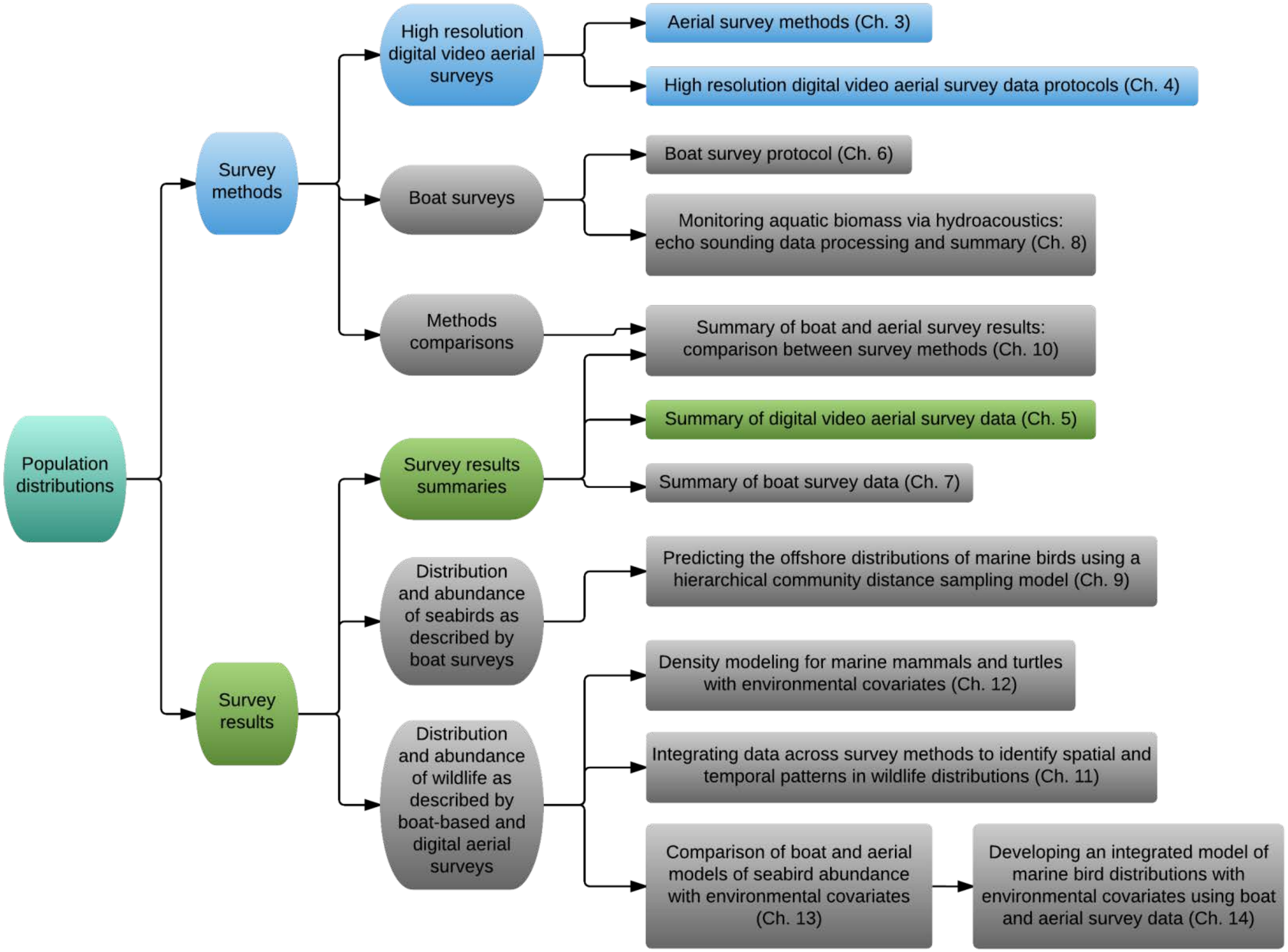

Figure I. Organization of chapters within this final report.

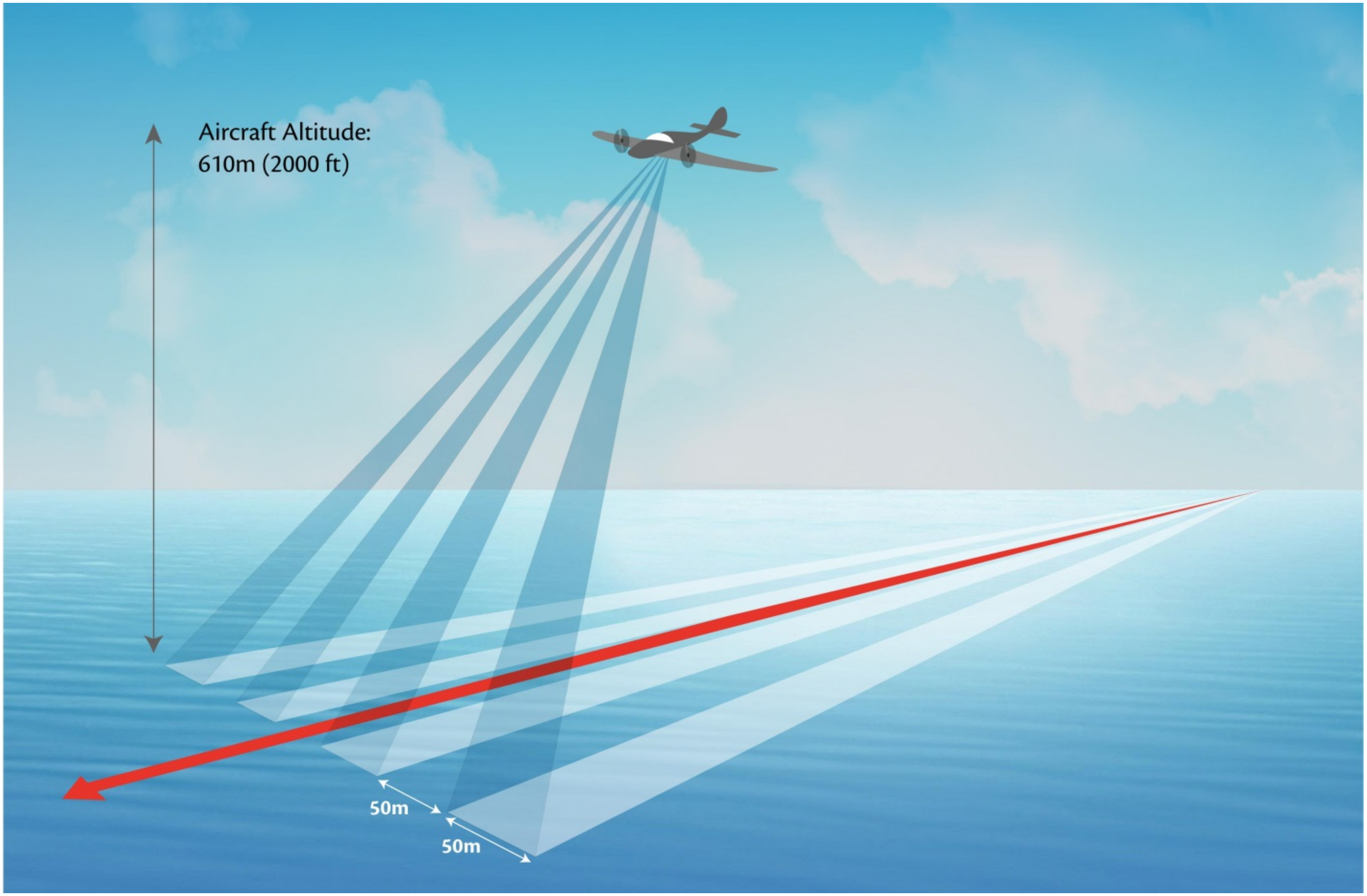

Figure II. Digital video aerial surveys were flown at 610 meters using a twin-engine aircraft with four belly mounted cameras. These cameras recorded non-overlapping 50 meter transect strips, for a 200 meter total transect strip width.

Chapter 3: High resolution digital video aerial survey methods

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

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Chapter 3 Highlights

Methods used to conduct high resolution digital video aerial surveys.

Context[1]

High resolution digital video aerial surveys are a new method for collecting distribution and abundance data on animals, and the Mid-Atlantic Baseline Studies and Maryland Project surveys were the first to use this method on a broad scale in the U.S. The technology was developed by HiDef Aerial Surveying, Ltd., in the U.K. These methods have largely replaced visual aerial surveys for offshore wind energy research in Europe, as they are safer for the pilot and crew, reduce or eliminate disturbance to wildlife during surveys, and produce archivable and auditable data. This chapter briefly describes the methods used to collect and analyze the survey data. Chapter 4 describes the data management, object identification, and audit processes conducted for digital video aerial survey data in further detail. Basic results from the digital video aerial surveys are summarized in Chapter 5, and the data are analyzed alongside boat survey data in Chapters 10-14 of this report.

Study goal/objectives addressed in this chapter

Provide the methods for data collection and analysis for the high resolution digital video aerial surveys.

Highlights

- Fourteen digital video aerial surveys were flown in the broader Mid-Atlantic Baseline Studies (MABS) study area over two years (March 2012-May 2014).
- Surveys from March 2013 to May 2014 expanded the high density survey coverage inshore and south of the Maryland Wind Energy Area (WEA). An additional 15th survey of the Maryland study area (including both the expansion area and the WEA) was flown in August 2013.
- Planes flew at a speed of approximately 250 km/hr and at an altitude of 610 m. Using camera technology developed by HiDef Aerial Surveying, Ltd. of the United Kingdom, four super high-definition video cameras captured a 200 m wide transect strip.
- Video data were analyzed by two teams to locate and identify objects in the footage.
- Flight heights were estimated for flying animals using a patented extended parallax method.
- Audit processes, including blind re-review of 20% of video data, were carried out as part of both the object location and identification procedures.
- Completed datasets are available online at our website and are also included in the U.S. Fish and Wildlife Service's Northwest Atlantic Seabird Catalog.

Implications

Results from the data collected following these methods are presented in Chapter 5 and Part IV of this report.

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[1] For more detailed context for this chapter, please see the introduction to Part II of this report.

Abstract

This chapter presents methods used to collect and analyze high resolution digital video aerial survey data. Fifteen high resolution digital video aerial surveys were conducted by Biodiversity Research Institute (BRI) and HiDef Aerial Surveying, Ltd. (hereafter, HiDef, the company that developed this technology in the United Kingdom) as part of a broader project to collect observations of marine birds, mammals, turtles, and other wildlife, and to inform siting and permitting processes for offshore wind energy development. Aerial transects were flown at high densities within the Delaware, Maryland, and Virginia Wind Energy Areas (WEAs); the remainder of the study area was surveyed on an efficient sawtooth transect path to provide broad-scale context for the intensive WEA surveys. As part of the Maryland Project, high-density surveys were also conducted adjacent to the Maryland WEA in 2013-2014. Precise wildlife locations, taxonomic identities, animal behaviors, and flight heights were determined from the resulting video images. Details on the analyses are found in the Video Aerial Survey Data Protocol in Chapter 4. Flight heights were calculated from video footage for flying animals using extended parallax methods developed by HiDef.

Introduction

Digital aerial survey technologies, using either video or still photography, have been developed and successfully deployed in Europe to assess marine wildlife populations in relation to offshore wind energy development (e.g., Buckland et al., 2012; Groom et al., 2013; Thaxter and Burton, 2009). Though they have become common practice for offshore wind energy planning and monitoring in Europe (Buckland et al., 2012), this study is the first to use these methods on a broad spatial and temporal scale in the United States. Digital aerial surveys have a high cost efficiency on broad spatial scales, and it has been suggested that they may eventually largely replace traditional visual surveys, by boat or aircraft, to collect distribution and abundance data on animals in the offshore environment in Europe (Buckland et al., 2012). Importantly, the data collected using digital surveys are recorded, allowing for species identification verifications, the application of rigorous audit protocols, and archiving of footage for later review.

High resolution digital video aerial surveys (hereafter, digital video aerial surveys) were conducted on the Mid-Atlantic Outer Continental Shelf offshore of Delaware, Maryland, and Virginia in 2012-2014 to inform siting and permitting processes for offshore wind energy development. In particular, aerial surveys were focused on obtaining detailed data on wildlife distributions in three federally designated Wind Energy Areas (WEAs). In the second year of surveys, this focus was extended west and south of the Maryland WEA to collect further information on wildlife offshore of Maryland. Wildlife locations, taxonomic identifications, animal behaviors, and flight heights were determined from the video images (discussed in additional detail in Chapter 4), and these data were used in further analyses, which are presented in Part IV of this report.

Data collection

As part of the Mid-Atlantic Baseline Studies Project (MABS), observations of marine birds, mammals, and turtles were collected in large-scale surveys across a 13,245 km^2 study area using super high-definition video on an aerial platform (Figure 3-1). Fourteen offshore surveys were flown by HiDef across the broader MABS study area from March 2012 to May 2014. Aerial transects were flown at high densities (1 km spacing, or 20% ground coverage) within the Maryland, Delaware, and Virginia WEAs. Beginning in Year 2 of the study (March 2013), the footprint of high density surveys was extended west of the Maryland WEA to the shoreline, and 10 km south of the Maryland WEA, with funding from the state of Maryland (Figure 3-1, Figure 3-2). These Maryland Project transects were the only video aerial transects that extended into state waters (e.g., within 3 miles of shore). The remainder of the MABS study area was surveyed using an efficient 'sawtooth' transect path to provide broad-scale context for the intensive WEA surveys (at about 2.1% ground coverage, beginning in September 2012; Figure 3-1). Early surveys included video footage at 2 cm GSR for the transects within the WEAs, and 3 cm GSR for the broader sawtooth survey; however, species identifications were problematic for 3 cm footage in early surveys, due to poor image clarity and color rendition, and this issue was addressed by project collaborators by discontinuing all use of 3 cm GSR for surveys beginning in September 2012 (Duron et al., 2015). The Maryland extension of the survey transects added about 21% of additional transect length to the existing study design, with total combined transect length for each survey at approximately 2,866 km in Year 1, and 3,613 km in Year 2. An eighth annual survey was also added in Year 2 of the study, with funding from the state of Maryland; this survey included only the Maryland WEA and Maryland extension transects, totaling approximately 1,088 km in length, and was flown in August 2013. The "Maryland study area," as referenced throughout this report (and indicated in Figure 3-1 and Figure 3-2), includes survey transects in the Maryland WEA and Maryland extension transects, as well as all MABS sawtooth transects offshore of the state of Maryland.

In addition to the fifteen surveys described above, HiDef also flew a survey specifically designed to allow for a comparison of aerial and boat-based data collection. The flight occurred during one of the regularly scheduled boat surveys (March 2013), and followed the paths of several of the boat transects, rather than the aerial transects used in other surveys. Details regarding this comparison study can be found in Williams et al. (2015).

HiDef worked with their video aerial survey vendor to outfit the survey aircraft and organize and schedule flights in the MABS and Maryland study areas (Figure 3-1, Figure 3-2). Each survey was completed using two small commercial aircraft, allowing complete coverage of the study areas in two to three days (weather permitting). The aircraft were twin-engined Cessnas, with long range fuel tanks to enhance safety when operating at sea, and had specially designed frames attached to the lower fuselage for survey cameras. Due to the height at which surveys were flown, no permits were required from the National Marine Fisheries Service (NMFS), but flights complied with all Federal Aviation Administration (FAA) regulations.

Each survey was conducted at approximately 250 km/hr and at 610 m (2,000 ft) above sea level using four super high-definition (five times HD) video cameras, angled at 30-45° from vertical and integrated with onboard navigation systems and server storage (Figure 3-3). Cameras captured up to 15 frames per second, and images were duplicated and stored onto a disk array of heavy duty disk drives or solid state recording devices within the aircraft. Video footage was shipped to the HiDef office in the UK by the video aerial survey vendor, and as a precaution video footage was also copied onto hard drives by the video aerial survey vendor and shipped to the BRI office in Gorham, Maine.

Each of the four cameras captured video images at a 50 meter strip width at sea level, resulting in a 200 meter wide transect strip (Figure 3-3). Surveys were flown under Visual Flight Rule (VFR) conditions and were completed in weather conditions appropriate for observations (<6 Beaufort with no low cloud cover, mist, or fog). All surveys were flown using GPS to ensure location accuracy.

Digital video data analyses

The HiDef team reviewed each frame of the recorded footage to mark visible objects and note object categories (e.g., Bird, Buoy, Fish). These data were output to an Excel spreadsheet and marker files were generated and saved for object identifications for the BRI team (see Chapter 4 for more details). HiDef observers re-reviewed 20% of the frames in each survey to determine the rate of agreement between observers; agreement had to be at least 90% for the audit to pass. If the audit did not pass that observer’s recent data were examined for consistent errors and issues were addressed. Data spreadsheets and markers for all objects that were found by the original observer and the auditor were sent to BRI staff for further analyses.

Trained BRI staff identified the objects to species, taxonomic group, or general category (e.g., flotsam and jetsam), and described animal behaviors. Identifications were based on size, shape, color, movement pattern, and clarity of the image, and confidence of identification was noted for each object. “Definite” indicated >95% certainty, “probable” indicated <95% but >50% certainty, and “possible” indicated <50% certainty in the identification. For example, if a reviewer could not substantiate that an object was a “possible Wilson’s Storm-Petrel,” then that object might be coded as a “definite unidentified storm-petrel,” based on the specific criteria used for identifications of that species or category (size, color, shape, flight pattern, clarity of image, etc., see Chapter 3 for more details). Some animals and objects were submerged underwater. Reviewers could see at some depth, but visibility of submerged objects varied based on turbidity and weather, and no formal steps were made to verify the range of depths within which animals could be accurately identified. All non-avian animals in the water column were marked as either submerged or surfacing. Completed data sheets with identification information were returned to HiDef in the UK for georeferencing and parallax calculations. Twenty percent of the identification data were audited by BRI, with at least 90% agreement required to pass. Detailed object ID, data management, and audit protocols for BRI analysis procedures are included in Chapter 4.

HiDef calculated flight altitude for moving targets using the measurement of “parallax” in the aerial video. Parallax is the apparent motion of an elevated object against a distant background due to the movement of the observer. With a known distance to the background and motion of the observer, the parallax was measured from relative positions in digital video frames and used to estimate the height of the object above the background (Hatch et al., 2013). Most objects were observed in at least eight video frames at the altitude and speed at which digital video aerial surveys were conducted. Flight height could not be accurately estimated using this approach when the animal was flying parallel to the plane and no displacement was detectable, or the animal was flying at high altitudes and was present in fewer video frames.

HiDef also georeferenced each video frame containing an animal, using GPS data from the survey flight and offset calculations to account for camera angles. Directions of movement were also translated into cardinal directions, based on the direction in which each camera was pointed during the recording time. Spreadsheets with flight height, animal direction of movement, and georeferenced data were returned to BRI to be joined with audited identification data by the data manager.

Aerial effort data were built from either the georeferenced camera reel data files or raw backup GPS data files. We preferentially built effort data from the georeferenced camera reels, which included a position for every camera frame while the survey cameras were active. This was the most accurate positional data from which to generate the effort data, as these files were only generated while the cameras were actively filming and collecting data. Early in the project, there were several partial surveys where the GPS associated with the cameras was not working properly and there were no positions associated with camera reels. However, backup GPS positioning was available, and we used these data along with planned transect lines to generate the effort for these transects. Custom scripts were written in Python for ArcGIS 10.2 (ESRI, Inc., Redlands, CA) to derive the effort lines from the camera reel geo-references and/or the backup GPS. We also generated effort polygons for the four camera stripes using another custom Python script; these stripes were derived from the transect lines, with the proper spacing between cameras (50m) and width of the cameras' field of view (50m each)[2]. Effort data were further associated with survey observations in post-processing.

Additional information

The complete digital video aerial survey dataset is available for download on the project website[3]. It has also been added to the Northwest Atlantic Seabird Catalog (formerly the Compendium of Avian Information; O'Connell et al., 2009), a publicly held database housed by the USFWS that is the main repository for observations and survey data collected in Atlantic waters from Florida to Maine since 1906 (including data on marine mammals, sea turtles, and other wildlife, as well as seabirds).

This study represents the first application of high resolution digital video aerial survey technology in North America, and was also the first broad-scale application of any type of digital aerial survey in the United States. A more detailed description of video data analysis and management procedures is available in the following chapter of this report (Chapter 4). The digital video aerial survey data are summarized in Chapter 5, and used alongside boat survey data in analyses in Chapters 10-14 of this report.

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[2] On the first three surveys, the sawtooth transect was flown at 3cm GSR, so the transect width was 75m and the spacing between cameras was 25m.

[3] www.briloon.org/mabs/data

Literature cited

Buckland, S.T., Burt, M.L., Rexstad, E.A., Mellor, M., Williams, A.E., Woodward, R., 2012. Aerial surveys of seabirds: The advent of digital methods. J. Appl. Ecol. 49, 960–967. doi:10.1111/j.1365-2664.2012.02150.x

Duron, M., Gilbert, A., Williams, K., Stenhouse, I., 2015. Recommendations for high resolution digital video aerial surveys in the 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.

Groom, G., Stjernholm, M., Nielsen, R.D., Fleetwood, A., Petersen, I.K., 2013. Remote sensing image data and automated analysis to describe marine bird distributions and abundances. Ecol. Inform. 14, 2–8. doi:10.1016/j.ecoinf.2012.12.001

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

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.

Thaxter, C.B., Burton, N.H.K., 2009. High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols, Report commissioned by COWRIE Ltd.

Williams, K.A., Stenhouse, I.J., Adams, E.M., Connelly, E.E., Gilbert, A.T., Duron, M., 2015. 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.

Figures

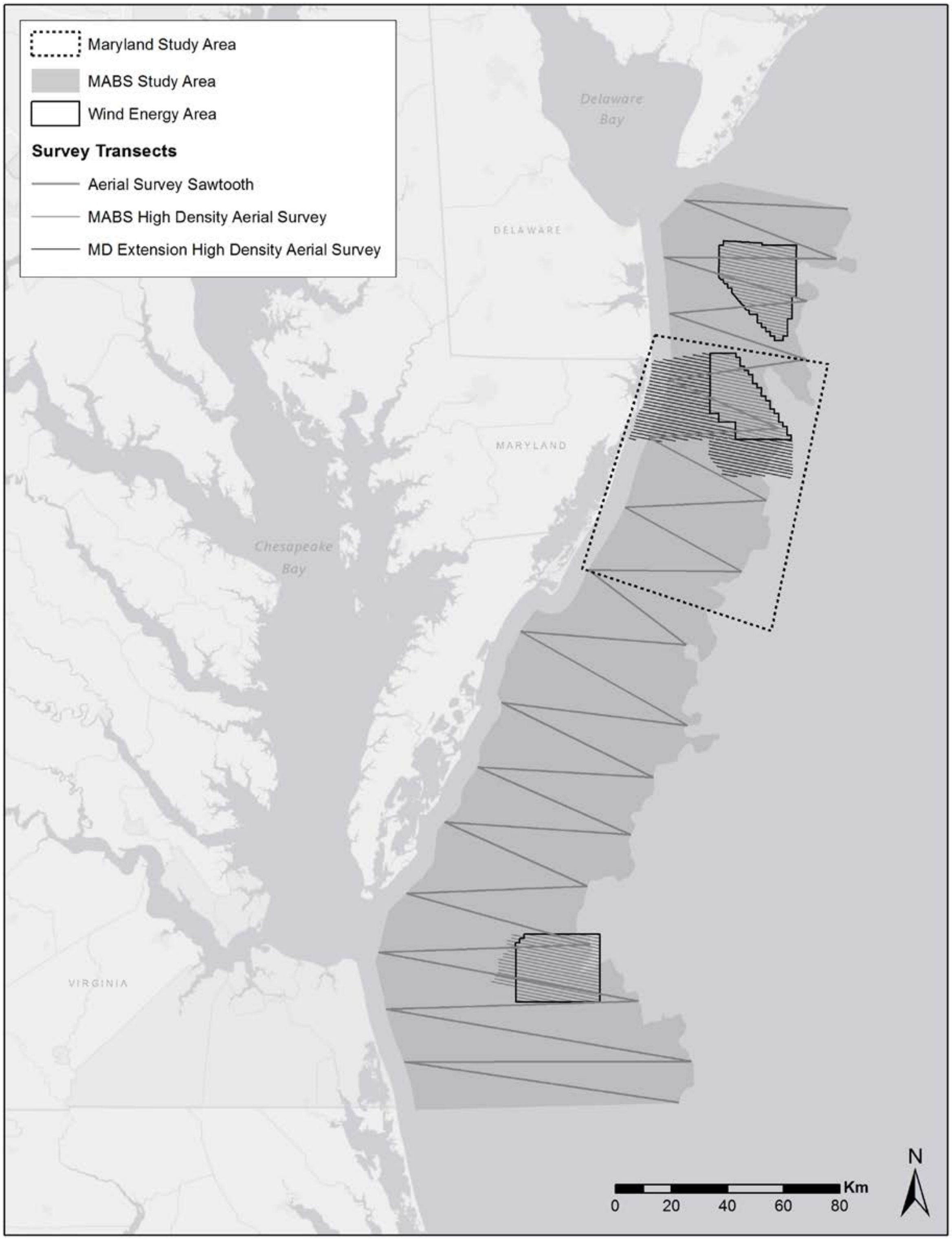

Figure 3-1. Map of digital video aerial survey transects for the Mid-Atlantic Baseline Studies and Maryland Projects (2012-2014). Mid-Atlantic Baseline Studies transects are shown in light gray. High-density Maryland transects are shown in dark gray.

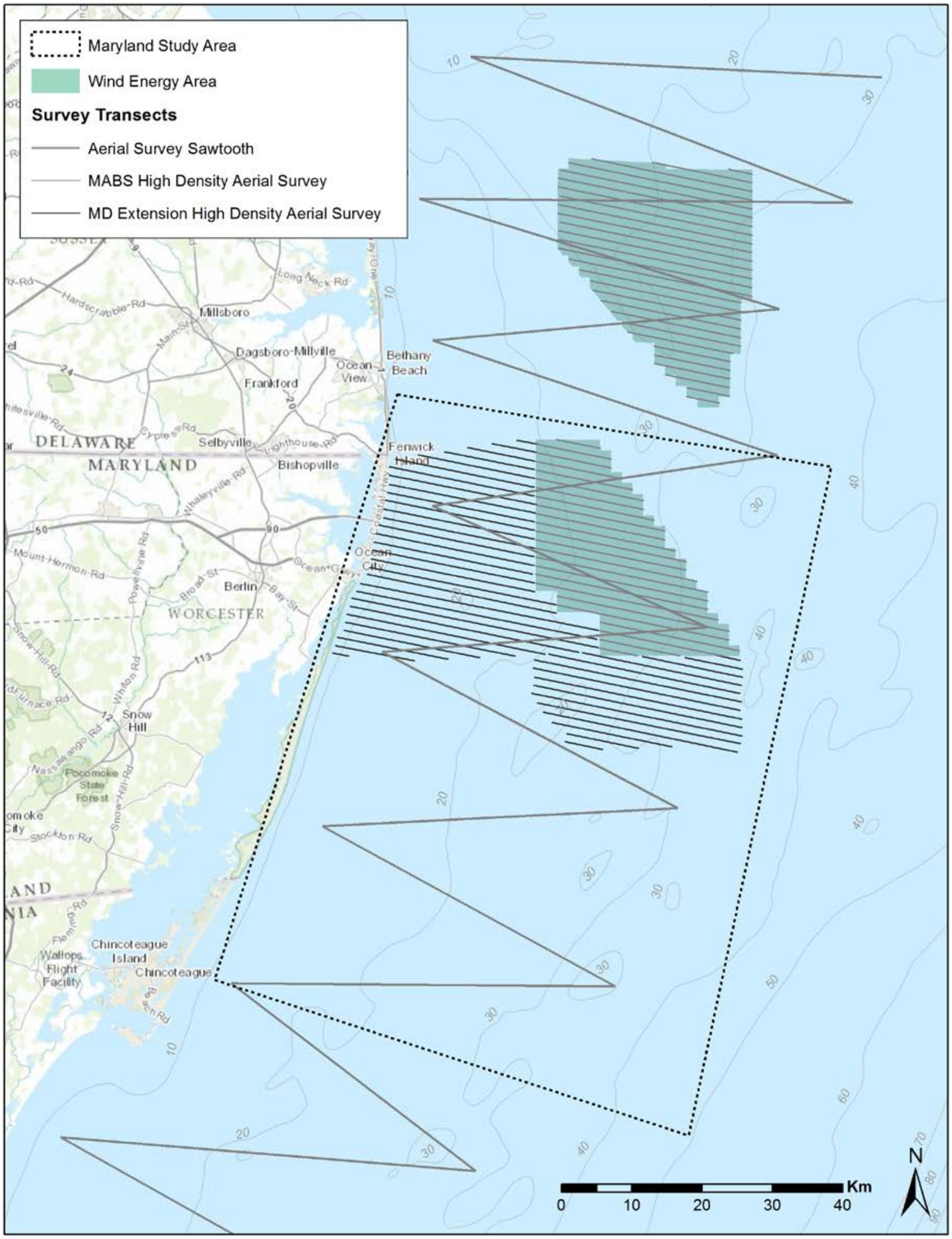

Figure 3-2. Detailed map of aerial survey transects within the Maryland study area. Mid-Atlantic Baseline Studies transects are shown in light gray. High-density Maryland transects are shown in dark gray.

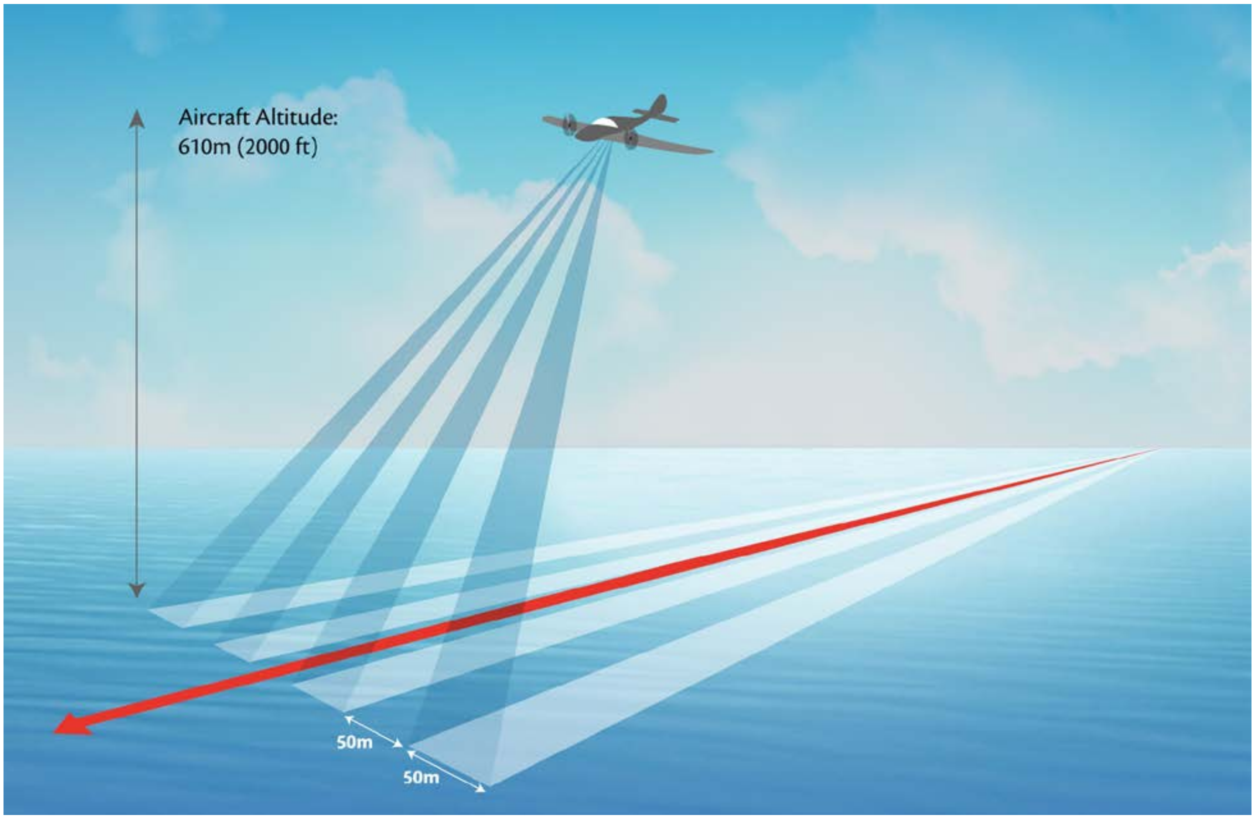

Figure 3-3. Digital video aerial surveys were flown at 610 meters using a twin-engine aircraft with four belly mounted cameras. These cameras recorded non-overlapping 50 meter transect strips for a total transect strip width of 200 meters. (Image created by Linda Mirabile and Glen Halliday).

Chapter 4: High resolution digital video aerial survey data protocols

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

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Chapter 4 Highlights

Protocol for data analysis, data management, and audit procedures for the high resolution digital aerial surveys in the Mid-Atlantic.

Context[1]

High resolution digital video aerial surveys are a relatively new method for collecting distribution and abundance data on animals in the offshore environment, and our study was the first to use this method on a broad scale in the U.S. The technology was developed by HiDef Aerial Surveying, Ltd., in the United Kingdom. This chapter describes the methods used to analyze the survey video, in particular describing the object identification and audit procedures in detail. Data collection methods and some analysis processes are described in Chapter 3. Basic results from the digital video aerial surveys are summarized in Chapter 5, and the data are analyzed alongside boat survey data in Chapters 10 through 14 of this report.

Study goal/objectives addressed in this chapter

Provide the detailed protocol for analysis, data management, and audits used for the high resolution digital aerial surveys in the Mid-Atlantic.

Highlights

- Aerial video data were collected on abundance and behaviors of marine birds, mammals, turtles, and other wildlife within the Mid-Atlantic Baseline Studies and Maryland Project areas.
- Locations of individual animals (or objects), taxonomic identifications, behaviors, and flight heights were determined from the video images.
- A random 20% of the objects identified were blindly audited through re-review with an extensive arbitration process in cases of disagreement.
- 100% of threatened and endangered species were audited with exact matches required.
- Example images, data collection spreadsheets, and definitions of identification categories are included.

Implications

Results from the data collected following these protocols are presented in Chapter 5 and Part IV of this report.

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[1] For more detailed context for this chapter, please see the introduction to Part II of this report.

Abstract

High resolution digital video aerial surveys were conducted in the Mid-Atlantic, as a part of the Mid-Atlantic Baseline Studies Project, to produce data to inform siting and permitting processes for offshore wind energy development. Data were collected on the abundance and behaviors of marine birds, mammals, turtles, and other wildlife. Wildlife locations, taxonomic identifications, animal behaviors, and flight heights were determined from the video images. This chapter describes the protocol used for the data analysis process, the procedure used for identifying objects, and quality assurance and quality control procedures. Example images are included to illustrate methods used during the analysis, along with definitions of identification categories used, and tables showing the types of data collected during video analyses.

Introduction

The goal of the Department of Energy-funded Mid-Atlantic Baseline Studies Project (2012-2015) and the Maryland Project (2013-2015) was to produce the data required to inform siting and permitting processes for offshore wind energy development in federal waters of the Mid-Atlantic region (DE-VA; Figure 4-1). Data on the abundance and movements of marine, coastal and migratory birds, marine mammals, sea turtles, and other megafauna were collected within federally designated Wind Energy Areas (WEAs) and elsewhere within the study area, and analyzed using a variety of technologies and methods.

As one component of this study, BRI and HiDef Aerial Surveying Limited (HiDef) conducted large-scale surveys across the entire study area using high resolution video on an aerial platform. HiDef's technique used an array of four high resolution video cameras (which were either belly or nose mounted depending on aircraft type) on twin-engine Cessna aircraft to capture detailed footage and a consistent viewing frame of the ocean surface; survey flights were conducted at 2,000 feet above sea level (Chapter 3). Wildlife were observed in the video footage, georeferenced, and identified to species or lowest taxonomic order. This technique also allowed assessment of individual behavior and estimation of animal flight height.

Some components of the survey and analysis procedures were conducted by HiDef, while others were conducted by the Video Review Laboratory at BRI. As digital video aerial surveys are a relatively new technique for monitoring wildlife in the offshore environment, protocols for data management, data analysis, and quality assurance procedures have only recently been developed by practitioners in Europe and elsewhere, and these protocols continued to be developed as techniques and technologies continued to be refined. In order to provide transparency and accountability for all video data review conducted by BRI during the project, Video Review Lab personnel developed detailed data protocols for the components of the data analysis and data management processes for which they were responsible.

Overview of data analysis process

The general process for recording and analyzing high definition video aerial data included the following steps. A glossary of terms may be found in Appendix 4A.

I. HiDef Aerial Surveying Ltd.

a) HiDef worked with their digital video aerial survey vendor to outfit the survey aircraft and undertake survey flights in the Mid-Atlantic region.

b) The digital video aerial survey vendor shipped the video footage to HiDef in the UK, and also made hard drive copies of the video and shipped them to the BRI office in Maine.

c) The HiDef review team viewed each frame to mark visible objects (or *targets*) using proprietary video processing software, and noted object categories (e.g., Bird, Buoy, Fish). These data were outputted to an Excel spreadsheet, and the markers generated through this process were used by BRI reviewers to locate animals within a frame. Example images of marked animals can be found in Appendix 4C.

d) On completion, 20% of the frames in each survey were re-reviewed (blind) by a second HiDef observer to determine the rate of agreement between observers. Agreement was at least 90% for the audit to pass. All objects found by both the observer and the auditor were included in the final file sent to BRI regardless of whether the audit passed. If the audit was not passed, that observer's recent data were examined for consistent errors and issues were addressed.

e) Spreadsheets with marked data were sent to BRI for object identifications (Appendix 4B).

II. Biodiversity Research Institute

a) The BRI review team examined video frames which contained marked targets. Each target was identified to species or group, at the lowest possible taxonomic level, or as abiota of various types (Appendix 4C; also see "ID Category" section below). An assessment of the reviewer's certainty level was associated with each identification. If possible, ancillary data, such as the animal's behavior, direction of movement, and age and sex, were also noted (Appendix 4B, Table 4B-2). Direction of movement was noted in relation to the viewing screen (e.g., up, down, left or right).

b) The identification data spreadsheets were returned to HiDef in the UK.

c) Twenty percent of the objects originally categorized as animals by the HiDef review team were re-reviewed by additional BRI reviewers to determine the rate of agreement between observers. Agreement was defined according to relationships described in the QA/QC Review Protocol below. If <90% agreement was obtained for a given survey, supplementary audit and review processes were conducted as outlined in this protocol.

III. HiDef Aerial Surveying Ltd.

a) HiDef calculated flight altitude for flying targets listed in the identification data spreadsheets, using their proprietary parallax technology (Hatch et al. 2013), and georeferenced each video frame containing target objects using GPS data from the survey flight. Direction of movement was translated into a cardinal direction, based on the direction in which each camera was pointed during the time of recording (Appendix 4B, Table 4B-2).

b) The spreadsheets were returned to BRI with added parallax, location, and direction of movement information.

IV. Biodiversity Research Institute

a) These data were joined to the audited data held by BRI and complete datasets were added to the Northwest Atlantic Seabird Catalog (formerly the Compendium of Avian Information), a publicly held database housed by the USFWS (O'Connell et al. 2009), as well as to project partners for statistical analysis.

Tasks II.a and II.c. are described in "Procedure for Target Identification" and "Quality Assurance and Quality Control of Data Collection," below. Detailed information on the survey and data management tasks completed by HiDef Aerial Surveying, Ltd. and their contractors are outside the scope of this protocol.

Procedure for target identification

Video data storage

Video footage was stored on external hard drives and shipped between the aerial operator, BRI, and HiDef. These hard drives were uploaded to the server at BRI upon arrival, and data were accessed by the review team through this server. When data analysis and management was completed for a survey, the video data were transferred to external hard drives for long-term storage in a fire safe at an external location.

Filename conventions for spreadsheets and sequence files

Video file names were in the following format: ZoneID#_Month#_SurveyDay_CameraNumber_Year (example: Zone19_M03_S01_D01_C2_12). Sequences, which contained camera reels, were named in the format 10-15-43.796.

In the above examples, Zone 19 referred to the Mid-Atlantic study region; M03 referred to the calendar month (e.g., 03=March); S01 referred to the first survey of that month; D01 referred to when the section was flown over the course of the survey (e.g., Day 1), and changed geographic location from survey to survey; C2 referred to one of the four cameras that the reel came from; and 12 referred to 2012, the year the survey was flown. Sequence 10-15-43.796 referred to the specific video reel and was named for the time that the survey plane started on that transect line.

Excel spreadsheets

Each camera for each day had an associated spreadsheet for analysis. HiDef completed several fields for each identified object: Location (Zone), Date of flight, Camera Number, Resolution, Reel Name, Observer, Time, Frame number, Category of object, and Marker Number[2] (Appendix 4B, Table 4B-1). The spreadsheet was protected to prevent changes being made to the columns that were needed for later processing. Columns (Appendix 4B) were filled out by the review team. Spreadsheets were stored on the BRI server in their respective year, survey, month, day and camera folders and were accessible to the entire review team.

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[2] For March through October of 2012, the marker number for each object identified within the frame was added manually by BRI reviewers. From December 2012 onwards, HiDef included the marker numbers for all objects in the data spreadsheets, eliminating the need for manual entry.

Reel selection

The object marker files were named to match reel names in video sequences. When a video sequence was unable to open, it was possible to repair the corrupted reel on-site using a proprietary module that re-built headers for each file. Review of video sequences was recorded in spreadsheets associated with each day and camera; reviewers tracked who was reviewing which reels on the video review room white board.

Frame review

Each object had a marker number and a frame number associated with it. The frame number referred to the frame that the HiDef reviewer marked as containing an object for review (e.g., the frame in which the object was closest to the red center line that bisected the camera field of view; Appendix 4C). The start or end of a reel or a section of footage containing atmospheric interference (e.g., clouds) was also assigned a frame number. Some frames contained zero or a single marker identified, while others contained multiple markers, when there were numerous animals in the frame (Appendix 4C). The frame number from the spreadsheet was equivalent to the number in the file header information located at the top of the proprietary video processing software.

Identification of a marked target

For each frame that featured a target marked by the HiDef review team, a BRI reviewer entered the frame number into the proprietary video processing software to view the object. The reviewer closely examined each target for features (size, shape, color, behavior, flight pattern) that allowed for identification to species according to defined criteria (Appendix 4E). When the object was not identified to species, the object was categorized to a higher taxon level or a broad category (e.g., "UNKN; Unknown"). The aim was to identify targets to the lowest taxonomic level possible, with accuracy. Reviewers moved through all of the frames in which that object was recorded to get a sense of the target's movement, and to find the clearest images for review. Using proprietary video processing software, reviewers adjusted the image brightness and other qualities to create a clearer image of the object being identified, or to pick up lighter or darker colors that were obscured (Appendix III).

Data fields completed by BRI

Fields L-AA in the data spreadsheet (Appendix 4B, Table 4B-2) were filled out for each marked object. When a reviewer finished reviewing the data for a spreadsheet, he or she checked their spreadsheet with a QA/QC checklist and made required edits (see Appendix 4G).

Marker Number

When an object was missed at the review stage and crossed the red line, a marker number was added to the spreadsheet and highlighted in bright yellow with a frame number filled in to the "Added Frame Number" column. A new marker number was added to the screen by clicking on the object and selecting "Ok" (Appendix 4C). Marker numbers were generated automatically by the proprietary video processing software and advanced sequentially. The marker number was added to the marker number column in the spreadsheet.

ID Category

Objects were identified to species, when possible, based on the animal's size, coloring, movement, general shape, and movement/flight pattern. Options included bird, mammal, shark, ray, fish, and turtle species, as well as algae and abiotic objects (a complete listing of codes employed through May 2014 is included in Appendix 4D). Species group codes were also used; these corresponded to groups of species that were difficult to differentiate. For example, the "SMTU" code ("small turtle") included green, Kemp's ridley, hawksbill, and loggerhead sea turtle species, and was used in cases where more definitive species identifications were deemed to be impossible. Other group codes included:

> CESS; Cetacean/Seal/Shark - Animal was too obscured to discern between a cetacean, a seal, a shark, or a large fish
>
> UNBI; Unidentified Bird – Object was a bird but no further taxonomic distinctions were determined

In addition, non-object codes were used for marked objects that were not placed in a biotic category:

> Nothing; Nothing – Something was marked as an object, but there was nothing there. This was also used when a wave or feces was marked as an object.
>
> ERRO; Error – This was used to identify objects in an inoperable or damaged reel that was unable to be repaired. This was also used to identify objects on land.

Species Confidence

All objects were assigned a confidence level (Table 4-1). For non-species based identifications (e.g., "DUPL; Duplicate," "NA; Not Applicable"), "Definite" was used as the confidence.

Behavior

When a target was identified as an animal, the general behavior of the target was described using the options in the drop-down menu (Appendix 4B, Table 4B-2). Some categories of behavior referred specifically to avian or bat targets (sitting, flying, taking off), while others referred to aquatic animals (stationary, moving). Direction of the animal's movement was indicated when applicable.

Flying at Sea Level

This designation was used for targets identified as birds or bats that were flying. Reviewers considered whether or not there was evidence that the animal in flight was flying close to the ocean surface. Splashing indicated the bird had just taken off, or a shadow close to the target object indicated it was low over the water (Appendix 4C).

Submerged

Reviewers noted whether the animal was submerged or surfacing within the recorded frames. This designator was only used for aquatic animals.

Approximate Age

When possible, reviewers noted the approximate age of the animal based on measurements of size (mammals, turtles, rays) or plumage (birds).

Plumage

Any details about plumage were noted in this text field. Options included gannet and fulmar plumages (see Appendix 4B, Table 4B-2).

Molt

Molt stages were noted for birds when possible (see Appendix 4B, Table 4B-2).

Probable Sex

Probable sex was noted where possible. There were many species that were not be identified to sex, so this was only marked when the reviewer was able to determine sex easily (e.g., scoters).

Measurements

When an on-screen measurement of an object was taken during the ID process using the proprietary point-to-point caliper module, the measurement was recorded in the Measurements[3] column in centimeters (Appendix 4C). The types of measurements included in this field (Appendix 4B, Table 4B-2) are listed in Table 4-2; all other measurement types (i.e., sitting birds, caudal fin measurements, partial measurements) were placed in the comments field.

Outside Zone

Animals were occasionally marked that did not cross the red line. When that happened, reviewers indicated this by choosing “Yes” here.

Flag

Flags were used to mark an animal that reviewers wanted to revisit for any reason. The reason for flagging was noted in the comments.

Added Frame

When an unmarked object was found, this was where the position of the marked object (frame number) was noted.

Comments

Reviewers filled out comments on the object when necessary. Reel names of any missing objects were included here. In addition, when changes were made to the data after they were sent back to HiDef for parallax and georeferencing, (for example, as the result of an audit arbitration; see QA/QC Review Protocol below) reviewers used the following wording in the comments: Post-parallax edits-MM/DD/YYYY and any other comments associated with the post-parallax change along with their initials. In addition, reviewers changed the ID Category fill color to dark green.

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[3] For March 2012, the measurement tool was not available and objects were measured using a ruler. Prior to December 2012, measurements did not follow the definitions found in Table 4-2.

Identification Date
Reviewers entered the date of identification for every line of data.

Identifier
Reviewers entered their initials here for every line of data at the time it was completed.

Completion of data analysis

Following the data analysis outlined above, as well as the data collection and data completion QA/QC procedures outlined in the QA/QC Review Protocol below, BRI sent data spreadsheets to the HiDef head office in the United Kingdom. The UK office georeferenced all frames with target objects, and estimated the approximate flight height of flying objects using a proprietary parallax technique (Hatch et al. 2013). The columns produced through this process were Latitude, Longitude, Flight Height, Flight Height Confidence, and a modified field for Behavior that included cardinal direction of movement where applicable (Appendix 4B, Table 4B-3). While HiDef was completing these data analyses for the survey, BRI concurrently began regular and Threatened and Endangered Species audit procedures as outlined in the QA/QC Review protocol below.

Quality assurance and quality control of data collection

Goals

The goals of QA/QC were to ensure:

1. Data were consistent, accurate, valid, and repeatable
2. Problem areas and successes were identified, addressed, documented, and reported
3. ID criteria and SOPs were up to date and applied consistently by each reviewer
4. Exceptional data quality was maintained for:
    a. Basic analysis/summary reports
    b. Statistical modeling
    c. Synchronization with current or similar datasets
    d. Collaborator analysis needs

Filename conventions

13_M09_Audit_JGO

13_M09_Arbitration_JGO

In the examples above, “13” represented the year in which the survey was flown, “M09” represented the month in which the survey was flown. “Audit” or “Arbitration” was the task performed. “JGO” represented the initials of the auditor or arbitrator.

Data collection QA/QC

To ensure consistency during data collection and the accuracy of data entry, spreadsheet formatting was locked and drop-down menus were used in fields with analyzable data. In addition, drop-down menus were extracted from a master code database, which was updated with definitions and codes on a regular basis (Appendix 4D). Ancillary data within the reviewer spreadsheet, such as measurements or comments, were recorded as text. To ensure repeatability and consistency, all reviewers referred to the same reference documents, such as measurement charts, seasonal distribution maps, and a "Confidence and Identification Criteria" document (Appendix 4E), which was based on a hierarchal matrix (Appendix 4F) that was developed from biota previously encountered on aerial and boat-based surveys conducted in the study area, as well as taxonomic pairings or groupings developed during HiDef's previous projects in Europe. In order for an object to be called a 'definite Dovekie', then all of the criteria for 'definite' and 'Dovekie' needed to be met. Otherwise, it was either downgraded to a lower confidence level or a higher taxonomic grouping, such as 'Unidentified Alcid'.

Data completion QA/QC

Reviewers checked for common data errors using a checklist (Appendix 4G). After target identification was complete, the QA/QC manager compiled the data by month and double-checked for errors, such as those listed in Appendix 4G. Errors were corrected by the original identifier, when available, and any corrections to the data by the team leader or QA/QC manager were noted in the comments field in the original spreadsheet.

Blind audit re-identifications

Following completion of the above steps for each survey's data, the compiled data were filtered for objects originally characterized by Hi-Def reviewers as biota. Buoys, boats, and reel locations did not qualify for audit. Twenty percent of the remaining objects were eligible for audit and this number was noted. In order to maximize the audit effort, and to reduce audit technical error, other objects were exempt from the audit, such as duplicate objects, outside zone objects, and objects that were not identified due to reel or marker number errors. Next, a formula was used to assign a random number to all eligible objects. Once those numbers were generated, the spreadsheet was sorted in numerical order by the random-generated number. The top 20% were chosen and pasted into a new tab. The original compiled spreadsheet was sorted for threatened and endangered (T&E) species and any T&E objects that did not get chosen for the random-generated audit were also added to the random audit. The objects were assigned a second random number and sorted in ascending order by the random-generated number. The spreadsheet was filtered by each original reviewer and those objects were evenly distributed to other BRI reviewers. All original answers were removed, new fields for audit identification were added, and a new "blind" spreadsheet was generated for each auditor. Auditors followed the same identification protocol as for the target ID process above, and their identifications were compared to the original identifications to determine how often the first and second reviewers agreed. A "pass" grade occurred when auditors agreed with ≥90% of original reviewers' data in the random audit, and 100% for the T&E audit.

Audit analysis: randomly chosen objects

Assessment of audit agreement rates was conducted via MS Access using pre-determined answer agreements (Appendix 4H; these were based on the 'Confidence and Identification Criteria' document and rules that applied to all biotic objects). The rules were (see Table 4-3 for examples):

1. Specific species identifications were considered to equal the next available higher taxonomic grouping as long as the next available grouping was not "UNBI; Unidentified Bird", "ID

Impossible; ID Impossible", or "CESS; Cetacean/Seal/Shark". In those instances, the species only equaled itself. For example, some species such as "NOGA; Northern Gannet" and "REBA; Red Bat" were singly defined in the audit answer status (see Appendix 4H) because they had no known similar species in the study area during the project period. Fully defined species such as "BODO; Bottlenose Dolphin" passed as an "SBCE; Small beaked Cetacean to 3m" in an audit.

2. Higher taxonomic grouping identifications were considered equal to the next lowest taxonomic level as well as next highest taxonomic grouping. For example, SBCE; Small beaked Cetacean to 3m equaled CODO; Common Dolphin or BODO; Bottlenose Dolphin, and also equaled UNDO; Unidentified Dolphin. However, it was not be a match to an even broader taxonomic category such as UNCE; Unidentified Cetacean.
3. Biota did not equal abiota.
4. For higher flying birds, such as gulls and terns, measurements had overlapping measurement error values, which were further exacerbated by unknown flight height of the bird at the time of identification. Therefore, groupings with size designations crossed sizes in the audit agreement rules and also equaled the next available higher taxonomic grouping. For example, UNMT; Unidentified Medium Tern: 32-45cm equaled UNLT; Unidentified large Tern as well as UNTE; Unidentified Tern.
5. Except for sea turtles, which all have a T&E status, T&E species only equaled themselves.

Some ID Categories were not yet fully defined and, therefore, were more likely to change in audit answer composition or were more flexible with the audit answers. This mostly occurred with non-avian biota, such as sharks and cetaceans, where reviewers were less certain of what species to expect, or whether there were enough ID criteria available in video footage to discern between higher and lower taxonomic groupings (see Appendix 4H).

When there was at least 90% agreement, then the audit was passed for that survey and no further analysis was needed. When the overall audit was in <90% agreement (meaning that for 100 objects, there was disagreement between the first and second reviewer on >10 objects), then biotic taxonomic groups that represented ≥20% overall object composition within the survey but had <90% agreement were discussed by the team to determine better methods for identification (see Table 4-4 for an example). After ID criteria were clarified and the 'Confidence and Identification Criteria' document was revised, all objects from those taxonomic groups were re-reviewed in the original data. After a repeated review of those target taxa, 20% of the target taxa that were not in the original audit were audited. When 90% agreement was achieved in this second audit, no further analysis was needed. When audit disagreement continued, the taxonomic grouping went into arbitration, whereby the object(s) in question were independently reviewed again by the entire team and a final answer was determined based on those results. Mismatches from taxa that did not represent ≥20% overall object composition within the survey were team-reviewed in order to improve identification methods and criteria.

Audit analysis: T&E species

All objects that were identified as state- and federally-listed species were included in the audit alongside randomly chosen objects[4]. Audit agreement had to be 100% for T&E species and in most cases, the T&E species had to match exactly. Since all sea turtles are federally listed, audit agreement allowed for a specific species of turtle to match “SMTU; small turtle” and vice versa. However, a specific species did not match another species in the turtle grouping. All mismatches of T&E species automatically went to arbitration.

Arbitration

Arbitration occurred when there was less than 20% agreement on biotic objects during the randomly chosen object audit and <100% agreement on T&E objects. Essentially, the objects in question were independently reviewed again by the entire team and final answers were determined based on those results.

Each arbitrator received a new spreadsheet with all audit mismatches and each object was reviewed on the video footage again. Each object mismatch was reviewed by the original reviewer, original auditor, a new informed reviewer, and a new uninformed reviewer. For those objects where the arbitrator role was original reviewer, original auditor or informed reviewer, the arbitrator viewed the original reviewer’s identification category and comments, as well as the original auditor’s identification category and comments. The arbitrators reviewed the video footage, assessed the original reviewer and auditor answers, and either chose one of those answers or an entirely new answer. For the uninformed arbitrator, the original reviewer’s identification category and comments as well as the original auditor’s identification category and comments were omitted.

Once the arbitration spreadsheets were complete, the final answers were determined by the level of Identification Category agreement. When the majority of the arbitrators chose the same Identification Category, then this was the final answer. In instances when there was no majority agreement, then the Identification Category with the highest taxonomic value was chosen. When the original answer was overturned in arbitration, corrections were then made to the original reviewer spreadsheet.

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[4] The T&E audit was conducted separately from the random audit for the first five surveys, but became integrated with rest of the audit beginning with December 2012.

Literature cited

Hatch, Shaylyn K., Emily E. Connelly, Timothy J. Divoll, Iain J. Stenhouse, and Kathryn A. Williams. 2013. “Offshore Observations of Eastern Red Bats (Lasiurus Borealis) in the Mid-Atlantic United States Using Multiple Survey Methods.” *PLoS ONE* 8 (12): 1–8. doi:10.1371/journal.pone.0083803.

O’Connell, A. F., B. Gardner, Andrew T Gilbert, and K. Laurent. 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*. Beltsville, MD: Prepared by the USGS Patuxent Wildlife Research Center.

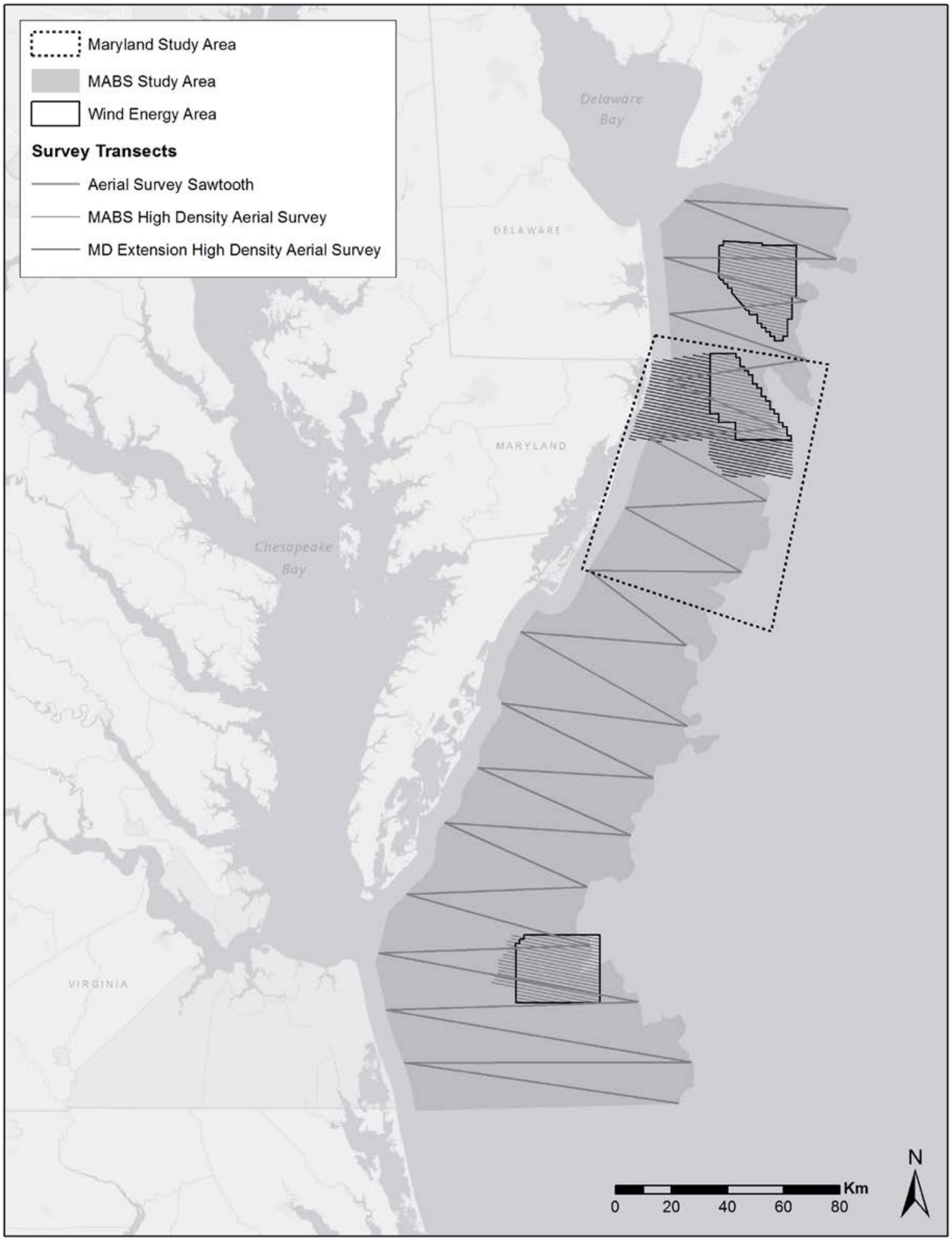

Figure 4-1. Map of digital video aerial survey transects for the Mid-Atlantic Baseline Studies and Maryland Projects (2012-2014). Mid-Atlantic Baseline Studies transects are shown in light gray. High-density Maryland transects are shown in dark gray.

Table 4-1. Species identification confidence levels.

Option	Definition
Possible	less than 50% certain
Probable	greater than 50%, but less than 95% certain
Definite	greater than 95% certain

Table 4-2 Measurement definitions for various taxonomic groups

Taxon Group	Measurement Format	Example
Birds in flight	Length (bill tip to tail tip) x Wingspan (wing tip to wing tip)	60 x 114
Bats in flight	Length (tip of head to tail tip) x Wingspan (wing tip to wing tip)	15 x 40
Sharks, Fish	Length (snout tip to caudal fin tip)	157
Cetaceans	Length (upper jaw tip to fluke notch)	225
Seals	Length (nose tip to tail tip)	190
Rays	Disc Width (pectoral fin tip to pectoral fin tip at the widest part)	90
Turtles	Straight Carapace Length (carapace top to carapace bottom at the midline)	84

Table 4-3. Excerpt from an audit showing examples of audit agreement and disagreement. The complete rules are contained in Audit Analysis: Randomly Chosen Objects.

Reviewer ID Category	Auditor ID Category	Audit Match?
CATE;Caspian Tern	UNTE;Unidentified Tern	Yes, rule 1
GRSH;Greater Shearwater	UNBI;Unidentified Bird	No, rule 1
TSMG;Tern/Small or Medium Gull	UNTE;Unidentified Tern	Yes, rule 2
UNBI;Unidentified Bird	UNKN;unknown	No, rule 3
UNMT;Medium Tern: 32-45 cm	UNLT; Unidentified large Tern	Yes, rule 4
UNMT;Medium Tern: 32-45 cm	UNBI;Unidentified Bird	No, rule 2
BODO;Bottlenose Dolphin	SBCE;Small beaked Cetacean to 3 m	Yes, rule 1
BODO;Bottlenose Dolphin	CESS;Cetacean/Seal/Shark	No, rule 1
COWR;Cownose Ray	UNRA;Unidentified ray	Yes, rule 1
COWR;Cownose Ray	CESS;Cetacean/Seal/Shark	No, rule 1
KRST;Kemp's Ridley Sea Turtle	SMTU;Small turtle	Yes, rule 5
SMTU;Small turtle	LOTU;Loggerhead Turtle	Yes, rule 5
SMTU;Small turtle	UNKN;unknown	No, rule 3&5
SCHA;Scalloped Hammerhead	HASH;Hammerhead shark	Yes, rule 1

Table 4-4. Example of disagreement in audit results. Overall agreement from the example audit below was 80%. Loons represented ≥20% overall object composition and received <90% agreement, resulted in re-review of all loon objects (n=548) and subsequent 20% re-audit of loons not in the original audit.

Taxonomic Grouping	n	Overall Object Composition	# Mismatches	# Matches	Total	% Agreement	Consequences
Egrets and Herons	2	0%	0	1	1	100%	None
Fish and Sharks	209	11%	5	42	47	89%	Team reviewed
Gannets (Sulidae)	71	4%	3	8	11	73%	Team reviewed
Gulls and Terns (Laridae)	341	18%	17	54	71	76%	Team reviewed
Jaegers and Skuas (Stercorariidae)	4	0%	0	0	0	NA	Not applicable
Jellyfish (Cnidaria)	1	0%	0	0	0	NA	Not applicable
Loons (Gaviidae)	**548**	**29%**	**31**	**76**	**107**	**71%**	**Re-review and re-audit**
Other Biota	26	1%	0	0	0	NA	Not applicable
Pelicans (Pelicanidae)	3	0%	1	0	1	0%	Team reviewed
Rays (Batoidea)	1	0%	0	0	0	NA	Not applicable
Scoters, Ducks, Geese (Anatidae)	1	0%	0	0	0	NA	Not applicable
Toothed Whales (Odontoceti)	200	11%	5	34	39	87%	Team reviewed mismatches
Turtles (Testudines)	**293**	**16%**	**3**	**56**	**59**	**95%**	**Arbitration**
Unidentified Birds (Aves spp.)	152	8%	10	20	30	67%	Team reviewed mismatches
Unidentified Marine Mammal or	20	1%	1	2	3	67%	Team reviewed mismatches
Unidentified Whale (Cetacea)	2	0%	1	0	1	0%	Team reviewed mismatches
Grand Total	**1874**	100%	**77**	**299**	**376**	**80%**	

Supplementary material

Appendix 4A. Glossary

Audit – Inspection of data conducted by reviewers after each major step of the data analysis process. A minimum of 20% of the data from each survey month was audited by a second observer, and objects on which the reviewers disagreed were re-reviewed in an arbitration process (the exact process varied between the marking audit and identification audit; for details on the identification audit process, see the Target Identification Protocol). The selection of data for regular audits was random. Threatened and Endangered Species audits (in which all species initially identified as a listed species of concern at the state or federal level were reviewed by a second observer) were comprehensive, and included 100% of these identified species for each audit.

BRI – Biodiversity Research Institute, the nonprofit research organization based in Maine that oversaw the Mid-Atlantic Baseline Studies and Maryland Projects (www.briloon.org).

Frame – individual image within a video reel. There were roughly 20,000 frames per reel. Frames were recorded at a rate of approximately one every 0.06 seconds of survey under normal circumstances.

GSD – ground sample distance, affected image resolution.

HiDef – HiDef Aerial Surveying Ltd., the organization based in the United Kingdom that developed the high resolution video camera system and captured and processed high resolution digital aerial video.

Marker number – number assigned by HiDef reviewers as a unique identifier for individual objects. This was recorded in the spreadsheet automatically during HiDef processing.

Maryland Project – Two year (2013-2015) extension to the Mid-Atlantic Baseline Studies Project funded by the Maryland Department of Natural Resources and the Maryland Energy Adminstration. Expanded high density survey coverage south and west of the Maryland WEA, including into Maryland state waters. These surveys were flown March 2013-May 2014 in conjunction with the MABS surveys. One additional survey of the Maryland study area and the Maryland WEA occurred in August 2013 as a part of the extension project.

Mid-Atlantic Baseline Studies Project (MABS) – three-year (2012-2015) project funded by the Department of Energy. The project included boat and digital video aerial surveys of animals in the Mid-Atlantic outer continental shelf, among other studies (www.briloon.org/mabs).

Parallax – the apparent motion of an elevated object against a distant background due to the movement of the observer (used to estimate flight height).

QA/QC – quality assurance and quality control.

Red line – midline of the video footage, and over which an object crossed to be included within the survey area- this red line represented 50 meters wide for 2 cm GSD, 75 meters wide for 3 cm GSD.

Reel – continuous stream of video footage. ID# for a reel was the exact (GPS) start time. One camera recorded one reel along one transect.

SOP – standard operating procedure.

T&E – threatened and endangered species.

Transect – line flown by aircraft during surveys. There were 152 individually numbered transects under the current survey design for the Mid-Atlantic Baseline Studies Project and Maryland Project (as of March 2013).

Video sequence – sequence of video collected by HiDef, split into individual reels.

WEA – federally designated Wind Energy Area, or geographic region that the Bureau of Ocean Energy Management identified as an area for potentially expedited permitting of offshore wind facilities.

Appendix 4B. Quick Guide to Video Identification Spreadsheet Fields

Table 4B-1. The fields completed by HiDef Review Team for every object identified. *Required information for all records.

Field	Description	*Example*
[redacted]	Zone surveyed.	*Zone 19*
[redacted]	Date of survey – mm/dd/yyyy.	*03/26/2012*
[redacted]	Number assigned to each camera in an array.	*1*
[redacted]	Ground sample distance in cm	*2cm*
[redacted]	Local time at start of reel. Noted as hours-minutes-decimal seconds in 24 hour time.	*11-36-07.796*
[redacted]	Initials of the HiDef reviewer.	*DC*
[redacted]	[redacted]	[redacted]
[redacted]	Frame number in which an object was marked. Frames were numbered sequentially at the beginning of each reel.	*159*
[redacted]	General category describing observation. Start and end of reels were also noted in this field.	*bird*
[redacted]	Number of the marker on the object to be identified.	*23*

Table 4B-2. The fields completed by BRI Review Team for relevant objects identified. Unused fields (for non-required information) were left blank. *Required information for all records.

Field	Description	Field Type	Drop-down Options or Text Examples
ID Category	Code for ID of object.	Drop-down	See Appendix D
Confidence	Degree of certainty.	Drop-down	Definite, Probable, Possible
Behaviour	General behavior of identified animals. Included direction of animal's movement in relation to camera applicable.	Drop-down	Sitting, Sitting on object, Loafing, Taking Off, Feeding, Following Vessel, Flying (Direction Unknown), Flying up (etc.), Stationary, Moving left (etc.), Haul-out (pinnipeds)
Flying at Sea Level	Splashing or shadow at ocean surface.	Drop-down	Yes, No
Submerged	Under or at water's surface.	Drop-down	Submerged, Surfacing

Field	Description	Field Type	Drop-down Options or Text Examples
Approximate Age	Adult= animals with adult plumage or mature body size; Immature= animals >1 year old that had not achieved adult plumage or full body size; Juvenile= young of the year, Hatch Year (HY) birds or any animal with known age <1 year.	Drop-down	Adult, Immature, Juvenile
Plumage	Gannet or Northern Fulmar plumages.	Drop-down	Light Phase, Dark Phase, Intermediate Phase, Gannet Plumage 1 – 6, Unknown
Molt	Bird molt stage.	Drop-down	Summer, Winter, Transitional, Primary Molt, No Primary Molt, Unknown
Probable Sex	Selected appropriate option from list.	Drop-down	Male, Female
Measurements	Estimated length or wingspan, in cm.	Number	105
Outside Zone	Marked when object did not cross line.	Drop-down	Yes or blank
Flag	Entry marked for later examination.	Drop-down	Yes or blank
Added Frame Number	Frame number where missed object was marked.	Number	485
Comments	Other notable features, description of what was seen, clarity of camera/frames.	Text	Too blurry to ID to species
Identification Date	Date of review – mm/dd/yyyy.	Number	5/29/2013
Identifier	Initials of the BRI reviewer.	Text	EC

Table 4B-3. Spreadsheet compiled by HiDef analysts in the parallax and georeferencing process.

Field	Description	Example
Behaviour	General behavior of identified animals. Direction of animal's movement was translated from the movement in relation to viewing screen (up, down, left, right) to cardinal direction when applicable.	Flying SE
Flight Height	Range of possible flight heights in meters for eligible objects.	0 - 20
Flight Height Confidence	Confidence of the flight height calculation.	100%
Latitude	Latitude of the frame number or "play pos" in decimal degrees.	36.93328
Longitude	Longitude of the frame number or "play pos" in decimal degrees.	-75.56408

Appendix 4C. Data Analysis Methods: example images from the proprietary video processing software.

Figure 4C-1. Footage of a Northern Gannet (*Morus bassanus)* in flight. The yellow circle with “65” inside (not visible) was the marker with a marker number. Animals were marked when they were close to the red midline, as shown in this picture.

Figure 4C-2. Gain was adjusted to help pick up different features on the object for identification. Here, gain was increased from the base image in **Figure 4C-1**, which caused the white on this bird to stand out.

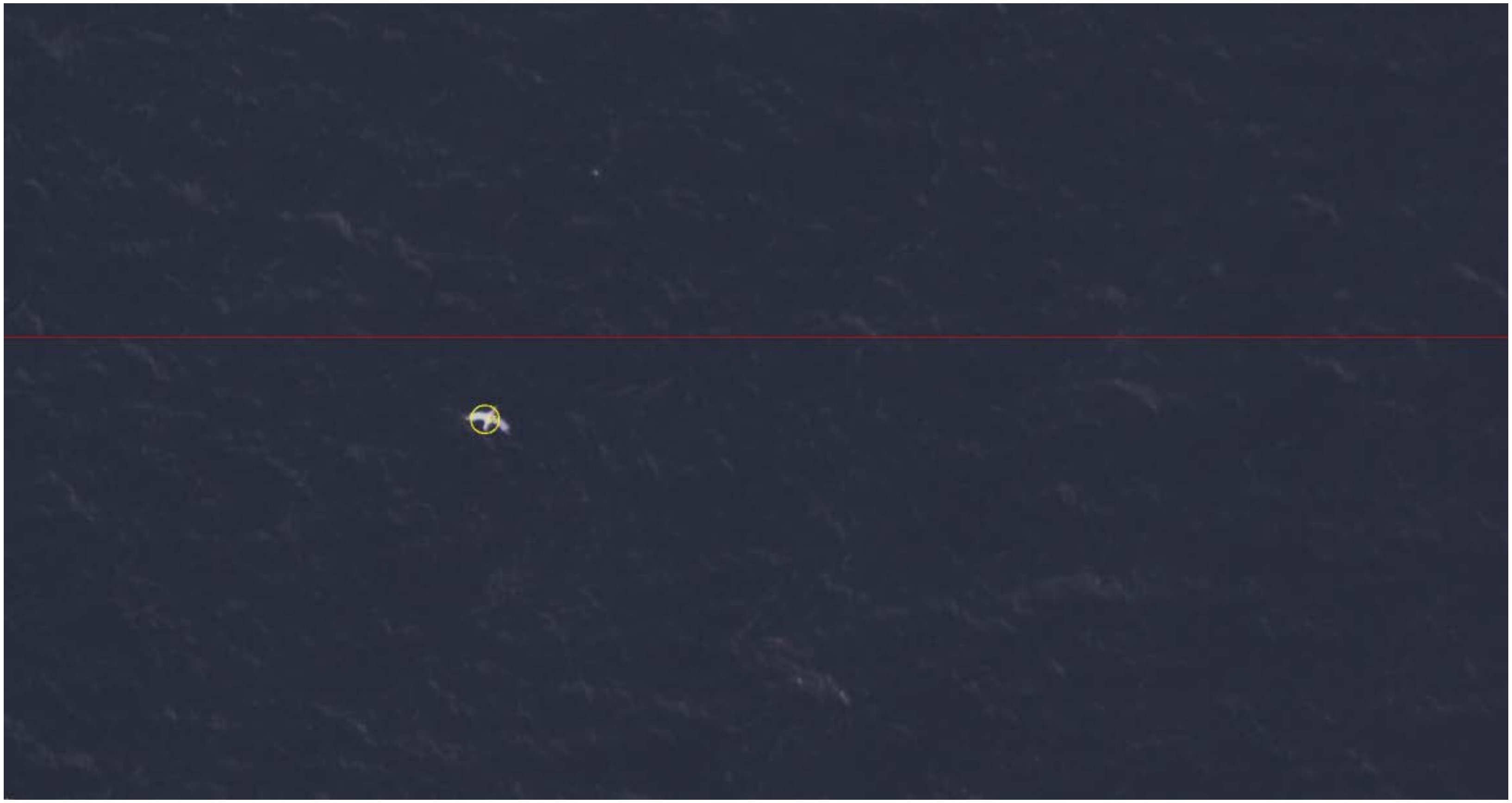

Figure 4C-3. Adjusting the Gain and Gamma gave greater overall contrast especially when viewing flying objects vs. submerged objects. The Gain adjusted the brightness of highlights or whites, while gamma was adjusted to deal with the brightness of mid-tones. In this image the Gain was lowered compared to **Figure 4C-2** and the Gamma was decreased. The adjustments allowed for the yellow coloration on the head and the black wing tips to stand out.

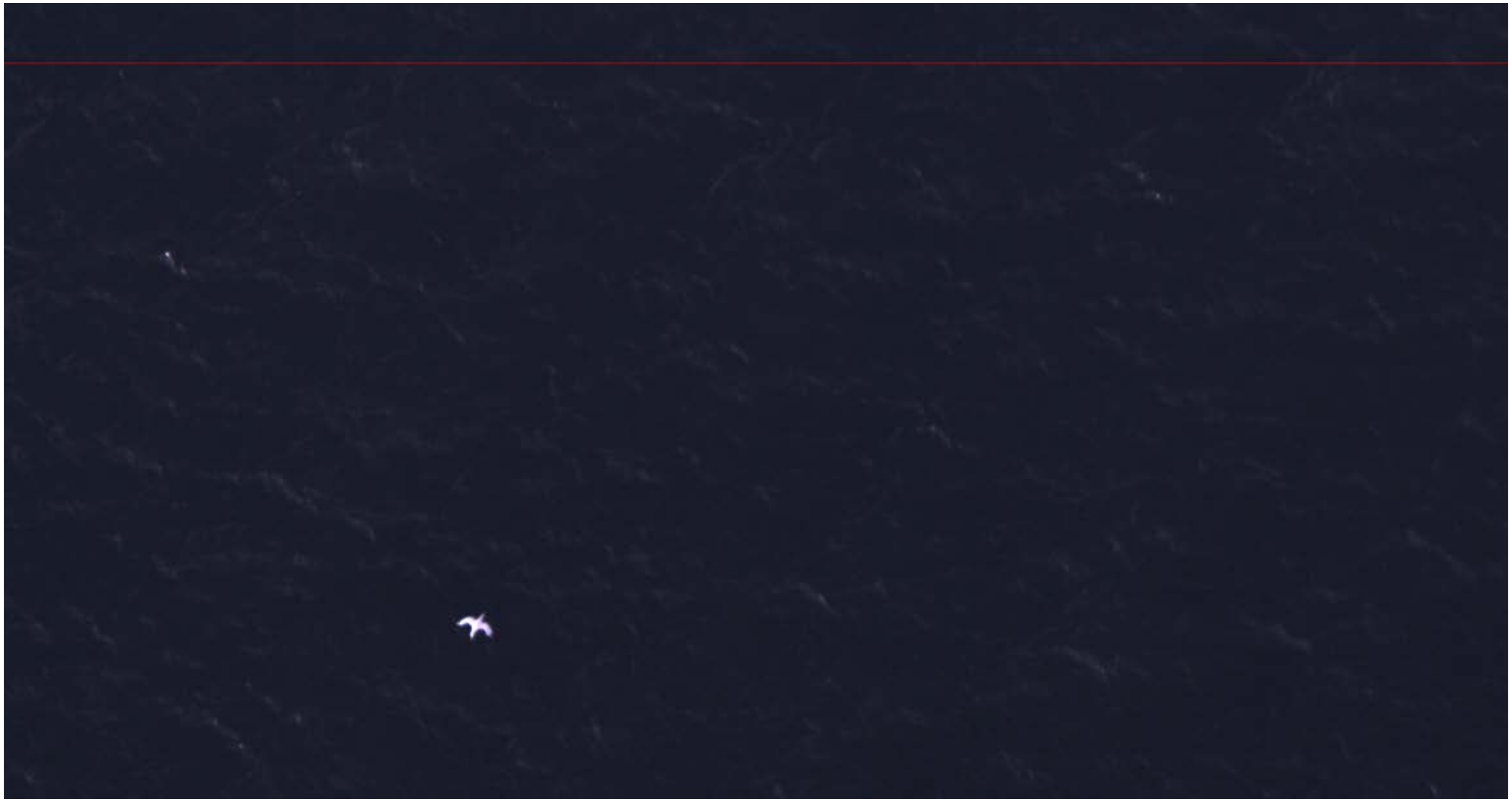

Figure 4C-4. Moving the footage backward and forward from the frame in which the object was marked allowed reviewers to examine animal movements such as wing flapping, diving, or turning a head. In this image the reviewer reversed to an earlier frame from the one shown in **Figure 4C-1**.

Figure 4C-5. It was important for reviewers to move through each frame when making identifications as some portions of the screen were blurry. These images of a Cownose Ray (*Rhinoptera bonasus*) showed how one image (left) was clear, while the subsequent frame (right) was blurry.

Figure 4C-6. Black Scoters (*Melanitta americana*) in flight with shadows visible. Each scoter in this image was counted as flying at sea level.

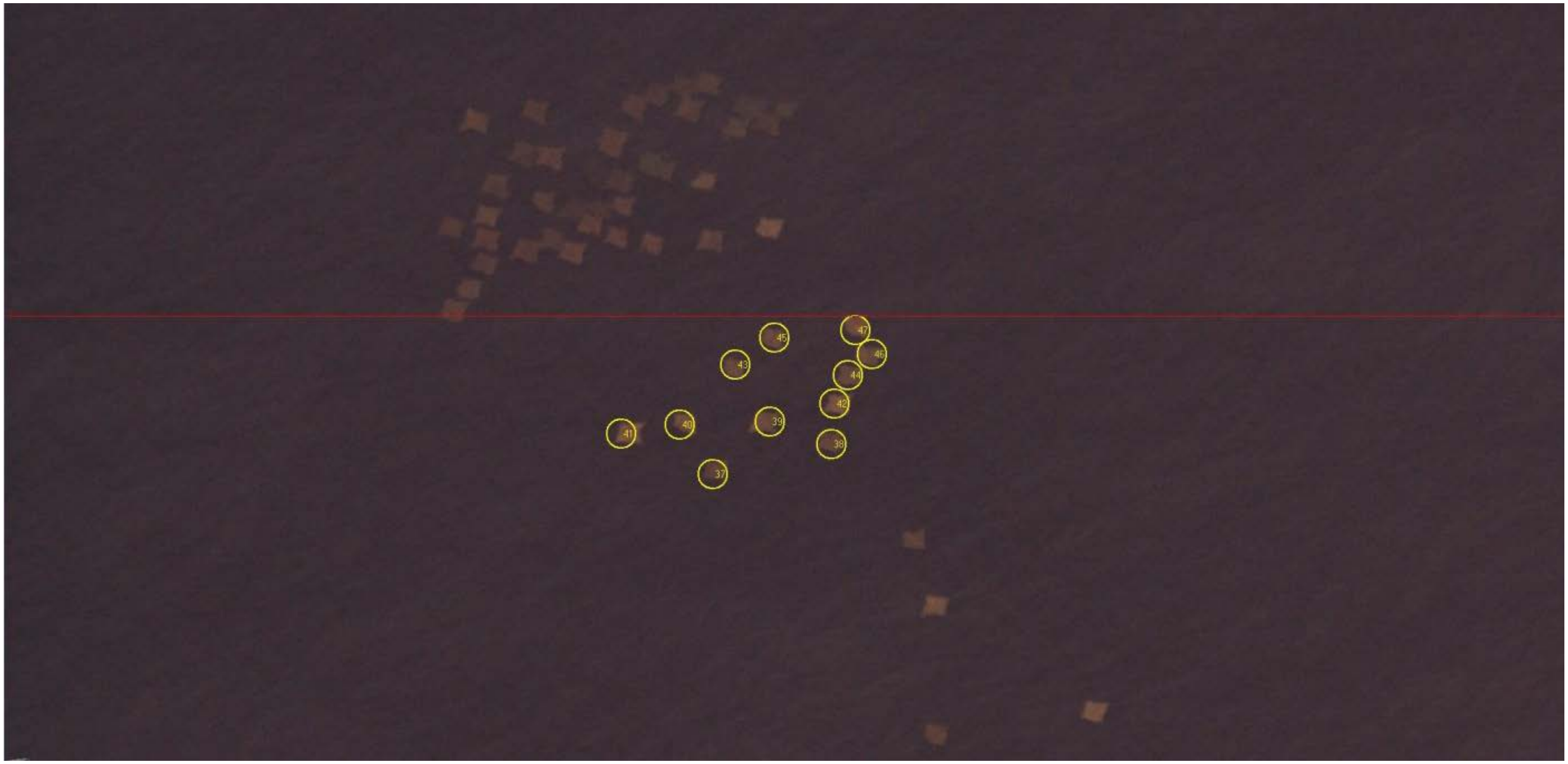

Figure 4C-7. Cownose Rays in a large school. Individuals that were close to the red midline were marked while those that passed or were approaching were marked in a different frame. This helped with data processing and identifying individual animals.

Figure 4C-8. Measurement of a Cownose Ray. Cownose Rays were measured from their widest point fin-to-fin, so it was important to choose a frame where both fin tips were seen. Note that this was a screen capture of the same rays as shown in the prior figure, but a few frames before it, so a different group of rays was marked by the marker numbers.

Appendix 4D. Identification Categories Used in Data Analysis

Table 4D-1. Identification (ID) categories used for aerial analysis. New categories or species were added as the need arised. All species codes used in the species included column were obtained from the ID Category column. Bird species codes largely adhered to AOU (American Ornithologists' Union) four-letter alpha codes.

ID Category	Explanation or Species Included	Occurred in Project?
AKSH;Auk or Shearwater	Included ATPU,AUSH,BLGU,COMU,DOVE,MASH,RAZO,TBMU	Yes
AMBI;American Bittern		Yes
ARTE;Arctic Tern		No
ASDO;Atlantic Spotted Dolphin		No
ATPU;Atlantic Puffin		Yes
AUSH;Audubon's Shearwater		No
BAEA;Bald Eagle		Yes
BAIT;bait ball		Yes
BALN;balloon		Yes
BAOR;Baltimore Oriole		Yes
BARS;Barn Swallow		Yes
BASH;Basking Shark		Yes
BBWH;Blainville's Beaked Whale		No
BCPE;Black-capped Petrel		No
BEKI;Belted Kingfisher		Yes
BLGU;Black Guillemot		No
BLKI;Black-legged Kittiwake		No
BLSC;Black Scoter		Yes
BLSH;Blue Shark		No
BLTE;Black Tern		Yes
BLVU;Black Vulture		Yes
BLWH;Blue Whale		No
BOAT;Boat--unidentified		Yes
BOBA;boat--barge/barge and tug		No
BOCA;Boat--cargo		Yes
BOCF;Boat--commercial fishing		Yes
BOCG;Boat--Coast Guard		Yes
BOCR;boat--cruise		Yes
BOCS;boat--container ship		Yes
BODO;Bottlenose Dolphin		Yes
BOFE;boat--ferry		No
BOFI;boat--fishing		Yes
BOGU;Bonaparte's Gull		Yes
BOLO;boat--lobster		No

ID Category	Explanation or Species Included	Occurred in Project?
BOME;boat--merchant		No
BOPL;boat--pleasure		Yes
BOPS;boat--purseiner		No
BORF;boat--recreational fishing		Yes
BORV;boat--research vessel		Yes
BOSA;boat--sail		Yes
BOTA;boat--tanker		Yes
BOTD;boat--trawler/dragger		No
BOTU;boat--tug		Yes
BOWW;boat--whale watch		No
BOYA;boat--yacht		Yes
BRAN;Brant		Yes
BRBO;Brown Booby		No
BRDO;Bridled Dolphin?	Members of genus Stenella. Included ASDO,CLDO,LSSD,PSDO,STDO	No
BRPE;Brown Pelican		Yes
BRTE;Bridled Tern		No
BRWH;Bryde's Whale		No
BUFF;Bufflehead		No
BUOY;Buoy		Yes
CANG;Canada Goose		No
CASW;Cave Swallow		No
CATE;Caspian Tern		Yes
CBWH;Cuvier's Beaked Whale		No
CEDW;Cedar Waxwing		Yes
CESS;Cetacean/Seal/Shark	Included all cetaceans/seals/sharks and fish.	Yes
CLDO;Clymene Dolphin		No
CODO;Common Dolphin	Short-beaked or Long-beaked Common Dolphin. Short-beaked was the more likely common dolphin in the Mid-Atlantic target area.	Yes
COLO;Common Loon		Yes
COME;Common Merganser		No
COMU;Common Murre		No
CONI;Common Nighthawk		Yes
COSH;Cory's Shearwater		Yes
COTE;Common Tern		Yes
COWR;Cownose Ray		Yes
DBSH;Dark-backed Shearwater	Included AUSH,MASH,SOSH	No
DCCO;Double-crested Cormorant		Yes

ID Category	Explanation or Species Included	Occurred in Project?
DOVE;Dovekie		Yes
DOWI;Dowitcher spp.	Short-billed or Long-billed Dowitcher	Yes
DUPL;Duplicate	The same object was marked in two different frames	Yes
ERRO;error		Yes
FIGE;fishing gear		Yes
FISH;Unidentified fish	All "Fish"	Yes
FISS;Unidentified fish school	All "Fish" schools	Yes
FIWH;Fin Whale		Yes
FKWH;False Killer Whale		No
FLJE;flotsam and jetsam		Yes
FOTE;Forster's Tern		No
FUMG;Fulmar or Medium Gull	Included BLKI,LAGU,NOFU,RBGU,SAGU	Yes
GBBG;Great Black-backed Gull		Yes
GBHE;Great Blue Heron		Yes
GBWH;Gervais' Beaked Whale		No
GLGU;Glaucous Gull		No
GMRA;Giant Manta Ray		Yes
GRBC;Great Shearwater or Black-capped Petrel (flying)	Included BCPE,GRSH	Yes
GRCO;Great Cormorant		No
GRCS;Great or Cory's Shearwater (on water)	Included COSH,GRSH	No
GRSE;Gray Seal		No
GRSH;Greater Shearwater		Yes
GRSK;Great Skua		No
GRTU;Green Turtle		Yes
GSGO;Greater Snow Goose		Yes
HAPO;Harbor Porpoise		Yes
HASE;Harbor Seal		No
HASH;Hammerhead shark		Yes
HATU;Hawksbill Turtle		Yes
HELI;Helicopter		No
HERG;Herring Gull		Yes
HOGR;Horned Grebe		Yes
HOSE;Hooded Seal		No
HUWH;Humpback Whale		Yes
ICGU;Iceland Gull		No
ID Impossible;ID Impossible	Biotic object lacked enough detail to place in a broad taxonomic grouping	Yes
JASK;Jaeger or Skua	Included GRSK,LTJA,PAJA,POJA,SPSK	No

ID Category	Explanation or Species Included	Occurred in Project?
KIWH;Killer Whale		No
KRST;Kemp's Ridley Sea Turtle		Yes
LABA;balloon--Latex		Yes
LAGU;Laughing Gull		Yes
LASH;Large Shorebird sp.		Yes
LBBG;Lesser Black-backed Gull		Yes
LESP;Leach's Storm-petrel		No
LETE;Least Tern		No
LETU;Leatherback Turtle		Yes
LFPW;Long-finned Pilot Whale		No
LIGU;Little Gull		No
LOTU;Loggerhead Turtle		Yes
LSSD;Long-snouted Spinner Dolphin		No
LTDU;Long-tailed Duck		Yes
LTJA;Long-tailed Jaeger		No
MACR;macroalgae		Yes
MARA;Unidentified Manta Ray		Yes
MASH;Manx Shearwater		Yes
MBCE;Medium beaked Cetacean 3-10 m	Medium sized cetaceans with beaks.	No
MIWH;Minke Whale		Yes
MNBC;Medium non beaked Cetacean 3-10 m	Medium sized Cetaceans with small or no beaks.	No
MOLA;Ocean Sunfish (Mola)		Yes
MYBA;balloon--Mylar		Yes
NA;Not Applicable	Used for the first and last frame of the reel, and any other descriptive tags (e.g., start and end of clouds).	Yes
NABW;North Atlantic Bottle-nosed whale		No
NOFU;Northern Fulmar		Yes
NOGA;Northern Gannet		Yes
Nothing;Nothing	Used for objects that were waves or bird feces	Yes
OSPR;Osprey		Yes
PAJA;Parasitic Jaeger		Yes
PEFA;Peregrine Falcon		No
PKWH;Pygmy Killer Whale		No
POJA;Pomarine Jaeger		Yes

ID Category	Explanation or Species Included	Occurred in Project?
PSDO;Pantropical Spotted Dolphin		No
RAZO;Razorbill		Yes
RBGU;Ring-billed Gull		Yes
RBME;Red-breasted Merganser		Yes
REBA;Red Bat		Yes
REPH;Red Phalarope		No
RIDO;Risso's dolphin		Yes
RIWH;Right Whale	North Atlantic Right Whale	Yes
RNGR;Red-necked Grebe		Yes
RNPH;Red-necked Phalarope		No
ROST;Roseate Tern		No
ROYT;Royal Tern		Yes
RSST;Roughtail or Southern Stingray		Yes
RTDO;Rough-toothed Dolphin		No
RTLO;Red-throated Loon		Yes
SAGU;Sabine's Gull		Yes
SATE;Sandwich Tern		Yes
SBCE;Small beaked Cetacean to 3 m	Smaller sized cetaceans with beaks. Included ASDO,BODO,CLDO,CODO,LSSD,PSDO,RTDO,STDO	Yes
SBWH;Sowerby's Beaked Whale		No
SCHA;Scalloped Hammerhead		Yes
SEDO;Seal/Dolphin	True Seals and small cetaceans	Yes
SEWH;Sei Whale		No
SFWH;Short-finned Pilot Whale		No
SHAR;Unidentified shark	Members of Chondrichthyes	Yes
SMSH;Small Shorebird sp.	Included REPH,RNPH	Yes
SMTU;Small turtle	Included GRTU,HATU,KRST,LOTU	Yes
SNBC;Small non beaked Cetacean to 3 m	Smaller sized Cetaceans with small or no beaks	No
SNEG;Snowy Egret		Yes
SOSH;Sooty Shearwater		Yes
SOTE;Sooty Tern		No
SPDO;Spinner Dolphins	Either Clymene, Short-snouted dolphin or long-snouted dolphin	No
SPSK;South Polar Skua		No
SPWH;Sperm Whale		No

ID Category	Explanation or Species Included	Occurred in Project?
STDO;Striped Dolphin		No
SUSC;Surf Scoter		Yes
SWAL;Unidentified Swallow	Included BARS,CASW	Yes
TBMU;Thick-billed Murre		No
TBWH;True's Beaked Whale		No
THSH;Thresher Shark	Thresher Shark or Bigeye Thresher	Yes
TSMG;Tern/Small or Medium Gull	Included ARTE,BLKI,BLTE,BOGU,BRTE,CATE,COTE, FOTE, LAGU,LETE,LIGU,RBGU,ROST,ROYT,SAGU,SATE, SOTE	Yes
UNAL;Unidentified Alcid	Included ATPU,BLGU,COMU,DOVE,RAZO,TBMU	Yes
UNBI;Unidentified Bird	Included all bird species	Yes
UNBW;Unidentified Baleen Whale	Members of Suborder Mysticeti	No
UNCE;Unidentified Cetacean	All whales and dolphins	Yes
UNCO;Unidentified Cormorant	Included DCCO,GRCO	No
UNDO;Unidentified Dolphin	Members of Family Delphinidae	Yes
UNDT;Dark Tern	Included BRTE,SOTE	No
UNDU;Unidentified Duck	Included BLSC,BUFF,COME,LTDU,RBME,SUSC,UNME, UNSC,WWSC	Yes
UNFS;Unidentified Fin/Sei	Fin or Sei Whale	Yes
UNGR;Unidentified Grebe	Included HOGR,RNGR	Yes
UNGU;Unidentified Gull	Included BLKI,BOGU,GBBG,GLGU,HERG,ICGU,LBBG, LAGU,LIGU,RBGU,SAGU	Yes
UNJA;Unidentified Jaeger	Included LTJA,PAJA,POJA	Yes
UNJE;Unidentified jellyfish	Members of Cnidaria	Yes
UNKN;unknown	Biotic or Abiotic objects	Yes
UNLA;Unidentified large alcid (Razorbill or Murre)	Included COMU,RAZO,TBMU	Yes
UNLG;Unidentified Large Gull	Included GBBG,GLGU,HERG,ICGU,LBBG,SAGU	Yes
UNLO;Unidentified Loon	Included COLO,RTLO	Yes
UNLT;Unidentified large Tern	Included CATE,ROYT	Yes
UNLW;Unidentified large whale	Large Cetacean > 10m	No
UNME;Unidentified Merganser	Included COME,RBME	No
UNMG;Medium Gull: 38-53 cm	Included BLKI,LAGU,RBGU,SAGU	Yes
UNMT;Medium Tern: 32-45 cm	Included ARTE,BRTE,COTE,FOTE,ROST,SATE,SOTE	Yes

ID Category	Explanation or Species Included	Occurred in Project?
UNMW;Unidentified Medium Whale	Medium-sized Cetacea. Included species BBWH,CBWH,FKWH,GBWH,KIWH,LFPW,MIWH,NABW,SFWH,SBWH,TBWH	Yes
UNPA;Unidentified Passerine		Yes
UNPH;Unidentified Phalarope	Included REPH,RNPH	Yes
UNRA;Unidentified ray	Included members of superorder Batoidea	Yes
UNRO;Unidentified Rorqual	Members of Family Balaenopteridae	No
UNRS;Unidentified ray school	School of unidentified rays were marked (instead of individual animals within the schools) in situations where individuals were too small, deeply submerged, or otherwise poorly visible to be able to reliably distinguish individuals.	Yes
UNSA;Unidentified small alcid (Puffin/Dovekie)	Included ATPU,BLGU,DOVE	Yes
UNSC;Unidentified Scoter	Included BLSC,SUSC,WWSC	Yes
UNSG;Unidentified small gull	Included BOGU,LIGU,SAGU	Yes
UNSH;Unidentified Shearwater	Included AUSH,COSH,GRSH,MASH,SOSH	Yes
UNSK;Unidentified Skua	Included GRSK,SPSK	No
UNSP;Unidentified Storm-petrel	Included BRSP,LESP,WFSP,WISP	Yes
UNST;Unidentified small Tern	Included BLTE,LETE	Yes
UNSW;Unidentified small whale	Small-sized Cetacea	No
UNTE;Unidentified Tern	Included ARTE,BLTE,BRTE,CATE,COTE,FOTE, LETE, ROST,ROYT,SATE,SOTE	Yes
UNTW;Unidentified Toothed Whales	Odontoceti	Yes
UTSE;Unidentified True Seal	Members of Family Phocidae	No
WFSP;White-faced Storm-Petrel		No
WHSH;Whale Shark		No
WISP;Wilson's Storm-Petrel		Yes
WSDO;Atlantic White-sided Dolphin		No
WTTR;White-tailed Tropicbird		No
WWSC;White-winged Scoter		Yes

Appendix 4E. Excerpt from the "Confidence and Identification Criteria" document

Examples of criteria used for identifying avian and non-avian biotic targets at different confidence and taxonomic levels. When an object did not meet the "Definite" criteria for a particular ID category, then it went to the next lower confidence level. When the object did not meet even the "Possible" level criteria, then it went to a higher taxonomic grouping (e.g., from "Possible Black Scoter" to "Definite Unidentified Scoter").

Table 4E-1. Excerpt from the Avian Confidence and Identification Criteria.

AVIAN				
ID Category	**Definite (Sitting)**	**Probable (Sitting)**	**Possible (Sitting)**	**Next Higher Taxonomic Group**
AKSH; Auk or Shearwater	To be determined as the need arose	Not used	Not used	UNBI; Unidentified Bird
DOVE; Dovekie	Dark bird < 21 cm (approximate sitting size[5]) with some white in front. Reddish bill was ruled out.	Dark bird < 21 cm (approximate sitting size) with some white in front. Bill was not seen.	To be determined	UNSA; Unidentified small alcid (Puffin/Dovekie)
NOGA; Northern Gannet	Adult: Large white, gannet-shaped bird with dark-tipped primaries and yellow to yellow-brown wash on head.	Adult: Bird was obscured due to position, orientation, or blurriness and the definite features were hard to discern.	Adult: General size and shape were present and buoy was ruled out.	UNBI; Unidentified Bird or UNKN;unknown
SUSC; Surf Scoter	Observed white patches on head. Observed yellow orange to red bill pixel. Shape, size, and color was like a scoter. Female was in close proximity to a definite male.	Shape, size, and color was like a scoter. Female or undetermined sex was in close proximity to a definite male or in all SUSC flock. Inconclusive bill color.	Shape, size, and color. Not enough frames to determine sex and species, but was in a SUSC flock.	UNSC; Unidentified Scoter
UNAL; Unidentified Alcid	An auk of indeterminate size with general auk shape, dark plumage, white on the sides and head, visible bill and face characteristics, but was unable to distinguish between species.	An auk of indeterminate size with general auk shape, dark plumage and white on the sides and head.	An auk of indeterminate size with general auk shape and color, but there were fewer frames or image obscurities that didn't allow for higher identification confidence.	AKSH; Auk or Shearwater or UNBI;Unidentified Bird

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[5] Sitting size was the measurement of a resting bird (not stretched out).

AVIAN				
ID Category	**Definite (Sitting)**	**Probable (Sitting)**	**Possible (Sitting)**	**Next Higher Taxonomic Group**
UNBI; Unidentified Bird	Object had shape, color, head, bill, and bird-like movement. Image quality or other factors didn't allow placement into a lower taxonomic grouping.	Shape, color, head, and bill with possible bird-like movement or posture.	Bird shape (body and head) and coloring.	ID Impossible;ID Impossible
UNSA; Unidentified small alcid (Puffin/Dovekie)	An auk between 15-30 cm (approximate sitting size) with general auk shape, had dark plumage, white on the sides and head, but no bill or face details to distinguish between species.	An auk between 15-30cm (approximate sitting size) with general auk shape and color, but there were fewer frames or image obscurities that didn't allow for higher identification confidence.	To be determined	UNAL; Unidentified Alcid
UNSC; Unidentified Scoter	Female or unknown sex in a mixed flock. Color and shape similar to scoters. No conclusive bill or head identifying features.	Single bird with color and shape similar to scoters. No conclusive bill identifying features.	To be determined	UNDU;Unidentified Duck or UNBI;Unidentified Bird

Table 4E-2. Non-Avian Confidence and Identification Criteria.

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
BAIT; bait ball	Small fish-shaped objects in a group with definite movement.	A more submerged or blurry bait ball.	Hard to determine definite movement. Speckling in the water was present but it was hard to determine if this was a bait ball. Reviewer most likely assessed whether this was a bait ball, ocean spray or debris in the water.	ID Impossible; ID Impossible
BASH; Basking Shark	Large, odd shaped shark with a pointed snout. When feeding, the shape of the gills extended out.	Large, odd shaped shark that was more submerged or seen in less frames.	Not used.	SHAR; Unidentified shark
BODO; Bottlenose Dolphin	No distinct color patterns and dolphin >300 cm.	Unsure if size >300, but was associating with a definite BODO.	Large(>300, unless it was a juvenile) cetacean that was submerged or blurry cetacean and was non-descript.	SBCE; Small beaked Cetacean to 3 m
CODO; Common Dolphin	Hourglass pattern on the side was clearly seen.	Can see hourglass pattern in a few frames. There was no identification by association with this species.	A submerged common dolphin with a probable CODO patterning on the side. Ruled out BODO and Striped Dolphin patterning. There was no identification by association with this species. Associated species without a hint of patterning was identified as a SBCE identification.	SBCE; Small beaked Cetacean to 3 m
COWR; Cownose Ray	Cownose was visible and therefore direction of movement was known. This was a single ray or part of a group.	An individual that was not identified to species, but was associating with a school member that was a definite cownose ray.	A deep or blurry individual that was associating with a cownose ray.	UNRA; Unidentified Ray
FIWH; Fin Whale	Slender whale with white under the lower right jaw.	Not used	Not used	UNFS; Unidentified Fin/Sei

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
GMRA; Giant Manta Ray	Dark ray with a disc width >122 cm.	Dark ray with a disc width >122 cm. Reviewer unfamiliarity with this species often caused a lower confidence.	Not used	MARA; Unidentified Manta Ray
GRTU; Green Turtle	Head width was consistently small through frames. SCL>90cm. Carapace shape was elliptical.	SCL >90 cm, head width smaller (up to 15 cm) and not broad	>90 cm, head width not consistent or unclear across some frames	SMTU; Small turtle
HAPO; Harbor Porpoise	Not used	Between 137-183 cm with no distinct markings and no beak. Also had a chunky appearance compared to other cetaceans.	The "no beak" appearance was seen in fewer frames. Since it was harder to definitively determine that a cetacean was non-beaked, reviewers more likely used the broader category, Unidentified Toothed Whale.	SNBC; Small non beaked Cetacean to 3 m
HASH; Hammerhead shark	Shark with a distinct hammer-shaped head was consistent across frames	Submerged or blurry shark with a hammer-shaped head.	Deeply submerged shark with a hint of a hammer-shaped head.	SHAR; Unidentified shark
HATU; Hawksbill Turtle	Overlapping scutes, color was like a Hawksbill. SCL>65 and <90 cm, head width smaller and not broad, jagged edges of scutes.	SCL>65 and <90 cm, head width smaller and not broad, jagged edges of scutes.	SCL>65 and <90 cm, head width smaller and not broad. Large tail indicating a mature male was present.	SMTU; Small turtle
HUWH; Humpback Whale	Stocky body with relatively long white pectoral fins.	Not used	Not used	UNBW; Unidentified Baleen Whale
ID Impossible; ID Impossible	Biotic object that was not able to be placed into a species grouping.	ID Impossible Probable was used in the first month of data, but then was not used after that. This should be the same as ID Impossible Definite.	Not used	UNKN; unknown
KRST; Kemp's Ridley Sea Turtle	>56 cm, round shell (width is almost equal to length), broad head compared to SCL (up to 13cm head width),	Carapace looked round, but measurements indicated a more elliptical shape.	Turtle was more submerged or in fewer frames, but shape and size was still observed.	SMTU; Small turtle

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
LETU; Leatherback Turtle	A turtle with a broad upper body with relatively long front flippers.	A more submerged individual or an individual in fewer frames. Dark coloring and overall shape was still present.	Large, dark-colored object that was mostly leatherback-shaped. Ruled out Molas and manta rays. Leatherback turtles that were not identified to Possible were likely identified as ID Impossible when there was movement and UNKN (Unknown) when there was no discernible movement.	ID Impossible; ID Impossible
LOTU; Loggerhead Turtle	SCL >90 cm, head width large (up to 28 cm) and broad, overall carapace was heart-shaped	SCL > 65 and <90, head was broad	Loggerhead features (broad head, carapace shape and etc.) were in fewer frames. Other species of sea turtles can be ruled out.	SMTU; Small turtle
MARA; Unidentified Manta Ray	Not used	A dark ray that was too submerged to get an accurate size. Overall shape and color of a Mylobatidae spp. Reviewer unfamiliarity with this grouping resulted in a lower confidence.	Not used	CESS; Cetacean/Seal/Shark
MIWH; Minke Whale	Not used.	Slender, comparatively small whale with a pointed rostrum. Saw white band on flippers.	A more submerged cetacean with the shape and size of a Minke Whale.	UNRO; Unidentified Rorqual

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
MOLA; Ocean Sunfish (Mola)	Large, irregular shaped fish with fins near the posterior end. A definite MOLA was consistently and definitively was a MOLA in almost all frames.	MOLA that was angled a bit in the water column where it was hard to see the shape. A probable MOLA was more submerged or blurry in some of the frames.	Either deeply submerged or seen in fewer frames. Ruled out small turtle and rays. Due to the irregular shape, MOLA not identified to the Possible confidence went to a broader category such as ID Impossible. When fins were not seen and there was no discernible movement, it was possible for a MOLA to go to the UNKN (Unknown) identification category.	FISH; Unidentified fish
REBA; Red Bat	Tone or color was reddish or rusty brown. Body shape was oblong to oval, which gave it a chunky appearance. Wing coloration was grayish, white or blurry. Wing was angled proximally to the body giving it a triangular appearance. All aforementioned characteristics were consistent across frames or an arm was seen.	Tail shape is wedged or "V" shaped like a bat and there was a triangular appearance to the wings. Red color was present.	To distinguish from an UNBI or ID Impossible, tail shape was wedged or "V" shaped like a bat and there was a triangular appearance to the wings.	ID Impossible; ID Impossible

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
RIDO; Risso's dolphin	Not used	Not used	Used only once, the reviewer cited that the cetacean was at least 387cm with a comparatively large back fin, and light-colored belly and side. When a cetacean was approximately 300 cm, then this was generally classified to the broader group, SBCE (Small beaked Cetacean to 3m).When the cetacean was >300cm, then this went to the broader group, UNDO(Unidentified Dolphin).	SBCE; Small beaked Cetacean to 3 m
RIWH; Right Whale	A robust whale with callosities on the rostrum.	Not used	Not used	UNBW; Unidentified Baleen Whale
RSST; Roughtail or Southern Stingray	Ruled out skate by size (disc width>107 cm) and shape (pointed wings). Disc width overlapped between species. There were not enough features present such as tail length to identify the stingray to species.	Not used	Not used	UNRA; Unidentified Ray
SBCE; Small beaked Cetacean to 3 m	Beak present. Cetacean was less than 3m.	Unknown if beak was present or unknown size, but was associating with a definite SBCE.	Beak not seen consistently across frames or single animal was deeply submerged.	UNDO; Unidentified Dolphin
SCHA; Scalloped Hammerhead	Not used	Hammerhead shark with a central notch on the head as well as smaller notches on either side of the central notch giving it a "scalloped" appearance.	"Scalloped" appearance was harder to ascertain due to submergence, blurriness or number of frames.	HASH; Hammerhead shark

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
SHAR; Unidentified shark	Caudal fin was vertical and animal was greater than 198 cm. Or, if a smaller animal, there was consistent sinusoidal movement.	Shark was more submerged but size, shape or movement was shark-like.	Shark shape, size or movement was seen in fewer frames.	CESS; Cetacean/ Seal/Shark
SMTU; Small turtle	SCL>65 and <90 cm, head width smaller and not broad, lack of jagged edges. Or, definitely turtle-shaped (carapace shape with at least two alternate flippers or head was seen with the carapace shape), but other criteria were not met in order to classify to species. Or, SCL <50 cm, then immature SMTU. Mola and ray were ruled out.	Turtle shape was not consistently seen in all frames, but in most frames. Mola and ray were ruled out.	Mola and ray were ruled out. There was often turtle-like movement. If it was a juvenile turtle, macroalgae was ruled out.	ID Impossible; ID Impossible
SNBC; Small non beaked Cetacean to 3 m	Not used	Not used	Not used	UNTW; Unidentified Toothed Whales
THSH; Thresher Shark	Elongated upper caudal fin lobe that appeared almost longer than the entire body was consistently seen across many frames.	Shark was more submerged and caudal fin was not seen consistently across frames.	Elongated upper caudal fin lobe was seen in fewer frames, was more submerged or blurry.	SHAR; Unidentified shark
UNBW; Unidentified Baleen Whale	Not used	Not used	Not used	UNLW; Unidentified large whale or UNMW; Unidentified Medium Whale
UNCE; Unidentified Cetacean	Cetacean tail. Unknown size or beak status.	A blurry or more submerged cetacean that was associating with a known cetacean.	Not used	SEDO; Seal/Dolphin or CESS; Cetacean/Seal/Shark
UNDO; Unidentified Dolphin	Unknown if a beak was present. Harbor Porpoise was ruled out.	Was associating with a definite UNDO.	Blurry or submerged cetacean that was associating with a group of unidentified dolphins.	UNTW; Unidentified Toothed Whales

NON-AVIAN				
ID Category	**Definite**	**Probable**	**Possible**	**Next Higher Taxonomic Group**
UNFS; Unidentified Fin/Sei	Sizes overlapped between Fin and Sei Whale. Rostrum and tail obscured. Overall slender whale.	Not used	Not used	UNRO; Unidentified Rorqual
UNKN; unknown	Shape was similar to flotsam/jetsam and animal.	NA	NA	NA
UNRA; Unidentified Ray	Single or group of ray-shaped objects where the nose shape or direction of movement was unknown.	A blurry or obscured individual with a ray shape or movement that was associating with definite rays.	A single ray or small group that consistently had a ray shape or ray movement. Turtle, Mola and trash were ruled out.	CESS; Cetacean/Seal/Shark
UNRO; Unidentified Rorqual	Not used	Not used	Not used	MNBC; Medium non beaked Cetacean 3-10 m or UNBW; Unidentified Baleen Whale
UNTW; Unidentified Toothed Whales	Unknown if a beak was present. Unknown size. Harbor Porpoise was ruled out.	A blurry or more submerged toothed whale with unknown size or beak, but was small enough to be a Harbor Porpoise.	Not used	UNSW; Unidentified small whale

Appendix 4F. Hierarchical Matrix of Target Taxonomic Groups

Prior to the start of video analysis, a list of anticipated biota was compiled from past boat surveys and bird and mammal surveys conducted in the project area. Groupings were either developed based on anticipated similarity in video or from boat survey codes and experience. Other codes were added as they were discovered (e.g AMBI;American Bittern and BEKI;Belted Kingfisher). This table guided the "Confidence and Identification Criteria" and development of audit rules. Starting with the ID Category, it shows how the animal or animal group moves from a lower taxonomic group (Group 1) to a higher taxonomic group (Group 6 or 8), depending on the quality of the image, certainty criteria, and other factors.

Group 1 consisted of mixed species from the same genera. It had a lesser amount of species associated with the grouping than Group 2 and in general, the grouping contained <4 associated species. It was also the lowest taxonomic grouping. Group 2 consisted of mixed species and mixed genus groupings. This group contained a size or color designation that further split the family down into fewer species' associations. Group 3 consisted of mixed genus groupings. It had a lower number of associated species than Broad Group 4 and in general contained a subset to all members of the family. Group 4 consisted of mixed genus groupings. In addition, it had a high number of species associated with this group. This likely contained a subset to all members of the family. Group 5 consisted of mixed order and mixed family groupings. Group 6 was the highest taxonomic bird grouping. It consisted of all bird orders.

Table 4F-1. Excerpt from Hierarchal Matrix of Avian Taxonomic Groups. Birds not identified to Group 6 (Unidentified Bird) were either identified to ID Impossible if there was movement or UNKN;Unknown if there was no discernible movement.

AVIAN						
ID Category	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**
AKSH; Auk or Shearwater						UNBI
DOVE;Dovekie		UNSA	UNAL			UNBI
NOGA; Northern Gannet						UNBI
SUSC; Surf Scoter	UNSC			UNDU or UNBI		UNBI
UNAL; Unidentified Alcid					AKSH	UNBI
UNSA; Unidentified small alcid (Puffin/Dovekie)			UNAL		AKSH	UNBI
UNSC; Unidentified Scoter				UNDU or UNBI		UNBI

Table 4F-2. Hierarchal Matrix of Non-Avian Taxonomic Groups. Non-avian biota not identified to Group 8 (CESS;Cetacean/Seal/Shark) were either identified to ID Impossible if there was movement or UNKN;Unknown if there was no discernible movement. Group definitions: Group 1 consisted of mixed species and mixed genus groupings. Group 2 consisted of mixed genus groupings. Group 3 consisted of mixed genus and mixed family groupings. It had a lower number of associated species than Broad Group 4 and in general contained a subset to all members of the family. Group 4 consisted of sub-order groupings. Group 5 consisted of mixed sub-order groupings based on size class. Group 6 consisted of order groupings. Group 7 consisted of mixed order and some mixed class groupings. Group 8 consisted of mixed classes and contained the most number of species.

NON-AVIAN								
ID Category	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**
BAIT;bait ball								
BASH;Basking Shark							SHAR or FISH	CESS
BODO;Bottlenose Dolphin		SBCE	UNDO	UNTW	UNSW	UNCE	SEDO	CESS
CESS;Cetacean/Seal/Shark								
CODO;Common Dolphin		SBCE	UNDO	UNTW	UNSW	UNCE	SEDO	CESS
COWR;Cownose Ray	UNRA							
FISH;Unidentified fish								CESS
FISS;Unidentified fish school								CESS
FIWH;Fin Whale	UNFS	UNRO		UNBW	UNLW	UNCE		CESS
GMRA;Giant Manta Ray	MARA							CESS
GRTU;Green Turtle	SMTU							
HAPO;Harbor Porpoise			SNBC	UNTW	UNSW	UNCE	SEDO	CESS
HASH;Hammerhead Shark							SHAR or FISH	CESS
HATU;Hawksbill Turtle	SMTU							
KRST;Kemp's Ridley Sea Turtle	SMTU							
LETU;Leatherback Turtle								
LOTU;Loggerhead Turtle	SMTU							
MARA;Unidentified Manta Ray								CESS
MIWH;Minke Whale		UNRO	MNBC	UNBW	UNMW or UNLW	UNCE		CESS
MNBC;Medium non beaked Cetacean 3-10 m	NOT USED IN THE AERIAL SURVEY							
MOLA;Ocean Sunfish (Mola)							FISH	CESS
REBA;Red Bat								
RIDO;Risso's Dolphin		SBCE	UNDO	UNTW	UNSW	UNCE	SEDO	CESS
RIWH;Right Whale				UNBW	UNLW	UNCE		CESS
RSST;Roughtail or Southern Stingray	UNRA							CESS

NON-AVIAN								
ID Category	**Group 1**	**Group 2**	**Group 3**	**Group 4**	**Group 5**	**Group 6**	**Group 7**	**Group 8**
SBCE;Small beaked Cetacean to 3 m			UNDO	UNTW	UNSW	UNCE	SEDO or CESS	CESS
SCHA;Scalloped Hammerhead	HASH						SHAR or FISH	CESS
SEDO;Seal/Dolphin								CESS
SHAR;Unidentified shark								CESS
SMTU;Small turtle								
SNBC;Small non beaked Cetacean to 3 m	NOT USED IN THE AERIAL SURVEY							
THSH;Thresher Shark							SHAR or FISH	CESS
UNBW;Unidentified Baleen Whale	NOT USED IN THE AERIAL SURVEY							
UNCE;Unidentified Cetacean							SEDO or CESS	CESS
UNDO;Unidentified Dolphin								CESS
UNFS;Unidentified Fin/Sei		UNRO		UNBW	UNLW	UNCE		CESS
UNJE;Unidentified jellyfish								
UNLW;Unidentified large whale	NOT USED IN THE AERIAL SURVEY							
UNMW;Unidentified Medium Whale						UNCE		CESS
UNRA;Unidentified ray								CESS
UNRO;Unidentified Rorqual	NOT USED IN THE AERIAL SURVEY							
UNRS;Unidentified ray school								CESS
UNSW;Unidentified small whale	NOT USED IN THE AERIAL SURVEY							
UNTW;Unidentified Toothed Whales								CESS

Appendix 4G. QA/QC checklist for reviewed data

Table 4G-1. QA/QC checklist for reviewed data – updated as of September 16, 2013. Upon completion of data, the following items were checked:

Missed objects were highlighted in yellow.
Missed objects had a frame number in the "Added Frame Number" column
All confidences were filled out.
Birds and bats were associated with appropriate behavior (flying, sitting, taking off, loafing, following vessel)
All objects in flight or taking off had a yes or no filled in the "Flying at sea level" field.
Birds did not have the submerged field filled out.
Non-avian biota were associated with appropriate behavior (stationary, moving, haul out)
All seals, sharks, turtles, cetaceans, and fish had the "Submerged" field filled out.
Made sure there were behaviors filled out for all animals.
Objects identified as Not Applicable, ID Impossible, UNKN, boats, balloons, FIGE, FLJE, MACR and buoys did not have behavior, flying at sea level, submerged, age, plumage, molt or sex filled out. Behaviors associated with UNKN, boats and ID Impossible were put in comments.
ID Impossible had a comment.
Made sure dates and initials were filled out for all lines in the spreadsheet.
In the "Category" column, all reel characterizations or bad condition comments such as Start of reel, end of reel, reached here, resumed here and end of cloud were classified as "NA; Not Applicable" in the "ID Category" column.
Made sure age and plumage match each other if both have been filled out.
Performed a quick check in comments for misspellings.
Checked for formatting in ID Category (lowercase vs uppercase).

Appendix 4H. Excerpt of allowed audit answers for a particular ID Category.

Table 4 H-1. Excerpt of allowed audit answers for a particular ID Category. Some ID categories such as "UNRA**;** Unidentified Ray" were not "Fully Defined" in the event that other species of rays were discovered during the project.

ID Category	Allowed Audit Answers	Audit Answer Status
AKSH; Auk or Shearwater	AKSH,UNAL,UNBI,UNSH,UNLA,DBSH	Fully defined
BODO;Bottlenose Dolphin	BODO,SBCE	Fully defined
COWR; Cownose Ray	COWR,UNRA	Fully defined
DOVE;Dovekie	DOVE,UNSA,UNAL	Fully defined
LOTU; Loggerhead Turtle	LOTU,SMTU	Fully defined
NOGA; Northern Gannet	NOGA	Single Defined-No similar spp
REBA;Red Bat	REBA	Single Defined-No similar spp
SBCE;Small beaked Cetacean to 3 m	BODO,CODO,SBCE,UNDO	Partial Defined-More Information needed
SMTU; Small turtle	GRTU,HATU,KRST,LOTU,SMTU	Fully defined
SUSC; Surf Scoter	SUSC,UNSC	Fully defined
UNAL; Unidentified Alcid	AKSH,ATPU,BLGU,COMU,DOVE,RAZO,TBMU,UNAL,UNBI,UNLA,UNSA	Fully defined
Unidentified Bird	AKSH,DBSH,FUMG,GRBC,GRCS,JASK,LASH,SMSH,TSMG,UNAL,UNCO,UNDU,UNDT,UNGR,UNGU,UNJA,UNLA,UNLG,UNLO,UNLT,UNME,UNMG,UNMT,UNPH,UNSA,UNSC,UNSG,UNSH,UNSK,UNSP,UNST,UNTE,UNBI	Fully defined
UNDO; Unidentified Dolphin	SBCE,UNDO,UNTW	Partial Defined-More Information needed
UNMT;Medium Tern: 32-45 cm	ARTE,BLTE,BRTE,CATE,COTE,FOTE,LETE,ROST,ROYT,SATE,SOTE,TSMG,UNDT,UNLT,UNMT,UNST,UNTE	
UNRA; Unidentified Ray	COWR,MARA,RSST,UNRA,UNRS	Partial Defined-More Information needed
UNSA; Unidentified small alcid (Puffin/Dovekie)	ATPU,BLGU,DOVE,UNAL,UNSA	Fully defined
UNSC; Unidentified Scoter	WWSC,BLSC,SUSC,UNDU,UNBI,UNSC	Fully defined
UNTW; Unidentified Toothed Whales	UNDO,UNTW	Partial Defined-More Information needed

Chapter 5: Summary of digital video aerial survey data

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

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Chapter 5 Highlights

Results from high resolution digital video aerial survey data collected in the Maryland study area and the Mid-Atlantic Baseline Studies (MABS) study area.

Context[1]

High resolution digital video aerial surveys are a recently developed method to collect animal distribution and abundance data, and our study was the first to use this method on a broad scale in the U.S. Chapters 3 and 4 focus on the methods used to collect the digital video aerial survey data. Chapter 5 reviews the results of these surveys for the Maryland study area and the MABS study area, including data on observed counts and species identification rates for birds, marine mammals, sea turtles, and other wildlife. Flight heights for flying animals were also estimated from the video footage, allowing for analysis of animal altitude in relation to potential wind turbine heights.

Building off of this summary chapter, Chapter 10 examines the differences between the boat-based and digital video aerial survey datasets, with a focus on the Maryland study area. Subsequent chapters in Part IV of this report (Chapters 11-14) focus on integrating the two survey methods to better understand the distribution and abundance of wildlife in the Mid-Atlantic United States.

Study goal/objectives addressed in this chapter

Summarize animal distribution and abundance data that were collected using a novel survey method in the Maryland and MABS study areas.

Highlights for the Maryland study area

- Over 25,000 animals were observed in the fifteen surveys of the Maryland study area, less than expected given the percent of the MABS area covered offshore of Maryland.
- Over 7,000 birds and 18,000 non-avian animals were observed (including cetaceans, sea turtles, rays, sharks, and fish).
- The most abundant animals observed in aerial video were rays (Batoidea), making up 61% of the study data. The most commonly observed birds were Gulls and Terns (Laridae, 5% of the data).
- Scoters, loons, and Northern Gannets were also observed in large numbers.
- Notable animal sightings included many sea turtles and several species of baleen whales.
- Most of the animals with calculated flight heights were observed at altitudes below the predicted lower end of the rotor swept zone (~20 m).

Implications

Digital aerial surveys appear to have certain advantages for obtaining information on the distributions of animals within the marine environment, particularly for aquatic species such as sea turtles and rays. However, there are certain taxa that can more readily be identified than others using this technology.

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[1] For more detailed context for this chapter, please see the introduction to Part II of this report.

Abstract

High resolution digital video aerial surveys are a relatively novel method for collecting information on marine wildlife distributions and abundances, and this study is the first to use these methods on a broad scale in the United States. Our study focused on collecting marine bird, mammal, and turtle data within the Maryland study area as well as the broader Mid-Atlantic Baseline Studies project area, though we also documented the movements of rays and sharks, noted large schools of forage fish, and captured the migration of terrestrial species in the marine environment. We observed over 25,000 animals within the study area, including over 7,000 birds and 18,000 non-avian animals. The most abundant birds observed were gulls and terns (Laridae), and were primarily Bonaparte's Gulls (*Choicocephalus philadelphia*) seen in the winter. The most abundant animals overall were rays, making up 61% of the data; the Cownose Ray (*Rhinoptera bonasus*) was the most abundant species, which was primarily observed in the study area in the spring through early fall. Other abundant species included scoters, especially Black Scoters (*Melanitta americana*), Common Loons (*Gavia immer*), and Northern Gannets (*Morus bassanus*); less abundant but notable animals include several species of sea turtles and baleen whales, as well as diurnal migrations of Eastern Red Bats (*Lasiurus borealis*) through the offshore study area in the fall. Rates of identification to species in video aerial surveys varied widely based on the quality of the footage, as well as the taxonomic group in question. Identification rates of small alcids were low, while scoters were more easily identifiable. Flight heights were estimable for 80% of flying animals, and showed that 56% of these animals were flying below the likely rotor swept zone for current offshore wind turbines (<20 meters). More detailed analyses of these data can be found in Part IV of this report.

Introduction

The Mid-Atlantic region is an important area for a broad range of marine wildlife species throughout the year. Some breed in the area, such as coastal birds and sea turtles, while others visit from the southern hemisphere in their non-breeding season, such as shearwaters. In the fall, many summer residents migrate south to breed or winter in warmer climes, and they are replaced by species that have travelled south from their northern breeding grounds to winter in the Mid-Atlantic. Additionally, many pelagic, coastal, and terrestrial species make annual migrations up and down the eastern seaboard and travel directly through the region in spring and fall. Thus, many species use or funnel through the Mid-Atlantic region each year, resulting in a complex ecosystem where the community composition is constantly shifting, and the temporal and geographic patterns are highly variable

In our study, we aimed to produce baseline data to inform siting and permitting processes for offshore wind energy development in the Mid-Atlantic. We collected information on bird, sea turtle, and marine mammal abundances and movements over a two-year period (2012-2014) using a variety of technologies and methods to examine spatial patterns and trends. One of these methods included the first application of a new technology in the United States, high resolution digital video aerial surveys (hereafter, digital video aerial surveys). Digital video aerial surveys are a relatively new method for collecting distribution and abundance data on animals in the marine ecosystem (Thaxter and Burton, 2009). Although digital video aerial surveys have become common practice for offshore wind energy planning and monitoring in Europe, this Department of Energy (DOE)-funded Mid-Atlantic Baseline

Studies Project (MABS) and state-funded Maryland Project are the first projects to use these methods on a large scale in the United States. We also conducted boat surveys for wildlife within the study area on the continental shelf, to accompany and compare with the data from the digital video aerial surveys. For details on boat survey approaches, and for comparisons between boat and aerial data, see Parts III and IV of this report, respectively. Here, we examine the digital video aerial survey results in detail, including discussion of observation rates, species identification rates, and flight height estimates for flying animals.

The broader MABS study area encompasses the coastal area from Delaware to Virginia, extending from 3 nautical miles from the coastline (the boundary between state and federal waters) out to the 30 m isobath or the eastern extent of the Wind Energy Areas (WEAs). The Maryland Project extended the original Department of Energy-funded aerial and boat survey transects west and south to include more of Maryland's state waters (Figure 5-1). The "Maryland study area," as referenced throughout this report, includes all transect lines that fall within the extended state boundaries for Maryland, including those funded by the DOE (Figure 5-1).

We discuss the results for the Cownose Ray (*Rhinoptera bonasus*) in particular detail to highlight the utility of offshore digital video aerial surveys for aquatic taxa. This species is found along the coast of the western Atlantic Ocean from the northeastern U.S. to Brazil, and migrates seasonally, likely prompted by changes in water temperatures (Goodman et al., 2011). There are limited studies on Cownose Ray migration, but the Mid-Atlantic may be an important area for migrating rays (Blaylock, 1993; Goodman et al., 2011). Their movements are of interest to fisheries regulators as they are commonly thought to depredate bivalve aquaculture beds (Myers et al., 2007), though little evidence of this has been documented (Fisher, 2010). An unregulated Cownose Ray fishery exists in Virginia (the only targeted ray fishery in the northwest Atlantic), and there are also high bycatch and discard rates of rays within other fisheries; population declines are predicted as a result (Barker, 2006; Goodwin, 2012). They are listed by the IUCN as "Near Threatened" globally largely due to heavy and unregulated fishing pressure in Central and South America (Barker, 2006). Aerial surveys have been used to study the species in the Chesapeake Bay (Blaylock, 1993; Goodman et al., 2011), but rarely cover migration in the open ocean, and this is the first example of digital video aerial surveys being used to monitor their distributions and relative abundance.

Methods

Between March 2012 and May 2014, HiDef Aerial Surveying, Ltd. conducted fifteen large-scale surveys using super high-definition video on an aerial platform (Figure 5-1). For fourteen surveys, transects were flown at high densities within the federally-designated WEAs off of Delaware, Maryland, and Virginia, while the remainder of the study area was surveyed on an efficient 'sawtooth' transect path to provide broad-scale context (Chapter 3). In the second year of surveys (March 2013-May 2014), additional high density transects were added to the west and south of the Maryland WEA (Figure 5-1 inset), and the fifteenth survey was conducted in just the Maryland WEA and adjacent high-density extension areas (Table 5-1). Both MABS and Maryland survey data are presented in this report. Early surveys included video footage at 2 cm Ground Spatial Resolution (GSR) for transects within the WEAs, and 3 cm GSR for the broader sawtooth survey; beginning in September 2012, all transects were surveyed at 2 cm GSR.

Final geoprocessing of the data was completed in January 2015. The project team identified wildlife locations, taxonomic identities, behaviors, and flight heights from the video footage. Detailed data collection, analysis, and data management protocols can be found in Chapters 3 and 4 of this report.

This chapter presents summaries of raw count data from the digital video aerial surveys on a monthly, seasonal, and annual basis with a focus on the Maryland study area. We also discuss identification rates for the most common species groups. We compared results for the Maryland study area to the findings within the larger MABS project area, and compare the actual and “expected” numbers observed within different animal groups. To calculate “expected” values, we took the number of animals observed in the combined MABS and Maryland study areas, and multiplied it by 32%, the percentage of the surveyed transect area (linear transect length multiplied by strip width) that was located within the Maryland study area. For these summaries, all identifications in the aerial data were taken at face value (e.g., an identified “possible Black Scoter [*Melanitta americana*]” was considered to be a Black Scoter, rather than an “Unidentified Scoter”; see Chapter 4 for additional information on certainty levels and identification criteria). Ray (Batoidea) densities were examined across the study area using counts of rays per Bureau of Ocean Energy Management (BOEM) 4.8 x 4.8 km lease block, corrected for survey effort within the lease blocks (km^2). All rays were included in the analysis, and the four survey periods with highest ray abundances were mapped using ArcGIS 10.1 (ESRI, Redlands, CA).

Flight heights were examined for different avian species groups to compare to the rotor-swept zone of offshore wind turbines. Flight heights were estimated using a proprietary estimation method, based on the principle of parallax, developed by HiDef Aerial Surveying, Ltd., which uses measurements of “parallax”, or the apparent motion of an elevated object against a distant background due to the movement of the observer (Hatch et al., 2013). Flight heights of flying animals could not be estimated when the animal was flying directly parallel to the plane, rendering calculations of displacement impossible, or the animal was present in an unusually small number of frames (Hatch et al., 2013). Flight heights were estimated in altitude bands (0-20, 20-50, 50-100, 100-200, and 200+ m).

Part IV of this report presents additional information comparing digital aerial and boat survey results, and integrating data from both survey types into in-depth analyses of wildlife distributions and relative abundance.

Results

A total of 15,698 km^2 were surveyed in the Maryland Study area, comprising approximately 32% of the entire MABS area (49,577 km^2). A total of 25,115 animals were observed in the fifteen surveys of the Maryland study area, less than expected given the percent of the MABS area covered within Maryland (35,008). Over 7,000 birds and 18,000 non-avian animals were observed (including cetaceans, sea turtles, rays, sharks, and fish; see Appendix 5A). At least 30 species of birds and 15 species of non-avian animals were represented. Overall, 43% of the animals observed in the study were identified to species level, close to the identification rate for the broader MABS data. The greatest numbers of animals were observed in July and September (Table 5-2). There were variations in data quality throughout the project, with low light in winter causing difficulty for identifications. It should be noted that data collected between the two years (as shown in Table 5-2 and Appendix 5A) are not entirely comparable across the duration of the study, as the study area was significantly expanded beginning in March of 2013. Additionally, the exact timing of surveys can have a huge effect on species counts, particularly during migration periods when large numbers of wintering birds could be moving in or out of the study area; a week's difference in survey dates could have a significant effect on observed overall abundance.

Quality assurance and quality control (QA/QC) protocols for analysis of the video data are presented in Chapter 4. An audit was not conducted for the first (March 2012) survey, as object identifications for those data were performed collectively among BRI biologists to develop a common identification process and pool their existing expertise. For all other surveys, object identifications were independently conducted by BRI biologists, and random audits (e.g., blind re-reviews of 20% of all objects, and 100% of object identified as state- or federally- listed threatened and endangered species) were conducted for all identifications. Early adjustments to the Ground Spatial Resolution (GSR) for surveys are discussed in Chapter 3; all Maryland Project surveys were conducted at 2 cm GSR. Audits for 2013-2014 surveys were conducted jointly for DOE-funded and Maryland-funded data from each survey period; agreement rates for the random audit varied from 87-98% between 2013-2014 surveys with DOE and Maryland funding (Connelly et al., 2015); when agreement was less than 90% (for random audit objects) or less than 100% (for threatened and endangered species) in a survey, then partial re-review of survey data and/or arbitration of disagreements among reviewers occurred (as described in detail in Chapter 4).

Relative abundance of counts

Birds

Gulls and terns were the most abundant avian species observed in the Maryland aerial surveys, making up 5.6% of the observations within Maryland, very close to the expected amount given the proportion of the MABS area included in Maryland (Figure 5-3). Gulls and terns were most commonly observed in the summer and fall surveys (Figure 5-7). Of those identified to the species level, Bonaparte's Gulls were the most common (*Choicocephalus Philadelphia*, 0.41%), and they were predominantly observed in winter. Great Black-backed Gulls (*Larus marinus*; 0.39%) were the next most abundant, and were seen throughout the year, mostly in the fall. Laughing Gulls (*L. atricilla*; 0.22%) were seen predominantly in the summer of 2013. The most abundant tern species seen was Black Tern (*Chlidonias niger*; 0.12%) followed by Caspian Tern (*Hydroprogne caspia*; 0.02%). There were an additional 4.2% of observations classified to higher taxonomic levels within the *Laridae* family (see Table 5-2 for details).

Scoters (*Melanitta* spp.) were the next most abundant avian group observed in the aerial surveys, making up 5.3% of MD observations, which is less than expected for the Maryland study area based on its size relative to the MABS area, and the numbers of scoters observed within the MABS area (Figure 5-3). Most were classified as *Melanitta* sp. (Black Scoter [*M. americana*], Surf Scoter [*M. perspicillata]*, or White-winged Scoter [*M. fusca*]), but could not be identified to the species level. Scoters were present in the winter and early spring (Figure 5-7). The most abundant species observed were the Black Scoter (1.49%) and Surf Scoter (0.53%).

Loons were the next most abundant avian family (5.05%), with most categorized as *Gaviidae* sp. (4.3%); this is also slightly fewer than would be expected based on the size of the Maryland study area (Figure 5-3), and most were observed in the winter (Figure 5-7). Identified loons were either Common Loons (0.56%) or Red-throated Loons (0.16%). Northern Gannets (*Morus bassanus*) made up 4.8% of the observations, fewer than expected (Figure 5-3). Alcids were observed at 0.31% of the Maryland study area data, and were mostly unidentified (0.25%). Of those identified, most were Dovekies (*Alle alle*; 0.03%).

Non-avian animals

Large numbers of animals were observed in aerial surveys at or below the surface of the water (Figure 5-4). There were major seasonal differences for aquatic animal abundance, most notably with very large numbers of rays observed in summer and fall surveys (Figure 5-8). Rays were the most common animal group observed in the Maryland study area (44%), and the number of rays observed very closely matched the expected quantity (Figure 5-5). Fish were the next most commonly observed non-avian animals; individually recognizable larger fish (>1 m in length) were counted as individual fish even if they were located within a school, and these are the only data presented in figures in this chapter. However, most fish observed in video footage were groups of small forage fish, or “bait balls,” of varying size, which were observed mostly between May and September, primarily inshore. The majority of bait balls within the entire MABS study area were seen on the September 2013 survey (4,142 schools of fish), and 7,514 schools were observed in all (61% were observed in the Maryland Project transects). Some schools were less than a m^2, while some extended across all four cameras and spanned many frames of footage (school size was not quantified during video analysis). Additional discussion of bait ball geographic patterns may be found in Chapter 11.

Dolphins were the most commonly observed marine mammals in the Maryland digital video aerial surveys (4.6% overall, Figure 5-4). Dolphins were seen throughout the study period, but Bottlenose Dolphins (*Tursiops truncatus*, the most commonly identified species; Appendix 5A) were most abundant in the spring and summer. Large cetaceans were also observed in Maryland surveys: one Humpback Whale (*Megaptera novaeangliae*) and one Minke Whale (*Balaenoptera acutorostrata)*, in February and May of 2014.

A notable number of sea turtles were observed (1.46% of observations), primarily in the spring, summer, and autumn. Most of the turtles were not identified to species (Figure 5-10). Loggerhead Turtles (*Caretta caretta*) and Leatherback Turtles (*Dermochelys coriacea*) were the two most commonly identified, with some observations of the rarer species (Kemp’s Ridley Turtle [*Lepidochelys kempii*], Green Turtle [*Chelonia mydas*], and Hawksbill Turtle [*Eretmochelys imbricate*]; Appendix 5A).

Identification rates

Identification rates varied by survey and season. June surveys had the highest rate of birds identified to species (55%), closely followed by October and December (54%); the lowest identification rates were in August and September (11% and 10%, respectively). Image quality, observer bias, and other factors, however, could also have varied through time and influenced identification rates.

Identification rates for Anatidae (geese, swans, and ducks) were strong relative to the rates for other avian groups (Figure 5-9), with 38% of anatids identified to species. This rate is lower than the identification rate for the broader MABS project area (53%, Figure 5-11). Gulls and terns were identified to species 24% of the time, less than the identification rate for the broader study area (35%, Figure 5-11). Only 14% of loons were identified, as the video footage was not always clear enough to distinguish the subtleties of winter plumage coloration between Red-throated Loons and Common Loons, and there is also a significant overlap in size between the two species in the Mid-Atlantic study area (Gray et al., 2014). This rate was the same between the Maryland and MABS areas (Figure 5-11). Small birds, like auks and terns, were seldom identified to species (Figure 5-9), but the rate was slightly higher in Maryland compared to the overall study area (11% MD, 6% MABS; Figure 5-11), often due to difficulty in picking out fine details in plumage variation.

Few individual fish were identified to species, as this taxon was not a focus of the current study, but video data will remain archived in case additional analysis of species identities or forage fish school sizes is warranted. Cownose Rays were the most commonly identified fish or shark species in this study (Figure 5-10). While most sea turtles were not identified to species (85%; Figure 5-10), all species observed in the area are federally endangered. Most non-Leatherback Turtles remained unidentifiable at the species level because of inconclusive carapace length measurements and/or insufficient detail visible on the carapace (often due to the animal being too deeply submerged in the water column to allow for detailed observation). Of all toothed whales (Odontoceti), 67% were not identified to species level, again in part due to animals being submerged to varying depths in the water column. These identification rates are similar to those observed in the broader MABS area.

Flight heights

Flight heights were estimated for 80% of flying animals (or 1,559 observations in the Maryland study area). Of all birds with estimable flight heights in the study area, 56% were estimated to be flying within 0-20 meters of the water's surface. Forty percent of observations occurred between 20 and 200 m in altitude (623 observations), a range that was used in one recent study to cover a variety of possible turbine types, foundations, and variations in tidal heights (Willmott et al., 2013). We observed nearly every avian taxonomic group flying within this zone, though the proportions of individuals in this latitude band varied by taxon. Within this range, 18% of birds were flying from 20-50 m, 14% were flying from 50-100 m, and 8% were flying from 100-200 m. An additional 8% of birds were flying above 200 m.

Of all the birds with estimated flight heights, the five most commonly observed avian families were all marine birds that forage in the study area and spend some time on the surface of the water, and were by far most commonly observed in the lowest 0-20 m altitude band (Figure 5-13).Gulls and terns were the most commonly observed species aloft, followed by Northern Gannets (Figure 5-12 and Figure 5-13). Gulls and terns were observed flying at the 20-50m flight band 19% of the time, 50-100m 15% of the time, and 100-200 m 6% of the time. Gannets had a similar distribution, and were observed flying at 20-50 m 17% of the time, 50-100 m 19% of the time, and 100-200 m 9% of the time. Scoters, ducks, and geese were generally observed flying lower, at 20-50 m 29% of the time, 50-100 m 2% of the time, and 100-200 m 1% of the time. Loons were also flying lower, in the 20-50 m altitude band 26% of the time, 50-100 m 0% of the time, and 100-200 m 3% of the time (for more details see Figure 5-13). Species groups that were less commonly observed in aerial surveys also had a more varied altitudinal distribution (Figure 5-14). While the majority of birds were observed flying below the rotor-swept zone, 40% of observations occurred between 20 and 200m in altitude (623 observations), and nearly every avian taxonomic group occurred within this zone. Gannets, gulls and terns, and loons all had high proportions of birds observed within this higher risk area (Figure 5-13). Flight height distributions were similar between the Maryland and MABS areas.

Fifteen Eastern Red Bats (*Lasiurus borealis*) were detected by observers in the September 2012 and 2013 MABS aerial surveys (Appendix 5A; Hatch et al. 2013). Fourteen of the bats were observed in one survey day in September of 2012, while an additional possible bat was seen on the September 2013 survey within the Maryland study area, and it was flying above 200 m. The bat observations were notable as they provided new evidence of offshore migrations of Eastern Red Bats, how high they fly while on migration, and the time of day that migrations may occur. Additional information may be found in Hatch et al. (2013).

Rays

Rays (Batoidea) represented over 61% of all observations from the Maryland aerial surveys (Table 5-2), a higher proportion than that found in the overall MABS area (44%). Cownose Rays were the most common ray species observed (47% of all rays, and almost 100% of all rays identified to species; Figure 5-10). Rays were not identified to species unless they were individually identifiable and their characteristic snouts were clearly visible, so many of the rays present in Cownose Ray schools (though they were not identifiable as Cownose Rays themselves) were likely also of the same species; the overwhelming majority of rays in video footage are thought to have been Cownose Rays. Some schools of rays were so densely packed and submerged that individuals could not be discerned, and these were identified as schools rather than as individuals (31 schools). These schools were primarily found in September (16 schools) when rays migrate through the study area (Goodman et al., 2011).

Rays were primarily observed during the summer and fall surveys (Figure 5-8), though there was a high level of variation between the two survey years: many more rays were observed in 2013 compared to 2012 (Table 5-2). The differences in observations between the two years, while partly attributable to the differences in survey coverage, may also reflect variation in water temperatures, timing of migration movements relative to our survey dates, or differences in migration behaviors. Rays additionally showed distinct monthly variation in abundance and distribution. Rays were distributed more broadly in the early summer surveys, June 2012 and July 2013 (Figure 5-15). More rays were seen in the July 2013 survey, and they were predominantly found further north along the coast of Virginia and Maryland compared to June 2012, when they were mostly found off the coast of Virginia and Chesapeake Bay. Rays in the September surveys were much more densely packed in pockets throughout the study area, but the 2013 survey had densities up to fifteen times those of the 2012 survey (Figure 5-15). High densities of rays were found in the Maryland Project study area during the September 2013 survey, a portion not surveyed in 2012, but other areas within the MABS study area showed high ray densities as well, particularly at the mouths of the Chesapeake Bay and Delaware Bay.

Discussion

Digital video aerial surveys and aquatic taxa

Digital aerial surveys have been noted to have less glare compared to visual aerial and boat surveys, and have an advantageous field of view for looking down on the water, both factors which increase visibility for aquatic animals such as sea turtles (Normandeau Associates, Inc. 2013), and we saw similar results in our study (Chapter 10). The high altitude of digital aerial survey aircraft also reduces disturbance compared to low-flying visual observation planes or survey vessels, which may play a role in increased detections (Normandeau Associates Inc. 2013). We discuss these differences in more detail in Chapter 10, where we directly compare the results of the two survey approaches.

We examine ray distributions and abundances in some detail in this chapter, as they were the most abundant animal in aerial surveys, and provided a good example of the use of digital video aerial surveys to monitor aquatic animals. Our study was the first to use digital video aerial surveys to monitor ray distributions and densities. Our findings not only illustrate the utility of the digital video aerial surveys for documenting the distributions of Cownose Rays, and aquatic animals in general, but add to the limited knowledge of Cownose Ray migratory movements in the Mid-Atlantic (Blaylock, 1993; Goodman et al., 2011). There is a continued risk of overfishing Cownose Rays, and a need to establish a baseline population assessment and develop an effective conservation and management plan (Goodwin, 2012). Additionally, rays could be affected by the formation of artificial reefs, as turbine foundations provide new habitats for benthic organisms, which could include species that they prey upon) (Andersson, 2011; Zucco et al., 2006). However, it is not clear whether Cownose Rays forage offshore during migration (e.g., in locations where turbines would be placed), so the potential for indirect effects to this taxon from such ecological changes is likewise unclear.

Many elasmobranchs are both magnetosensitive and electrosensitive, senses which are though tot be used to locate prey, predators, or conspecifics, as well as for navigation(Normandeau Associates Inc. et al., 2011). As a result, elasmobranchs can detect electromagnetic fields (EMF) produced by power transmission cables in the marine environment, including cables associated with offshore wind development (Gill et al., 2009; Normandeau Associates Inc. et al., 2011). It has been hypothesized that EMF could affect the navigation or foraging behaviors of these species, possibly causing disruption of migratory routes or influencing foraging patterns, although evidence of such effects is limited, and the results of the limited experimental studies on rays have been mixed (Boehlert and Gill, 2010; Gill, 2005; Gill et al., 2009). Experiments using EMF of similar types and intensities to those emitted by sub-sea cables showed some response by the EM-sensitive benthic Thornback Ray (*Raja clavata*), with some individuals showing increased searching effort for prey in the presence of EMF (presumably because the EMF were similar to those emitted by prey), but the response was not predictable (Gill et al., 2009). Cownose Rays do use electroreception to detect their prey, but their ability to detect and tendency to react to EMFs from sub-sea cables has not yet been determined (Boehlert and Gill, 2010; Smith and Merriner, 1985). In addition, the species could only be affected by EMF if they are at or near the ocean floor, within range of the fields (Boehlert and Gill, 2010). While the species is known to forage for mollusks on the seafloor in coastal bays during the summer breeding season (Smith and Merriner, 1985), it is unknown whether they behave similarly during migration, as we were only able to observe rays in the upper few meters of the water column.

Distribution and relative abundance patterns

Gulls and terns were the most abundant bird group observed in the aerial data in the Maryland study area, with scoters, ducks, and geese, gannets, and loons also observed in large numbers. This pattern was similar to that found in the broader MABS area, though scoters were the most abundant avian group in the MABS area, and most avian groups had fewer than the expected numbers of birds given the proportional spatial coverage of the Maryland study area compared to the MABS area. This pattern was also similar to that found in the boat-based surveys (Chapter 7), though much higher numbers of birds were found in the boat surveys (Chapter 10). Gulls and terns were the most abundant in the summer and fall, when several species were breeding onshore and foraging in the study area, though Bonaparte's Gulls were most abundant in the winter (Nisbet et al., 2013). Maryland and the Mid-Atlantic region are important wintering grounds for gannets, scoters, and loons (Barr et al., 2000; Bordage and Savard, 2011; Mowbray, 2002; Savard et al., 1998), and in this study, all three of these species groups were most commonly found in the study area in the winter and spring. Fewer aquatic animals were seen in the Maryland study area in the winter, but many fish were observed in spring, and rays were extremely abundant in the spring, summer, and fall. Toothed whales were observed in highest numbers in the spring; in general, Bottlenose Dolphins were present in the warmer months, and Common Dolphins (*Delphinus delphis*) more abundant in the cooler months (Chapter 12).

Other notable observations include many observations of sea turtles, including all five species present in the study area. There was also a sighting of an Eastern Red Bat in the Maryland study area, as well as over a dozen other red bat observations in the MABS study area in the fall, providing evidence for offshore migration in this species. Two large whales were seen migrating through the Maryland study area in cooler months. Some passerines were observed migrating through the study area as well, though they were not identified to species; more passerines were observed from the boat platform than in aerial video. Most passerines migrate at night, however, when surveys do not occur (Adams et al., 2015a, 2015b).

Flight heights and collision risk

Flight height data is often used alongside information on avoidance behaviors, turbine specifications, and other data in models that attempt to estimate avian collision risk for offshore wind energy projects in Europe (e.g., Band 2012), although there is still debate in the European literature regarding the factors that best predict this risk (e.g., Cook et al. 2012, Douglas et al. 2012, Langston 2013, Furness et al. 2013). Flight heights are suspected to vary in relation to weather and time of day, for example, so collision risk is likely to be highest at night, and in particular on nights with poor visibility (Dirksen et al., 2000; Hüppop et al., 2006). Our surveys were limited to daytime hours and periods of clear weather, when cameras had adequate visibility for observing and identifying animals (Chapter 3), which may limit the applicability of these flight height data for estimating collision risk.

In our study, we compared the estimated flight heights of birds and bats in relation to the potential rotor-swept zones (RSZ) of offshore wind turbines. The RSZ depends on the turbine type; for example, the RSZ for Siemens 3.6 MW offshore turbines is about 28-132 m, while the RSZ for Siemens 6 MW turbines is about 27-177 m, though specific altitudes will vary by site[2]. Larger turbines are also possible, and prototypes have already been deployed in some locations in Europe[3]. While the majority of birds were observed flying below 20 meters, and thus below the expected RSZ, 40% of observations occurred between 20 and 200 m in altitude (623 observations), and nearly every avian taxonomic group was observed within this zone at some point in our study. Gannets, gulls and terns, loons, and scoters, ducks, and geese all had high proportions of birds within this altitude range (Figure 5-13).

Species identifications

Identification rates for some animal groups were low in this study. In future, it is likely that many of the issues related to identification rates and lower-confidence observations that occurred in this study will be addressed through technical improvements to the camera systems, but analytical approaches can also help address this issue. The development and use of a metric for image quality, which could be applied to all video data, would be helpful for assessing identification rates relative to changing atmospheric conditions (Duron et al., 2015). Inter-observer and inter-survey bias in species identifications could also be examined using a double observer approach during video analysis. This approach would be relatively straightforward to incorporate into existing audit protocols for object location and species identification.

Early digital video aerial surveys were conducted at 2 cm GSR in some areas, and 3 cm GSR in others. Initial review of these video data indicated that, despite the high number of easily identifiable scoters in early surveys, the clarity of the 3 cm video was not sufficient to identify many taxa to species (Duron et al., 2015). The study design was adjusted beginning in September 2012 to conduct all survey flights at 2 cm GSR. While this reduced the sampled area for the sawtooth transects from roughly 3.2% of the study area to 2.1% (since a higher GSR necessitates a narrower transect strip), project collaborators felt it was necessary to improve video clarity and species identification rates. Newer generations of these camera systems, currently in operation in Europe, have a wider strip width and better clarity and color rendition, thus rendering this tradeoff largely unnecessary (A. Webb pers. comm.).

Other analyses of digital video aerial survey data

Chapters in Part IV of this report further analyze digital video aerial data, either separately or alongside boat survey data. Two chapters focus on contrasting boat and digital video aerial survey approaches (Chapters 10 and 13). In other cases, digital video aerial survey data and boat survey data are used jointly to describe distributions and abundance of animals across the study area (Chapters 11-12, 14).

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[2] http://www.energy.siemens.com/hq/en/renewable-energy/wind-power/platforms/

[3] http://www.windpowermonthly.com/10-biggest-turbines

Literature cited

Adams, E., Chilson, P., Williams, K., 2015a. 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.

Adams, E., Lambert, R., Connelly, E., Gilbert, A., Williams, K., 2015b. 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.

Andersson, M.H., 2011. Offshore wind farms-ecological effects of noise and habitat alteration on fish. Stockholm University.

Band, B., 2012. Using a Collision Risk Model to Assess Bird Collision Risks for Offshore Wind Farms. The Crown Estate Strategic Ornithological Support Services.

Barker, A.S., 2006. Rhinoptera bonasus [WWW Document]. IUCN Red List Threat. Species Version 2012.2. URL iucnredlist.org (accessed 4.11.13).

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.

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

Boehlert, G.W., Gill, A.B., 2010. Environmental and Ecological Effects of Ocean Renewable Energy Development: A Current Synthesis. Oceanography 23, 68–81.

Bordage, D., Savard, J.-P.L., 2011. Black Scoter (Melanitta americana), in: Poole, A. (Ed.), Birds of North America Online. Cornell Lab of Ornithology, Ithaca, New York.

Connelly, E., Duron, M., Williams, K., Stenhouse, I., 2015. Summary of high resolution digital video aerial survey data, 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.

Cook, A.S.C.P., Johnston, A., Wright, L.J., Burton, N.H.K., 2012. A Review of Flight Heights and Avoidance Rates of Birds in Relation to Offshore Wind Farms (No. BTO Research Report Number 618), Report prepared on behalf of The Crown Estate. British Trust for Ornithology.

Dirksen, S., Spaans, A.L., Winden, J. Van Der, 2000. Studies on Nocturnal Flight Paths and Altitudes of Waterbirds in Relation to Wind Turbines : A Review of Current Research in The Netherlands. San Diego, California.

Douglas, D.J.T., Follestad, A., Langston, R.H.W., Pearce-Higgins, J.W., 2012. Modelled sensitivity of avian collision rate at wind turbines varies with number of hours of flight activity input data. Ibis (Lond. 1859). 154, 858–861.

Duron, M., Gilbert, A., Williams, K., Stenhouse, I., 2015. Recommendations for high resolution digital video aerial surveys in the 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.

Fisher, R.A., 2010. Life history, trophic ecology, & prey handling by cownose ray, Rhinoptera bonasus, from Chesapeake Bay, Report to National Oceanic and Atmospheric Administration. Virginia Institute of Marine Science, Virginia Sea Grant, College of William and Mary, Gloucester Point, VA.

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

Gill, A.B., 2005. Offshore renewable energy: ecological implications of generating electricity in the coastal zone. J. Appl. Ecol. 42, 605–615. doi:10.1111/j.1365-2664.2005.01060.x

Gill, A.B., Huang, Y., Gloyne-Philips, I., Metcalfe, J., Quayle, V., Spencer, J., Wearmouth, V., 2009. COWRIE 2.0 Electromagnetic Fields (EMF) Phase 2: EMF-sensitive fish response to EM emissions from sub-sea electricity cables of the types used by the offshore renewable energy industry, Report commissioned by COWRIE Ltd. COWRIE Ltd.

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.

Goodwin, H.B., 2012. Skate and Ray Management in the Northwest Atlantic: An Overview of Current Management and Recommendations for Conservation. Dalhousie University, Halifax, NS.

Gray, C.E., Paruk, J.D., DeSorbo, C.R., Savoy, L.J., Yates, D.E., Chickering, M.D., Gray, R.B., Taylor, K.M., Long, D., Schoch, N., Hanson, W., Cooley, J., Evers, D.C., 2014. Body Mass in Common Loons (Gavia immer) Strongly Associated with Migration Distance. Waterbirds 37, 64–75. doi:10.1675/063.037.sp109

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

Hüppop, O., Dierschke, J., Exo, K.-M., Fredrich, E., Hill, R., 2006. Bird migration studies and potential collision risk with offshore wind turbines. Ibis (Lond. 1859). 148, 90–109. doi:10.1111/j.1474-919X.2006.00536.x

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

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.

Myers, R.A., Baum, J.K., Shepherd, T.D., Powers, S.P., Peterson, C.H., 2007. Cascading effects of the loss of apex predatory sharks from a coastal ocean. Science 315, 1846–1850. doi:10.1126/science.1138657

Nisbet, I.C.T., Veit, R.R., Auer, S.A., White, T.P., 2013. Marine Birds of the Eastern United States and the Bay of Fundy. Nuttall Ornithological Club, Cambridge, MA.

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., Exponent Inc., Tricas, T., Gill, A., 2011. Effects of EMFs from Undersea Power Cables on Elasmobranchs and Other Marine Species (No. OCS Study BOEMRE 2011-09), Report prepared under BOEMRE Contract M09PC00014. Bureau of Ocean Energy Management, Regulation and Enforcement, Camarillo, CA.

Savard, J.-P.L., Bordage, D., Reed, A., 1998. 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

Smith, J.W., Merriner, J. V, 1985. Food habits and feeding behavior of the cownose ray, *Rhinoptera bonasus*, in lower Chesapeake Bay. Estuaries 8, 305–310.

Thaxter, C.B., Burton, N.H.K., 2009. High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols, Report commissioned by COWRIE Ltd.

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.

Zucco, C., Wende, W., Merck, T., Köchling, I., Köppel, J., 2006. Ecological Research on Offshore Wind Farms: International Exchange of Experiences, Part B: Literature Review of Ecological Impacts.

Figures and tables

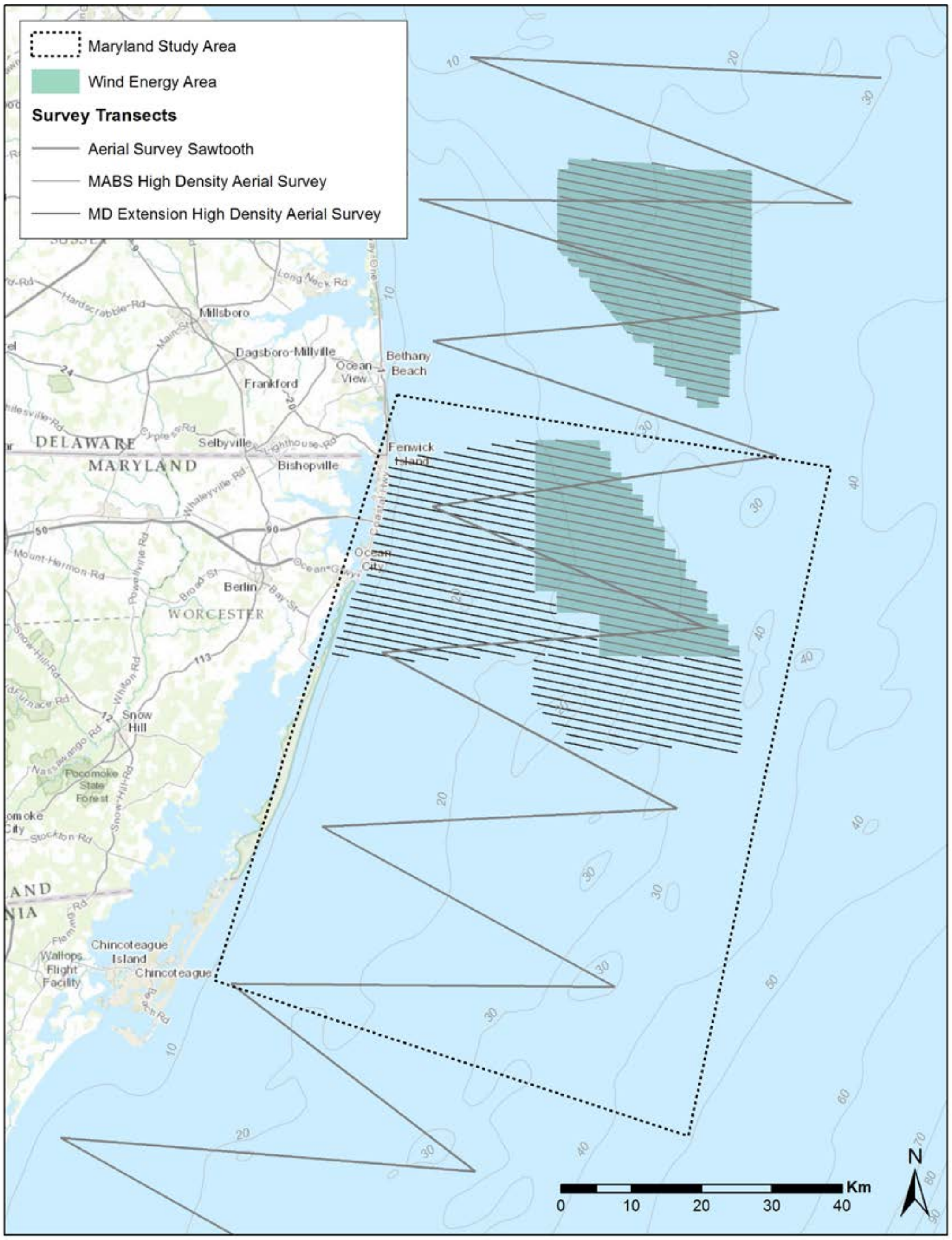

Figure 5-1. Map of aerial survey transects for the Maryland Project. The northern part of the MABS study area is also shown. The Maryland study area (black box) includes all boat and aerial survey transects in waters offshore of Maryland (both DOE and Maryland-funded surveys, 2012-2014). The Maryland Project surveys are a subset of the surveys within the Maryland study area that were specifically funded by the state of Maryland in 2013-2014 (shown in darker gray).

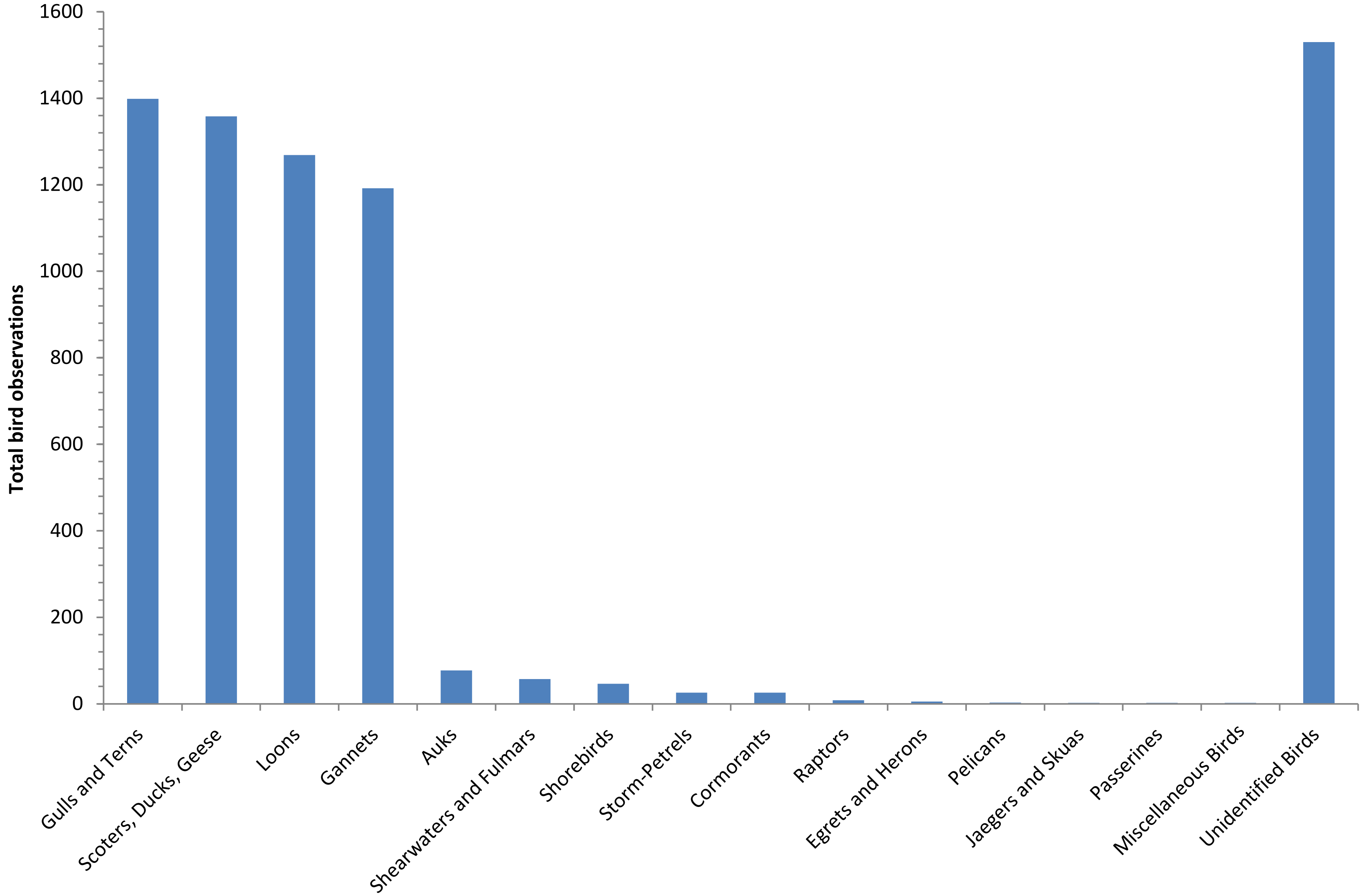

Figure 5-2. Avian observations from the Maryland study area digital video aerial surveys by family (March 2012 - May2014). Unidentified birds are all birds not identified to species or to any higher level taxonomic groups. Birds from all levels of identification are taken at face value (e.g., possible Northern Gannet is counted as Northern Gannet).

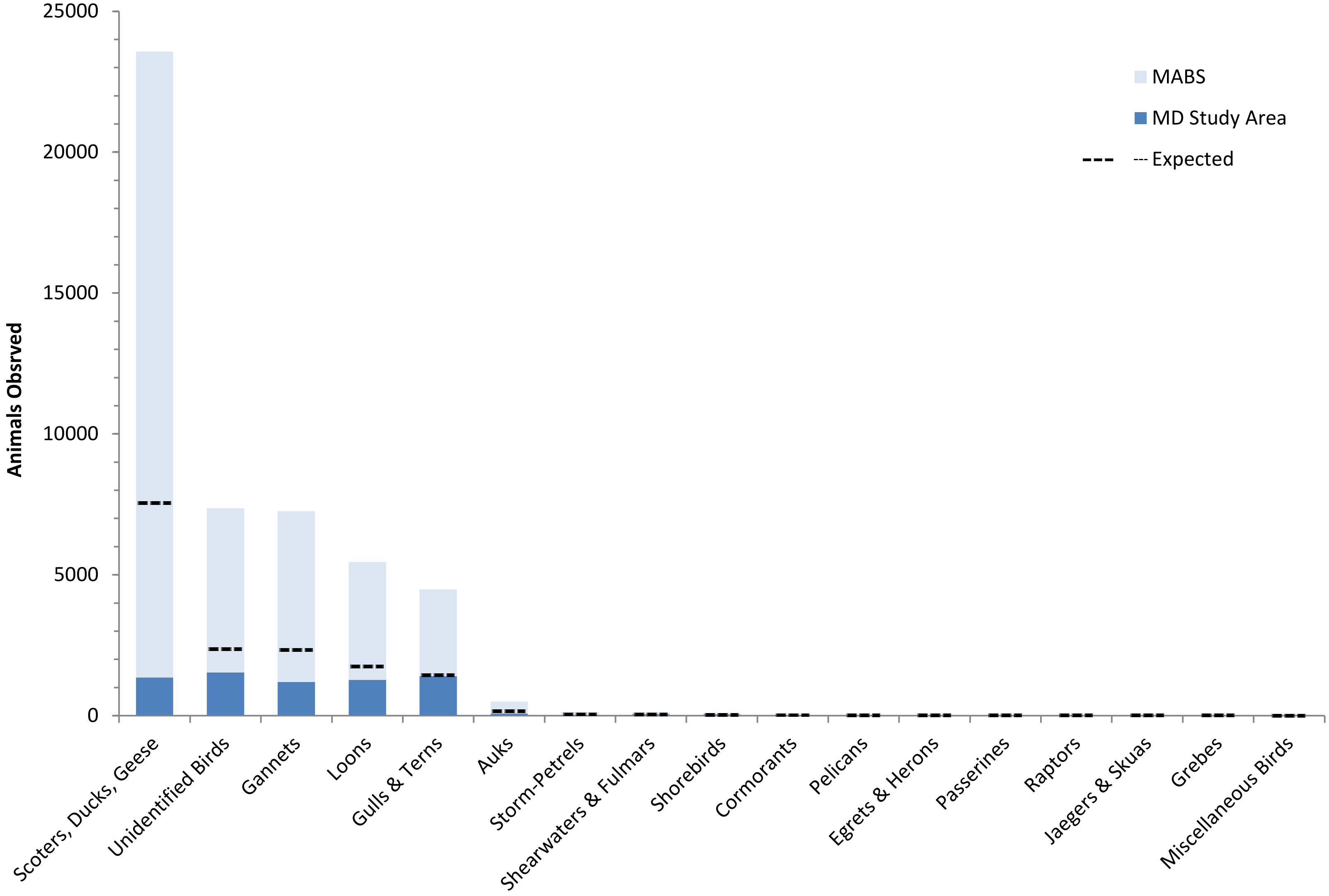

Figure 5-3. Birds observed in the Maryland study area and the Mid-Atlantic Baseline Studies project area (Figure 5-1). The expected number of animals given the proportion of the study area covered in the Maryland project area (32%) is shown for each bird group using a dashed line.

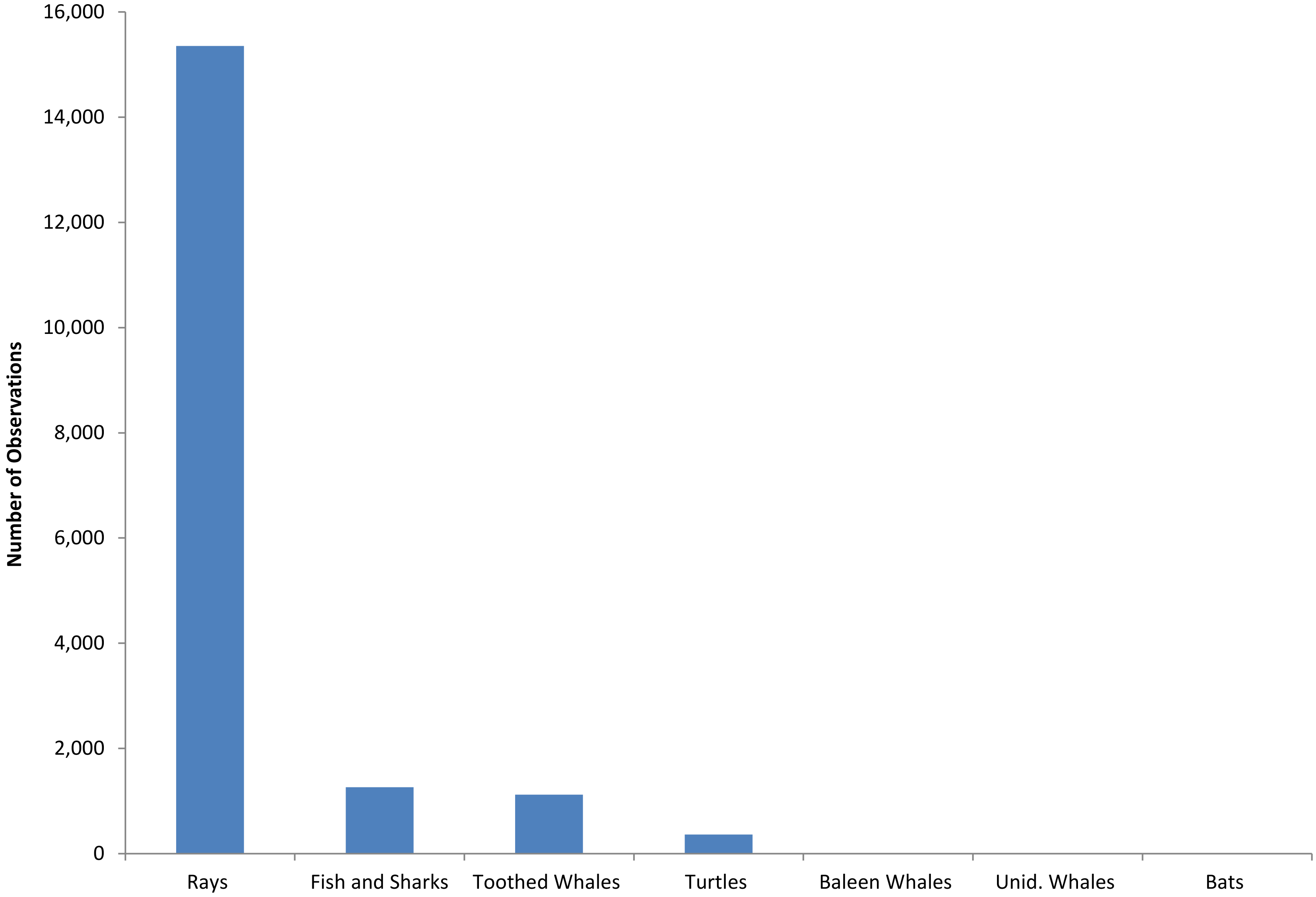

Figure 5-4. Observations from the Maryland digital video aerial surveys of other non-avian animals by family group (March 2012 – May 2014). Note that the numbers presented here do not include schools of rays or fish, so these data are an underestimate of the total counts of these animals.

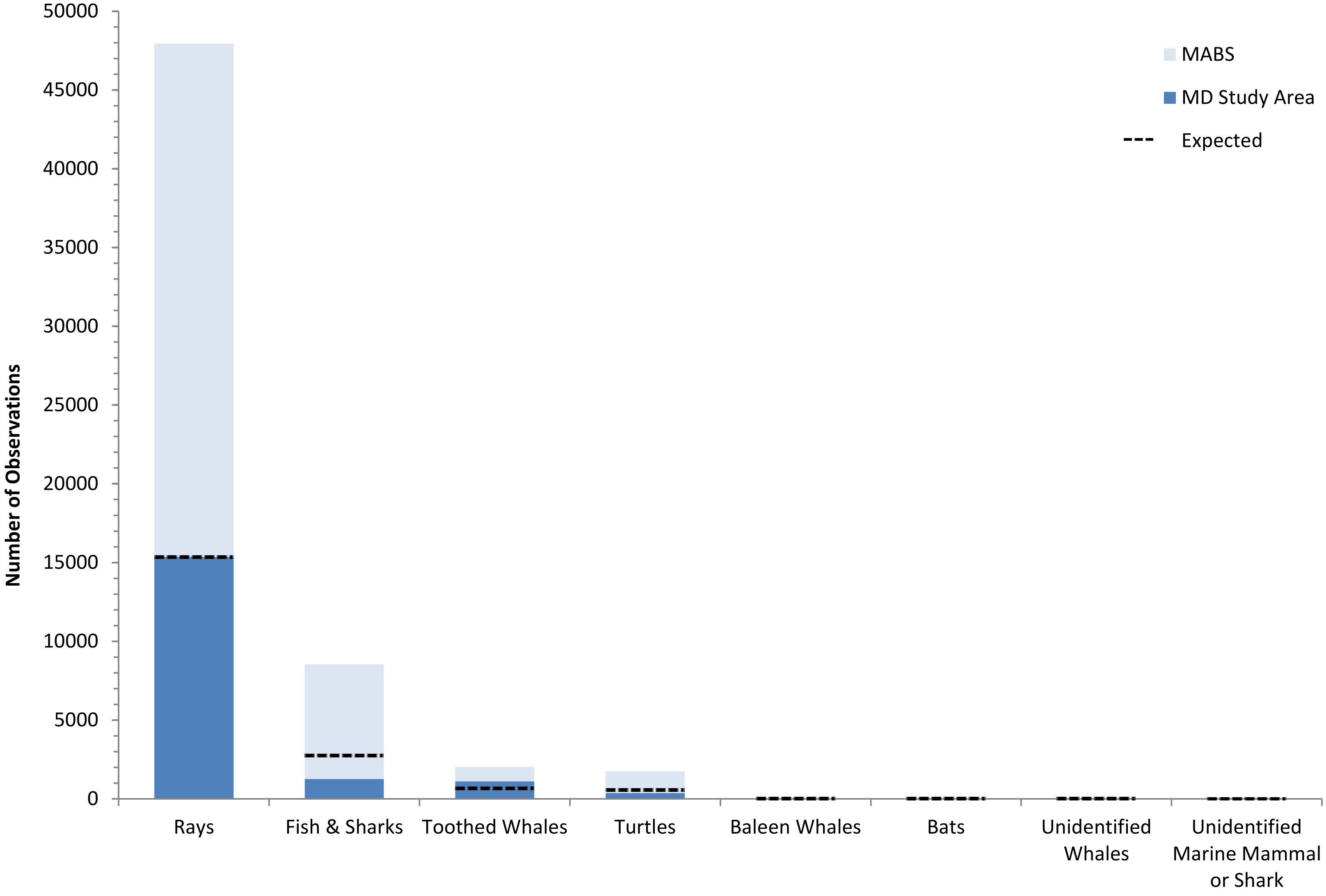

Figure 5-5. Aquatic animals observed in the Maryland study area and the Mid-Atlantic Baseline Studies project area (Figure 5-1). The expected number of animals given the proportion of the study area covered in the Maryland project area (32%) is shown for each group using a dashed line.

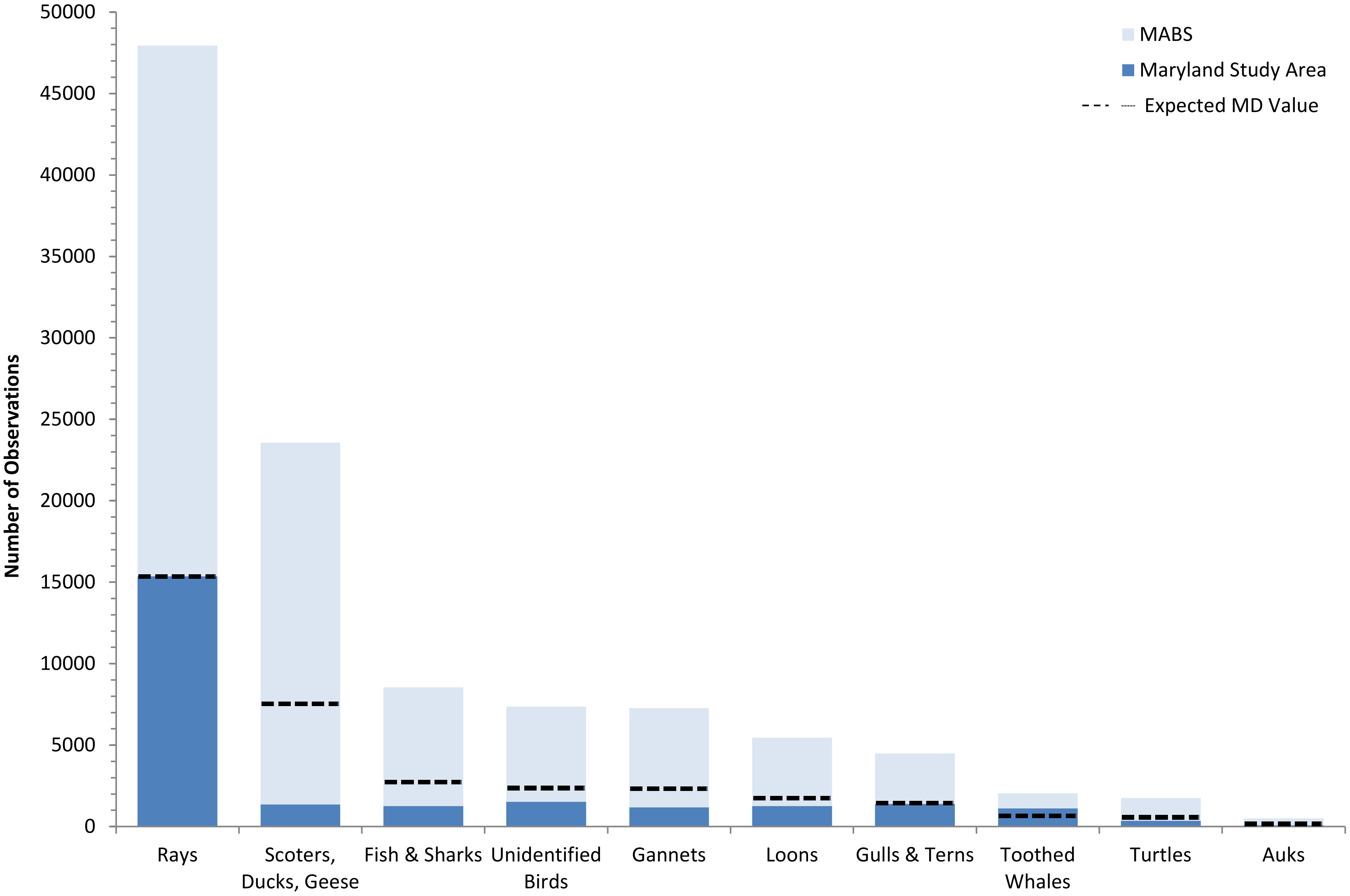

Figure 5-6. Observations of the most abundant animal groups from Maryland study area and the Mid-Atlantic Baseline Studies project area (Figure 5-1). The dashed line represents the expected number of animals given the proportion of the overall study area that includes Maryland (32%).

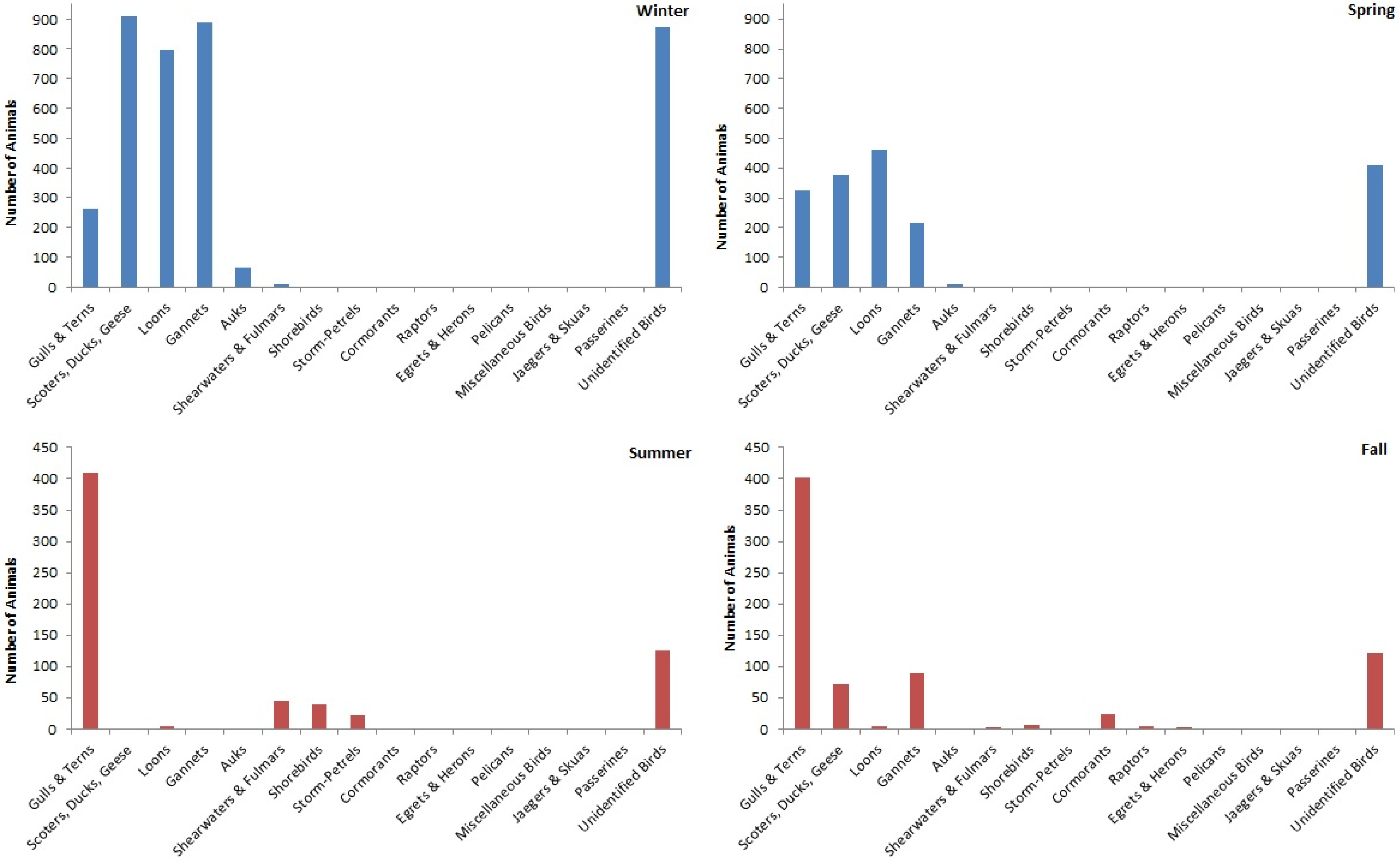

Figure 5-7. Abundance of birds by family or group in winter (December through February), spring (March and May), summer (June, July, August), and fall (September and October). Note different y-axis between top and bottom graphs. X-axes are in order of overall abundance by family or group across all surveys.

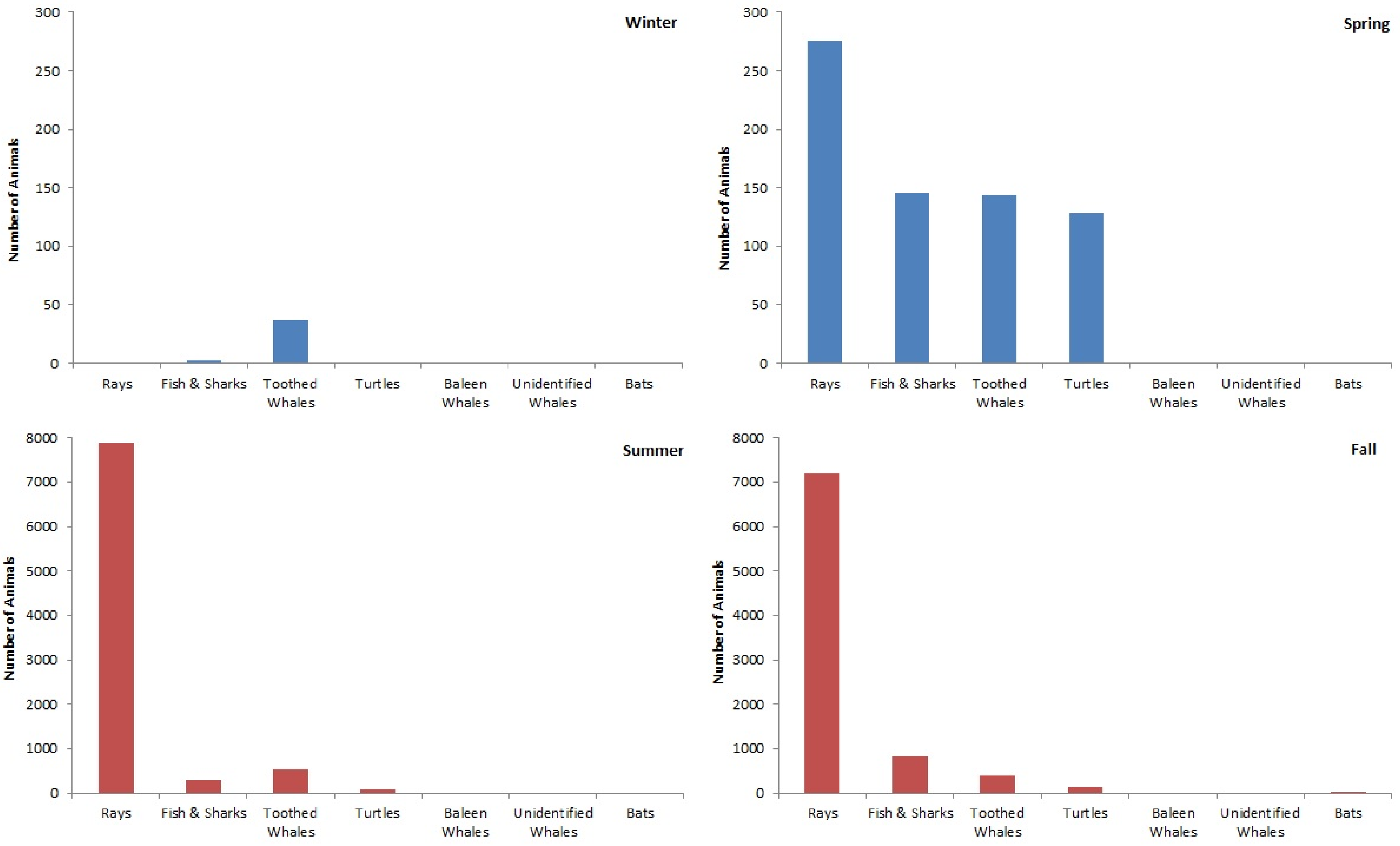

Figure 5-8. Abundance of non-avian animals by group in winter (December to February), spring (March and May), summer (June, July, August), and fall (September and October). Note different y-axis between the top and the bottom graphs. X-axes are in order of overall abundance by family or group across all surveys.

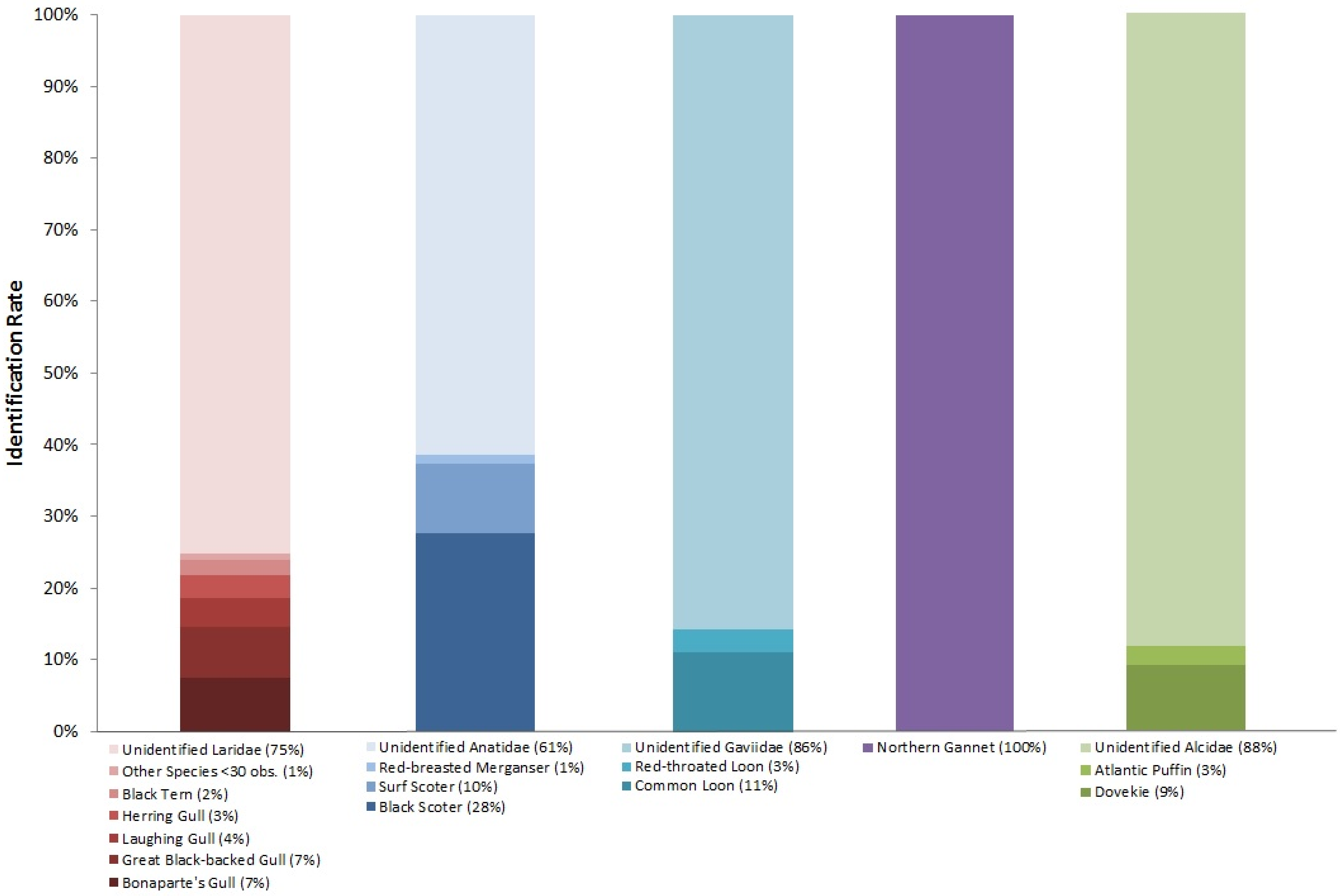

Figure 5-9. Rates of species-level identifications of most abundant avian families from the Maryland study area digital aerial surveys. "Other Species" in the Laridae (red, n=1399) column can be found in Appendix 5A. Sample sizes for Anatidae, Gaviidae, Sulidae, and Alcidae are 1358, 1269, 1192, and 77, respectively. Birds from all levels of identification are taken at face value (e.g., possible Black Scoter is counted as Black Scoter).

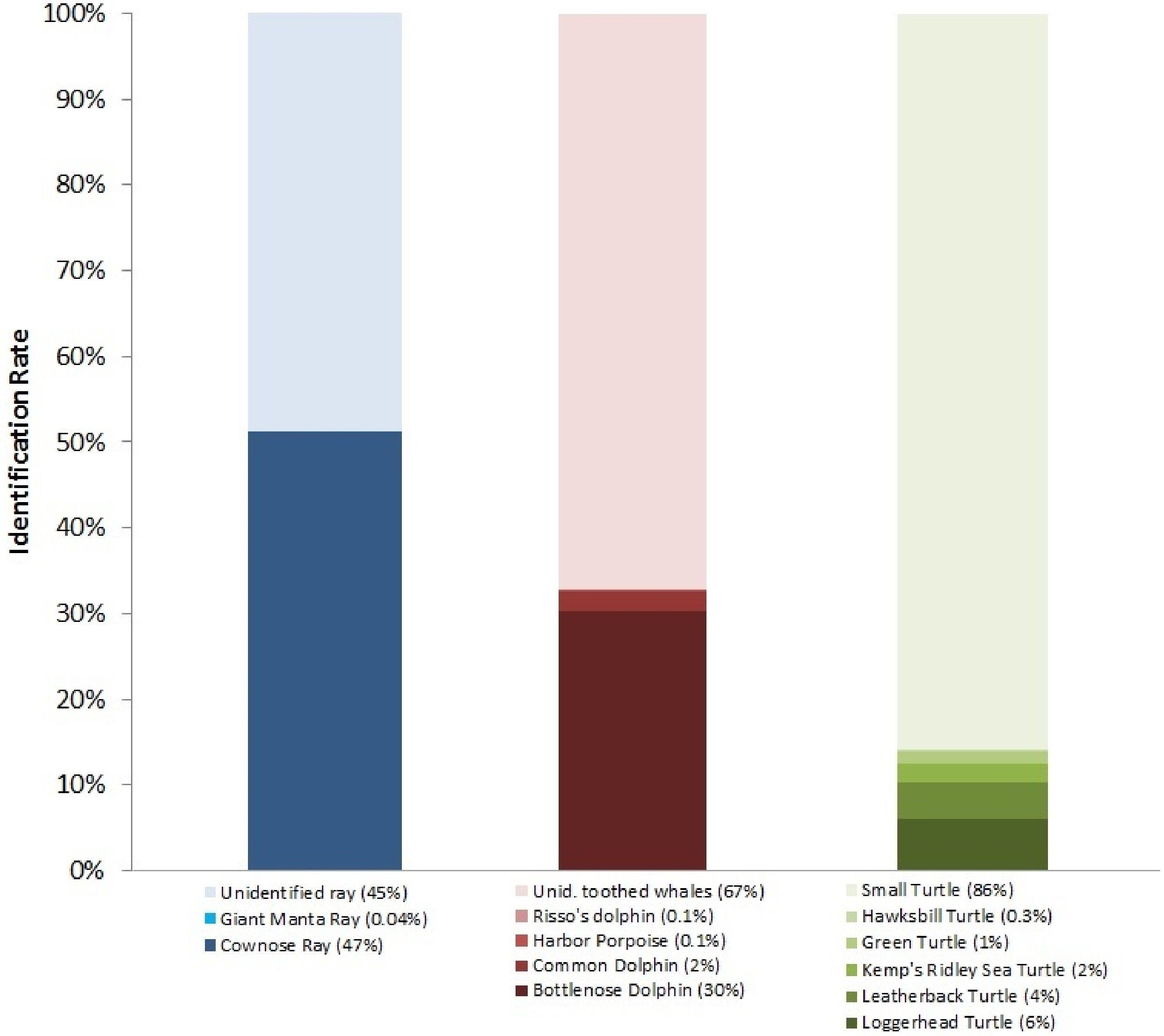

Figure 5-10. Rates of species-level identifications of aquatic animal groups from the Maryland study area digital video aerial surveys. Sample sizes for rays, dolphins, and turtles are 15357, 1121, and 366, respectively.

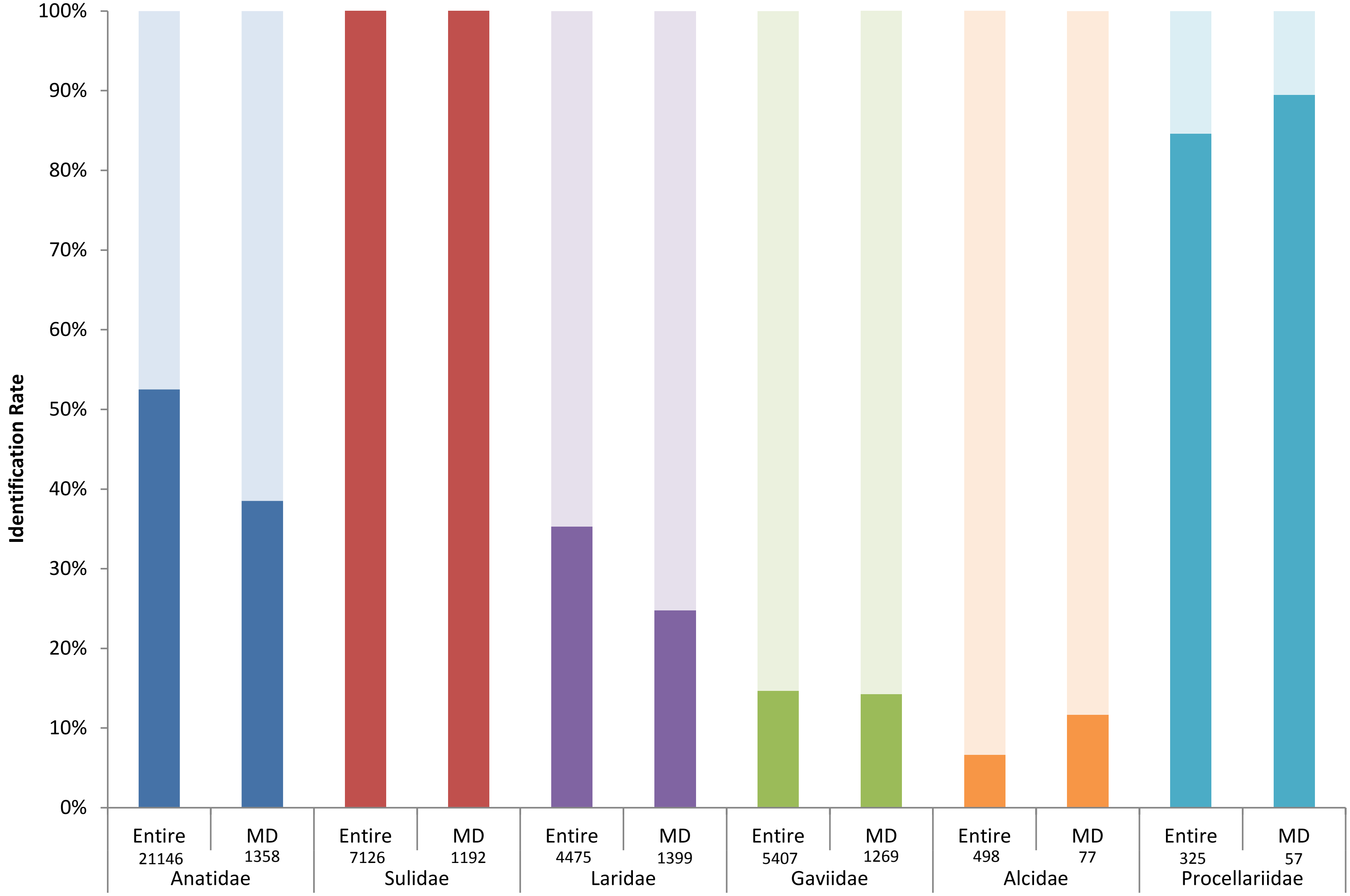

Figure 5-11. Rates of species-level identifications for the five most abundant avian groups from the Mid-Atlantic Baseline Studies and Maryland Projects (Entire) and the Maryland Study Area specifically (MD). Within each taxonomic group, birds that were identified to the species level are shown in dark colors, and those identified to a higher taxonomic level are shown in lighter colors. The total number of birds in each category is given below the bar.

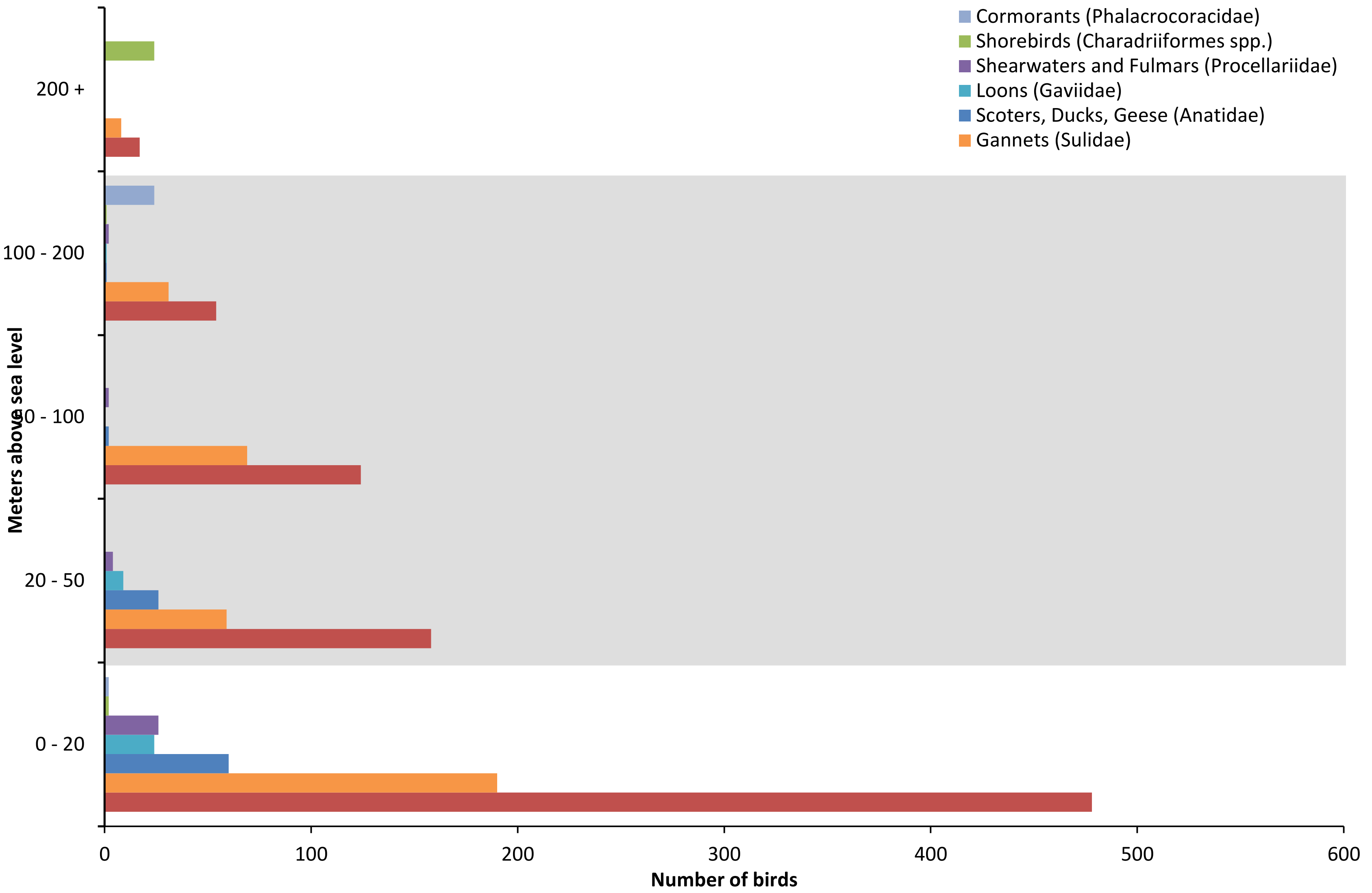

Figure 5-12. Flight height above sea level (meters) of the most abundant bird families from digital video aerial surveys in the Maryland study area. Data are presented as number of animals observed at the given height range. All confidence levels are included for this figure. Grey hatch marks indicate a possible range of altitudes for the rotor-swept zone for offshore wind turbines.

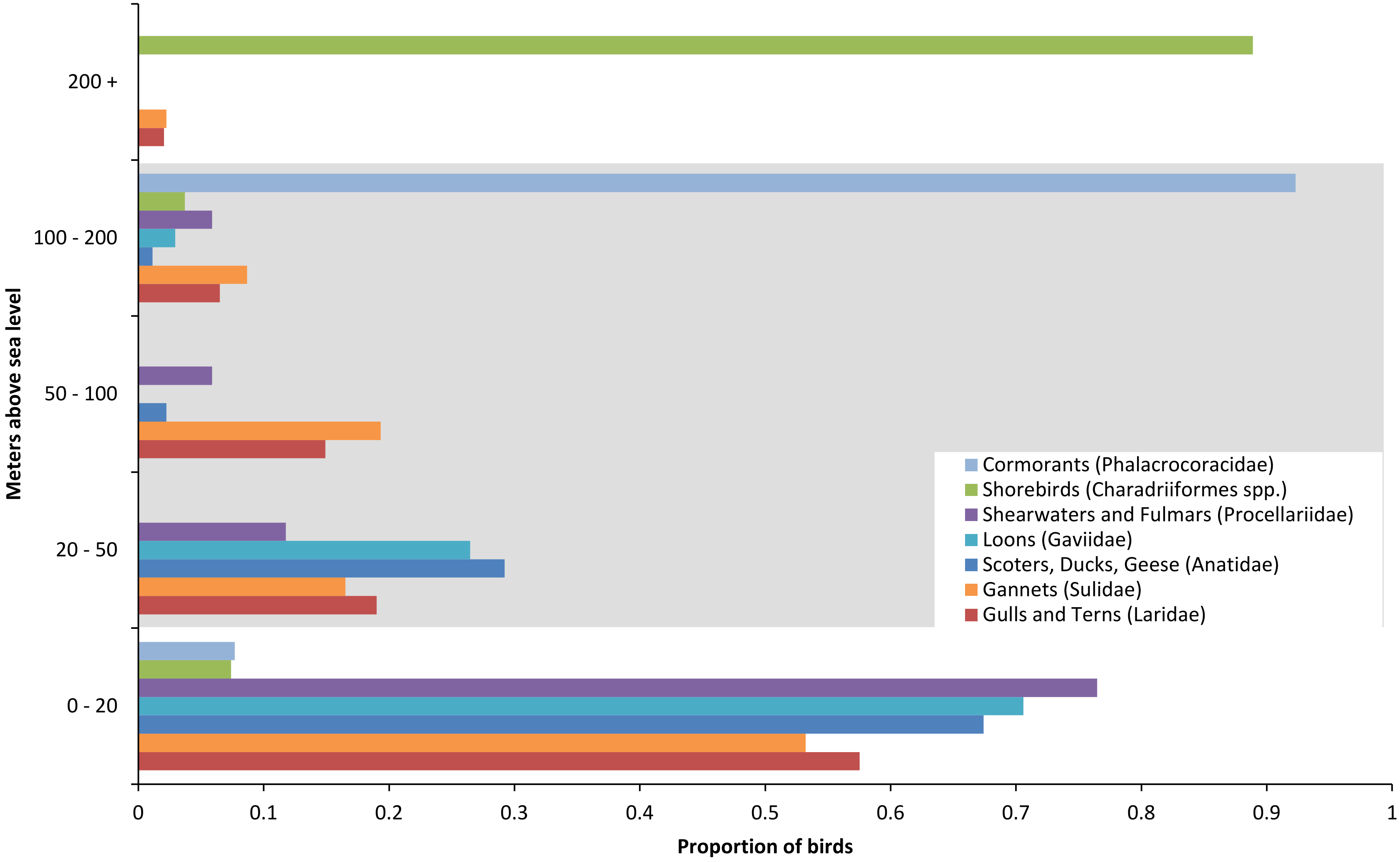

Figure 5-13. Flight height above sea level (meters) of the most abundant bird families from digital video aerial surveys in the Maryland study area. Data are presented as the proportion of each species group observed at the given height range. All confidence levels are included for this figure. Grey hatch marks indicate a possible range of altitudes for the rotor-swept zone for offshore wind turbines.

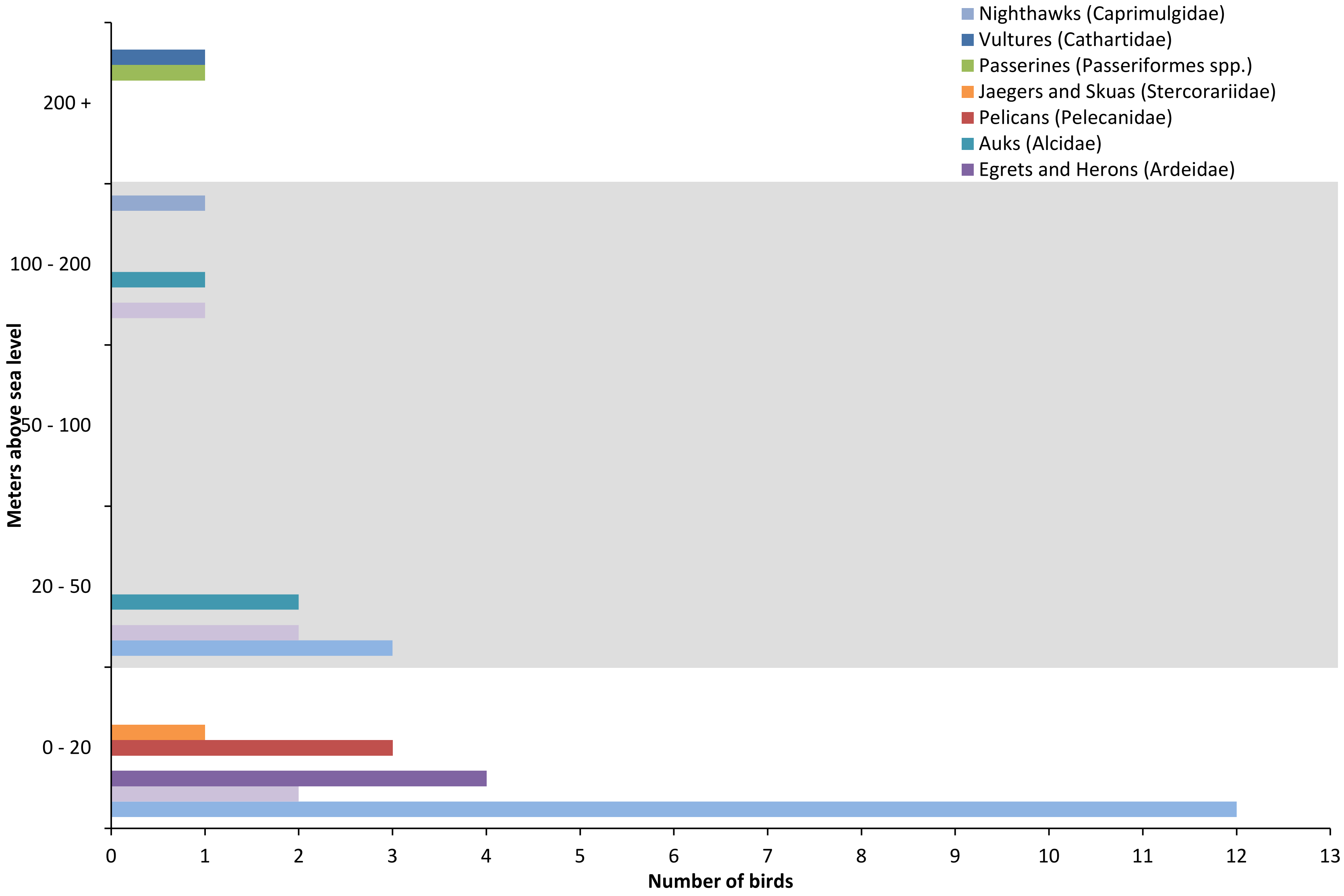

Figure 5-14. Flight height above sea level (meters) for eight less abundant bird families or groups from digital video aerial surveys in the Maryland study area. In several cases, less common families have been combined into broader taxonomic categories (e.g., Passerines). Data are presented as number of animals observed at the given height range. All confidence levels are included for this figure. Grey hatch marks indicate a possible range of altitudes for the rotor-swept zone for offshore wind turbines.

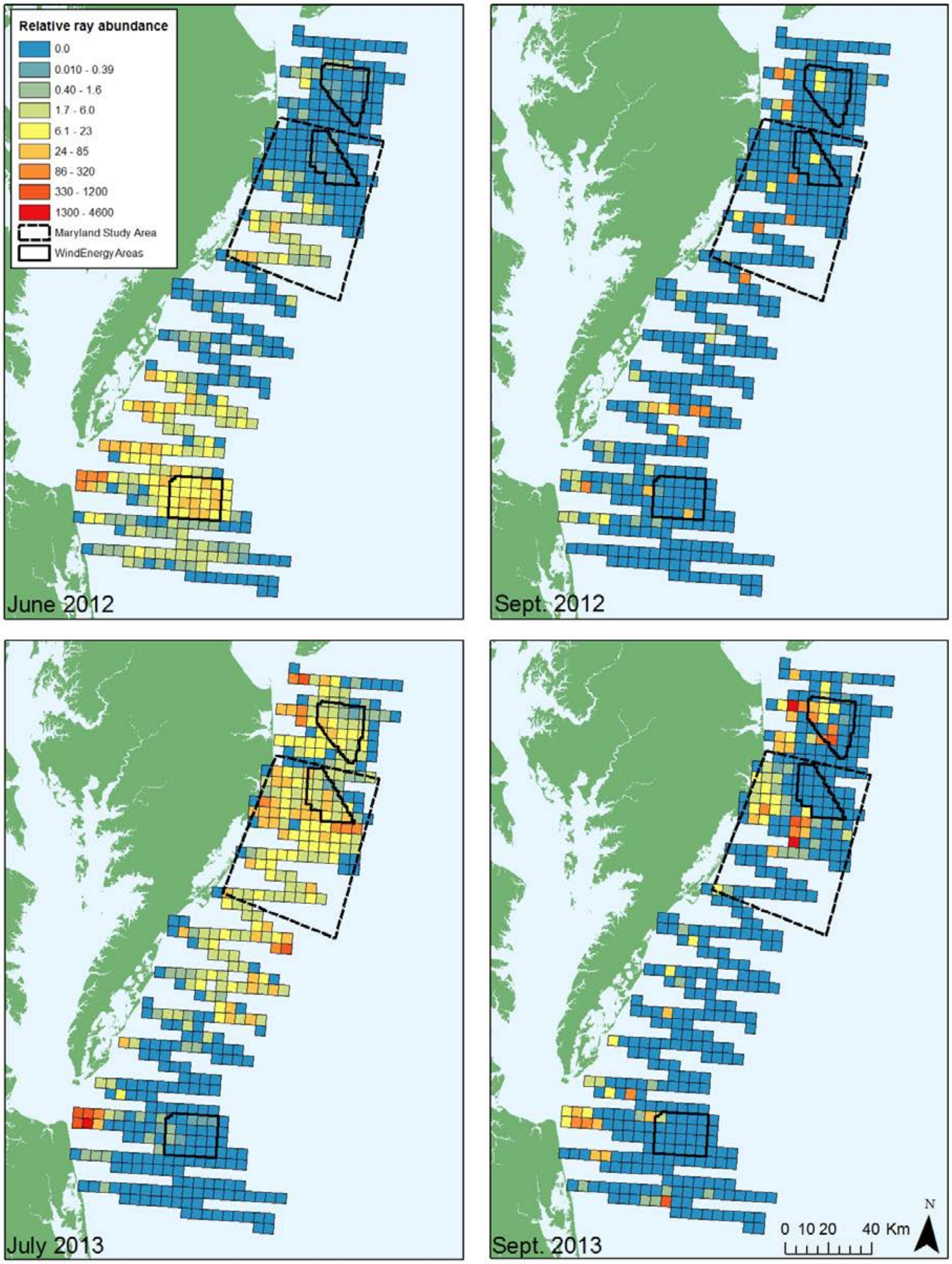

Figure 5-15. Effort-corrected ray counts within lease blocks for the four surveys when they were the most abundant. Count data were corrected by area surveyed within each lease block. Values have not been corrected for detection bias and should be considered as relative estimates of density, not as estimates of actual ray densities. The Wind Energy Areas and Maryland study area are indicated in black.

Table 5-1 Weeks in which digital aerial video surveys were completed during the Mid-Atlantic Baseline Studies Project. Each survey took from one to eleven survey days to complete, depending upon weather, plane availability, and other factors. Surveys colored in gray only included Mid-Atlantic Baseline Studies transects; surveys in blue included Maryland Project transects as well. The survey noted in pale blue (August 2013) included only Maryland Project transects and coverage of the Maryland WEA.

	Jan.				Feb.				Mar.				Apr.				May				Jun.				Jul.				Aug.				Sep.				Oct.				Nov.				Dec.			
2012												▨					▨						▨											▨				▨								▨	▨	
2013						▨	▨				🟦														🟦	🟦	🟦					▒	🟦						🟦								🟦	🟦
2014	🟦	🟦					🟦	🟦	🟦										🟦																													

Table 5-2. Summary data for the Maryland aerial surveys (by species group). Data include the Maryland Project surveys, the Maryland MABS WEA surveys, and the DOE Sawtooth surveys that fall within Maryland waters (**Figure 5-1**). Data are presented in order of abundance based on the total count from all surveys. Counts include definite, probable, and possible identifications (see text). Grey survey headings and totals include only the MABS surveys; darker blue surveys include the Maryland Project in addition to the MABS WEA and sawtooth surveys; and the light blue survey included only the Maryland Project and the Maryland WEA.

Animal Group	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
Unidentified Birds (Aves spp.)	17	36	24	11	15	51	199	221	19	83	52	44	330	326	102	1530	6.09%
Gulls and Terns (Laridae)	37	109	25	16	55	31	14	31	122	262	197	134	205	15	146	1399	5.57%
Scoters, Ducks, Geese (Anatidae)	1	0	0	0	0	14	328	229	0	0	0	73	185	383	145	1358	5.41%
Loons (Gaviidae)	16	90	2	0	3	64	240	234	1	2	1	1	248	268	99	1269	5.05%
Gannets (Sulidae)	31	4	0	0	16	66	267	168	1	0	1	72	413	151	2	1192	4.75%
Auks (Alcidae)	0	0	0	0	0	31	8	6	0	0	0	1	21	10	0	77	0.31%
Shearwaters and Fulmars (Procellariidae)	0	0	46	0	1	0	0	0	0	0	0	2	1	6	1	57	0.23%
Shorebirds (Charadriiformes spp.)	0	0	0	7	0	0	0	0	32	7	0	0	0	0	0	46	0.18%
Storm-Petrels (Hydrobatidae)	0	0	10	0	0	0	0	0	8	5	0	1	0	0	2	26	0.10%
Cormorants (Phalacrocoracidae)	0	0	0	0	24	0	0	0	0	0	0	0	0	0	2	26	0.10%
Raptors (Accipitridae and Pandionidae)	0	0	0	0	0	0	0	0	0	0	2	4	0	0	2	8	0.03%
Egrets and Herons (Ardeidae)	0	0	0	0	4	0	0	0	0	1	0	0	0	0	0	5	0.02%
Pelicans (Pelecanidae)	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	3	0.01%
Miscellaneous Birds	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2	0.01%
Jaegers and Skuas	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0.01%

Animal Group	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
(Stercorariidae)																	
Passerines (Passeriformes spp.)	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0.01%
Total Birds	**102**	**240**	**109**	**34**	**118**	**257**	**1056**	**890**	**184**	**361**	**255**	**333**	**1403**	**1159**	**501**	**7002**	**27.88%**
Rays (Batoidea)	0	0	298	593	121	1	0	0	7224	374	6463	7	0	0	276	15357	61.15%
Fish and Sharks	1	65	15	126	88	2	0	1	177	96	610	4	0	1	79	1265	5.04%
Toothed Whales (Odontoceti)	2	37	41	98	1	21	11	8	203	284	311	2	0	5	97	1121	4.46%
Turtles (Testudines)	0	24	20	27	59	0	0	0	46	25	43	17	0	0	105	366	1.46%
Baleen Whales (Mysticeti)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	2	0.01%
Unidentified Whale (Cetacea)	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.00%
Bats (Chiroptera)	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.00%
Non-Avian Total	**3**	**126**	**374**	**844**	**269**	**24**	**11**	**9**	**7650**	**779**	**7428**	**30**	**0**	**8**	**558**	**18113**	**72.12%**
Total	**105**	**366**	**483**	**878**	**387**	**281**	**1067**	**899**	**7834**	**1140**	**7683**	**363**	**1403**	**1167**	**1059**	**25115**	**100.00%**

Supplementary material

Appendix 5A. Summary of animals observed in Maryland during aerial surveys

Table 5A-1 Summary of animals observed in Maryland during 14 aerial surveys in 2012-2014. Data include the Maryland Project surveys, the Maryland DOE WEA surveys, and the DOE Sawtooth surveys that fall within Maryland waters (**Figure 5-1**). Data are presented in order of abundance by family, based on the total count from all surveys. Note the August 2013 survey included only the Maryland WEA and Maryland Project study area. Grey survey headings and totals include only the MABS surveys; darker blue surveys include the Maryland Project in addition to the MABS WEA and sawtooth surveys; and the light blue survey included only the Maryland Project and the Maryland WEA.

Common Name	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
Unidentified Bird	17	36	24	11	15	51	199	221	19	83	52	44	330	326	102	1530	6.09%
Unidentified Birds (Aves spp.) Total	**17**	**36**	**24**	**11**	**15**	**51**	**199**	**221**	**19**	**83**	**52**	**44**	**330**	**326**	**102**	**1530**	**6.09%**
Unidentified Gull	5	7	1	1	15	4	9	22	26	89	60	44	69	9	34	395	1.57%
Unidentified Tern	0	18	4	9	6	0	0	0	46	75	47	22	0	0	57	284	1.13%
Tern/Small or Medium Gull	12	29	3	1	7	1	1	1	3	14	7	4	43	3	36	165	0.66%
Bonaparte's Gull	13	0	0	0	0	12	1	1	0	0	0	0	76	1	0	104	0.41%
Great Black-backed Gull	0	3	0	0	10	13	1	3	2	3	10	40	9	1	4	99	0.39%
Unidentified Large Gull	0	2	3	1	10	0	2	0	4	16	48	7	2	0	0	95	0.38%
Laughing Gull	0	0	2	0	0	0	0	1	31	7	4	5	0	0	6	56	0.22%
Herring Gull	3	2	3	0	4	1	0	3	0	3	5	10	6	1	5	46	0.18%
Medium Tern: 32-45 cm	0	42	2	1	0	0	0	0	0	0	0	0	0	0	0	45	0.18%
Black Tern	0	0	0	0	0	0	0	0	0	26	4	0	0	0	0	30	0.12%
Unidentified small Tern	0	0	0	1	0	0	0	0	2	14	4	0	0	0	0	21	0.08%
Unidentified large Tern	1	3	3	0	0	0	0	0	3	1	5	0	0	0	4	20	0.08%
Unidentified small gull	3	0	0	0	0	0	0	0	3	13	0	0	0	0	0	19	0.08%
Medium Gull: 38-53 cm	0	3	2	1	2	0	0	0	0	0	0	0	0	0	0	8	0.03%
Sabine's Gull	0	0	0	0	0	0	0	0	0	1	1	2	0	0	0	4	0.02%
Caspian Tern	0	0	1	1	0	0	0	0	2	0	0	0	0	0	0	4	0.02%
Lesser Black-backed Gull	0	0	0	0	1	0	0	0	0	0	2	0	0	0	0	3	0.01%
Common Tern	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0.00%
Gulls and Terns (Laridae) Total	**37**	**109**	**25**	**16**	**55**	**31**	**14**	**31**	**122**	**262**	**197**	**134**	**205**	**15**	**146**	**1399**	**5.57%**

Common Name	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
Unidentified Scoter	0	0	0	0	0	1	186	103	0	0	0	24	43	330	144	831	3.31%
Black Scoter	1	0	0	0	0	13	123	82	0	0	0	45	100	10	1	375	1.49%
Surf Scoter	0	0	0	0	0	0	19	36	0	0	0	2	34	42	0	133	0.53%
Red-breasted Merganser	0	0	0	0	0	0	0	6	0	0	0	0	8	1	0	15	0.06%
Unidentified Duck	0	0	0	0	0	0	0	2	0	0	0	2	0	0	0	4	0.02%
Scoters, Ducks, Geese (Anatidae) Total	**1**	**0**	**0**	**0**	**0**	**14**	**328**	**229**	**0**	**0**	**0**	**73**	**185**	**383**	**145**	**1358**	**5.41%**
Unidentified Loon	16	30	1	0	2	51	172	224	0	2	1	1	232	261	95	1088	4.33%
Common Loon	0	52	1	0	1	10	44	6	1	0	0	0	16	7	3	141	0.56%
Red-throated Loon	0	8	0	0	0	3	24	4	0	0	0	0	0	0	1	40	0.16%
Loons (Gaviidae) Total	**16**	**90**	**2**	**0**	**3**	**64**	**240**	**234**	**1**	**2**	**1**	**1**	**248**	**268**	**99**	**1269**	**5.05%**
Northern Gannet	31	4	0	0	16	66	267	168	1	0	1	72	413	151	2	1192	4.75%
Gannets (Sulidae) Total	**31**	**4**	**0**	**0**	**16**	**66**	**267**	**168**	**1**	**0**	**1**	**72**	**413**	**151**	**2**	**1192**	**4.75%**
Unidentified Alcid	0	0	0	0	0	11	7	6	0	0	0	0	20	7	0	51	0.20%
Unidentified large alcid (Razorbill or Murre)	0	0	0	0	0	13	0	0	0	0	0	0	0	0	0	13	0.05%
Dovekie	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	7	0.03%
Unidentified small alcid (Puffin/Dovekie)	0	0	0	0	0	0	1	0	0	0	0	0	0	3	0	4	0.02%
Atlantic Puffin	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	2	0.01%
Auks (Alcidae) Total	**0**	**0**	**0**	**0**	**0**	**31**	**8**	**6**	**0**	**0**	**0**	**1**	**21**	**10**	**0**	**77**	**0.31%**
Greater Shearwater	0	0	32	0	0	0	0	0	0	0	0	0	0	0	0	32	0.13%
Cory's Shearwater	0	0	6	0	1	0	0	0	0	0	0	2	0	0	0	9	0.04%
Northern Fulmar	0	0	1	0	0	0	0	0	0	0	0	0	1	6	0	8	0.03%
Unidentified Shearwater	0	0	5	0	0	0	0	0	0	0	0	0	0	0	1	6	0.02%
Sooty Shearwater	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2	0.01%
Shearwaters and Fulmars (Procellariidae) Total	**0**	**0**	**46**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**1**	**6**	**1**	**57**	**0.23%**
Dowitcher spp.	0	0	0	0	0	0	0	0	32	0	0	0	0	0	0	32	0.13%
Unidentified Phalarope	0	0	0	6	0	0	0	0	0	3	0	0	0	0	0	9	0.04%
Small Shorebird sp.	0	0	0	1	0	0	0	0	0	4	0	0	0	0	0	5	0.02%

Common Name	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
Shorebirds (Charadriiformes spp.) Total	**0**	**0**	**0**	**7**	**0**	**0**	**0**	**0**	**32**	**7**	**0**	**0**	**0**	**0**	**0**	**46**	**0.18%**
Wilson's Storm-Petrel	0	0	10	0	0	0	0	0	2	0	0	0	0	0	2	14	0.06%
Unidentified Storm-petrel	0	0	0	0	0	0	0	0	6	5	0	1	0	0	0	12	0.05%
Storm-Petrels (Hydrobatidae) Total	**0**	**0**	**10**	**0**	**0**	**0**	**0**	**0**	**8**	**5**	**0**	**1**	**0**	**0**	**2**	**26**	**0.10%**
Double-crested Cormorant	0	0	0	0	24	0	0	0	0	0	0	0	0	0	2	26	0.10%
Cormorants (Phalacrocoracidae) Total	**0**	**0**	**0**	**0**	**24**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**26**	**0.10%**
Osprey	0	0	0	0	0	0	0	0	0	0	2	2	0	0	2	6	0.02%
Bald Eagle	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	2	0.01%
Raptors (Accipitridae and Pandionidae) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**4**	**0**	**0**	**2**	**8**	**0.03%**
Great Blue Heron	0	0	0	0	3	0	0	0	0	1	0	0	0	0	0	4	0.02%
American Bittern	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.00%
Egrets and Herons (Ardeidae) Total	**0**	**0**	**0**	**0**	**4**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**5**	**0.02%**
Brown Pelican	0	0	1	0	0	0	0	0	1	0	0	1	0	0	0	3	0.01%
Pelicans (Pelecanidae) Total	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**1**	**0**	**0**	**0**	**3**	**0.01%**
Common Nighthawk	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0.00%
Black Vulture	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00%
Miscellaneous Birds Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**2**	**0.01%**
Unidentified Jaeger	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0.01%
Jaegers and Skuas (Stercorariidae) Total	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0.01%**
Unidentified Passerine	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	0.01%
Passerines (Passeriformes spp.) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**0**	**2**	**0.01%**
Avian Total	**102**	**240**	**109**	**34**	**118**	**257**	**1056**	**890**	**184**	**361**	**255**	**333**	**1403**	**1159**	**501**	**7002**	**27.88%**
Cownose Ray	0	0	38	438	38	0	0	0	4130	97	2981	0	0	0	143	7865	31.32%
Unidentified ray	0	0	260	155	83	1	0	0	3094	277	3475	7	0	0	133	7485	29.80%
Giant Manta Ray	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	7	0.03%
Rays (Batoidea) Total	**0**	**0**	**298**	**593**	**121**	**1**	**0**	**0**	**7224**	**374**	**6463**	**7**	**0**	**0**	**276**	**15357**	**61.15%**

Common Name	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
Unidentified fish	1	54	8	108	70	2	0	1	133	58	479	0	0	1	64	979	3.90%
Unidentified shark	0	2	6	16	0	0	0	0	34	33	115	0	0	0	1	207	0.82%
Ocean Sunfish (Mola)	0	9	1	2	18	0	0	0	0	1	2	4	0	0	9	46	0.18%
Hammerhead shark	0	0	0	0	0	0	0	0	5	3	13	0	0	0	0	21	0.08%
Thresher Shark	0	0	0	0	0	0	0	0	5	1	1	0	0	0	5	12	0.05%
Fish and Sharks Total	**1**	**65**	**15**	**126**	**88**	**2**	**0**	**1**	**177**	**96**	**610**	**4**	**0**	**1**	**79**	**1265**	**5.04%**
Small beaked Cetacean to 3 m	0	22	10	57	0	7	1	4	98	213	178	1	0	0	53	644	2.56%
Bottlenose Dolphin	0	15	31	41	1	0	0	1	95	39	74	0	0	0	43	340	1.35%
Unidentified Dolphin	2	0	0	0	0	0	4	2	3	32	58	0	0	0	1	102	0.41%
Common Dolphin	0	0	0	0	0	14	5	0	7	0	1	0	0	0	0	27	0.11%
Unidentified Toothed Whales	0	0	0	0	0	0	1	0	0	0	0	0	0	5	0	6	0.02%
Harbor Porpoise	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0.00%
Risso's dolphin	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0.00%
Toothed Whales (Odontoceti) Total	**2**	**37**	**41**	**98**	**1**	**21**	**11**	**8**	**203**	**284**	**311**	**2**	**0**	**5**	**97**	**1121**	**4.46%**
Small turtle	0	21	18	12	42	0	0	0	42	24	38	15	0	0	102	314	1.25%
Loggerhead Turtle	0	2	2	6	7	0	0	0	1	1	2	1	0	0	0	22	0.09%
Leatherback Turtle	0	0	0	5	4	0	0	0	3	0	2	1	0	0	1	16	0.06%
Kemp's Ridley Sea Turtle	0	0	0	2	3	0	0	0	0	0	1	0	0	0	2	8	0.03%
Green Turtle	0	1	0	2	2	0	0	0	0	0	0	0	0	0	0	5	0.02%
Hawksbill Turtle	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0.00%
Turtles (Testudines) Total	**0**	**24**	**20**	**27**	**59**	**0**	**0**	**0**	**46**	**25**	**43**	**17**	**0**	**0**	**105**	**366**	**1.46%**
Minke Whale	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0.00%
Humpback Whale	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.00%
Baleen Whales (Mysticeti) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**1**	**2**	**0.01%**
Unidentified Medium Whale	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0.00%
Unidentified Whale (Cetacea) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**1**	**0.00%**
Red Bat	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	0.00%
Bats (Chiroptera) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**1**	**0.00%**

Common Name	Mar. 2012	May. 2012	Jun. 2012	Sep. 2012	Oct. 2012	Dec. 2012	Feb. 2013	Mar. 2013	Jul. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Feb. 2014	May. 2014	Grand Total	Percent
Non-Avian Total	3	126	374	844	269	24	11	9	7650	779	7428	30	0	8	558	18113	72.12%
Grand Total	105	366	483	878	387	281	1067	899	7834	1140	7683	363	1403	1167	1059	25115	100.00%

Introduction to Part III
Examining wildlife distributions and abundance using boat surveys

Report structure

The chapters in this report represent a broad range of study efforts focused on understanding wildlife population distributions in Atlantic waters offshore of Maryland (and elsewhere in the Mid-Atlantic United States). Some chapters are purely methodological in nature, while others present a variety of analyses and results (Figure I). Part I of this report (the Executive Summary and Chapters 1-2) summarizes and synthesizes project results. The 12 subsequent chapters and their relationships to each other are shown in Figure I. In Parts II (Chapters 3-5) and III (Chapters 6-9), we describe methods and results for high resolution digital video aerial surveys and boat-based surveys, respectively. Part IV of this report (Chapters 10-14) combines data from both survey approaches to develop a comprehensive understanding of marine wildlife populations that use the Mid-Atlantic study area.

Part III: Examining wildlife distributions and abundance using boat surveys

Standardized boat-based surveys with distance estimation are a widely used and well-established method of obtaining density data for birds, sea turtles, and marine mammals. There are four chapters in Part III of this report, focused on the use of boat surveys to examine wildlife distributions and abundance:

Chapter 6. Protocol for conducting boat surveys for wildlife.

Chapter 7. Basic summary of boat survey observation data.

Chapter 8. Scientific echo sounding study to obtain aquatic biomass data (includes data management and analysis protocols as well as a basic data summary).

Chapter 9. Prediction of seabird densities across the study area by season, based on an incorporation of environmental data into a multi-species modeling approach.

The survey protocol (Chapter 6) explains our boat survey study design in detail, and is referenced throughout the following chapters (also see Figure II). Surveys were particularly optimized for avian species, and detected a wide variety of seabird species as well as raptors, passerines, shorebirds, and other avian taxa. Boat surveys also recorded marine mammals, sea turtles, rays, sharks, fish, and bats (Chapter 7). Data collected on boat surveys provided some substantial advantages in species identification over digital data collected from aircraft. Species-specific information can be important, as even closely related species often have differences in their conservation status, ecology, and habitat requirements.

While conducting surveys, we collected environmental covariate data in order to assess fine-scale patterns of environmental variables in relation to wildlife densities. In particular, fisheries sonar (a scientific echo sounder) was used to estimate relative biomass of aquatic prey in the same areas as boat survey observations (Chapter 8). Identifying the spatial and temporal associations and lags between aquatic biomass and seabird behavior can be helpful for understanding how these birds are making decisions in the marine environment, and the simultaneous collection of in situ data on seabirds and their prey can allow for a better understanding of the ecological drivers of seabird distributions (e.g., by allowing analysis of co-occurrence at very fine geographic and temporal scales, or linking predator distributions to specific prey species; Veit et al. 1993, Santora et al. 2010).

A broader geographic and temporal scale of analysis is required to develop wildlife data appropriate for siting future development projects, however, or 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 Chapter 9, 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 (Sollmann et al. 2015). This was a novel multi-species approach for estimating seabird abundance and distributions that explicitly estimates detection as well as abundance parameters. By sharing information across species, this community model allowed for inference 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, Chapter 9 examines survey data from 15 boat surveys to develop geospatial models that predict seabird densities by season. By incorporating remotely collected environmental covariate data into the hierarchical modeling structure in this expanded analysis, we predict seabird abundance throughout the study area, including areas that were not directly surveyed. The seasonal abundance maps presented in this chapter, for both seabird communities and individual species, predict animal distributions and abundance on a broad geographic scale and are useful for identifying important habitat use areas and seasonal patterns. Unlike several chapters in Part IV of this report, which utilize approaches for combining boat and digital aerial survey data, Chapter 9 focuses on using data from a single, well understood survey method to do the best possible job of describing patterns of abundance.

These survey results 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 anthropogenic activities in that they:

- Inform the siting of future projects, by incorporating wildlife patterns into marine spatial planning and decision making, and by using exposure data as a first step towards defining relative risk by location
- Inform the permitting process for projects, by contributing data towards National Environmental Protection Act (NEPA) and other regulatory requirements, and by helping to define target taxa or research priorities on which to focus on during site-specific monitoring studies
- Inform mitigation, by presenting temporal data on community composition, distributions, and abundance that can be used to time certain activities to coincide with reduced potential for exposure of certain populations.

Boat survey data and analyses can also be used to assess changes to wildlife populations as a result of offshore wind energy development, climate change, and other factors. Results from this project represent a baseline that can be used for comparison with compatible future surveys, and to assess changes due to development or other causes. Future research to fill data gaps on hazards and vulnerability can be targeted towards species with high levels of exposure, as well as species most likely to be impacted due to their conservation status or life history.

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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.

Literature cited

Gardner, B., P. J. Sullivan, S. Epperly, and S. J. Morreale. 2008. Hierarchical modeling of bycatch rates of sea turtles in the western North Atlantic. Endangered Species Research 5:279–289. doi: 10.3354/esr00105.

Mordecai, R. S., B. J. Mattsson, C. J. Tzilkowski, and R. J. Cooper. 2011. Addressing challenges when studying mobile or episodic species: hierarchical Bayes estimation of occupancy and use. Journal of Applied Ecology 48:56–66. doi: 10.1111/j.1365-2664.2010.01921.x.

Santora, J. A., C. S. Reiss, V. J. Loeb, and R. R. Veit. 2010. Spatial association between hotspots of baleen whales and demographic patterns of Antarctic krill Euphausia superba suggests size-dependent predation. Marine Ecology Progress Series 405:255–269. doi: 10.3354/meps08513.

Sollmann, R., B. Gardner, A. Gilbert, K. Williams, and R. Veit. 2015. A community distance sampling model to investigate the abundance and distribution of seabirds. (K. Williams, E. Connelly, S. Johnson, and I. Stenhouse, Eds.) 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. Biodiversity Research Institute, Portland, ME.

Veit, R. R., E. D. Silverman, and I. Everson. 1993. Aggregation Patterns of Pelagic Predators and Their Principal Prey, Antarctic Krill, Near South Georgia. Journal of Animal Ecology 62:551–564. doi: 10.2307/5204.

Zipkin, E. F., B. Gardner, A. T. Gilbert, A. F. O’Connell, J. A. Royle, and E. D. Silverman. 2010. Distribution patterns of wintering sea ducks in relation to the North Atlantic Oscillation and local environmental characteristics. Oecologia 163:893–902. Retrieved March 28, 2012, from http://www.ncbi.nlm.nih.gov/pubmed/20364388.

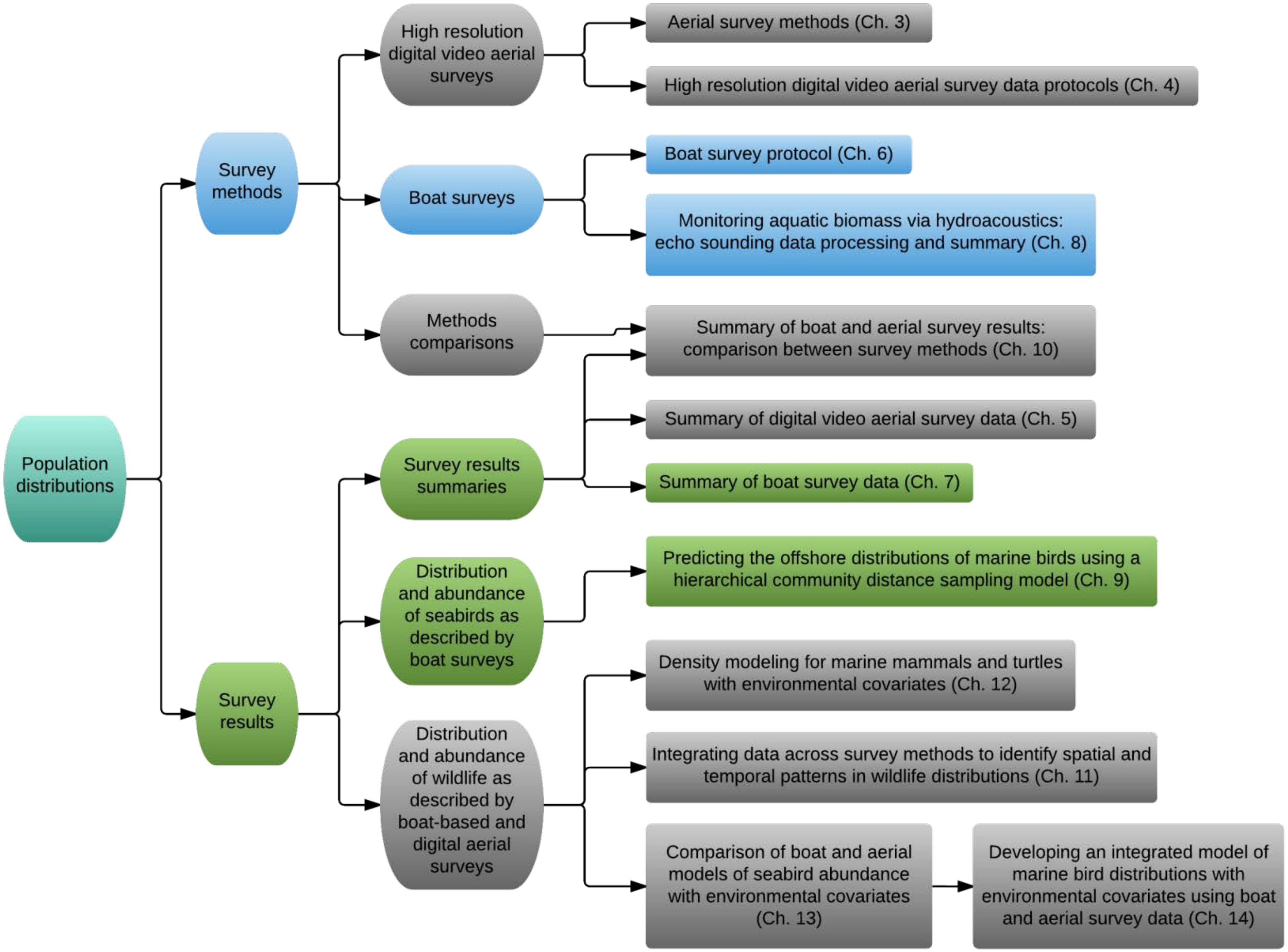

Figure I. Organization of chapters within this final report.

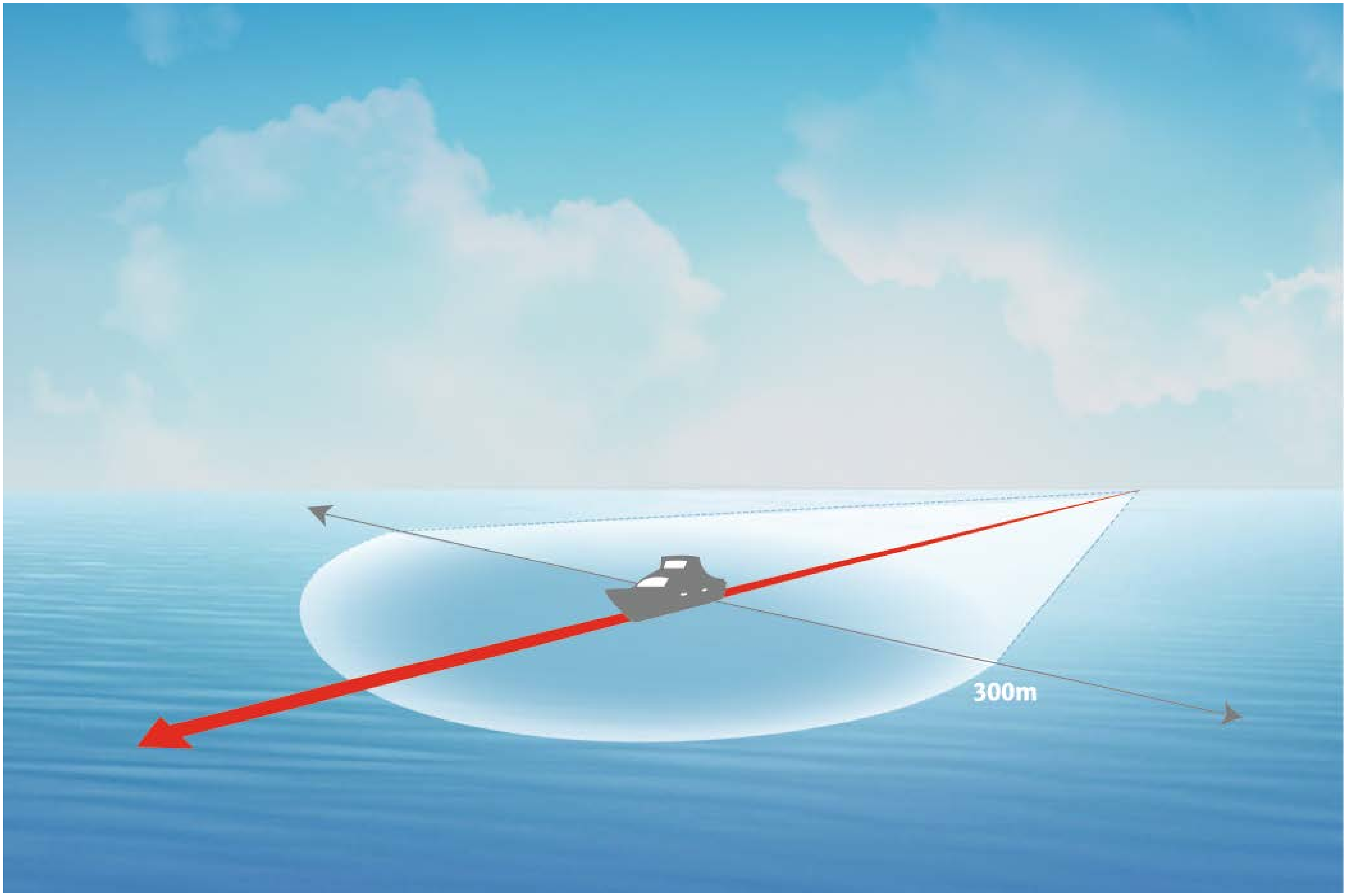

Figure II. Diagram showing the field of view available during boat surveys. The boat transect had an intended minimum strip width of 300 m on one side of the vessel, although observations of animals were generally recorded from both sides of the vessel and up to 1,000 m away.

Chapter 6: Boat survey protocol for Mid-Atlantic Baseline Studies and Maryland Projects

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

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Chapter 6 Highlights

The study design, data collection, and data processing protocols for boat-based surveys

Context[1]

Boat-based surveys with distance estimation are a well-established method of surveying marine wildlife such as seabirds and marine mammals. This chapter describes the study design and protocols used while collecting and post-processing boat survey data for the Maryland Project and Mid-Atlantic Baseline Studies projects. These survey data are summarized in Chapter 7, and are used in subsequent analyses in Chapters 9-14. Chapter 9 uses data from boat-based surveys alongside environmental covariate data to predict seabird abundance throughout the study area. This boat survey protocol is also referenced alongside digital video aerial survey data in Part IV of this report (Chapters 10-14), including comparisons of the two survey methods and efforts aimed at integrating data from both surveys.

Study goal/objectives addressed in this chapter

Provide the protocol followed when conducting boat-based wildlife surveys in the Mid-Atlantic.

Highlights

- Sixteen surveys were conducted over two years between April 2012 and May 2014.
- Each survey included 12 linear transects in the vicinity of three Wind Energy Areas (WEAs) in the Mid-Atlantic region, totaling approximately 559 km. In the second year of surveys (March 2013-Feb 2014), an additional total of 12.5 km of transects were added onto the western ends of three transects to extend them into Maryland state waters, increasing the total to 572 km.
- Surveys were conducted on a 55-foot charter vessel during daylight hours by teams of two observers using a combination of strip and line transect sampling.
- Observers recorded all observed species within a 360˚ arc during normal survey conditions. During inclement weather or when too many animals were present to accurately record observations in 360˚, observers recorded all observed species within a 90˚ arc and within 300 m from the boat.
- Data collected per observation included species, number of individuals seen, behavior, direction of movement, radial distance, degree of the animal's angle to the bow of the boat, and where possible, age and molt state.

Implications

Results from the data collected following this protocol are presented in Chapter 7 and Part IV of this report.

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[1] For more detailed context for this chapter, please see the introduction to Part III of this report.

Abstract

This chapter outlines the protocol followed while conducting boat-based surveys within the Maryland Project and Mid-Atlantic Baseline Studies study areas. Sixteen surveys were conducted over two years between April 2012 and April 2014. Each survey included 12 transects within the vicinity of three Wind Energy Areas offshore of Delaware, Maryland, and Virginia, USA, totaling 559 km in 2012-2013 and 572 km in 2013-2014, with the additional of approximately 12.5 km of transect in Maryland state waters in 2013 for the Maryland Project. Surveys were conducted on a 55-foot charter vessel during daylight hours using distance sampling. Data collected per observation included species, number of individuals seen, behavior, direction of movement, radial distance, degree of the animal's angle to the bow of the boat, and, where possible, age and molt state. Additionally, environmental covariate data including water temperature, salinity, and hydroacoustic data were collected. Data were post-processed and quality assured/quality controlled prior to use in data analyses discussed elsewhere in this report.

Boat survey protocol

Boat survey transects extended perpendicularly to the coastline from three nautical miles offshore to the 30 m isobath or the eastern extent of the Wind Energy Areas (WEAs), whichever was furthest (Figure 6-1, Figure 6-2). For Mid-Atlantic Baseline Study (MABS) surveys beginning in 2012, each survey included 12 transects spaced 10 kilometers apart. The transect lines extended at least one transect north and south of each WEA. Total transect distance was approximately 559 km. Approximately 60% of Maryland's federal waters were covered by this transect design, including four transects in areas within and to the west of the Maryland WEA, but surveys did not extend into Maryland state waters. In the second year of the study, an additional 12.35 km of transects were added to each survey, extending three transects farther west into Maryland state waters (Figure 6-1, Figure 6-2) to include offshore shoal areas. The western edge of these transects were defined by the 10m isobath. The "Maryland study area" as referenced throughout this report (and indicated in Figure 6-1 and Figure 6-2) includes both the original boat transect lines offshore of Maryland and these extension transects.

We conducted eight surveys per year on a scheduled basis as the weather allowed. Each survey was conducted during a 2-4 week window (Table 6-1); generally a survey was conducted at the earliest opportunity (based on weather) during each window. Surveys took 4 to 5 days to complete. Our surveys were conducted on a 55-foot charter vessel, the *Stormy Petrel II*, and were staffed with four observers who worked in teams of two. Surveys were run from Ocean City, Maryland, and Virginia Beach, Virginia (Figure 6-1). Surveys began at first daylight, once light enough for correct species identification. Survey speed was 10 knots unless weather conditions or boat traffic dictated otherwise. The boat returned in the evenings to overnight in port during surveys, with the exception of 7 nights which were spent offshore of Maryland and Virginia. Surveys were postponed due to foul weather, for safety reasons, at the discretion of the Captain.

Because of the narrow beam of the *Stormy Petrel II* and unobstructed view from the flying bridge, we recorded all birds seen on a 360° scan (Figure 6-3). Since most surveys were conducted in good weather, this method enabled us to scan both sides of the boat with ease and enabled extensive collection of "distance sampled" data. This was a fairly unusual situation for observations, however; on most survey vessels (and on the *Stormy Petrel II* in periods with high numbers of animals, where we could not accurately count all individuals in a full 360° scan) our protocol was to focus scanning efforts in a 90° arc within a 300 m strip to one side of the boat (Figure 6-3). The side of the vessel used for counts was noted in the data, so that it would be possible to separate observations within the area of primary focus from observations made in the remaining 270° degrees of visibility, if needed. The transect was surveyed continuously using the naked eye or binoculars. Observers regularly scanned ahead for marine mammals and diving birds, or for sitting birds that may have been flushed off the water. Animals within 300 m received priority for recording, though animals outside of the 300 m strip transect were also usually recorded.

One observer continuously scanned for birds, mammals, turtles, and fish, while the second recorded all observations into a Toughbook computer (Panasonic Corp. of North America, Newark, NJ) using the dLOG data entry program (Ford, 1999). Locations, date, and time were automatically recorded every 5 seconds and observations were individually georeferenced. At the beginning of each survey, the recorder entered sea state data using the Beaufort scale (Table 6-2), transect number, observer's initials, visibility, survey ID, station, and platform, changing each as needed throughout the survey (Table 6-3). The second observer/recorder also scanned ahead and to the horizon for marine mammals and sea turtles when possible. We used distance sampling under most conditions, recording distance and angle to every bird or flock of birds, but used the more restricted strip transect (width = 300 m) in areas of high bird density. We defined "high density" as being a greater number of birds in the area than the observers could keep track of, impeding the ability to count all birds present. For each animal, the team recorded: species, number seen, behavior, direction of movement, radial distance, degree of the animal's angle to the bow of the boat, and, where possible, age and molt state (see Table 6-3 for more details about data entry). Behavior codes were assigned based on the behavior initially displayed when the animal was first observed (Table 6-4). Four-letter codes were used to record species identification, as well as abiotic objects of interest such as boats or flotsam and jetsam (Table 6-5).

Animal movements were recorded in such a way as to allow for vector analysis (Spear et al., 1992). Radial distance was estimated from the observer to the animal or the center of a group of animals, based on the initial observation. Distance estimates were calibrated between observers using a handmade distance gauge (Gjerdrum et al., 2012) by estimating distances to stationary objects and were estimated as closely as possible (often to the nearest tens of meters for animals closer to the boat, and to the nearest 50 m for animals farther from the boat). The two teams of observers alternated every two hours. At the end of each day of surveying, all data were backed up on portable hard drives.

When weather deteriorated to the point that salt spray threatened the computer, observers moved inside the pilot house (Figure 6-3). Any changes in observer location were recorded in the data (Table 6-3). Although observing from the pilot house restricted the observer's field of vision, compared to observing from the bridge, observers were able to maintain complete view of the strip transect (300 m distance and 90˚ arc).

Environmental data were recorded during the surveys. Sea state and visibility were recorded hourly. Sea surface temperature and salinity were recorded every half hour, using a YSI Pro30 conductivity device (Yellow Springs, OH), with water drawn up from the ocean through the vessel's saltwater pump (located in the vessel's hull) into a bucket. These measurements were taken by off-duty observers to allow the active observers to maintain their positions. Biomass densities were recorded continuously using a Simrad EK60 scientific echo sounder (Kongsberg Maritime AS), employing a 120 kHz transducer. Echo sounding data were processed using Echoview (Myriax Software Pty, Ltd., Hobart, Australia) processing software (Chapter 8). When staying offshore overnight, a passive acoustic monitoring system was operated from the deck of the vessel to record flight calls of nocturnally migrating birds (Adams et al., 2015).

We photographed cetaceans, whenever possible, and submitted these for individual identification using the established North Atlantic Fin Whale[2] and North Atlantic Right Whale[3] catalogues. Surveys were conducted in passing mode, where the boat stayed on transect and at survey speed except when complying with National Marine Fisheries Service (NMFS) rules regarding approaching marine mammals, including rules on vessel speed and encounters with endangered North Atlantic Right Whales (*Eubalaena glacialis*). Surveys in passing mode have been shown to have reduced bias in estimated encounter rates of marine mammals, though they also have lower rates of species identification and poorer estimation for pod size (Barlow, 1997; Douglas et al., 2014). Our research group believed passing mode surveys to be the best method available to ensure that we obtained accurate counts for all other taxa.

Data were collected using methods allowing for vector analysis, or analysis of relative movement (Spear et al., 1992). Constantly counting flying birds can, in some situations, provide a measure of bird “flux” or an overestimation, rather than a true density of birds (Spear et al., 1992). Using the vector method, however, one can estimate the distance of an animal from the observer; the angle from the observer, and the direction of movement. If desired, these data can be combined with known average flight speeds for avian species to calculate a correction factor during data analysis and find absolute densities of flying birds.

Data from boat surveys were consolidated and subject to a quality assurance/quality control (QA/QC) process. Each day of data collection produced an individual .csv file. These data were compiled in Excel for each survey and examined for errors. Common adjustments made during this QA/QC process included: concatenation of split fields; correction of longitude values to make values negative; addition of temperature and salinity measurement fields and incorporation of those data into the table from the comment fields; and ensuring that sighting data were entered in to the correct columns and were checked for consistency. After the initial QA/QC process, data were entered in to an Access database. Data managers then added a unique ID field for each survey and for individual records within each survey, concatenated date and time fields, converted GMT to EST for actual track time, checked for and corrected errors in species codes used, and added taxonomic information for each observation (for full list of species codes and corresponding common and Latin names, see Table 6-5). Finally, the data were geoprocessed to check for locational errors and missing data points. Fully QA/QC’d data were entered in to the USGS Compendium of Avian Occurrence (O’Connell et al., 2009).

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[2] http://www.coa.edu/nafwc.htm

[3] http://rwcatalog.neaq.org/Terms.aspx

Literature cited

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.

Barlow, J., 1997. Preliminary estimates of cetacean abundance off California, Oregon, and Washington based on a 1996 ship survey and comparisons of passing and closing modes (No. LJ-97-11). Southwest Fisheries Science Center.

Douglas, A.B., Calambokidis, J., Munger, L.M., Soldevilla, M.S., Ferguson, M.C., Havron, A.M., Camacho, D.L., Campbell, G.S., Hildebrand, J.A., 2014. Seasonal distribution and abundance of cetaceans off southern California estimated from CalCOFI cruise data from 2004 to 2008. Fish. Bull. 112, 198–220.

Ford, R.G., 1999. dLOG: data entry and real-time mapping program. Software and documentation for integration of GPS location and observer data.

Gjerdrum, C., Fifield, D.A., Wilhelm, S.I., 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms, Canadian Wildlife Service Technical Report Series No. 515. Atlantic Region. vi + 37 pp.

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.

Spear, L., Nur, N., Ainley, D.G., 1992. Estimating absolute densities of flying seabirds using analyses of relative movement. Auk 109, 385–389.

Figures and tables

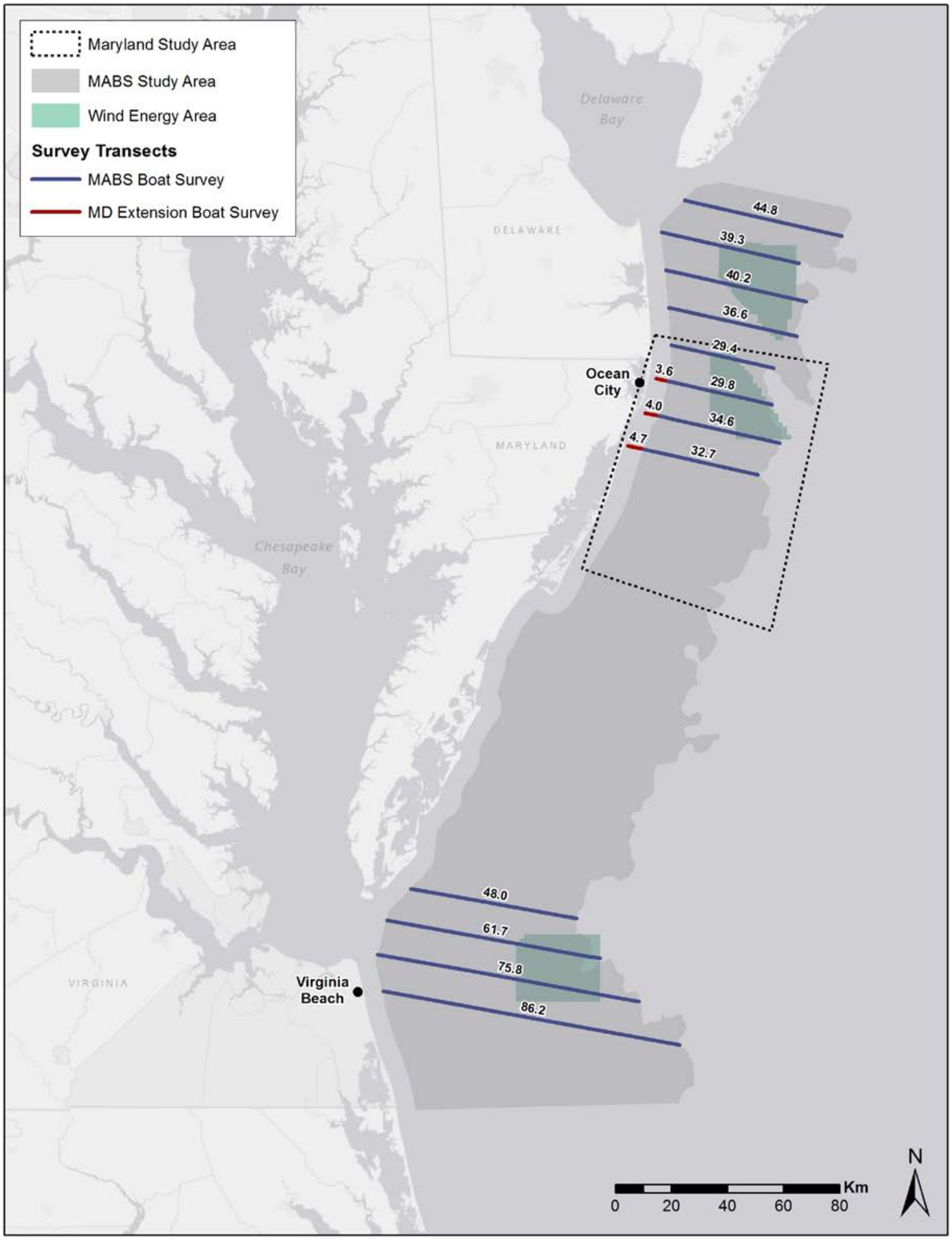

Figure 6-1. Boat survey map with transect length (km) indicated on each line. Mid-Atlantic Baseline Studies transects are shown in dark blue; Maryland Project transects are shown in lighter blue. Surveys were conducted out of Ocean City, MD and Virginia Beach, VA.

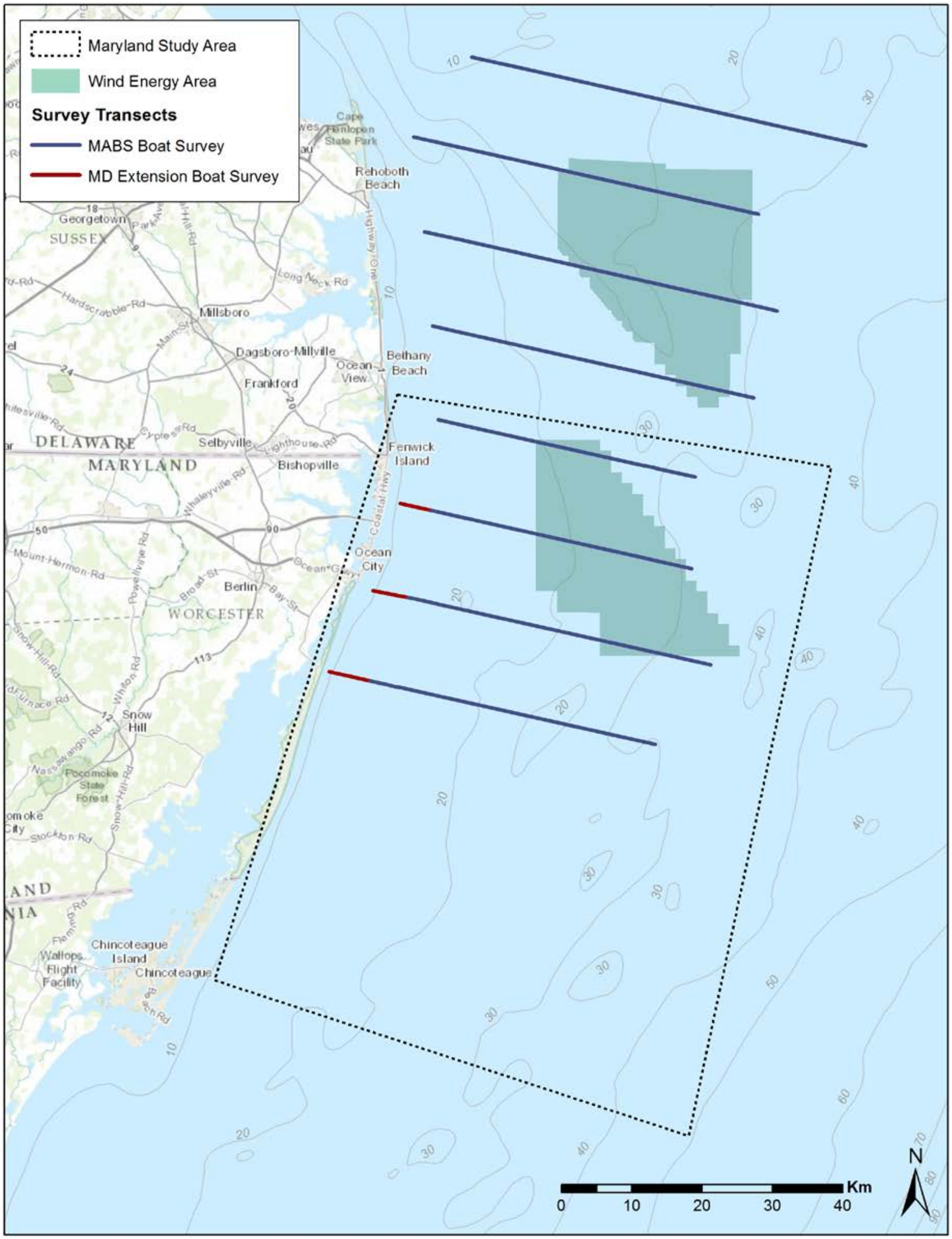

Figure 6-2. Detailed map of boat survey transects within the Maryland study area. Mid-Atlantic Baseline Studies transects are shown in dark blue; Maryland Project transects are shown in lighter blue.

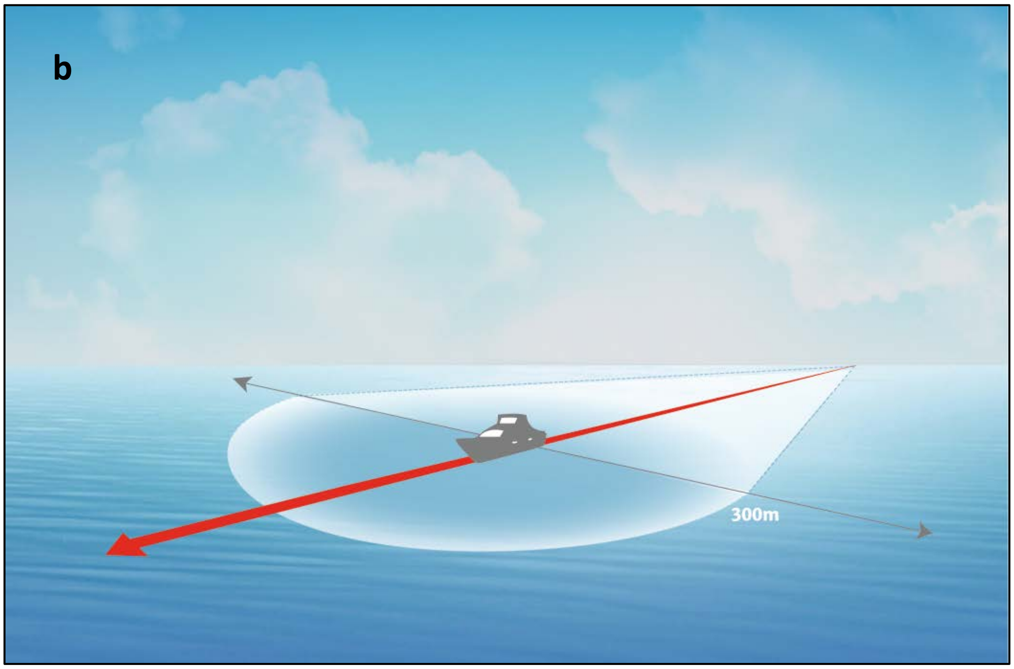

Figure 6-3. (a) Photograph of the Stormy Petrel with an observer surveying from the flying bridge, above the pilot house. (b) Diagram illustrating the field of view available during boat surveys. The boat transect has an intended minimum strip width of 300 m, although observations were made up to 1,000 m from the vessel. In most conditions, observers surveyed the full 360˚ from the flying bridge. In inclement weather (when surveying from within the pilot house), and when it was not possible to continuously survey the entire 360˚ arc, observers focused survey efforts within a 90˚arc on one side of the boat.

Table 6-1. Ideal schedule for boat surveys.

Survey Period	Timing for Boat Surveys
Early spring	Late March (into early April if needed)
Late spring	Early to mid-May
Early summer	June (pref. late June)
Late summer	Early August
Early fall	September (pref. early to mid-Sept.)
Late fall	October (pref. mid- to late Oct.)
Early winter	December (pref. mid-Dec.)
Late winter	Late Jan. or early Feb.

Table 6-2. Beaufort scale.

Beaufort Wind Force	Wind Speed (knots)	Sea state description	Beaufort wind force and description
0	0	Calm, mirror-like	Calm
1	1 – 3	Ripples with the appearance of scales are formed, but without foam crests.	Light air
2	4 – 6	Small wavelets, still short but more pronounced. Crests have glassy appearance and do not break.	Light breeze
3	7 – 10	Large wavelets. Crests begin to break. Foam of glassy appearance. Perhaps scattered white caps.	Gentle breeze
4	11 – 16	Small waves, becoming longer, fairly frequent white caps.	Moderate breeze
5	17 – 21	Moderate waves, taking a more pronounced long form; many white caps formed. Chance of some spray.	Fresh breeze
6	22 - 27	Large waves begin to form; the white foam crests are more extensive everywhere. Probably some spray.	Strong breeze
7	28 – 33	Sea heaps up and white foam from breaking waves begins to be blown in streaks along the direction of the wind.	Moderate gale
8	34 – 40	Moderate high waves of greater length; edges of crests begin to break into spindrift. The foam is blown in well-marked streaks along the direction of the wind.	Fresh gale
9	41 – 47	High waves. Dense streaks of foam along the direction of the wind. Crests of waves begin to topple, tumble and roll over. Spray may affect visibility.	Strong gale
10	48 – 55	Very high waves with long over-hanging crests. Foam blown in dense white streaks along the direction of the wind. Sea takes a white appearance. Visibility affected.	Whole gale
11	56 – 63	Exceptionally high waves (small and medium-sized ships might be for a time lost behind the waves). The sea is completely covered with long white patches of foam lying along the direction of the wind. Edges of the wave crests are blown in to froth. Visibility affected.	Storm
12	64 +	The air is filled with foam and spray. Sea completely white with driving spray; visibility very seriously affected.	Hurricane

Table 6-3. Data fields, descriptions, and examples for each field. All fields were required, unless noted otherwise in the description. Fields in italics were automatically entered by dLOG every 5 seconds. Fields in bold and italics were entered by the recorder at the start of the survey and changed when necessary (i.e., sea state changes, observers switch). Fields in bold were entered by the recorder when entering a record for a sighting, temperature and salinity readings, or other notes.

Field	Description	Example
Latitude	GPS-entered Latitude	36.944967
Longitude	GPS-entered Longitude	-75.93854
Hour	GPS-entered Hour	11
Minute	GPS-entered Minute	8
Second	GPS-entered Second	0
Year	GPS-entered Year	2013
Month	GPS-entered Date - Month	3
Day	GPS-entered Date - Day	20
Type	Notes whether data are entered by user or by computer. “GPS” data are entered by the computer every 5 seconds from the built in GPS. When a user enters a sighting or any other information this field is coded as USER.	USER
Spp	Four letter species code (See Table 6-5 for details). Also includes codes for boats and other items of interest.	HERG
Count	Number of animals seen.	2
Behavior	Add one word describing animal's behavior. Field is not locked. Common behaviors are described in Table 6-4 below.	FLYING
Direction	Optional. Direction of movement. Possible options are N, NE, E, SE, S, SW, W, or NW. Not applicable for birds that are milling, feeding, or sitting, or for other animals that are stationary.	N
Distance	Radial distance from the observer to the animal or the center of the group of animals. This distance is based on the observer’s estimate, calibrated to other observers. Estimate based on the first instance you see the animal. Distance estimate is rounded to the nearest 50 or 100 m, unless the animal is within 50 meters of the boat and a more accurate estimate is possible.	100
Degree	The animal’s location in degrees from the bow of the boat. The bow is 0°, one quarter around towards the starboard is 90°, directly off the stern is 180°, and three quarters around off of port is 270°. Estimate is based on the first instance that you see the animal, and is rounded to the nearest 10°.	350
Plumage	Optional. Describe the stage of the bird’s molt, whether it is a light or dark morph bird, or the gannet plumage type.	PRIMARY MOLT
Age	Optional. Adult, Immature, or Juvenile - or go in to more detail about the bird’s age (e.g., 1S for a first summer gull).	2W
Comment	Optional. Any additional comments about the sighting. Also use this field for temperature and salinity measurements or any notes as needed.	WITH GBBG
Beaufort	Approximate description of the current sea state using the Beaufort Scale (see Table 6-2). Update every hour.	3
Transect	Transect number. If recording between transects use T11 – T12 to indicate which transects you are moving between. Update at the start and end of each transect.	T11
Obs	Observer’s three initials. Update every time the observer changes.	ETB
Visib	Visibility. Options are 5 = 5 miles plus, 4= 3-5 miles, 3= 1-3 miles, 2= 500 m-1 mile; 1 = 300-500 m visibility. Update as visibility changes.	5
SurveyID	ID code for the survey taking place. Remains the same throughout the survey.	DOEMARCH2013

Field	Description	Example
	Use the formula DOE(MONTH)(YEAR) as in DOEFEB2013.	
Station	Report which side of the boat the observer is standing on using PORT or STARBOARD. Update when the observer changes sides.	STARBOARD
Platform	Name of the vessel used for surveys. On the *Stormy Petrel II*, we conduct surveys on the flying bridge. If weather conditions deteriorate and observers must go inside the pilot house, indicate that by changing the platform to ONBRIDGE and make a note explaining the change in location. If you return to the flying bridge make a note and change back to STORMYPET	STORMYPET

Table 6-4. Common behavior codes. Codes apply to an animal's initial behavior when first observed.

Behavior	Description
FLYING	Bird or bat is flying – indicate flight direction
MILLING	Not flying in any specific direction but circling around above the water. This can indicate birds in a feeding flock.
SITTING	Bird sitting on the water. If sitting on an object use this code and make a note saying what it is on.
DIVING	Animal at the surface dives under water.
TAKING OFF	Bird taking off from the water.
FEEDING	Active feeding behaviors observed.
PLUNGE DIVING	Specific to birds that feed by plunge diving (e.g., gannets, terns, shearwaters, gulls)
PATTERING	Flying low and hitting the water's surface with feet, mainly storm-petrels
FOLLOWING	Bird following the boat. This code is used when a bird has already been counted, but continues to follow along with the boat.
STATIONARY	Non-avian animal stationary in the water.
SWIMMING	Non-avian animal swimming – indicate direction of movement.
PORPOISING	Marine mammal moving through the water like a porpoise, up and down through the water.
BREACHING	Whale rising up and breaking through the surface of the water and splashing back down into the water.
BLOWING	Whale blowing from its spout at the surface.
DEAD	Dead animal.

Table 6-5. Boat survey species code list for the Mid-Atlantic Baseline Studies and Maryland Projects. Codes are listed in alphabetical order of common name.

Species Code	Common Name	Latin Name
ALGA	Algal bloom	
ABDU	American Black Duck	*Anas rubripes*
AMCO	American Coot	*Fulica americana*
AMPI	American Pipit	*Anthus rubescens*
AMRE	American Redstart	*Setophaga ruticilla*
AMRO	American Robin	*Turdus migratorius*
HOCR	Atlantic Horseshoe Crab	*Limulus polyphemus*
ATPU	Atlantic Puffin	*Fratercula arctica*
ASDO	Atlantic Spotted Dolphin	*Stenella frontalis*
AUSH	Audubon's Shearwater	*Puffinus lherminieri*
BAIT	bait ball	
BAEA	Bald Eagle	*Haliaeetus leucocephalus*
BALN	balloon	
BARS	Barn Swallow	*Hirundo rustica*
BLSC	Black Scoter	*Melanitta nigra*
BLSK	Black Skimmer	*Rynchops niger*
BLTE	Black Tern	*Chlidonias niger*
BLVU	Black Vulture	*Coragyps atratus*
BLKI	Black-legged Kittiwake	*Rissa tridactyla*
BLPW	Blackpoll Warbler	*Dendroica striata*
BTBW	Black-throated Blue Warbler	*Dendroica caerulescens*
BOAC	boat--aircraft carrier	
BOBA	boat--barge/barge and tug	
BOCA	Boat--cargo	
BOCF	Boat--commercial fishing	
BOCS	boat--container ship	
BOCR	boat--cruise	
BOFI	boat--fishing	
BOPL	boat--pleasure	
BORF	boat--recreational fishing	
BORV	boat--research vessel	
BOSA	boat--sail	
BOSU	boat--submarine	
BOTA	boat--tanker	
BOTD	boat--trawler/dragger	
BOAT	Boat--unidentified	
BOGU	Bonaparte's Gull	*Larus philadelphia*
BODO	Bottlenose Dolphin	*Tursiops truncatus*

Species Code	Common Name	Latin Name
BRAN	Brant	*Branta bernicla*
BRPE	Brown Pelican	*Pelecanus occidentalis*
BHCO	Brown-headed Cowbird	*Molothrus ater*
BUFF	Bufflehead	*Bucephala albeola*
CANG	Canada Goose	*Branta canadensis*
CATE	Caspian Tern	*Sterna caspia*
CEDW	Cedar Waxwing	*Bombycilla cedrorum*
CHAN	Change in personnel, station, transect, etc.	
CODO	Common Dolphin	*Delphinus delphis*
COGO	Common Goldeneye	*Bucephala clangula*
COLO	Common Loon	*Gavia immer*
COMU	Common Murre	*Uria aalge*
COTE	Common Tern	*Sterna hirundo*
COSH	Cory's Shearwater	*Calonectris diomedea*
DASC	Dark scoter - either black scoter or surf scoter	
DEJU	Dark-eyed Junco	*Junco hyemalis*
DCCO	Double-crested Cormorant	*Phalacrocorax auritus*
DOVE	Dovekie	*Alle alle*
DUNL	Dunlin	*Calidris alpina*
FIWH	Fin Whale	*Balaenoptera physalus*
FLJE	flotsam and jetsam	
FOTE	Forster's Tern	*Sterna forsteri*
GLGU	Glaucous Gull	*Larus hyperboreus*
GCKI	Golden-crowned Kinglet	*Regulus satrapa*
GBBG	Great Black-backed Gull	*Larus marinus*
GBHE	Great Blue Heron	*Ardea herodias*
GREG	Great Egret	*Ardea alba*
GRSH	Greater Shearwater	*Puffinus gravis*
GRHE	Green Heron	*Butorides Virescens*
GWTE	Green-winged Teal	*Anas crecca*
HERG	Herring gull	*Larus argentatus*
HOGR	Horned Grebe	*Podiceps auritus*
HUWH	Humpback Whale	*Megaptera novaeangliae*
LAGU	Laughing Gull	*Larus atricilla*
LESA	Least Sandpiper	*Calidris minutilla*
LETE	Least Tern	*Sterna antillarum*
LETU	Leatherback Turtle	*Dermochelys coriacea*
LBBG	Lesser Black-backed Gull	*Larus fuscus*

Species Code	Common Name	Latin Name
LEYE	Lesser Yellowlegs	*Tringa flavipes*
LIGU	Little Gull	*Larus minutus*
LOTU	Loggerhead Turtle	*Caretta caretta*
LTDU	Long-tailed Duck	*Clangula hyemalis*
MALL	Mallard	*Anas platyrhynchos*
MASH	Manx Shearwater	*Puffinus puffinus*
MERL	Merlin	*Falco columbarius*
MIWH	Minke Whale	*Balaenoptera acutorostrata*
MOON	Moon Jellyfish	*Aurelia aurita*
MOWA	Mourning Warbler	*Oporornis philadelphia*
MYWA	Myrtle Warbler	*Dendroica c. coronata*
NONE	none	
NOFL	Northern Flicker	*Colaptes auratus*
NOFU	Northern Fulmar	*Fulmarus glacialis*
NOGA	Northern Gannet	*Morus bassanus*
NOHA	Northern Harrier	*Circus cyaneus*
NOWA	Northern Waterthrush	*Seiurus noveboracensis*
NOTE	note	
MOLA	Ocean Sunfish (Mola)	*Mola mola*
OSPR	Osprey	*Pandion haliaetus*
PAWA	Palm Warbler	*Dendroica palmarum*
PAJA	Parasitic Jaeger	*Stercorarius parasiticus*
POJA	Pomarine Jaeger	*Stercorarius pomarinus*
PONY	Pony	
PMOW	Portuguese Man o' War	*Physalia physalis*
PUMA	Purple Martin	*Progne subis*
RAZO	Razorbill	*Alca torda*
REBA	Red Bat	*Lasiurus borealis*
REPH	Red Phalarope	*Phalaropus fulicaria*
RBME	Red-breasted Merganser	*Mergus serrator*
RBNU	Red-breasted Nuthatch	*Sitta canadensis*
RNGR	Red-necked Grebe	*Podiceps grisegena*
RNPH	Red-necked Phalarope	*Phalaropus lobatus*
RTLO	Red-throated Loon	*Gavia stellata*
RWBL	Red-winged Blackbird	*Agelaius phoeniceus*
RIWH	Right Whale	*Eubalaena glacialis*
RBGU	Ring-billed Gull	*Larus delawarensis*
ROST	Roseate Tern	*Sterna dougallii*
ROYT	Royal Tern	*Sterna maxima*
RCKI	Ruby-crowned Kinglet	*Regulus calendula*

Species Code	Common Name	Latin Name
RUTU	Ruddy Turnstone	*Arenaria interpres*
SAGU	Sabine's Gull	*Xema sabini*
SAND	Sanderling	*Calidris alba*
SEWH	Sei Whale	*Balaenoptera borealis*
SEPL	Semipalmated Plover	*Charadrius semipalmatus*
SESA	Semipalmated Sandpiper	*Calidris pusilla*
SBDO	Short-billed Dowitcher	*Limnodromus griseus*
SMTU	Small turtle - Loggerhead, Green, Hawksbill, or Kemp's Ridley	
SOSP	Song Sparrow	*Melospiza melodia*
SOSH	Sooty Shearwater	*Puffinus griseus*
SUBU	Sulfur Butterfly spp.	*Coliadinae spp.*
SUSC	Surf Scoter	*Melanitta perspicillata*
TEWA	Tennessee Warbler	*Vermivora peregrina*
TBMU	Thick-billed Murre	*Uria lomvia*
TRAN	transect point (such as temperature/salinity values)	
TRES	Tree Swallow	*Tachycineta bicolor*
UNAL	Unidentified Alcid	*Alcidae spp.*
BUMB	Unidentified Bee	
UNBI	Unidentified Bird	*Aves*
UBUT	Unidentified Butterfly	
UNCO	Unidentified Cormorant	*Phalacrocorax spp*
UNDO	Unidentified Dolphin	*Unidentified Delphinidae*
UNDU	Unidentified Duck	
UNEI	Unidentified Eider	*Somateria spp.*
FISH	Unidentified Fish	*Osteichthyes*
UFFI	Unidentified Flying Fish	*Exocoetidae spp.*
UFOB	Unidentified flying object (animal-origin)	
UNGU	Unidentified Gull	
UNHU	Unidentified Hummingbird	
UNJA	Unidentified Jaeger	*Stercorarius spp.*
UNJE	Unidentified Jellyfish	*Scyphozoa spp.*
UNLA	Unidentified Large Alcid (Razorbill or Murre)	
UNLG	Unidentified Large Gull	
UNLW	Unidentified Large Whale	*Cetacea spp.*
UNLO	Unidentified Loon	*Gavia spp.*
UNMM	Unidentified Marine Mammal	*Mammalia*

Species Code	Common Name	Latin Name
UNPA	Unidentified Passerine	
PEEP	Unidentified Peep	
UNPH	Unidentified Phalarope	*Phalaropus spp.*
UNRA	Unidentified Ray	*Rajiformes spp.*
SCAU	Unidentified Scaup	*Aythya marila or A. affinis*
UNSC	Unidentified Scoter	*Melanitta spp.*
TURT	Unidentified Sea Turtle	
UNSH	Unidentified Shearwater	*Procellariidae spp.*
SHOR	Unidentified Shorebird	
UNSK	Unidentified Skua	*Stercorarius spp.*
UNSA	Unidentified Small Alcid (Puffin/Dovekie)	*Alle alle/Fratercula arctica*
UNSS	Unidentified Small Shearwater (Audubon's, Manx, or Little)	*Puffinus lherminieri , P. puffinus, or P. assimilis*
SPAR	Unidentified Sparrow	*Emberizidae spp.*
UNSP	Unidentified Storm-petrel	
SWAL	Unidentified Swallow	*Hirundinidae spp.*
TEAL	Unidentified Teal	
UNTE	Unidentified Tern	*Sterna spp.*
THSH	Unidentified Thresher Shark	
UNWA	Unidentified Warbler	
UNWH	Unidentified Whale	*Cetacea spp.*
UNKN	unknown	
WHIM	Whimbrel	*Numenius phaeopus*
WRSA	White-rumped Sandpiper	*Calidris fuscicollis*
WWSC	White-winged Scoter	*Melanitta fusca*
WILL	Willet	*Catoptrophorus semipalmatus*
WIPL	Wilson's Plover	*Charadrius wilsonia*
WISP	Wilson's Storm-petrel	*Oceanites oceanicus*
WODU	Wood Duck	*Aix sponsa*

Chapter 7: Summary of boat survey data

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

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Chapter 7 Highlights

Results from boat-based survey data collected in the Maryland study area.

Context[1]

Standardized boat-based surveys are widely used to obtain density data for birds, sea turtles, and marine mammals. Chapter 6 describes the standardized protocol used to collect data. This chapter describes the basic results of the boat surveys, including counts of various species and groups, and a discussion of identification rates. Chapter 8 describes the methods used to collect data on relative biomass of aquatic prey below the study vessel, using a scientific echo sounder that was deployed on all surveys. Chapter 9 uses data presented here in hierarchical Bayesian statistical approaches to estimate abundances and distribution patterns of seabirds in relation to habitat variables, while correcting for certain biases associated with boat methodologies (e.g., distance bias). Part IV of this report (Chapters 10-14) combines data from boat-based surveys with data from digital video aerial survey approaches to develop a more comprehensive understanding of marine wildlife populations that use the Mid-Atlantic and Maryland study areas.

Study goal/objectives addressed in this chapter

Summarize animal distribution and abundance data that were collected in the Maryland study area using a well-known and widely used survey method.

Highlights

- There were 10,078 animals observed over two years of surveys; most of the animals were birds (over 9,700) though there were aquatic animals observed as well.
- The highest counts of animals occurred in February, October, and November.
- The most abundant animals observed were gulls and terns (*Laridae* spp., 33% of the data).
- Other abundant or commonly observed animals included several species of scoters (*Melanitta* spp.), Northern Gannets (*Morus bassanus*), loons (*Gavia* spp.), and dolphins (*Odontoceti*).
- Rates of identification of animals to species were high for most animals, with the exception of scoters.

Implications

Boat-based surveys are a well-established means to collect distribution and abundance data for marine animals, and the study design used for these surveys may have been particularly useful for monitoring many species of birds. Many taxa were readily identified using this method, though there were few aquatic animals observed relative to birds.

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[1] For more detailed context for this chapter, please see the introduction to Part III of this report.

Abstract

Information on bird, sea turtle, and marine mammal movements and abundance was collected from a boat platform using a standardized protocol. Between 2012 and 2014, 16 surveys were conducted along twelve transect lines that focused on three offshore Wind Energy Areas (WEAs) in the Mid-Atlantic U.S.; data from four of these 12 transects, located offshore of Maryland, are summarized here. A total of 10,078 animals were observed on the survey, including over 9,700 birds and 300 aquatic animals in a cumulative 2,607 km of transects. The most animals were observed in February, October, and November, when large flocks of wintering birds were present in the study area. Gulls and Terns (*Laridae*) were the most abundant animal, making up 33% of observations, and were primarily Laughing Gulls (*Leucophaeus atricilla*) and Bonaparte's Gulls (*Choicocephalus philadelphia*). Scoters (*Melanitta* spp.) were the next most abundant animal group, at 25% of observations. Northern Gannets (*Morus bassanus*), loons (*Gavia* spp.), and auks (*Alcidae* spp.) were also commonly observed. Smaller numbers of aquatic animals such as dolphins, sea turtles, and baleen whales were observed. Rare observations included two Roseate Terns (*Sterna dougallii*), three Minke Whales (*Balaenoptera acutorostrata*), and one Humpback Whale (*Megaptera novaeangliae*). Most animals were successfully identified to species, save for scoters, which were often observed in large flocks at some distance from the vessel. More in-depth analyses of the boat survey data can be found in subsequent chapters in this report.

Introduction

In terms of major geographic features, the marine environment of Maryland is dominated by the massive and highly productive Chesapeake Bay, but Maryland also has a significant swath of oceanic waters off its eastern shore. These offshore waters lie centrally within the broader Mid-Atlantic region, and support a high level of productivity. As such, Mid-Atlantic is an extremely important area for a broad range of marine wildlife species throughout the year. Some species breed in the area, such as coastal birds and sea turtles, while others visit from the southern hemisphere in their non-breeding season, such as shearwaters. In the fall, many summer residents migrate south to breed or winter in warmer climes, and they are replaced by species that have travelled south from their northern breeding grounds to winter in the Mid-Atlantic. Additionally, many pelagic, coastal, and terrestrial species make annual migrations up and down the eastern seaboard and travel directly through the Mid-Atlantic region in spring and fall. Thus, many species use or funnel through the Mid-Atlantic region each year, resulting in a complex ecosystem where community composition is constantly shifting, and the temporal and geographic patterns are highly variable.

In this study, we aimed to produce the baseline data required to inform siting and permitting processes for offshore wind energy development in the Mid-Atlantic. We collected information on bird, sea turtle, and marine mammal abundance and movements over a two-year period (2012-2014) using a variety of technologies and methods to examine spatial patterns and trends. Standardized boat-based surveys are a widely used method of estimating densities for coastal and marine birds, sea turtles, and marine mammals (Gjerdrum et al., 2012; Tasker et al., 1984), and are a key part of the Department of Energy-funded Mid-Atlantic Baseline Studies (MABS) project and state-funded Maryland Project. We conducted boat surveys for wildlife within the MABS and Maryland study areas on the Outer Continental Shelf to accompany and compare with the data from simultaneously conducted digital aerial surveys (for more information on aerial surveys, and for analyses synthesizing boat and aerial datasets, see Parts II and IV of this report).

The broader MABS study area encompasses the coastal area from Delaware to Virginia, extending from 3 nautical miles from the coastline out to the 30 m isobath or the eastern extent of the Wind Energy Areas (WEAs) (Figure 7-1). Maryland funded an expansion of the study area and extended three of the original DOE aerial and boat survey transects in the Maryland WEA west into Maryland's state waters (Figure 7-1). In this report, we include all transect lines that fall within the extended state boundaries for Maryland, including those funded by the Department of Energy (Figure 7-1). Here, we examine the boat survey results for the Maryland study area in detail, including discussion of observation rates and species identification rates.

Methods

Between April 2012 and April 2014, project partners conducted sixteen large-scale boat based visual surveys (Table 7-1) across the MABS study area along 12 transect lines that focused on three offshore WEAs (total transect length = 559 km, Figure 7-1). Details on survey design for our boat surveys can be found in Chapter 6. In the second year of surveys (March 2013-January 2014), the western ends of three survey lines off of Maryland were extended into state waters (total transect length = 571 km, Figure 7-1). Data presented here include boat survey observations from all four transect lines off of Maryland (Figure 7-1).

This chapter presents summaries of raw count data from the boat surveys on a monthly, seasonal, and annual basis. We also discuss identification rates for the most common species groups. Chapter 9 presents additional analyses of the boat survey data, and Chapters 10-14 present additional information comparing the results of digital aerial and boat-based survey results, and integrating data from both survey platforms in in-depth analyses of wildlife distributions and relative abundances.

Results

A total of 10,078 animals were observed in the sixteen surveys in the Maryland study area, including over 9,700 birds and 353 aquatic animals (including cetaceans, sea turtles, sharks, and fish; Appendix 7A). At least 61 species of birds and 6 species of aquatic animals are represented in this dataset. Seventy-seven percent of animals observed in the study were identified to species level; most unidentified animals were scoters, with an approximately 91% identification rate excluding this taxon. The greatest numbers of animals were observed in February, October, and November, when large flocks of marine birds were in the study area (Table 7-2). It should be noted that data collected between the two years are not entirely compatible, as the study area was slightly different between the two years, and exact timing of surveys can have a huge effect on species counts, particularly in migration periods when large numbers of wintering birds could be moving in or out of the study area, and a week's difference in survey dates could affect overall abundance observed.

Relative abundance of counts

Birds

Gulls and terns (Laridae) were observed throughout the year (Figure 7-6) and were the most abundant animal group (33% of all data; Table 7-2). Laughing Gull (*Leucophaeus atricilla*) was the most abundant gull (11% overall), and was present in the study area from the spring, summer, and fall. Bonaparte's Gull (*Choicocephalus philadelphia)* was the next most common gull species observed (6.7% overall), and was most abundant in the winter months (Appendix 7A). Great Black-backed Gulls (*Larus Marinus*; 3.3%) and Herring Gulls (*L. smithsonianus,* 3.0%) were observed consistently throughout the year in almost every survey, but with peaks in abundance in the fall. Four other gull species were also observed in smaller numbers. Common Terns (*Sterna hirundo*) were abundant in several of the surveys, and present through the spring and fall (2.4%). Two federally endangered Roseate Terns (*Sterna dougallii*) were observed feeding May 9, 2013. Five other tern species were observed in the study area. There were approximately the expected number of gulls and terns observed in the study, given the proportion of the study area included in the Maryland surveys (Figure 7-3).

Scoters, a genus of sea ducks that in the Mid-Atlantic includes Black Scoter (*Melanitta americana*), White-winged Scoter (*M. fusca*), and Surf Scoter (*M. perspicillata*), were the next most abundant avian taxonomic group observed in the boat surveys (Figure 7-2), constituting 25% of the observations. Scoters were mostly in the region from the winter into the early spring, from December through April (Figure 7-6). Six other species of anatids (ducks and geese) were observed in the study area (Appendix 7A). There were many fewer scoters observed within the Maryland transects than expected based on the relative size of the Maryland study area to the MABS study area, and the high numbers of scoters observed within the MABS study area (Figure 7-3).

Northern Gannets (*Morus bassanus*) were the next most abundant bird observed (18% of all data; Figure 7-2), and were most common in the winter to early spring, with the highest numbers observed in the fall (Figure 7-6). Fewer Northern Gannets than expected were observed in the Maryland study area (Figure 7-3).

Other avian taxa observed in boat surveys included loons (Gaviidae), auks (Alcidae), storm-petrels (Hydrobatidae), shearwaters and fulmars (Procellariidae), shorebirds (Charadriiformes), and landbirds (Passeriformes). Loons made up 13% of all observations and were observed mostly in the winter and spring (Figure 7-4), with the highest number of loons observed in January of 2014. Common Loons (*Gavia immer*) were observed more frequently than Red-throated Loons (*G. stellata*; Figure 7-8). Auks were observed in the winter and early spring (Figure 7-6). Razorbills (*Alca torda*; 2.1%) were the most abundant, followed by Dovekies (*Alle alle*; 1.9%). Wilson's Storm-Petrels (*Oceanites oceanicus*) were observed in the study during summer surveys (1.5%). Six species of shorebirds and five species of procellarids were observed; procellarids were mostly Cory's Shearwater (*Calonectris diomedea*; 0.17%). Only three species of landbirds were observed in the study, many fewer than in the MABS area (21 species).

Aquatic animals

Dolphins were the most common non-avian animal group observed (Figure 7-4), with Bottlenose Dolphins (*Tursiops truncates*) the most abundant (2.4%); they were observed predominantly in warmer months (Figure 7-7). Fewer Common Dolphins (*Dellphinus delphis*) were observed (0.26%; Figure 7-9). Large whales were also observed in the study in winter (Figure 7-7), including three Minke Whales (*Balaenoptera acutorostrata*) and one Humpback Whale (*Megaptera novaeangliae*). Dolphins were mostly identified to species, but there were four sightings of unidentified whales (Figure 7-9). Two species of sea turtles were observed in the summertime (0.20%, Appendix 7A). Of the two species observed, Loggerhead Turtles (*Caretta caretta*) were the most common (0.15%), and Leatherback Turtles (*Dermochelys coriacea*) were less common (0.03%).

Identification rates

Identification rates for the Maryland study area were similar to the broader MABS project area (Figure 7-10). The bulk of the scoters (67%) were unidentified to the species level, but those identified were predominantly Surf Scoters and Black Scoters (4.6% and 2.7% respectively; Figure 7-8). Scoters were often observed in large flocks, some far from the boat, which led to lower levels of identification (for additional discussion of this topic, see Williams et al., 2015). Identification rates for other avian species were fairly high; most gull and tern observations were made to the species level (87%), as were 89% of alcids and 93% of loons (Figure 7-8). Toothed whales were primarily identified to species (90%), most commonly Bottlenose Dolphins (Figure 7-9). Larger whales were identified to species 50% of the time, and Minke Whales were the most commonly identified, but the “passing mode” in which surveys were conducted prevented accurate species identification and probably accurate estimation of group sizes for cetaceans in some cases (see Chapters 6 and 12 for more information). Sea turtles were almost always identified to species (90%), and most were Loggerhead Sea Turtles.

Discussion

The most abundant animals observed in the boat-based surveys were gulls, scoters, Northern Gannets, and loons, which is similar to the high resolution digital video aerial surveys (Chapter 5). One notable difference between the results of the two study methods was the number of aquatic animals observed relative to the number of animals observed overall; a much higher number of aquatic animals were seen from the digital video aerial study, likely in part as a result of the differences between the observers’ perspectives. However, the boat observers’ perspective looking forward from the survey vessel (Chapter 6) appeared to provide an excellent means to spot distant large birds (e.g., Northern Gannets, shearwaters), large flocks of birds (e.g., scoters), the spouts and surfaced body parts of large whales, and pods of dolphins. Further examination of the differences in results from the two survey methods may be found in Chapter 10.

Rates of identification to species level were quite high for boat surveys, especially for avian groups. The notable exception was scoters, likely because many large flocks of scoters were visible at great distances from the boat, and were called either unidentified scoters (*Melanitta* spp.) or “dark scoters” (Black Scoter or Surf Scoter). The ability to see large flocks of birds at a great distance may be an advantage of boat surveys, but depending on the taxon, identifications to species level may be difficult in these cases. Even closely related species often have differences in their conservation status, ecology, and habitat requirements, so obtaining species-specific information on distributions, abundance, and habitat use is often important for identifying potential conflicts with anthropogenic activities in the marine environment.

Many of the subsequent chapters in Parts III and IV of this report use modeling approaches to investigate the distribution and abundance data from the boat-based surveys (including Chapters 9 and 12-14). These methods estimate detection as well as abundance, which helps correct for various types of observation bias, including distance bias, where observers are less likely to see animals located farther from the survey transect (Gardner et al., 2008; Spear et al., 2004). These methods can also incorporate environmental covariates into the model structure, in order to predict animal distributions and abundance on a broader geographic scale than where surveys were actually conducted.

Estimating spatial patterns in relative abundance in the offshore environment can be difficult, as these systems are extremely dynamic, animals tend to show high degrees of spatial autocorrelation or aggregative behaviors, and surveys are logistically challenging and more expensive than terrestrial equivalents. In the past century, offshore surveys have mostly been carried out by direct visual observation of wildlife from boats (or aircraft). Standardized methods using strip or line transects are common for monitoring marine species on boat-based surveys (Camphuysen and Garthe, 2004; Camphuysen et al., 2004; Gjerdrum et al., 2012; Tasker et al., 1984), and have been refined over the last few decades to achieve more accurate estimates of population size (Buckland et al., 2001, 1993; Evans and Hammond, 2004; Kaschner et al., 2012). These survey results 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 several ways. These data can inform the siting of future projects, and can also be used to inform the permitting process for projects, by contributing data towards National Environmental Protection Act (NEPA) and other regulatory requirements, and by helping to define target taxa or research priorities on which to focus on during site-specific pre- and post-construction monitoring studies. Detailed baseline survey data can also inform mitigation efforts, by presenting temporal data on community composition, distributions, and abundance that can be used to time certain activities to coincide with reduced potential for exposure of key populations.

Literature cited

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 1993. Distance sampling: estimating abundance of biological populations. Chapman and Hall, London, UK.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L., Thomas, L., 2001. Introduction to Distance Sampling: Estimating abundance of Biological Populations. Oxford University Press, Oxford, UK.

Camphuysen, C., Garthe, S., 2004. Recording Foraging Seabirds at Sea Standardised Recording and Coding of Foraging Behaviour and Multi Species Foraging Associations. Atl. Seabirds 6, 1–32.

Camphuysen, K.C.J., Fox, T.A.D., Leopold, M.M.F., Petersen, I.K., 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K., COWRIE - BAM - 02-2002. Royal Netherlands Institute for Sea Research, Texel, Netherlands.

Evans, P.G.H., Hammond, P.S., 2004. Monitoring cetaceans in European waters. Mamm. Rev. 34, 131–156. doi:10.1046/j.0305-1838.2003.00027.x

Gardner, B., Sullivan, P.J., Epperly, S., Morreale, S.J., 2008. Hierarchical modeling of bycatch rates of sea turtles in the western North Atlantic. Endanger. Species Res. 5, 279–289. doi:10.3354/esr00105

Gjerdrum, C., Fifield, D.A., Wilhelm, S.I., 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms, Canadian Wildlife Service Technical Report Series No. 515. Atlantic Region. vi + 37 pp.

Kaschner, K., Quick, N.J., Jewell, R., Williams, R., Harris, C.M., 2012. Global Coverage of Cetacean Line-Transect Surveys: Status Quo, Data Gaps and Future Challenges. PLoS One 7. doi:10.1371/journal.pone.0044075

Spear, L.B., Ainley, D.G., Hardesty, B.D., Howell, S.N.G., Webb, S.W., 2004. Reducing biases affecting at-sea surveys of seabirds: Use of multiple observer teams. Mar. Ornithol. 32, 147–157.

Tasker, M.L., Jones, P.H., Dixon, T., Blake, B.F., 1984. Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardized approach. Auk 101, 567–577. doi:10.2307/4086610

Williams, K., Stenhouse, I., Adams, E., Connelly, E., Gilbert, A., Duron, M., 2015. 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 Program, Award Number: DE-EE0005362. BRI ID# 2015-11. Biodiversity Research Institute, Portland, ME.

Figures and tables

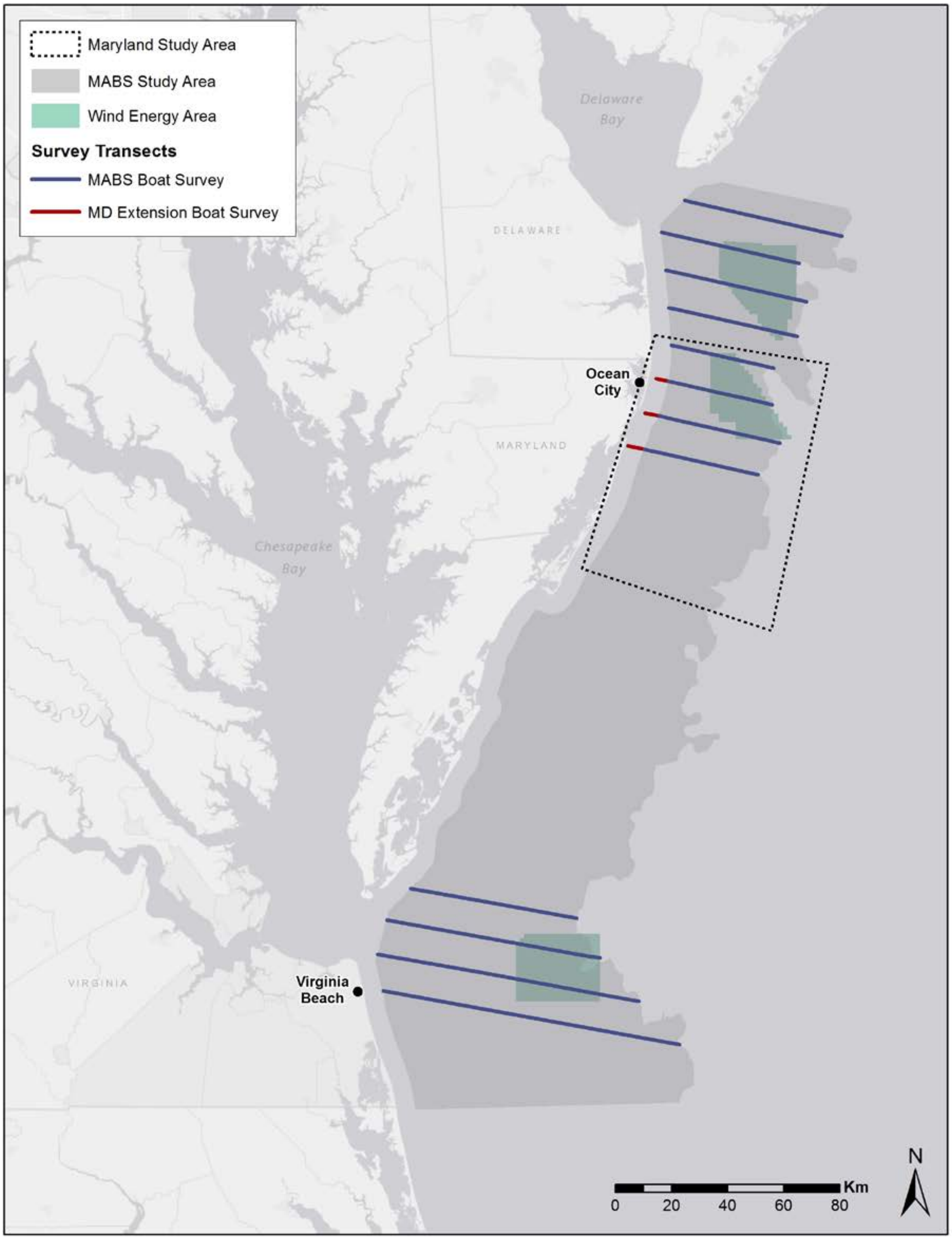

Figure 7-1. Map of boat survey transects for the Mid-Atlantic Baseline Studies and Maryland Projects. Lines in dark blue are part of the Mid-Atlantic Baseline Studies, and lines in dark red indicate the Maryland transects. See Chapter 5 for more details.

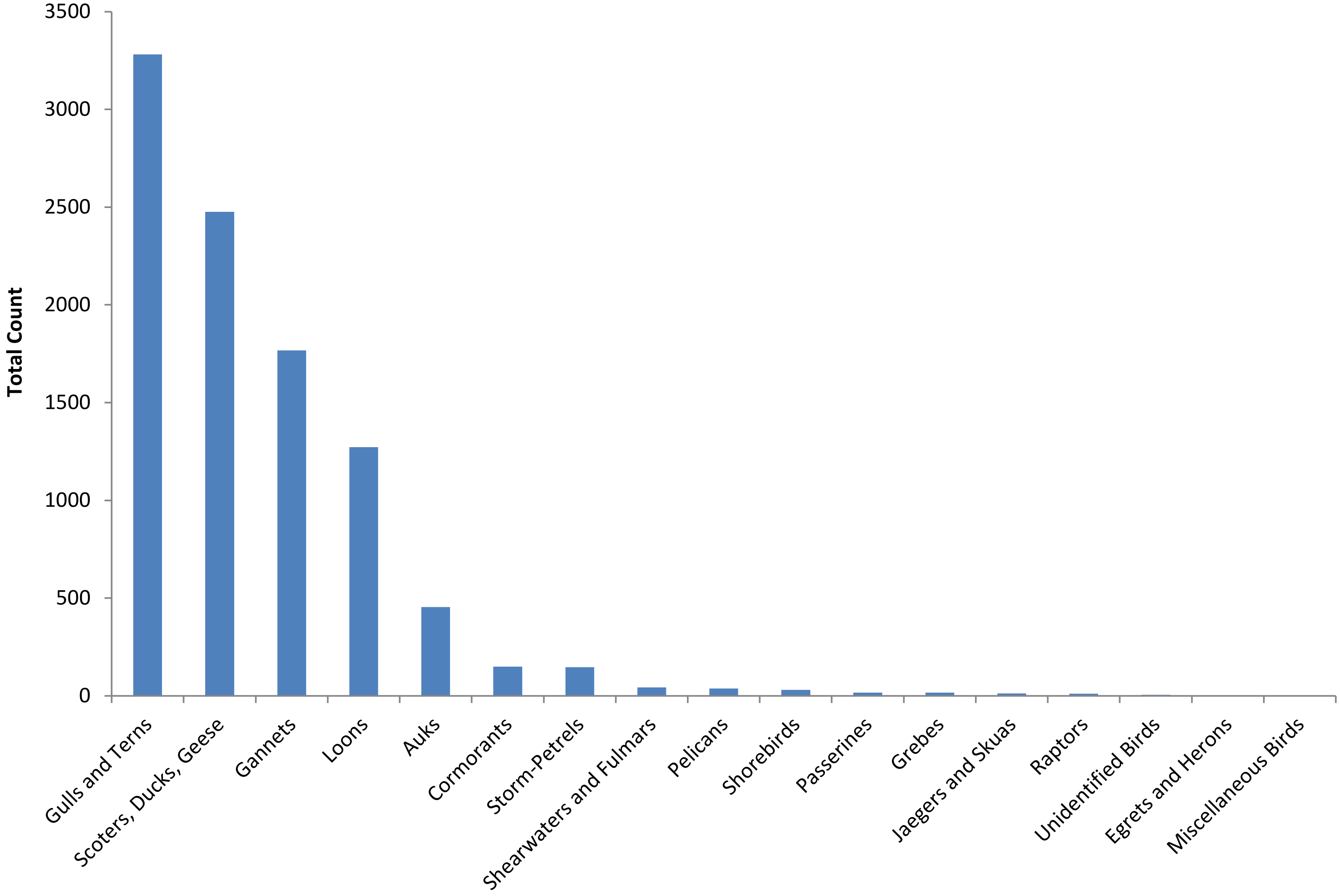

Figure 7-2. Avian observations from April 2012-April 2014 boat surveys within the Maryland study area by species group. “Miscellaneous birds” are coots. “Unidentified birds” were not identified to species or to a specific avian taxonomic group.

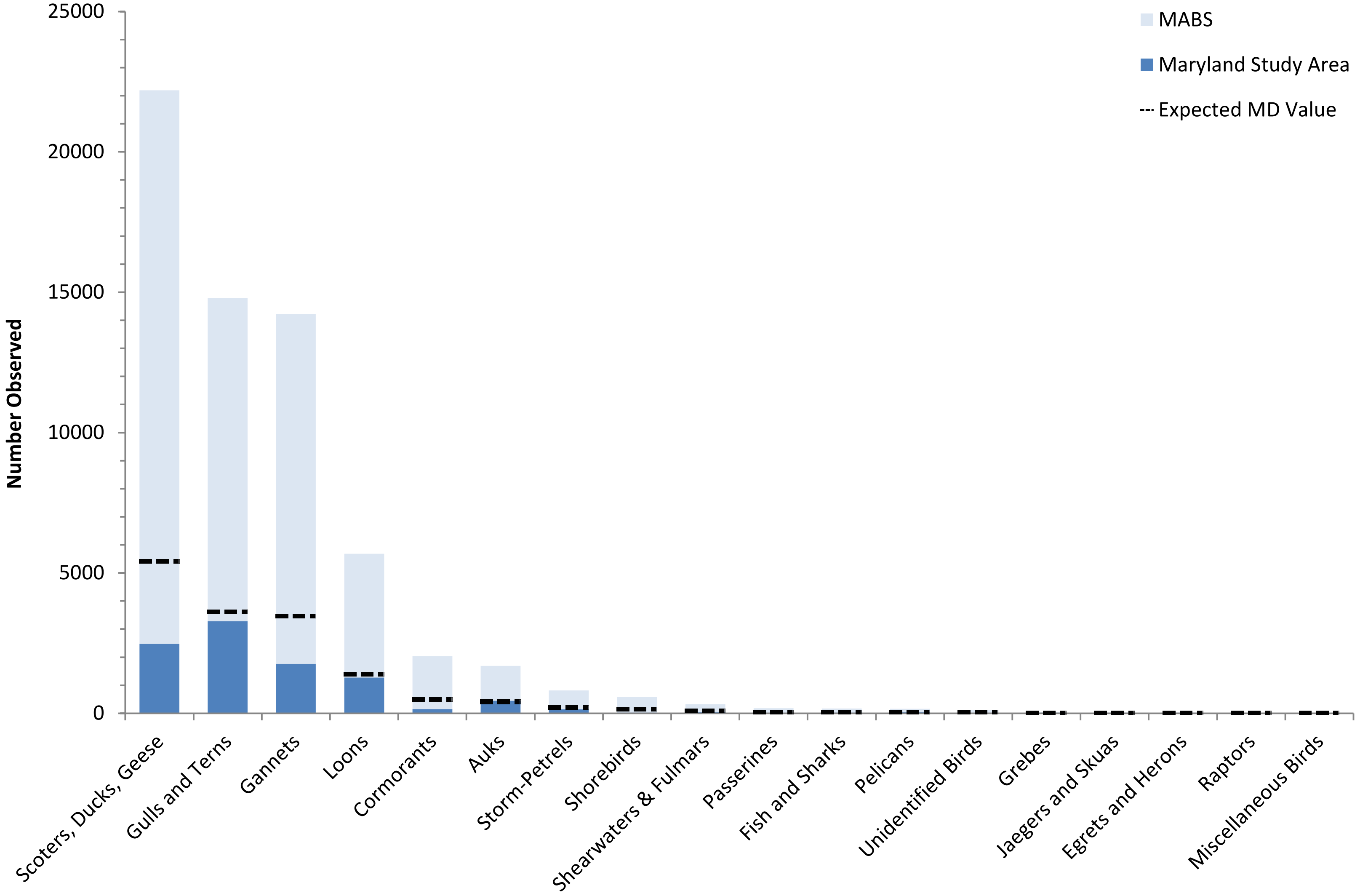

Figure 7-3. Birds observed in the Maryland study area and the Mid-Atlantic Baseline Studies project area (Figure 7-1). The expected number of animals given the proportion of the study area covered in the Maryland project area (24%) is shown for each bird group using a dashed line.

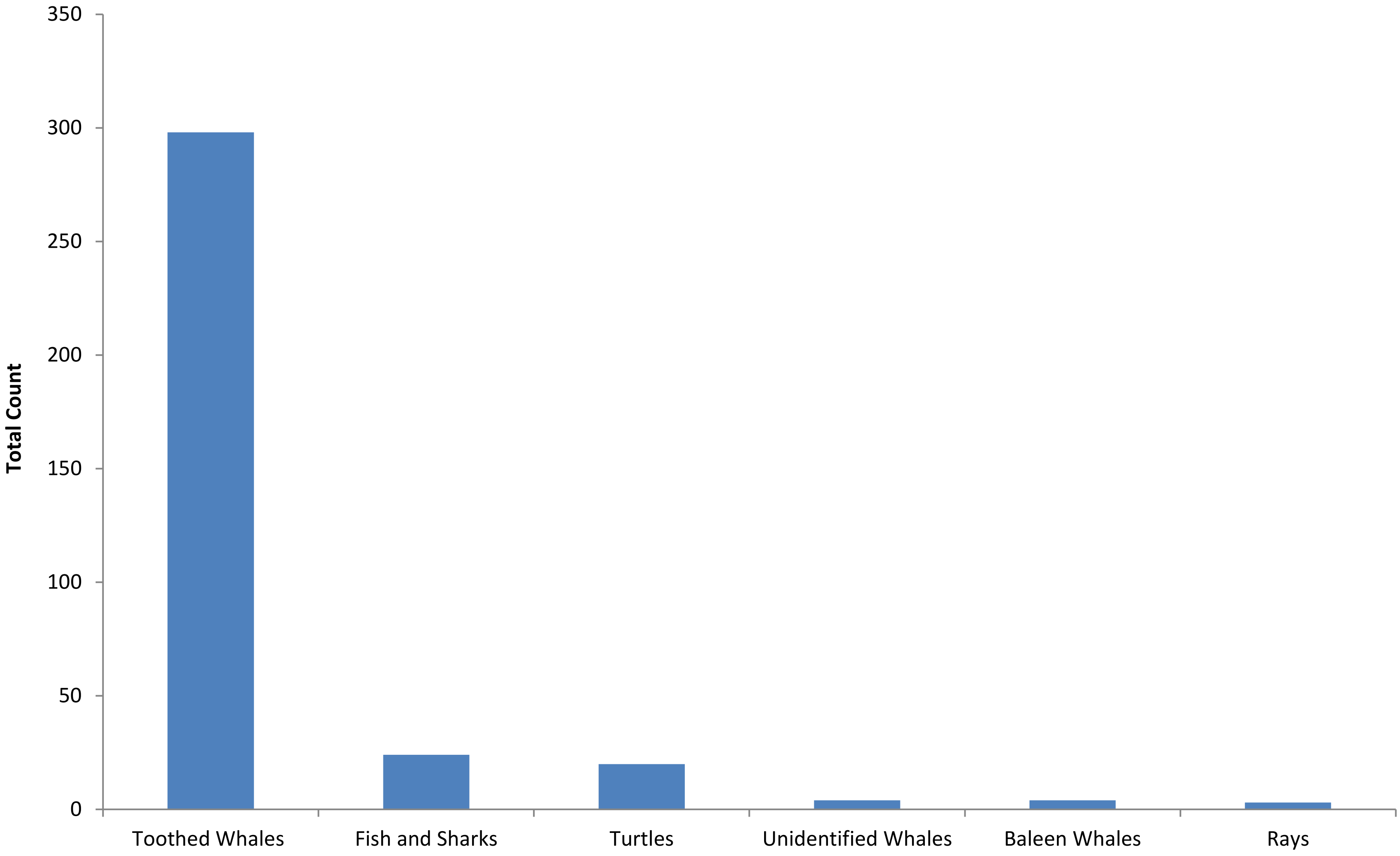

Figure 7-4. Observations of aquatic animals and bats from April 2012-April 2014 boat surveys within the Maryland study area by species group. Schools of fish were excluded from this figure.

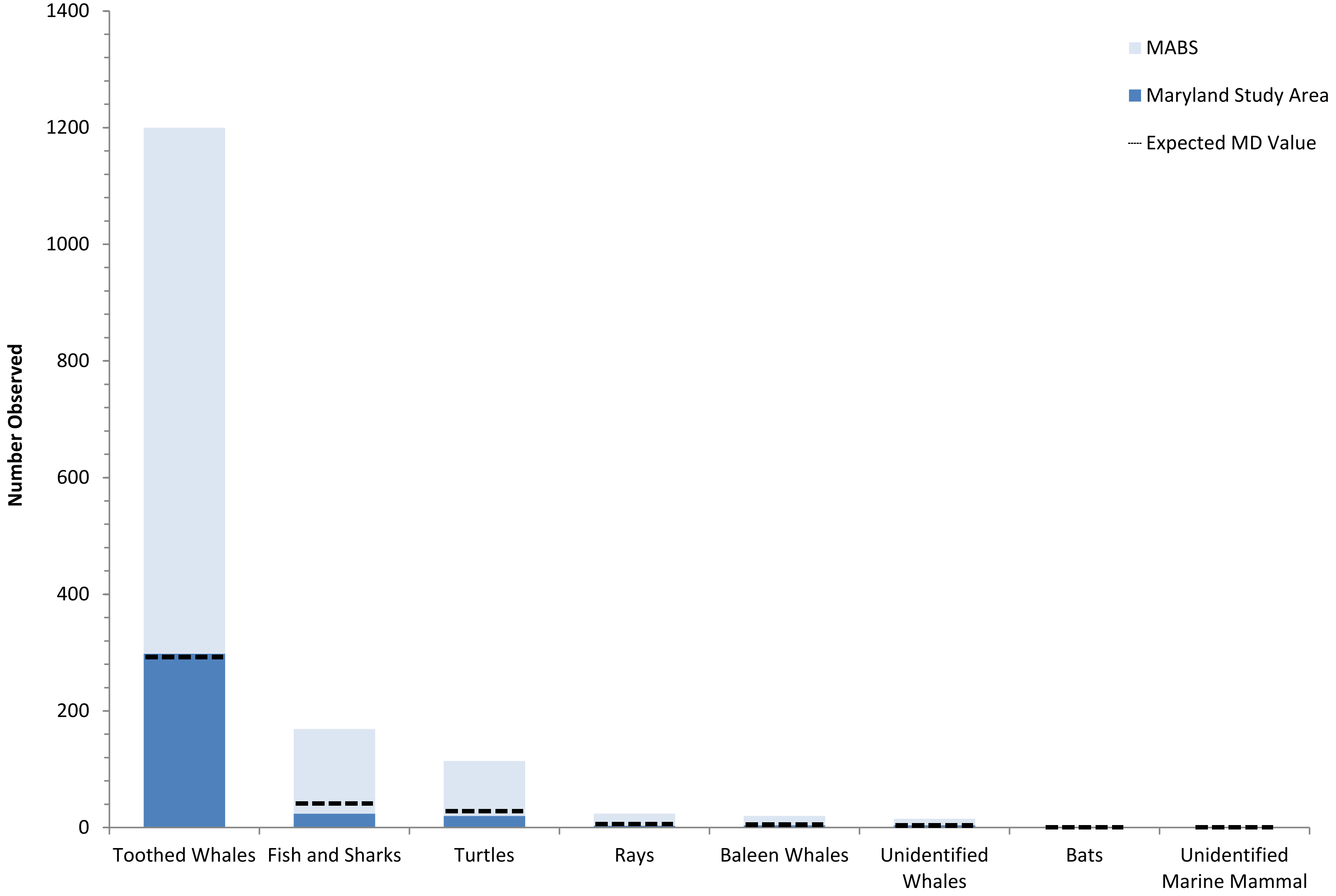

Figure 7-5. Aquatic animals observed in the Maryland study area and the Mid-Atlantic Baseline Studies project area (Figure 7-1). The expected number of animals given the proportion of the study area covered in the Maryland project area (24%) is shown for each group using a dashed line.

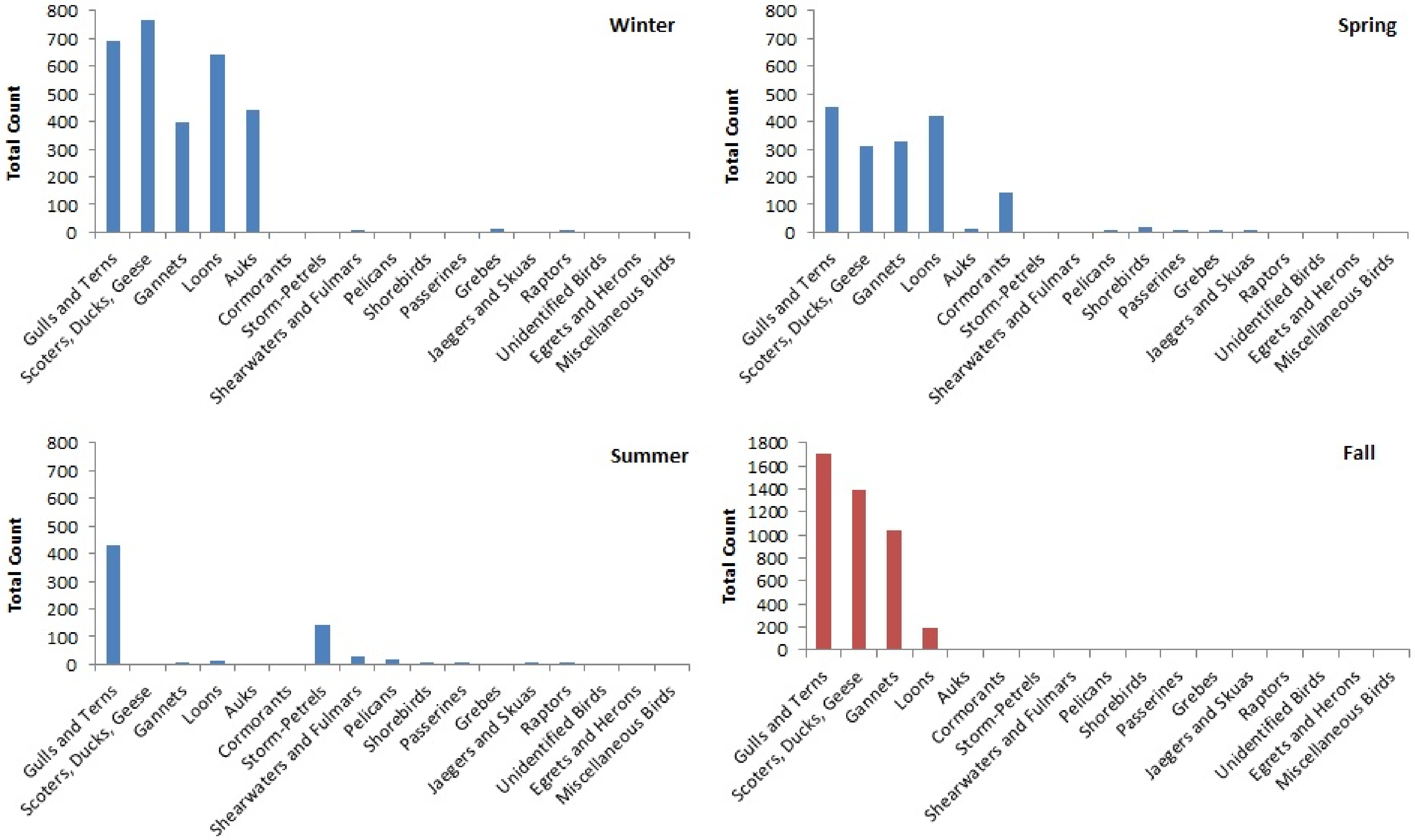

Figure 7-6. Abundance of birds by family or group in boat surveys in winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November) within the Maryland study area. Note different y-axis between the first three graphs the last. X-axes are in order of overall abundance by family or group across all surveys.

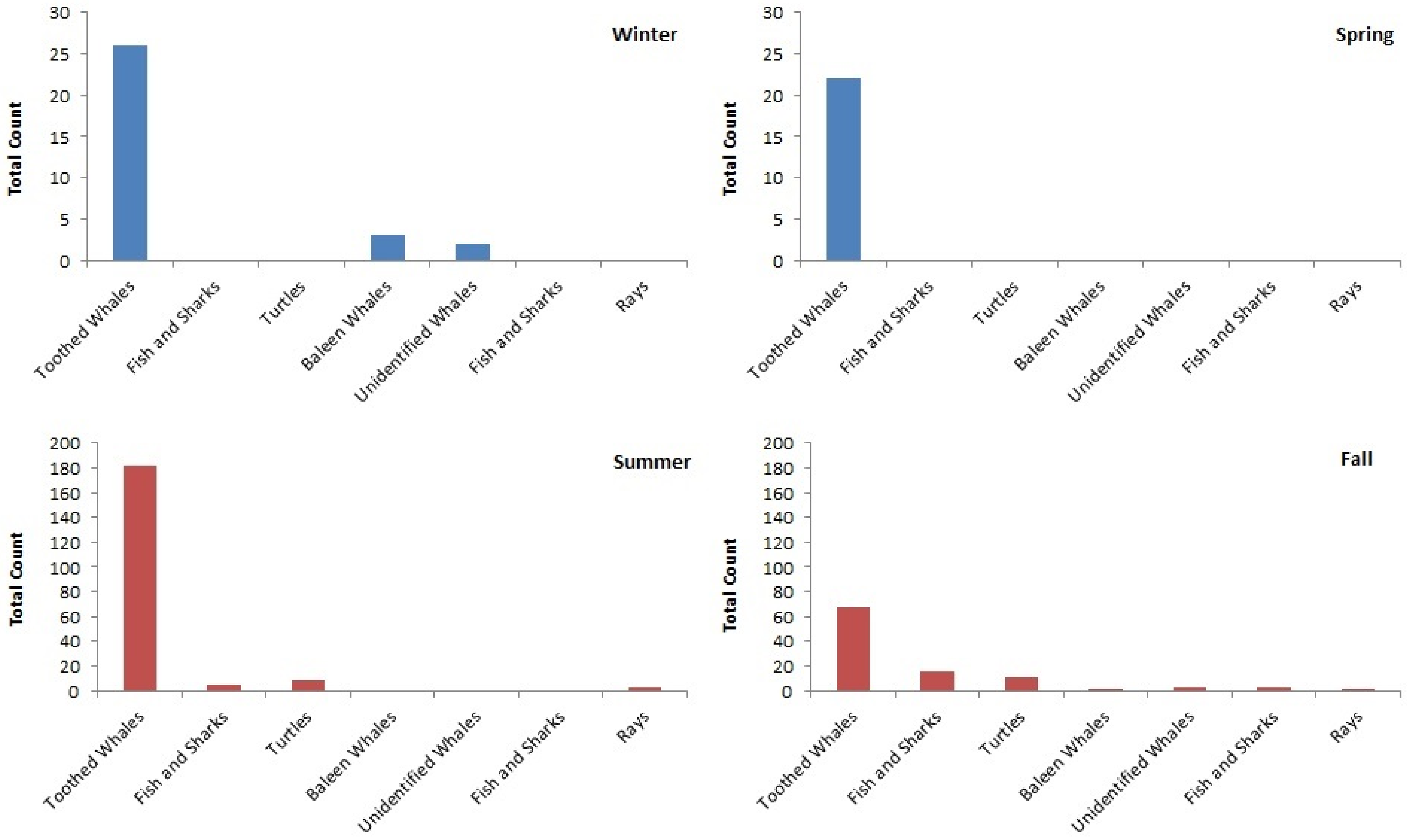

Figure 7-7. Abundance of non-avian animals by family or group in boat surveys in winter (December, January, February), spring (March, April, May), summer (June, July, August), and fall (September, October, November) within the Maryland study area. Note different y-axis between the top and bottom graphs. X-axes are in order of overall abundance by family or group across all surveys.

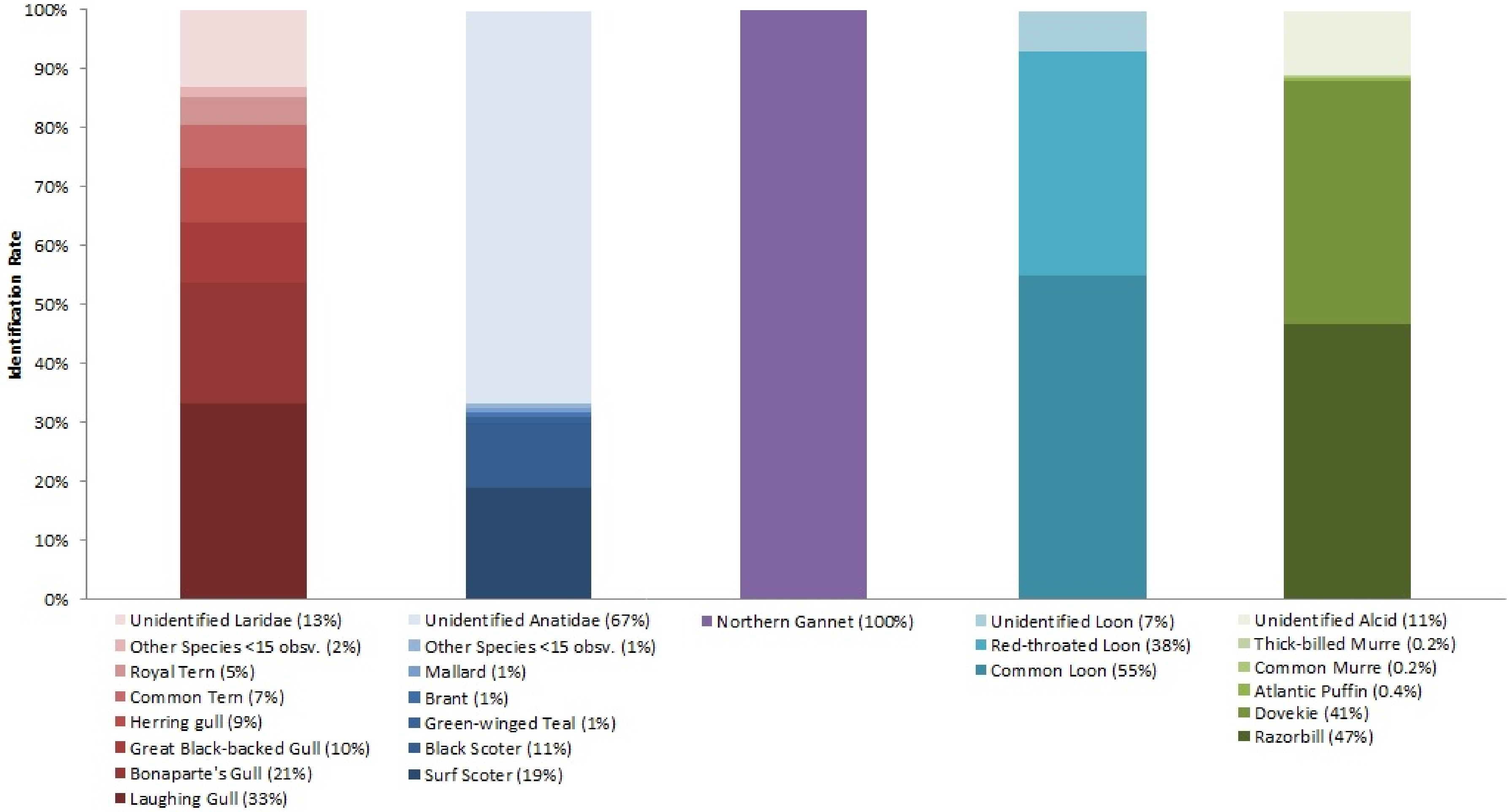

Figure 7-8. Identification rates of the most common bird groups observed in the Maryland study area boat survey data. “Other species” in the Laridae (red, n=3281) and Anatidate (blue, n=2476) can be found in Appendix 7A. Sample sizes for gannets, loons, and auks are 1767, 1272, and 454 respectively.

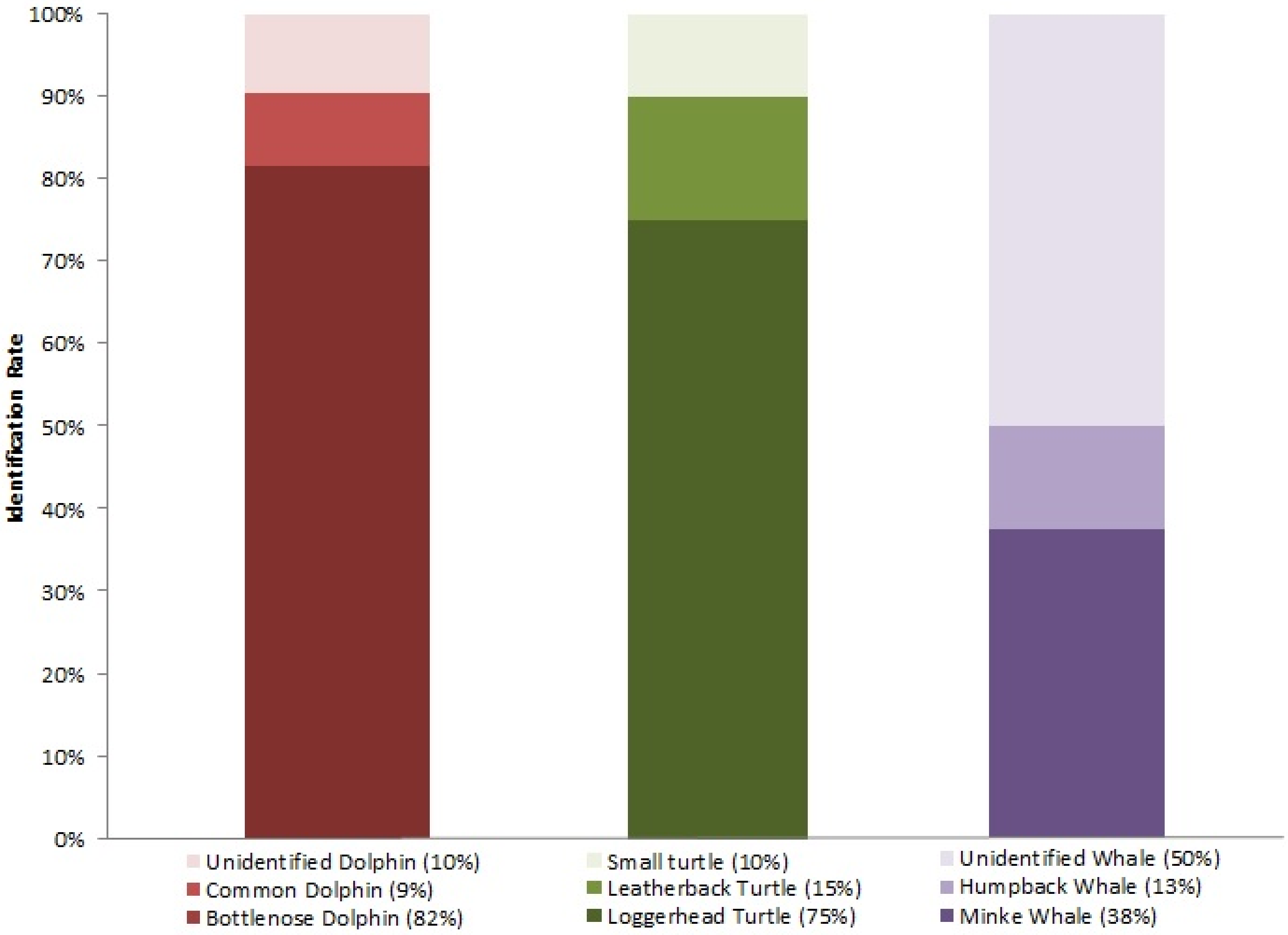

Figure 7-9. Identification rate of aquatic animal groups observed in the Maryland study area boat study data. Sample sizes for dolphins, turtles, and whales are 298, 20, and 8 respectively.

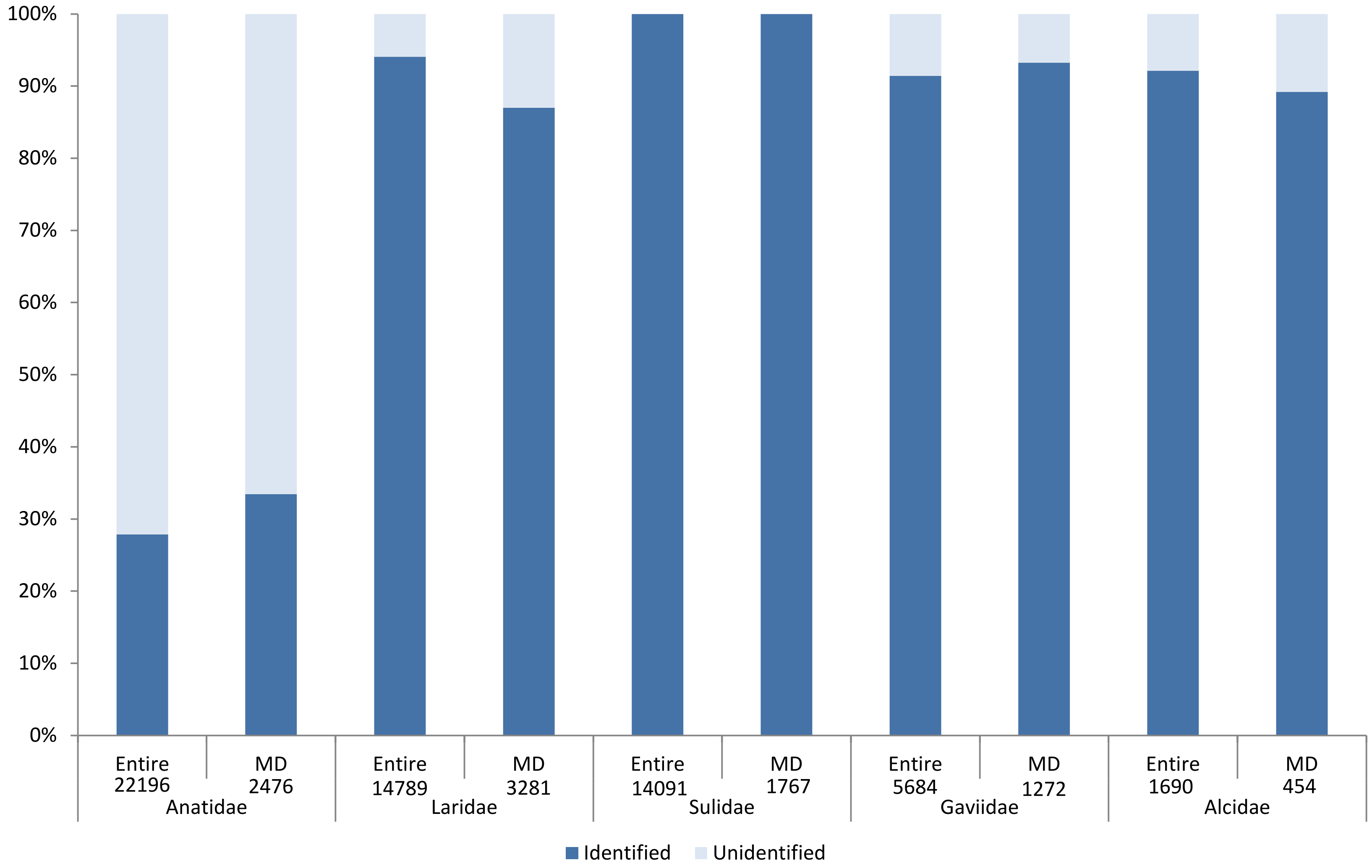

Figure 7-10. Rates birds were identified to the species level for the five most abundant avian groups from the Mid-Atlantic Baseline Studies and Maryland Projects (Entire) and the Maryland Study Area specifically (MD). The total number of birds in each category is given below the bar.

Table 7-1. Weeks in which boat surveys were completed during the Mid-Atlantic Baseline Studies and Maryland Projects. Each survey took from one to five days to complete, depending upon weather, ship availability, and other factors. Surveys colored in gray only included Mid-Atlantic Baseline Studies transects; surveys in blue also included Maryland Project transects.

	Jan.				Feb.				Mar.				Apr.				May				Jun.				Jul.				Aug.				Sep.				Oct.				Nov.				Dec.			
2012																▨							▨							▨			▨	▨							▨	▨					▨	
2013	▨			▨	▨						🟦	🟦					🟦	🟦					🟦					🟦	🟦					🟦						🟦						🟦	🟦	
2014				🟦	🟦								▨																																			

Table 7-2. Summary data for April 2012-April 2014 Maryland study area boat surveys (by species group). Data are presented in order of abundance based on the total counts from all Maryland surveys. Grey survey headings and totals include only the original MABS transect lines that fall within the Maryland study area, while surveys in blue include the Maryland Project transects in addition to the MABS transect lines.

Animal Group	**Apr. 2012**	**Jun. 2012**	**Aug. 2012**	**Sep. 2012**	**Nov. 2012**	**Dec. 2012**	**Jan. 2013**	**Mar. 2013**	**May. 2013**	**Jun. 2013**	**Aug. 2013**	**Sep. 2013**	**Oct. 2013**	**Dec. 2013**	**Jan. 2014**	**Apr. 2014**	**Grand Total**	**% of Total**
Gulls and Terns (Laridae)	76	75	79	112	509	56	44	61	249	101	176	230	855	529	64	65	3281	**32.56%**
Scoters, Ducks, Geese (Anatidae)	0	0	0	20	143	33	29	222	75	0	0	0	1235	97	608	14	2476	**24.57%**
Gannets (Sulidae)	48	1	0	0	509	34	176	107	15	0	0	0	528	83	107	159	1767	**17.53%**
Loons (Gaviidae)	81	4	0	0	181	23	56	63	102	9	0	0	18	175	389	171	1272	**12.62%**
Auks (Alcidae)	0	0	0	0	0	56	234	12	0	0	0	0	0	5	146	1	454	**4.50%**
Cormorants (Phalacrocoracidae)	0	0	0	0	0	0	0	0	142	0	0	0	7	0	0	0	149	**1.48%**
Storm-Petrels (Hydrobatidae)	0	26	53	2	0	0	0	0	0	33	33	0	0	0	0	0	147	**1.46%**
Shearwaters and Fulmars (Procellariidae)	0	2	0	0	1	0	0	0	0	26	2	0	6	0	6	0	43	**0.43%**
Pelicans (Pelecanidae)	0	5	0	6	0	0	0	0	1	2	13	4	6	0	0	0	37	**0.37%**
Shorebirds (Charadriiformes spp.)	1	0	1	5	0	0	0	0	18	0	4	2	0	0	0	0	31	**0.31%**
Grebes (Podicipedidae)	1	1	0	1	3	0	0	0	2	0	7	0	1	0	0	1	17	**0.17%**
Passerines (Passeriformes spp.)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	15	1	16	**0.16%**
Jaegers and Skuas (Stercorariidae)	5	0	0	0	2	0	0	0	1	2	0	0	3	0	0	0	13	**0.13%**
Raptors (Pandionidae, Falconidae, and	0	3	0	1	0	0	0	0	0	1	0	4	1	1	0	0	11	**0.11%**

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
Accipitridae)																		
Unidentified Birds (Aves spp.)	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	6	**0.06%**
Egrets and Herons (Ardeidae)	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	**0.03%**
Miscellaneous Birds	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	**0.02%**
Total Birds	**212**	**117**	**133**	**153**	**1349**	**202**	**539**	**465**	**605**	**174**	**235**	**240**	**2664**	**890**	**1335**	**412**	**9725**	**96.50%**
Toothed Whales	19	93	15	15	0	8	6	2	1	9	65	1	52	0	12	0	298	**2.96%**
Fish and Sharks	0	5	0	0	1	0	0	0	0	0	0	0	18	0	0	0	24	**0.24%**
Turtles (Testudines)	0	1	2	2	2	0	0	0	0	4	2	1	6	0	0	0	20	**0.20%**
Unidentified Whale (Cetacea)	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	4	**0.04%**
Baleen Whales (Mysticeti)	0	0	0	0	1	0	2	0	0	0	0	0	0	1	0	0	4	**0.04%**
Rays (Batoidea)	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	**0.03%**
Non-Avian Total	**19**	**101**	**17**	**18**	**6**	**9**	**9**	**2**	**1**	**13**	**67**	**2**	**76**	**1**	**12**	**0**	**353**	**3.50%**
Grand Total	**231**	**218**	**150**	**171**	**1355**	**211**	**548**	**467**	**606**	**187**	**302**	**242**	**2740**	**891**	**1347**	**412**	**10078**	**100.00%**

Supplementary material

Appendix 7A. Animals observed during the Maryland study area boat surveys.

Table 7A-1. Animals observed during the Maryland study area boat surveys. Data are presented in order of abundance by family, based on the total count from all surveys, with avian species first. Grey survey headings and totals include only the original MABS transect lines that fall within the study area, while surveys in blue include the Maryland Project transects in addition to the MABS transect lines.

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
Laughing Gull	22	40	61	32	100	0	0	2	13	51	115	90	558	3	0	1	1088	**10.80%**
Bonaparte's Gull	5	0	0	0	318	13	0	1	1	0	0	0	0	292	12	34	676	**6.71%**
Great Black-backed Gull	0	14	0	2	27	28	33	29	16	3	15	17	113	18	17	2	334	**3.31%**
Unidentified Gull	0	0	0	26	15	4	0	4	73	1	0	1	5	193	6	2	330	**3.27%**
Herring gull	17	1	0	3	32	9	10	25	21	5	0	2	114	16	19	24	298	**2.96%**
Common Tern	19	13	4	15	8	0	0	0	107	18	12	47	0	0	0	0	243	**2.41%**
Royal Tern	9	3	12	23	0	0	0	0	2	19	34	47	4	0	0	0	153	**1.52%**
Unidentified Tern	2	4	0	5	3	0	0	0	9	0	0	19	55	0	0	0	97	**0.96%**
Black-legged Kittiwake	0	0	0	0	2	1	1	0	0	0	0	0	1	2	5	0	12	**0.12%**
Ring-billed Gull	0	0	0	0	2	1	0	0	0	0	0	0	5	1	4	0	13	**0.13%**
Forster's Tern	0	0	0	1	0	0	0	0	0	0	0	4	0	4	0	2	11	**0.11%**
Least Tern	0	0	0	0	0	0	0	0	5	4	0	0	0	0	0	0	9	**0.09%**
Lesser Black-backed Gull	2	0	0	0	2	0	0	0	0	0	0	0	0	0	1	0	5	**0.05%**
Black Tern	0	0	2	4	0	0	0	0	0	0	0	0	0	0	0	0	6	**0.06%**
Roseate Tern	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	**0.02%**
Caspian Tern	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	2	**0.02%**
Glaucous Gull	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	**0.01%**
Sabine's Gull	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	**0.01%**
Gulls and Terns (Laridae) Total	**76**	**75**	**79**	**112**	**509**	**56**	**44**	**61**	**249**	**101**	**176**	**230**	**855**	**529**	**64**	**65**	**3281**	**32.56%**

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
Dark scoter - either black scoter or surf scoter	0	0	0	0	0	0	0	141	75	0	0	0	662	71	23	6	978	**9.70%**
Unidentified Scoter	0	0	0	0	54	7	19	0	0	0	0	0	0	9	566	0	655	**6.50%**
Surf Scoter	0	0	0	0	5	0	8	13	0	0	0	0	433	4	5	0	468	**4.64%**
Black Scoter	0	0	0	0	58	24	2	68	0	0	0	0	115	1	7	4	279	**2.77%**
Green-winged Teal	0	0	0	0	0	0	0	0	0	0	0	0	22	0	0	0	22	**0.22%**
Brant	0	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	20	**0.20%**
Mallard	0	0	0	20	0	0	0	0	0	0	0	0	0	0	0	0	20	**0.20%**
Unidentified Duck	0	0	0	0	1	2	0	0	0	0	0	0	0	9	0	3	15	**0.15%**
White-winged Scoter	0	0	0	0	0	0	0	0	0	0	0	0	3	2	7	0	12	**0.12%**
American Black Duck	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	5	**0.05%**
Red-breasted Merganser	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	**0.01%**
Long-tailed Duck	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	**0.01%**
Scoters, Ducks, Geese (Anatidae) Total	**0**	**0**	**0**	**20**	**143**	**33**	**29**	**222**	**75**	**0**	**0**	**0**	**1235**	**97**	**608**	**14**	**2476**	**24.57%**
Northern Gannet	48	1	0	0	509	34	176	107	15	0	0	0	528	83	107	159	1767	**17.53%**
Gannets (Sulidae) Total	**48**	**1**	**0**	**0**	**509**	**34**	**176**	**107**	**15**	**0**	**0**	**0**	**528**	**83**	**107**	**159**	**1767**	**17.53%**
Common Loon	75	4	0	0	150	17	38	8	25	9	0	0	13	76	226	59	700	**6.95%**
Red-throated Loon	6	0	0	0	28	6	12	45	20	0	0	0	5	97	155	112	486	**4.82%**
Unidentified Loon	0	0	0	0	3	0	6	10	57	0	0	0	0	2	8	0	86	**0.85%**
Loons (Gaviidae) Total	**81**	**4**	**0**	**0**	**181**	**23**	**56**	**63**	**102**	**9**	**0**	**0**	**18**	**175**	**389**	**171**	**1272**	**12.62%**
Razorbill	0	0	0	0	0	22	68	11	0	0	0	0	0	5	106	1	213	**2.11%**
Dovekie	0	0	0	0	0	31	154	1	0	0	0	0	0	0	2	0	188	**1.87%**
Unidentified Alcid	0	0	0	0	0	2	6	0	0	0	0	0	0	0	26	0	34	**0.34%**
Unidentified large	0	0	0	0	0	0	2	0	0	0	0	0	0	0	11	0	13	**0.13%**

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
alcid (Razorbill or Murre)																		
Unidentified small alcid (Puffin/Dovekie)	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	**0.02%**
Atlantic Puffin	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	2	**0.02%**
Common Murre	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	**0.01%**
Thick-billed Murre	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	**0.01%**
Auks (Alcidae) Total	**0**	**0**	**0**	**0**	**0**	**56**	**234**	**12**	**0**	**0**	**0**	**0**	**0**	**5**	**146**	**1**	**454**	**4.50%**
Double-crested Cormorant	0	0	0	0	0	0	0	0	142	0	0	0	7	0	0	0	149	**1.48%**
Cormorants (Phalacrocoracidae) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**142**	**0**	**0**	**0**	**7**	**0**	**0**	**0**	**149**	**1.48%**
Wilson's Storm-petrel	0	25	53	2	0	0	0	0	0	33	33	0	0	0	0	0	146	**1.45%**
Unidentified Storm-petrel	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	**0.01%**
Storm-Petrels (Hydrobatidae) Total	**0**	**26**	**53**	**2**	**0**	**0**	**0**	**0**	**0**	**33**	**33**	**0**	**0**	**0**	**0**	**0**	**147**	**1.46%**
Cory's Shearwater	0	1	0	0	0	0	0	0	0	12	2	0	2	0	0	0	17	**0.17%**
Great Shearwater	0	1	0	0	0	0	0	0	0	7	0	0	0	0	0	0	8	**0.08%**
Northern Fulmar	0	0	0	0	0	0	0	0	0	0	0	0	1	0	6	0	7	**0.07%**
Manx Shearwater	0	0	0	0	0	0	0	0	0	5	0	0	2	0	0	0	7	**0.07%**
Unidentified Shearwater	0	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	3	**0.03%**
Sooty Shearwater	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	**0.01%**
Shearwaters and Fulmars (Procellariidae) Total	**0**	**2**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**26**	**2**	**0**	**6**	**0**	**6**	**0**	**43**	**0.43%**
Brown Pelican	0	5	0	6	0	0	0	0	1	2	13	4	6	0	0	0	37	**0.37%**
Pelicans	**0**	**5**	**0**	**6**	**0**	**0**	**0**	**0**	**1**	**2**	**13**	**4**	**6**	**0**	**0**	**0**	**37**	**0.37%**

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
(Pelecanidae) Total																		
Short-billed Dowitcher	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	7	**0.07%**
Willet	0	0	0	0	0	0	0	0	6	0	0	0	0	0	0	0	6	**0.06%**
Red-necked Phalarope	0	0	0	4	0	0	0	0	0	0	0	2	0	0	0	0	6	**0.06%**
Unidentified shorebird	0	0	0	1	0	0	0	0	1	0	4	0	0	0	0	0	6	**0.06%**
Whimbrel	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**0.02%**
Semipalmated Sandpiper	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	2	**0.02%**
Red Phalarope	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**0.01%**
Least Sandpiper	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	**0.01%**
Shorebirds (Charadriiformes spp.) Total	**1**	**0**	**1**	**5**	**0**	**0**	**0**	**0**	**18**	**0**	**4**	**2**	**0**	**0**	**0**	**0**	**31**	**0.31%**
Red-necked Grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	1	13	**0.13%**
Horned Grebe	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	3	**0.03%**
Grebes (Podicipedidae) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**15**	**1**	**16**	**0.16%**
Unidentified Swallow	0	0	0	0	0	0	0	0	0	0	6	0	0	0	0	0	6	**0.06%**
Myrtle Warbler	0	0	0	0	2	0	0	0	0	0	0	0	1	0	0	0	3	**0.03%**
Unidentified Passerine	0	0	0	0	1	0	0	0	2	0	0	0	0	0	0	0	3	**0.03%**
Barn Swallow	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	**0.02%**
Unidentified Warbler	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	**0.01%**
Unidentified sparrow	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	**0.01%**
Purple Martin	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	**0.01%**
Passerines (Passeriformes	**1**	**1**	**0**	**1**	**3**	**0**	**0**	**0**	**2**	**0**	**7**	**0**	**1**	**0**	**0**	**1**	**17**	**0.17%**

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
spp.) Total																		
Parasitic Jaeger	5	0	0	0	2	0	0	0	1	0	0	0	2	0	0	0	10	**0.10%**
Unidentified Jaeger	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	2	**0.02%**
Pomarine Jaeger	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1	**0.01%**
Jaegers and Skuas (Stercorariidae) Total	**5**	**0**	**0**	**0**	**2**	**0**	**0**	**0**	**1**	**2**	**0**	**0**	**3**	**0**	**0**	**0**	**13**	**0.13%**
Osprey	0	3	0	0	0	0	0	0	0	1	0	4	0	0	0	0	8	**0.08%**
Northern Harrier	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	**0.01%**
Bald Eagle	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	**0.01%**
Merlin	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	**0.01%**
Raptors (Pandionidae, Falconidae, and Accipitridae) Total	**0**	**3**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**4**	**1**	**1**	**0**	**0**	**11**	**0.11%**
Unidentified Bird	0	0	0	6	0	0	0	0	0	0	0	0	0	0	0	0	6	**0.06%**
Unidentified Birds (Aves spp.) Total	**0**	**0**	**0**	**6**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**6**	**0.06%**
Great Blue Heron	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	**0.03%**
Egrets and Herons (Ardeidae) Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**	**0**	**0**	**0**	**3**	**0.03%**
American Coot	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	2	**0.02%**
Miscellaneous Birds Total	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**0**	**2**	**0.02%**
Total Birds	**212**	**117**	**133**	**153**	**1349**	**202**	**539**	**465**	**605**	**174**	**235**	**240**	**2664**	**890**	**1335**	**412**	**9725**	**96.50%**
Bottlenose Dolphin	19	68	14	14	0	0	0	0	1	9	65	1	52	0	0	0	243	**2.41%**
Unidentified Dolphin	0	25	1	1	0	0	0	0	0	0	0	0	0	0	2	0	29	**0.29%**
Common Dolphin	0	0	0	0	0	8	6	2	0	0	0	0	0	0	10	0	26	**0.26%**
Toothed Whales (Odontoceti) Total	**19**	**93**	**15**	**15**	**0**	**8**	**6**	**2**	**1**	**9**	**65**	**1**	**52**	**0**	**12**	**0**	**298**	**2.96%**
Unidentified fish	0	5	0	0	1	0	0	0	0	0	0	0	15	0	0	0	21	**0.21%**

Animal Group	Apr. 2012	Jun. 2012	Aug. 2012	Sep. 2012	Nov. 2012	Dec. 2012	Jan. 2013	Mar. 2013	May. 2013	Jun. 2013	Aug. 2013	Sep. 2013	Oct. 2013	Dec. 2013	Jan. 2014	Apr. 2014	Grand Total	% of Total
Unidentified thresher shark	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	3	**0.03%**
Unidentified ray	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3	**0.03%**
Fish and Sharks Total	**0**	**7**	**0**	**1**	**1**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**18**	**0**	**0**	**0**	**27**	**0.27%**
Loggerhead Turtle	0	1	2	0	2	0	0	0	0	3	2	1	4	0	0	0	15	**0.15%**
Leatherback Turtle	0	0	0	1	0	0	0	0	0	0	0	0	2	0	0	0	3	**0.03%**
Small turtle - Loggerhead, Green, Hawksbill, or Kemp's Ridley	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2	**0.02%**
Turtles (Testudines) Total	**0**	**1**	**2**	**2**	**2**	**0**	**0**	**0**	**0**	**4**	**2**	**1**	**6**	**0**	**0**	**0**	**20**	**0.20%**
Unidentified Whale	0	0	0	0	2	1	1	0	0	0	0	0	0	0	0	0	4	**0.04%**
Minke Whale	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	3	**0.03%**
Humpback Whale	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	**0.01%**
Whale (Cetacea) Total	**0**	**0**	**0**	**0**	**3**	**1**	**3**	**0**	**0**	**0**	**0**	**0**	**0**	**1**	**0**	**0**	**8**	**0.08%**
Non-Avian Animal Total	**19**	**101**	**17**	**18**	**6**	**9**	**9**	**2**	**1**	**13**	**67**	**2**	**76**	**1**	**12**	**0**	**353**	**3.50%**
Grand Total	**231**	**218**	**150**	**171**	**1355**	**211**	**548**	**467**	**606**	**187**	**302**	**242**	**2740**	**891**	**1347**	**412**	**10078**	**100.00%**

Chapter 8: Monitoring aquatic biomass via hydroacoustics: echo sounding data processing and summary

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

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Chapter 8 Highlights

Outlines data collection and data processing protocols for echo sounding data collected during boat-based surveys, and provides a brief summary of results

Context[1]

Part III of this report focuses on boat-based surveys for wildlife in the offshore environment, including methodological reviews and data analyses. Most chapters within this section deal directly with the survey data itself (i.e., observations of marine birds, mammals, and sea turtles). While collecting survey data, however, various environmental covariate data were simultaneously collected, including sea state, sea surface water temperature and salinity, and hydroacoustic data.

This chapter focuses exclusively on the collection and data processing of hydroacoustic data collected on boat survey transects, and provides a simple summary of results. These data provide us with the relative abundance of underwater biomass, and can be used to approximate prey (i.e., fish and plankton) biomass availability to seabirds and other marine predators.

Study goal/objectives

Estimate the relative abundance of hydroacoustically detected biomass along boat survey transects, using a scientific echo sounder.

Highlights

- Data were collected along boat survey transects during 16 surveys conducted between 2012-2014, using a Simrad EK60 echo sounder unit (Kongsberg Maritime AS, Horten, Norway).
- Raw data were processed using Echoview 5.3 (Myriax Software Pty. Ltd., Hobart, Australia)
- Data were integrated by 1 x 500 m cells across the depth and length of each survey, calculating a biomass index value per cell.
- Total biomass varied widely both within and between surveys, indicating a high level of spatial and temporal variation of prey biomass abundance across the Mid-Atlantic Outer Continental Shelf, and throughout the year.
- The mean depth of biomass did not vary significantly between seasons.
- Total biomass was higher in nearshore areas in the summer and fall, and in the southern end of the Mid-Atlantic Baseline Studies (MABS) study area during winter surveys.

Implications

Hydroacoustic echo sounding data can be used to investigate relative abundances of prey biomass and look for relationships with seabird distributions and abundances (Veit, 2015). There was a high level of spatial and temporal variation of prey biomass with high total biomass nearshore in summer and fall, and in the southern end of the regional study area in winter.

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[1] For more detailed context for this chapter, please see the introduction to Part III of this report.

Abstract

This chapter outlines the methods used in the collection and processing of hydroacoustic echo sounding data collected as part of the Mid-Atlantic Baseline Studies Project, and provides a basic summary of results. Hydroacoustic data were collected during 16 boat-based surveys offshore of Delaware, Maryland, and Virginia, USA between 2012 and2014, using a Simrad EK60 echo sounder unit. Raw data were processed by trained personnel using Echoview 5.3 software. Data were filtered to remove small particles, surface noise, bottom substrates, and anomalous data. Data were integrated into 500 m cells across the length of each survey and 1 m depth strata, calculating a biomass index value (Nautical Area Scattering Coefficient; NASC) per 1 x 500 m cell. Due to removal of surface noise and bottom substrates, data are limited to the water column between 2m depth and the bottom substrate, and do not include surface and benthic biomass. Total biomass varied widely both within and between surveys, indicating a high level of spatial and temporal variation of prey biomass (i.e., fish and large plankton) abundance across Mid-Atlantic Outer Continental Shelf throughout the year. Total biomass was higher in nearshore areas in the summer and fall, and in the southern end of the Mid-Atlantic Baseline Studies (MABS) study area during winter surveys.

Introduction

Non-invasive, quantitative estimates of fish abundance and aquatic biomass have been made possible in recent years with the development and subsequent improvement of acoustic echo sounding hardware, including split- and multi-beam transducers employing echo-counting and interpretation software. During the past decade, the development of stable, scientific echo sounders, multi-frequency applications, new transducer deployment techniques, standardized calibration procedures, and more realistic models of the sound-scattering properties of biological targets have improved accuracy of biomass estimations (Rudstam et al., 2013; Simrad, 2012).

While conducting boat-based surveys for higher trophic level wildlife (birds, marine mammals, sea turtles, and other taxa) in the Mid-Atlantic region, we employed echo sounding technology in order to estimate the biomass and size classes of aquatic prey species (fish and zooplankton) present beneath the survey vessel. The echo sounder sends acoustic signals into the water column and detects resulting backscattered energy reflected from fish and other objects. Data from the Simrad EK60 scientific echo sounder were automatically processed using appropriate software, manually vetted, and integrated and summed by distance and depth intervals in order to estimate the contribution of backscattered energy from all targets within each sampling volume. These data were subsequently used to calculate estimates of fish size class and biomass by area and by volume along the survey transects.

Data collection

Hydroacoustic data were collected during all 16 boat-based surveys, totaling 66 of 68 survey days. Data were not collected during the boat-based surveys conducted on February 3 and June 18, 2013 due to errors with equipment and surveyor oversight. Data were collected using a Simrad EK60 scientific echo sounder unit with a hull mounted 120 kHz split-beam transducer, transceiver, and a laptop computer with Simrad-EK60 echo sounder software, run off an external marine battery. A Garmin Map60CSX GPS (Garmin International, Inc., Olathe, KS) was attached to the data collection computer for georeferencing the echo sounder data. Transducer settings can be found in Table 8A-1. The unit was calibrated using a tungsten carbide calibration sphere in a monofilament harness, following calibration guidelines given in the Simrad EK60 reference manual (Simrad, 2012).

Data processing

Raw data files were processed by trained personnel at BRI or Aquacoustics, Inc. (Sterling, AK). Data files were post-processed using Echoview 5.3, and the results summarized in Microsoft Excel. GPS data were reviewed to ensure spatial referencing was complete and accurate, and hydroacoustic data were calibrated for the speed of sound and absorption coefficients using mean sea surface temperature and salinity values collected every 30 minutes during boat-based surveys (Chapter 6).

Several steps were taken to filter and exclude data within the Sv fileset echogram that were generated from sources other than fish or zooplankton biomass. The Sv echogram is a visual representation of the volumetric backscattering of hydroacoustic signals sent and received by the echo sounder (Echoview, 2015). Data were initially filtered at -60 dB to exclude very small targets (< 2 cm) and low-intensity surface noise. A surface line was drawn at a depth of 2 m below the water surface (roughly 0.8 m below the surface of the transducer), and a bottom line was generated at roughly 20 cm above the ocean floor. Within the Sv echogram window, the bottom line was manually edited to exclude the bottom substrate and targets indistinguishable from the bottom substrate, as well as to ensure that the line was continuous from the beginning to the end of the survey. All backscattering signals occurring above the surface line or below the bottom line were excluded from analysis. Additionally, the Sv echogram was reviewed in order to exclude anomalous data from analysis, such as surface disturbances, non-fish objects, or other anomalies. After manual review, and per the recommendation of fishery acoustics specialists at Aquacoustics, Inc., data from surveys conducted in August, September, and October of 2013, and data for depths ranging from 25-40 m in April and June of 2012 were filtered at -54 dB rather than at -60 dB, to compensate for high densities of abnormal low-frequency signals (possibly caused by small invertebrates or suspended particulate matter; D. Degan pers. comm.).

The Sv echogram was integrated by 1 m depth intervals (or “layers”) and 500 m distance intervals (or “intervals”), calculating the mean volume backscattering strength (Sv Mean), the area backscattering coefficient (ABC), and nautical area-scattering coefficient (NASC) value for each 1 x 500 m cell within the survey, among other variables and coefficients (Appendix 8B). Frequency distributions of ABC values were plotted and outliers were reviewed to ensure that the resulting ABC values were representative of biomass rather than an error in data filtering.

While the Sv echogram represents volumetric backscattering, the Single Target echogram represents individual targets (i.e., fish or large plankton) derived from single points. The Single Target echogram was also reviewed and integrated using the same exclusion criteria (surface line, bottom line, and anomalous data regions) established while vetting the Sv echogram. Single target detection variable properties defined prior to integration are listed in Table 8A-2.

The resulting integrated data gives the estimated number of individual targets per cell, as well as each target's compensated target strength (TS Comp) value. The length of each target (cm) was calculated using a simplification for Love's dorsal aspect equation for 120 kHz frequency (Love, 1971):

$$\text{Length} = (10^{(TS\_Comp\ +\ 26.1)/19.1})\bullet 100$$

Additionally, the backscattering cross-section (σ_{bs}) value for each target was calculated using the following equation (Echoview, 2015; Simmonds and MacLennan, 2005):

$$\sigma_{bs} = 10^{(TS\_Comp/10)}$$

The ABC value, Sv Mean, and mean backscattering cross-section value by layer ($\overline{\sigma}_{bs}$) were then used to calculate aerial density (number of targets/m^2) and volumetric density (number of targets/m^3) for each cell within the survey, using the following equations (Echoview, 2015; Simmonds and MacLennan, 2005):

$$\text{Aerial density} = ABC/(\overline{\sigma}_{bs})$$

$$\text{Volumetric density} = 10^{(Sv\_Mean/10)}\ /(\overline{\sigma}_{bs})$$

Data for each survey-day were processed separately and combined in a unified Microsoft Access database after undergoing QA/QC procedures outlined below.

Quality assurance and quality control (QA/QC)

For each survey day, the following post-processing steps were implemented to ensure that data within and between each survey were processed consistently and accurately:

1) GPS data were reviewed to ensure that correct spatial data were assigned to each dataset;
2) Calibration files were reviewed to ensure that correct temperature and salinity data were used in determining speed of sound and absorption coefficients;
3) Sv echogram cells with the highest ABC values were reviewed to ensure that values were representative of biomass; and
4) Integrated data were examined by interval and layer to look for instances where biomass was identified in Layer 3 (from 2-3 m in depth), and no biomass was identified in Layer 4, as this pattern may indicate the presence of surface noise that was not completely excluded from analysis. In these instances, the corresponding cell within the Sv echogram was reviewed to see if the values were representative of actual biomass.

If corrections were made during any of these four steps, cell integration of Sv and Single Target data as well as subsequent calculations were performed again, and corrected data were incorporated into the final dataset.

Surveys conducted on January 1-3, 2013 were independently analyzed by both a BRI analyst and a fishery acoustics specialist from Aquacoustics, Inc., to determine the repeatability and comparability of analyses. This comparison was conducted by an expert at Aquacoustics, who concluded that analyses were highly comparable, and differences were within the expected margin of error.

Data summary

Data below are summarized by total NASC (m^2/nmi^2), or the NASC values summed across all depths within an interval or survey. This metric represents an index of total prey biomass in the water column. We chose to use this metric rather than fish density estimates as we are interested in representing total prey availability rather than estimated densities or numbers of individual fish. Total NASC was highly variable between individual surveys within the Maryland study area (Table 8-1) as well as within the MABS study area (Johnson et al., 2015). In the Maryland study area, total NASC values per survey ranged from 899 in January 2014, to 1,038,328 in October 2013, with a mean (± SD) of 132,387 (± 248,946). Total NASC was also highly variable within each survey, indicating variable geographic distributions of prey biomass within the MABS and Maryland study areas. For example, within the Maryland study area, the mean total NASC per 500 m interval in October 2013 was 2,941, with a standard deviation nearly an order of magnitude higher (14,288). This spatial variability within surveys was typical across all surveys (Table 8-1).

Total prey biomass within the water column also varied geographically by season. Within the Maryland study area, higher nearshore distributions were observed in the summer and fall, with more ubiquitous distributions in the winter and spring. Similar patterns were observed across the MABS study area, except with notably higher distributions observed off the coast of Virginia and the mouth of the Chesapeake Bay during winter surveys (Figure 8-1). Within the Maryland study area, the mean depth of biomass (± SD) did not vary significantly between seasons, ranging from 12.0 (± 5.7) m in fall surveys to 19.0 (± 8.5) m in spring surveys (Figure 8-2); these values were similar to the seasonal mean depths of biomass across the MABS study area, which ranged from 13.3 (± 6.8) m in fall surveys to 18.5 (± 8.3) m in spring surveys (Johnson et al., 2015).

Further analysis and caveats

These data paint a picture of the distribution and relative abundance of prey biomass within the MABS and Maryland study areas throughout the year. They can also be used in combination with the boat-based survey observations to examine the relationship between acoustically detected prey and observed predators such as gannets, gulls, and terns (Sollmann et al., 2015; Veit, 2015). However, several limitations of these data should be noted prior to further explorations and interpretation of predator and prey correlations. First, it is important to keep in mind that the top several meters of the water column were excluded from integration due to surface noise backscatter. Surface noise typically extended to 2 m in depth during calm conditions, so a minimum of the top 2 m of the water column were excluded across all surveys. The depth to which the surface noise extended varied with sea state, however, and there were many instances where surface noise penetrated to greater depths, commonly requiring exclusion of the top 4-6 m of the water column for several kilometers within a survey, and on occasion requiring exclusion of the top 10-12 m. Similarly, this technique does not measure the biomass of benthic biota, such as shellfish, as they cannot be distinguished from the bottom substrate within the echogram. Thus, species that forage exclusively within the top few meters of water (such as storm-petrels, Hydrobatidae) and species that forage on benthos (such as scoters, *Melanitta* spp.) are unlikely to show direct correlations with distributions of biomass as detected by the echo sounder. Even for species which forage within our surveyed water depths, the relevance of aquatic biomass distributions will vary depending upon the species composition and size classes present in the water column. We did not directly measure the sizes or abundance of fish and plankton that would be consumed by our target species (e.g., seabirds, marine mammals, and sea turtles), as “ground truthing” the hydroacoustic data would have required substantial additional resources (and was not the focus of this study). However, measured aquatic biomass can be used as an index of prey availability (Santora et al., 2011, 2009; Simmonds and MacLennan, 2005). The relationship between acoustically detected biomass and observed seabird predators, along with these limitations, are further discussed in Sollmann et al. (2015) and Veit (2015).

Literature cited

Echoview, 2015. Echoview Help File 6.1.11.

Johnson, S., Williams, K., Gilbert, A., 2015. Monitoring aquatic biomass via hydroacoustics: echo sounding data processing and sumary of results, 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.

Love, R.H., 1971. Dorsal-aspect target strength of an individual fish. J. Acoust. Soc. Am. 49, 816–823.

Rudstam, L.G., Jech, J.M., Parker-Stetter, S.L., Horne, J.K., Sullivan, P.J., Mason, D.M., 2013. Fisheries Acoustics, in: Zale, A. V., Parrish, D.L., Sutton, T.M. (Eds.), Fisheries Techniques. American Fisheries Society, Bethesda, MD, pp. 1–40.

Santora, J.A., Ralston, S., Sydeman, W.J., 2011. Spatial organization of krill and seabirds in the central California Current. ICES J. Mar. Sci. 68, 1391–1402. doi:10.1093/icesjms/fsr046

Santora, J.A., Reiss, C.S., Cossio, A.M., Veit, R.R., 2009. Interannual spatial variability of krill (Euphausia superba) influences seabird foraging behavior near Elephant Island, Antarctica. Fish. Oceanogr. 18, 20–35. doi:10.1111/j.1365-2419.2008.00490.x

Simmonds, J., MacLennan, D.N., 2005. Fisheries Acoustics: Theory and Practice, 2nd ed. ed. Blackwell Publishing, Oxford.

Simrad, 2012. Simrad EK60 Reference Manual, Release 2.4.X. Kongsberg Maritime AS.

Sollmann, R., Gardner, B., Gilbert, A., Williams, K., Veit, R., 2015. A community distance sampling model to investigate the abundance and distribution of seabirds, 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.

Veit, R., 2015. Spatial association between seabirds and prey on the Mid-Atlantic Outer Continental Shelf, 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.

Figures and tables

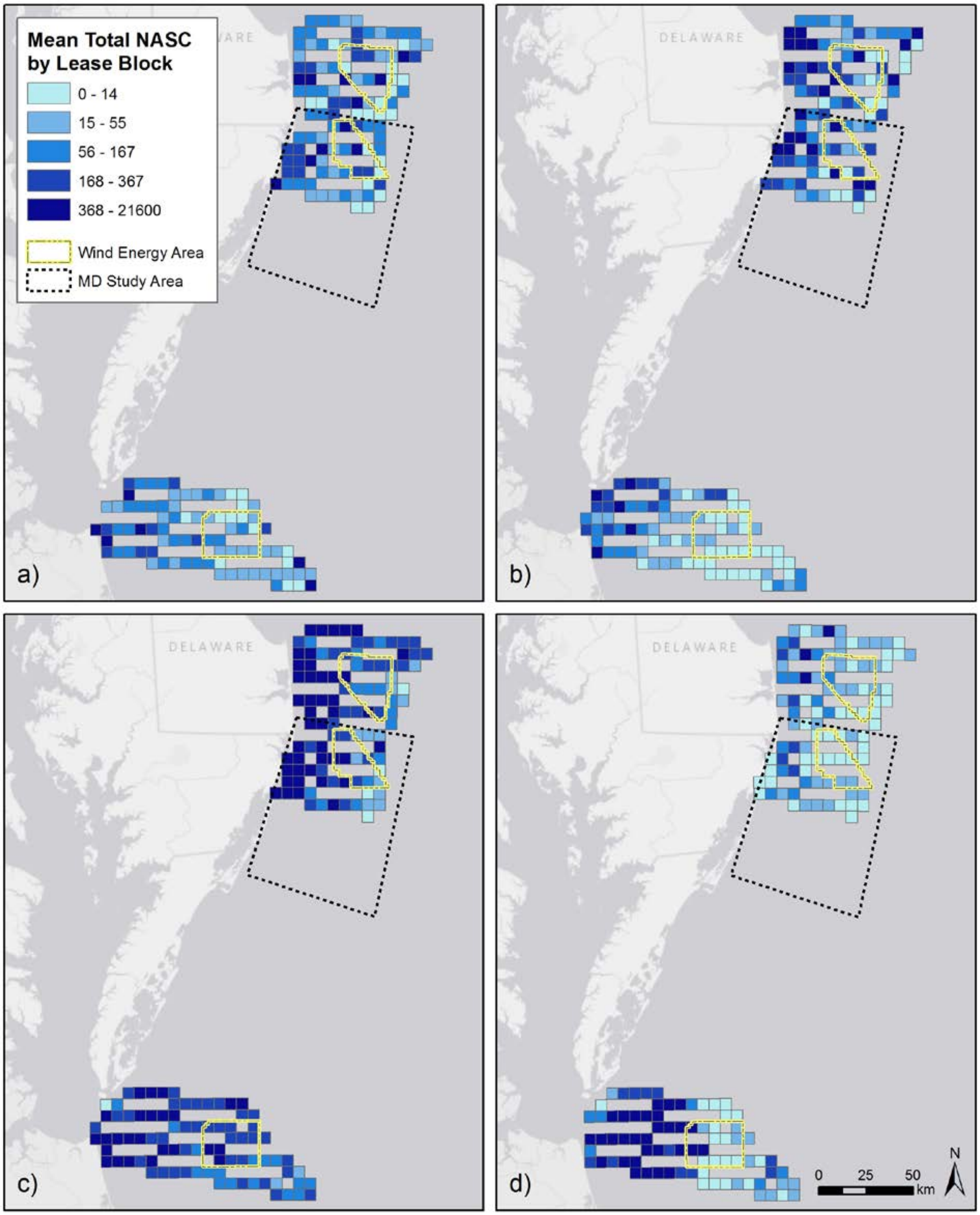

Figure 8-1. Seasonal mean total NASC per lease block. a) Spring, March 1 – May 31; b) Summer, June 1 – August 31; c) Fall, September 1 – November 30; d) Winter, December 1 – February 28. Total NASC was calculated by summing NASC across all depths for each 500 m interval within each survey. Total NASC values were binned and averaged by lease block. Mean total NASC is categorized by quintiles for mapping purposes.

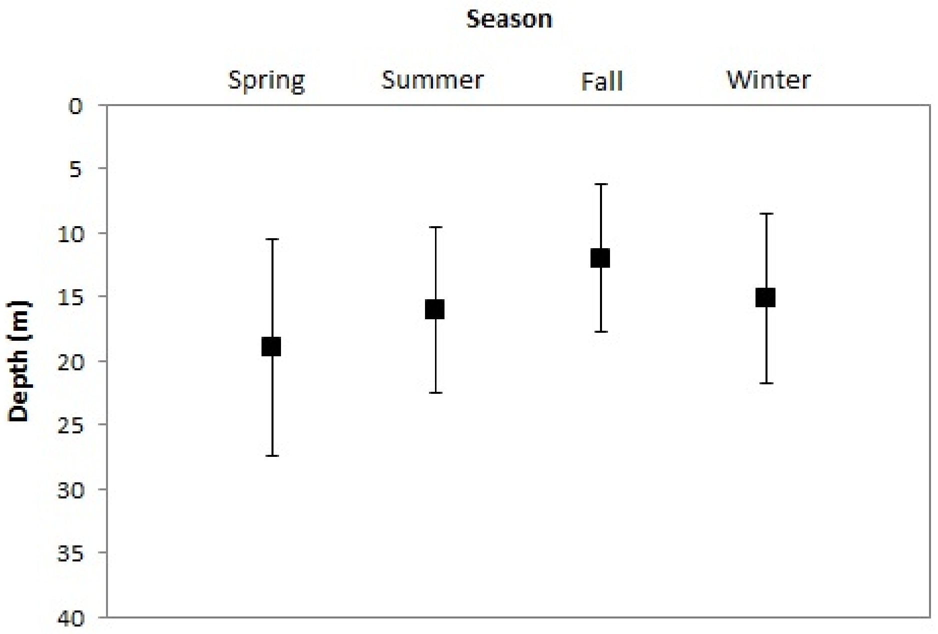

Figure 8-2. Seasonal mean depth ± SD of biomass within the water column in the Maryland study area. Total NASC by layer by season was calculated by summing NASC values within a layer across all survey intervals seasonally. Depth was weighted by the corresponding total NASC value in order to calculate the seasonal mean depth of biomass. Spring: March 1 – May 31; Summer: June 1 – August 31; Fall: September 1 – November 30; Winter: December 1 – February 28.

Table 8-1. Total NASC by survey and interval, representing an index of total prey biomass within the water column in the Maryland study area.

Survey	Total NASC by Survey	Total NASC by Interval			
		Mean	SD	Min.	Max.
Survey 1 April 2012	124,620	409	1,992	0	20,762
Survey 2 June 2012	139,460	483	2,890	0	44,376
Survey 3 August 2012	63,561	209	1,131	0	13,147
Survey 4 September 2012	219,800	714	2,311	0	31,218
Survey 5 November 2012	74,849	221	337	2	3,842
Survey 6 Dec. 2012/Jan. 2013	6,900	22	98	0	1,053
Survey 7 Jan./Feb. 2013	33,450	101	526	0	7,582
Survey 8 March 2013	53,220	163	803	0	10,735
Survey 9 May 2013	98,707	285	3,194	0	59,263
Survey 10 June 2013	40,861	119	381	0	5,253
Survey 11 July/Aug. 2013	70,881	203	815	0	11,239
Survey 12 September 2013	135,410	398	1,223	0	10,645
Survey 13 October 2013	1,038,328	2,941	14,288	0	123,833
Survey 14 December 2013	13,721	39	271	0	4,828
Survey 15 Jan./Feb 2014	899	3	10	0	170
Survey 16 April 2014	3,518	11	82	0	1,345

Supplementary material

Appendix 8A. Transducer settings and integration variable properties

Table 8A-1. Split-beam transducer settings used while collecting hydroacoustic data during boat surveys.

Field Name	Setting
Transducer draft (m)	0.000
Sample interval (s)	0.000064
Transmit power (W)	250.0
Pulse length (ms)	0.256
Transducer gain (dB)	27.000
Sa correction (dB)	0.000
Minor-axis beam width (degrees)	7.000
Major-axis beam width (degrees)	7.000
Frequency (kHz)	120.000
Two-way beam angle (dB re 1 Steradian)	-21.000

Table 8A-2. Single target detection variable properties parameters set prior to single target cell integration.

Field Name	Setting
TS Threshold (dB)	-60.0
Pulse length determination level (dB)	6.0
Minimum normalized pulse length	0.7
Maximum normalized pulse length	1.75
Beam compensation model	Simrad LOBE
Maximum beam compensation (dB)	6.0
Maximum standard deviation of minor-axis angles (degrees)	0.6
Maximum standard deviation of major-axis angles (degrees)	0.6

Appendix 8B. Exported data fields and definitions

Table 8B-1. Sv data set field names and definitions. Definitions are adapted from the Echoview glossary, through personal communications with specialists at Aquacoustics Inc. (Echoview, 2015; D. Degan, personal communication, 10 February 2014). Fields marked with an asterisk (*) were added to the dataset and calculated post cell-integration. All other fields were exported during the cell-integration process.

Field	Example	Definition
Surv_Date*	11/4/2012	Date of survey.
ABC	1.04E-07	Area backscattering coefficient (m^2/m^2). Measure of area scattering rather than volume scattering.
NASC	4.46	Nautical area-scattering coefficient (m^2/nmi^2). Scaled version of ABC, equal to $4\pi(1852)^2$(ABC).
Sigma*	5.75E-06	The back-scattering cross-section, or a measure of the backscatter strength from the target (m^2), calculated using data from the single target dataset. The mean sigma value per layer per day ($\overline{\sigma}_{bs}$) is presented here, and is used as a scalar when converting area and volume backscattering measurements to absolute numbers.
Aerial Density*	0.0137	Aerial fish density in the region (number of fish per square meter for a given thickness layer). Calculated as ABC/($\overline{\sigma}_{bs}$).
Volumetric Density*	0.0412	Volumetric fish density in the region (number of fish per cubic meter). Calculated as $10^{(Sv\_Mean/10)}$ /($\overline{\sigma}_{bs}$).
Thickness_mean	1.008047	The mean thickness (m) of an analysis domain (i.e., the average thickness of each layer within the 500 m bin).
Interval	1	The sequentially numbered 500 m survey segment by which data is binned.
Layer	3	The layer or stratum number of the cell being analyzed (e.g., the number of the domain layer, counting from the water surface downwards).
Sv_mean	-55.74	The linear mean Sv value for all samples in the 500 m bin, or domain, in (m^2/m^3). Another definition: the mean volume backscattering strength of the domain being integrated.
Height_mean	1.008047	The mean height (m) of the domain layer across the 500 m interval, or the projection of thickness mean onto the vertical axis taking transducer geometry into account. Height mean and thickness mean are equal for this project, due to the orientation of the transducer.
Depth_mean	2.494063	The mean depth (m) of the domain layer across the 500 m interval.
Layer_depth_min	2	The minimum depth (m) of the domain layer across the 500 m interval.
Layer_depth_max	3	The maximum depth (m) of the domain layer across the 500 m interval.
Ping_S, Ping_M, Ping_E	15126	A ping is the representation of the return signal (echo trace) measured after the transmission of a single acoustic pulse. Ping_S reports the sequential number of the first ping in the analysis domain (500 m interval) (S for start); Ping_M reports the number of the middle ping (M for middle); and Ping_E reports the number of the last ping (E for end).
Dist_S, Dist_E	499.867146	The distance (measured by GPS, in meters) from the first ping in the survey to the first ping (S for start) of the 500 m interval, or from the first ping in the survey to the last ping (E for end) in the 500 m interval.
Date_S, Date_M, Date_E	20121104	The date of the first ping (S for start), middle ping (M for middle), and last ping (E for end) in the 500 m interval.
Time_S, Time_M, Time_E	10:49:40.70	The time of day at which the first ping (S for start), middle ping (M for

Field	Example	Definition
		middle), and last ping (E for end) in the 500 m interval occurred. Time was recorded in GMT.
Lat_M	36.93391333	The latitude in decimal degrees of the middle ping in the analysis domain (i.e., the center latitude of the 500 m interval).
Lon_M	-76.04724667	The longitude in decimal degrees of the middle ping in the analysis domain (i.e., the center longitude of the 500 m interval).
Exclude_below_line_depth_mean	15.421739	The mean depth of the bottom line, or exclude-below line, for the 500 m interval.
Minimum_Sv_threshold_applied	1	A value of 1 indicates that a minimum Sv threshold has been applied (see Minimum_integration_threshold), 0 indicates otherwise.
Minimum_integration_threshold	-60	The value of the minimum threshold entered on the Data page of the Variable Properties dialog box for the variable which was analyzed (dB re $1m^2/m^3$). For this project the threshold was set to -60 or -54 dB.
Maximum_Sv_threshold_applied	0	A value of 1 indicates that a maximum Sv threshold has been applied; 0 indicates otherwise. A maximum threshold was never applied for this project.
Exclude_above_line_applied	1	A value of 1 indicates that the exclude above line has been applied; 0 indicates otherwise. For this project the exclude above line was always applied.
Exclude_above_line_depth_mean	2	The mean depth (m) of exclude-above line across the 500 m interval.
Exclude_below_line_applied	1	A value of 1 indicates that the exclude-below line has been applied; 0 indicates otherwise. For this project the exclude below line was always applied.
Standard_deviation	9.20E-09	The standard deviation of all sample values in the analysis domain (1 x 500 m cell). This is calculated in the linear domain (not the dB domain).
Range_mean	1.344063	The distance (m) between the mean depth of the layer, and the depth of the center of the transducer face, within the 500 m interval.
Exclude_below_line_depth_min	14.165446	The minimum depth of the exclude-below line (or essentially the minimum bottom depth) within the 500 m interval.
Exclude_below_line_depth_max	16.602294	The maximum depth of the exclude below line (or essentially the maximum bottom depth) within the 500 m interval.

Chapter 9: Predicting the offshore distribution and abundance of marine birds from shipboard surveys, using a hierarchical community distance sampling model

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

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Chapter 9 Highlights

Prediction of seabird densities across the Mid-Atlantic study area by season, based on an incorporation of environmental data into a multi-species modeling approach

Context[1]

A broad geographic and temporal scale of analysis is required to assess exposure to wildlife from proposed development projects. Unlike several other chapters of this report that utilize approaches for combining boat and digital aerial survey data, Chapter 9 focuses on using data from a single, well understood survey method to describe abundance patterns. Standardized boat-based surveys with distance estimation are a well-established method of obtaining density data for wildlife.

Project collaborators developed a community distance sampling (CDS) model for seabirds using data from the first boat survey (Sollmann et al. 2015). Building on this novel multi-species approach, Chapter 9 analyzes data from 15 boat surveys and incorporates remotely-collected environmental covariate data into the hierarchical modeling structure. This approach accounts for imperfect detection to estimate "true" abundance, and predicts seabird distributions by season to help identify important habitat use areas and patterns.

Study goal/objectives addressed in this chapter

Evaluate potential exposure of the marine bird community to offshore development by: 1) quantifying the detectability of 40 avian species to predict their seasonal abundance across the Mid-Atlantic study area; and 2) identifying ecological drivers of distribution and abundance, both within and among species.

Highlights

- Abundance and species composition varied across the Mid-Atlantic study area, as well as by season.
- Distance to shore was generally the most common significant predictor of abundance.
- Estimated abundance was highest in the winter, and for most species was higher in the second (2013-14) than first (2012-13) winter of surveys. Species richness was also higher in the second winter.
- High species density and diversity also occurred in spring and fall, suggesting that migratory and overwintering species dominate the region's species composition.
- Although species abundance and richness was generally lower during the summer, members of some protected species were present during the summer, largely closer to the shore.

Implications

Identifying areas more or less suitable for development involves identifying and giving special consideration to areas rich in abundant species, as well as important areas for species of concern (such as terns) that may be vulnerable even at low numbers.

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[1] For more detailed context for this chapter, please see the introduction to Part III of this report.

Abstract

Proposed offshore wind energy development on the Atlantic Outer Continental Shelf has brought attention to the need for baseline studies of marine birds. We compiled line transect data from 15 shipboard surveys (June 2012 to April 2014), along with associated remotely-sensed habitat data, in the lower Mid-Atlantic Bight off the coast of Delaware, Maryland, and Virginia. We used observations from 40 marine bird species to inform a hierarchical community distance sampling model that estimated the seasonal detection and abundance of marine birds in the regional study area. We hypothesized that avian benthivores (bottom-feeders) respond more to static covariates that characterize seafloor variability, and that piscivores (fish-eaters) respond primarily to dynamic covariates that quantify surface productivity. Treating each season separately, we included six oceanographic parameters to estimate seabird abundance: three static (distance to shore, slope, sediment grain size), and three dynamic covariates (sea surface temperature, salinity, primary productivity). We compared the variation in species-specific and community-level responses to these habitat features, including for rare and protected species, and predicted the abundance for each species across the Mid-Atlantic study area. Our hypothesis was partially supported by our results, but there was wide interannual, seasonal, and interspecies variation in habitat relationships. We found that abundance and diversity was highest for overwintering species. These results show the importance of quantifying detection and determining the ecological drivers of a community's distribution and abundance, within and among species, for evaluating the potential exposure of marine birds to offshore development.

Introduction

Proposed offshore energy development in the United States over the last decade has brought increased public attention to potential species-level impacts of anthropogenic activities on marine life (Caldow et al. 2015; Winiarski et al. 2014). We present a method of examining species and community-level exposure of marine birds to potential development within wind energy areas (WEAs) in federal U.S. waters on the Atlantic Outer Continental Shelf. Identifying important habitat for marine communities of mammals, fish, and birds presents one of the most effective mitigation techniques for wind energy development's effects on wildlife: that is, avoiding 'hotspots', defined as locations where high diversity and densities of sensitive species persist (Marques et al. 2014). Characterizing hotspots of seabird communities is important in assessing potential impacts from offshore development, particularly because as meso-predators, marine birds are useful indicators of environments that support high biodiversity (Lascelles et al. 2012).

The dynamic nature of pelagic marine communities is important to consider in siting offshore development, since marine predators locate prey in an environment characterized by exceptionally high spatial and temporal variability (Davoren et al. 2010; Fauchald et al. 2011). However, "enduring" features of the seafloor (e.g., shelf margins) can also drive the persistence or predictability of hotspots (Santora and Veit 2013). In the state of Maryland, examples of dynamic influences on habitat include sea surface temperature (SST) effects from the Gulf Stream, salinity gradients from the Delaware Bay outlet, and primary productivity, which tends to be high along the coast. Examples of static covariates include distance to shore, seafloor slope (which increases from the Delaware Bay to the Baltimore Canyon), and seafloor substrate (e.g., fine to coarse sand). Our primary objective was to quantify the spatial and temporal variability of marine bird abundance and its relationship with habitat covariates in the offshore waters in and around the three WEAs located in the lower Mid-Atlantic Bight, off the coasts of Delaware (DE), Maryland (MD), and Virginia (VA; Figure 9-1).

We evaluated seasonal species abundance and community composition using two years of shipboard surveys and recently-developed hierarchical community distance sampling (HCDS) models (Sollmann et al. 2015). The high rates of identification in shipboard surveys make them a reliable method of documenting species richness for identifying important bird areas (Camphuysen et al. 2004; Smith et al. 2014). Increasing interest in quantifying species richness, as a measure of biodiversity, has spurred the development of community models in the field of ecology (Royle and Dorazio 2008). We use site-specific covariates in a hierarchical distance sampling model to estimate the abundance of multiple species (Royle et al. 2004), all within a single community model (Sollmann et al. 2015). Distance sampling accounts for imperfect detection to estimate 'true' (as opposed to relative) abundance (Buckland et al. 1993). In community models, certain parameters are shared and informed by all species, which improves the predictive power of rare species, because "borrowing strength" from the rest of the community renders the model robust to spurious covariate effects (Madon et al. 2013). Accurately representing the breadth of environmental variability across the study area is one of the most important factors in predicting the distribution and abundance of seabirds to unsampled areas, for assessing their potential post-construction displacement (Lapeña et al. 2011). Our approach enables us to incorporate infrequently detected species that may otherwise be excluded from modeling efforts, and thus we make use of the full shipboard survey dataset in analyzing species abundance and habitat relationships.

Seasonality in species richness or abundance is an important factor in determining when it is possible to minimize disturbance from the construction of wind facilities (Bailey et al. 2014). In our Mid-Atlantic study area, breeders (e.g., pelicans, terns) and southern hemisphere winterers (e.g., storm-petrels) are generally present during the North Atlantic summer (see Table 9-1 for Latin names). Migratory and pelagic species that range throughout the region include ospreys, phalaropes, jaegers, fulmars and shearwaters. Overwintering, nonbreeding species in the region include northern breeders such as Northern Gannets, grebes, cormorants, gulls, loons, sea ducks, and alcids (e.g., murres). Generally, these species fall into three feeding categories: piscivores (fish-eaters, e.g., Northern Gannets), planktivores (e.g., storm-petrels) or benthivores (bottom-feeding divers, e.g., sea ducks). Sea ducks such as scoters sometimes feed on fish and plankton, but primarily rely on more sessile benthic prey such as molluscs (Loring et al. 2014). The spatial and temporal patterns of marine birds at sea are largely determined by these foraging ecologies, which factors into the cumulative impacts of disturbance, displacement, or collision risk from offshore wind energy development (for review, see Bailey et al. 2014; Langston 2013).

We hypothesized that habitat use would correspond to the foraging ecology of different species groups. We expected static seafloor characteristics to have a larger effect on benthivores (e.g., scoters), and dynamic sea surface characteristics (e.g., related to currents, etc.) to have a stronger effect on piscivores and planktivores (hereafter referred to as surface-feeders). Using the HCDS approach (Sollmann et al. 2015), we evaluate the relationships of species abundance with static and dynamic oceanographic parameters. The results of this study provide seasonal information on community composition and habitat use offshore of Maryland and elsewhere in the lower Mid-Atlantic Bight. We predict the distribution and abundance of seabirds for the purpose of minimizing effects to those populations from offshore wind energy development.

Methods

Marine bird data collection

From June 2012 to April 2014, we collected shipboard data on 15 surveys that lasted 4-5 days each. Two surveys were conducted in each year and season, defined as spring (Mar-May), summer (Jun-Aug), fall (Sep-Nov), and winter (Dec-Feb). We chartered a 55-ft vessel, which departed from the ports of Ocean City, MD and Virginia Beach, VA, to transit 12 transects across the Mid-Atlantic Outer Continental Shelf offshore of Maryland, Delaware, and Virginia (Figure 9-1). Eight of the 15 surveys (from March 2013 to February 2014) included extensions of three transects farther west into Maryland state waters, with a total additional transect length of approximately 12 km per survey. Two pairs of observers alternated 2-h shifts collecting standard line-transect data using distance sampling (Buckland et al. 1993). While the recorder entered data into the program dLOG (R.G. Ford Consulting, Inc.), and regularly updated changes in environmental conditions (Beaufort sea state, etc.), the observer scanned the horizon, focusing on one forward quadrant on either side of the vessel. We continuously recorded the species, count, distance, and angle to seabird observations (see Appendix 9A and Chapter 6 for more details on data collection methods).

Data analysis

We implemented a set of HCDS models to estimate abundance and flock size while accounting for imperfect detection (Royle et al. 2004; Sollmann et al. 2015). Because HCDS requires spatial replication, we split the 12 tracklines for each survey into segments that averaged approximately 4 km, each of which is considered an individual '*site*' in the model (Equation 1). We used seabird data observed up to one km perpendicular to the track line, beyond which there were few observations identified to species. We calculated mean habitat values per segment for six remotely-sensed covariates downloaded from online databases (Appendix 9A): three static (distance to shore, '*Dst*'; seafloor slope, '*Slp*'; sediment grain size, '*Grn*') and three dynamic (daily sea surface temperature [SST], '*Sst*'; daily salinity, '*Sal*', monthly chlorophyll anomaly, '*Chl*'). Sediment grain size ranged from fine to coarse sandy substrate, and is a proxy for variations in benthic prey assemblages (Loring et al. 2013). Chlorophyll anomaly is an index of high or low phytoplankton density, or extreme values of primary productivity at the sea surface (Santora and Veit 2013). Additional information on covariates may be found in Appendix 9A.

In a community model, multiple species are combined into one analysis that encompasses both abundant and uncommon species (Royle and Dorazio 2008). Here, we defined the marine bird community as a guild composed of species that are known to cohesively use marine habitat (we list those included in the community models in Table 9-1). Because scoters were largely identified to genus, as opposed to species, we removed them from the community model and treated them as a single group in a separate 'scoter' model (made up of White-winged Scoters, Black Scoters, and Surf Scoters; Table 9-2, Appendix 9A). We separated analyses by season to accommodate temporal changes in species composition resulting from migratory patterns, and to allow species-level covariate effects to vary independently by season for breeders and nonbreeders. Therefore, we present the results from one distance sampling model for scoters during the nonbreeding seasons when scoters were present in the area (first year: Nov 2012 – Mar 2013; second year: Oct 2013 – Apr 2014). We also present the results of one HCDS model for each of seven seasons (first year summer, fall, and winter, Jun 2012 – Jan 2013; second year spring, summer, fall, and winter, Mar 2013 – Feb 2014). There were at least 5 species with a single detection in each season of the second year (observed number of flocks = 1), which we removed to avoid problems with model convergence.

The sampling unit of analysis was an observation of a 'flock' containing one or more individuals. The model included two components that estimated (1) abundance of flocks (number of seabird clusters) based on distance sampling, and (2) flock size for each species to calculate total abundance (number of individuals). For the first component, we fit either a half-normal or negative-exponential detection function on the observed distances to a flock, selecting the best fitting distance function by computing Bayesian p-values using Freeman-Tukey fit statistics (Gelman et al. 2014). We also report this measure of goodness of fit for flock abundance and flock size.

Due to overdispersion, which is common in seabird counts (Zipkin et al. 2014), we assumed that the flock abundance, N_{ij}, of species i at site j followed a Negative Binomial distribution. We modeled the variation in mean abundance of flocks, λ_{ij}, as a function of the covariates such that:

$$N_{ij} \sim Negative\ Binomial(\lambda_{ij}, r)$$

$$\log(\lambda_{ij}) = \alpha_{0,i} + offset(\log site\ length_j) + \alpha_{1,i}Dst_j + \alpha_{2,i}Slp_j + \alpha_{3,i}Grn_j + \alpha_{4,i}Sst_j + \alpha_{5,i}Sal_j + \alpha_{6,i}Chl_j \quad (1)$$

where we included the log of the length of each segment as an offset in the model to standardize for slight variations in the true survey tracks (see Appendix 9A). Each parameter (e.g., $\alpha_{0,i}$…$\alpha_{6,i}$) was species-specific, governed by a hyperdistribution. For example, each species i had an intercept $\alpha_{0,i}$, such that:

$$\alpha_{0,i} \sim Normal(\mu_{\alpha 0}, \sigma_{\alpha 0})$$

where the hyperparameters of these distributions, here $\mu_{\alpha 0}$ and $\sigma_{\alpha 0}$, are shared and informed by all species within the model. This allowed us to (1) retain species with few detections that would have otherwise been discarded from analysis, and (2) compare habitat use by each species to the overall mean community response. We modeled the observed flock sizes, $\boldsymbol{F}_i$, a vector of flock sizes for each species i, as an outcome of a zero-truncated Poisson – Negative Binomial mixture model, which allowed us to accommodate overdispersion, but with limits due to small sample sizes (Appendix 9A).

To predict to areas between and around the sampled transects, we first established a grid that contained the regional study area (Figure 9-2) based on the data layer with the coarsest spatial resolution (chlorophyll at 4 km). Daily covariate values made up the finest temporal resolution used in the model input, therefore, we used data from the midpoint of each season to predict overall abundance of flocks on that day (spring: 15 Apr, summer: 15 Jul, fall: 15 Oct, winter: 15 Jan). For example, we predicted the abundance for fall 2012 using the posterior mean parameter estimates and data from Oct 2012 for chlorophyll anomaly, and 15 Oct 2012 for SST and salinity. We implemented the HCDS models in a Bayesian framework using the package "rjags" to run the software JAGS (Plummer 2003) in program R version 2.15.3 (R Development Core Team 2013). We diagnosed convergence on three parallel chains that ran for 30,000 iterations (Gelman et al. 2014).

Results

For the community models, we analyzed a total of 40 marine bird species that fell into 11 taxonomic families (Table 9-1). Community composition differed between years (Table 9-3): there were 29 species observed in the first year (15 summer, 22 fall, 16 winter) and 35 observed in the second year (18 spring, 11 summer, 16 fall, 21 winter). The separate scoter group models included the three aforementioned species, White-winged, Black, and Surf Scoters, which were observed during the nonbreeding season (Table 9-2). The first year showed higher observed, estimated, and predicted abundance of scoters across the entire Mid-Atlantic study area (Table 9-2). In the MD WEA, predicted scoter abundance was twice as high in the first year (708,071.4) as the second year (305,325.7). Extended sampling of the MD transects (primarily in the second year) led to more scoters observed in the segments closest to the MD coast in the second year (504 individuals) compared to the first year(83 individuals), while more scoters were observed on the remaining transect segments in Year 1 (249 scoters), than in Year 2 (182 scoters).

Overall patterns of estimated and predicted abundance for the entire community in most seasons reflect the influence of the shoreline, to which most species adhered closely (Figure 9-2 and Figure 9-3).

Exceptions to this pattern included several spring migrant species that were predicted in higher numbers offshore, such as Common Terns and Red Phalaropes, some wintering alcids (e.g., Dovekies), and Wilson's Storm-petrels in summer (Figure 9-4). Only in the fall of the first and second year did a covariate (grain size or distance to shore, respectively) have a strong effect on the entire community (Table 9-4), which was generally driven by the more abundant species (Table 9-3). Similar patterns occurred in waters offshore of Maryland, as for the broader Mid-Atlantic study area, with generally more nearshore distributions for many species (Figure 9-2 and Figure 9-3). Major exceptions to this pattern included several spring migrant species such as Common Terns and Red Phalaropes, some wintering alcids (such as Dovekies), and Wilson's Storm-petrels in summer, which were predicted in higher numbers in offshore areas (Figure 9-4). Coefficient of variation (CV) maps (Figure 9-5) were calculated for the estimated number of flocks to show uncertainty relative to the predicted mean flock abundance. In the case of scoters, the higher CV towards the edge of the Outer Continental Shelf was due to sparse data and estimated flock abundances close to zero in these areas (Figure 9-3 and Figure 9-5).

Bayesian p-values (Table 9-5) indicated that the Negative Binomial distribution was a good fit for abundance for all species. Mean estimated flock sizes for each species corresponded closely to mean observed flock sizes (Table 9-1), although variation in the overdispersion of flocks produced poor fit statistics for a few of these models (Table 9-5), likely due to few observed flocks (small sample size) but large variation in the observed flock size that we could not adequately model. For the detection function, the half-normal distribution fit the first year summer community, while the negative-exponential function fit the other seasons and the scoter observations (Table 9-5). As expected, we found that detection was significantly lower at higher Beaufort sea states (the 95% Bayesian credible interval [BCI] did not overlap zero) for the community (Table 9-4) and scoters (the coefficient on rough seas was negative): during the nonbreeding season of the first year, the intercept β_0 = 5.0, BCI = 4.9-5.2 and the coefficient for Beaufort 3-6 β_1 =¯0.3, BCI = ¯0.3-¯0.3; in the second year, β_0 = 5.0, BCI = 4.9-5.2; β_1 = ¯0.2, BCI = ¯0.1-¯0.2. Additionally, more conspicuous species such as Northern Gannets were detectable at farther distances than scoters (Appendix 9B).

To evaluate our hypothesis, we compared species (Figure 9-6, Figure 9-7) and community-level (Table 9-4) effects on the surface-feeding community to group-level habitat effects on scoters (benthivores, Figure 9-8); responses were not consistent between species, seasons or years, as described below. In many cases, the community mean for the coefficient of distance to shore was not significantly different from zero (Table 9-4), but the species-specific parameter was significant (Figure 9-6, Figure 9-7). The three dynamic covariates (SST, salinity, and chlorophyll) were also significant predictors in many models, although their effects varied by species (Figure 9-7) and were much more important in some seasons (e.g., SST in the first fall) than others. During the fall of 2012, the surface-feeding community as a whole was associated with fine sediment grain size, which was driven by Royal Terns, Common Terns, Laughing Gulls, Northern Gannets, and Double-crested Cormorants; in fall 2013, the entire community was likely to be close to shore, driven by 13 of the 16 species (the main exception being Cory's Shearwater).

We focus primarily on winter models below, due to the high abundance and species diversity within the regional study area in this season. For details on the distribution and abundance of species in response to covariate effects in the spring, summer, and fall, see Appendix 9B and Figure 9-7.

Winter

In the nonbreeding season across both years (2012-2014), scoter abundances had a significant relationship with distance to shore (a static covariate) and to high primary productivity (i.e., chlorophyll anomaly, a dynamic covariate; Figure 9-8). During the first year (2012-13), two static covariates (gentle slope and fine sediment) were strong predictors of scoter abundance but not of the wintering surface-feeding community. Additionally, scoter abundance was not associated with the dynamic covariate SST, but several wintering surface-feeders abundances were (Bonaparte's Gull, Manx Shearwater, Common Loon, Great Black-backed Gull, and Dovekie; Figure 9-6). In the second year (2013-14), scoter abundances were not related to those same two static covariates as in the year prior (slope and grain size), but they did associate with cold water, a dynamic covariate. During that same second year winter, surface-feeder abundances were not significantly correlated with sediment grain size, but several surface-feeding species (Northern Gannets and three larids: Bonaparte's Gulls, Herring Gulls, and Ring-billed Gulls) were positively related with gentle slopes. The surface-feeders that associated with cold water in the second year winter were Northern Gannets, Herring Gulls, and Razorbills. Overall and across the MD study area, salinity was significantly higher in the first year summer, fall, and winter (mean 36.1 ± 0.7 practical salinity units [PSU]; 36.3 ± 0.2 in the MD study area) than in the second year (mean 33.2 ± 1.7 PSU; 33.0 ± 1.5 in MD). Mean SST also contrasted sharply between winters; values used in model fit (i.e., along the sampled survey transects) were considerably warmer in the second year (mean 12.3 ± 2.8°C) compared to the first year (7.7 ± 2.8°C); this difference was significant in the MD study area (12.8 ± 1.0 and 6.1 ± 1.2°C).

Among surface-feeders (Figure 9-6), Northern Gannets had higher estimated abundances close to shore (both years), as did Red-throated Loons; the same was true only for Year 2 Common Loons. SST and primary productivity drove loon habitat partitioning in the first year, when Common Loons associated with higher SST, and Red-throated Loons associated with higher primary productivity. Alcids were observed farther from shore (i.e., closer to the continental shelf edge), particularly Atlantic Puffins (Year 1) and Razorbills (Year 2). Bonaparte's Gull abundances showed variable responses from the first to second year: in Year 1, they were associated with warm water and proximity to shore, while in Year 2 they associated with low salinity over gentle slope, further from shore. In the second year, Northern Gannets associated with gentle slope and cold water. Alcids also associated with cold water, specifically Dovekies (Year 1) and Razorbills (Year 2). With respect to chlorophyll anomaly (primary productivity), Dovekie abundances were negatively associated (Year 1), and Razorbills positively (Year 2). In the first year winter, Dovekies abundances had a positive relationship with cold water and low primary productivity, which resulted in higher winter 2013 predictions along the Outer Continental Shelf (Figure 9-4). Horned Grebes also were estimated to have higher abundances in areas of higher primary productivity. Manx Shearwaters, which are northern breeders, had estimated higher abundance in warmer waters (Year 1).

Discussion

Marine bird abundance estimates revealed that some species adhered closely to the shoreline (e.g., scoters), and were more common in the Delaware and Maryland WEAs, while some species showed pelagic distributions (e.g., during migration), and were more common in the Virginia WEA. By accounting for reduced detectability of scoters, which were present during the nonbreeding season, their estimated abundance was comparable to that of the more common surface-feeding species (e.g., Northern Gannet, Bonaparte's Gulls, and Common Loons in the spring, fall, or winter; Wilson's Storm-petrel, Laughing Gulls, Common Terns and Royal Terns in the summer). The HCDS model allowed us to include rare or elusive species, so as to directly compare habitat use in distinct seabird groups to the entire seabird community, and to document within- and between-species variability across seasons. The results show some consistencies with our hypothesis that the distribution of scoters would relate more to static covariates (distance to shore, slope, sediment grain size), compared to dynamic covariates (SST, salinity, chlorophyll anomaly), which we expected to drive the community of surface-feeders.

In line with our hypothesis, during the first year nonbreeding season (2012-2013), overwintering benthivores (scoters) showed significant relationships with static covariates characterizing seafloor variability (slope, sediment grain size), to which the wintering surface-feeders did not respond. Furthermore, scoter abundances were not associated with the dynamic covariate SST, which was a significant predictor of the abundance of wintering surface-feeders. Scoters are known to adhere closely to the shoreline, where they have easier access to benthic prey at shallower depths (Loring et al. 2014). In our Mid-Atlantic study area, primary productivity was high along the coast, which could explain the association between this dynamic covariate and high scoter abundance. However, during the second year winter season (2013-2014), scoter abundance was positively related to cold water (a dynamic covariate), and not significantly related to static covariates characterizing seafloor variability (slope, sediment grain size), unlike the first year. During that same winter, surface-feeders did not respond to sediment grain size, as we would expect, but a few species did respond to gentle slope. SST in the second year was significantly warmer compared to the first year, which could be due to eddies from the Gulf Stream off the Atlantic Outer Continental Shelf (Shealer 2001), or to variation in the North Atlantic Oscillation (Veit and Manne 2015), and may have influenced scoter selection of relatively colder water. This, along with the lack of an association with static seafloor characteristics, may also reflect dynamic movements of scoters in response to unstable sandy sediment (Dalyander et al. 2013) or ephemeral secondary productivity (zooplankton) and benthic prey resources in the second year (Loring et al. 2014).

Distance to shore dominated as one of the most consistent predictors of seabird distributions in our Mid-Atlantic study area. Since it is an easily quantifiable metric for predicting abundance, distance to shore presents a useful foundation on which to base marine spatial planning efforts, but not to the exclusion of the other static and dynamic covariates that drive seabird abundance in this region. For example, northerly-migrating Common Tern abundance in the spring of 2013 had a positive relationship with warm water and low primary productivity, which led to predicted pre-breeding spatial distributions far from shore. Their positive association with fine sediment also resulted in a prediction of high Common Tern abundances at the center of the VA WEA in the spring (Figure 9-4). Considering that sediment grain size is a static covariate, we did not expect it to have a strong effect on the surface-feeding community, as occurred during the spring and first year fall. However, fine grain size correlated positively with proportion of sand, and terns are known to forage over sandy shoals that provide good habitat for high quality forage fish such as sandlance (*Ammodytes* spp., Goyert 2015; Robards et al. 2000). Further research should investigate whether such a pattern in sediment grain size reflects the distribution of prey, and whether it is likely to persist during the migratory season from year to year, particularly in the WEAs.

We observed 'hotspots' around the mouth of the Delaware and Chesapeake Bay (for example, high richness and abundance of loons, razorbills, gannets, terns, gulls, scoters and others), which were likely driven by a salinity front and high primary productivity. This suggests that future efforts to assess the potential cumulative impacts of offshore wind energy development and shipping-channel traffic on seabird movements and populations may want to closely examine these regions (Chapter 1; Schwemmer et al. 2010). Productivity in our regional study area ranged from 1-5 mg m^{-3}, which corresponds to the lower end of the longer-term chlorophyll values that had strong positive effects on Common Loons in a study by Winiarski et al. (2013). Productivity relationships with loon abundance varied depending on the season. However, Red-throated Loons were consistently located closer to shore and in areas over colder water than Common Loons, which matched where productivity was generally higher in our study area (Powers and Cherry 1983). The fact that Dovekies associated with low primary productivity seems counterintuitive, but is likely a function of their distribution away from the highly productive coastline and over the outer edge of the shelf, where cold upwelled water can produce high concentrations of zooplankton (i.e., secondary productivity; Lieske et al. 2014; Veit and Guris 2008). Studies have shown that in the Northwest Atlantic, top-down forcing (negative predator-prey associations) occurs in subarctic waters under low productivity conditions, whereas bottom-up control (resource limitation inducing positive predator-prey relationships) dominates in waters off the east coast of the US where there is relatively higher primary or secondary productivity and species richness (Frank et al. 2007).

Observed species richness was highest in the second year winter and first year fall. High species diversity also extended to the spring, suggesting that migratory and overwintering species dominate the region's species composition. It is important that management considerations include the risk of displacement of nonbreeders that use this habitat while passing through the study area. For example, the procellarids and hydrobatids observed in our study were likely to be observed far from shore, associating with warm Gulf Stream water on the Outer Continental Shelf (e.g., Wilson's Storm-petrels, Figure 9-6, Watson et al. 2013). Depending on climate patterns (e.g. the North Atlantic Oscillation), the region may continue to see increasing trends in the abundance of Cory's shearwaters, which reflects their northerly movement with increasingly warmer water along the US East Coast since 2009 (RR Veit unpublished data).

Many of the above-mentioned patterns predicted across the broader Mid-Atlantic study area were consistent with predictions specifically for the Maryland study area. Species with highest predicted abundance within the MD study area and WEA included Northern Gannets, Common Loons, Razorbills, Bonaparte's Gulls and scoter spp. in winter, Laughing Gulls in fall, Wilson's Storm-petrels and Royal Terns in summer, and Common Terns in Spring (Figure 9-3, Figure 9-4). Overall avian abundance within the MD study area and WEA was highest in winter and lowest in summer (Figure 9-2). Fall (Year 2) and spring were predicted to be the seasons of next-highest community abundance in the MD study area and WEA, though it should be noted that only one complete spring season was included in our dataset. Although the MD extensions increased sampling close to shore in the second year, the sampling was limited enough as to not result in higher predicted abundance of scoters in the MD study area or WEA during the second year.

While species abundance and richness was generally lower during the summer (breeding season for Northern Hemisphere species), some federally and state-listed Threatened or Endangered species were present in the region during that time of year (U.S. Fish & Wildlife Service, Delaware Division of Fish & Wildlife, Maryland Wildlife and Heritage Service, Virginia Department of Conservation and Recreation's Division of Natural Heritage). Examples include Roseate Terns (listed in DE, MD, VA and federally in the USA), Least Terns (DE, MD), Common Terns (DE, MD), Forster's Terns (DE), and Royal Terns (MD). These species were primarily observed nearshore during summer months, while Common Terns were additionally abundant offshore MD in the spring, which corresponds to the pre-breeding migratory season. Studies have suggested that the foraging and breeding behavior of terns places them at risk of collision with offshore wind facilities (e.g., flying within rotor-height during repeated trips through facility footprints to feed chicks at the nest; Bradbury et al. 2014; Everaert 2014). The community distance sampling model enabled us to accommodate these relatively rare species. For example, in the fall, we had only 21 detections of Common Terns in the first year, and 6 in the second year, which might prohibit fitting a fully parameterized distance sampling model to those data. By combining data across species, we were able to estimate fall abundance for Common Terns and estimate their relationships with habitat features, improving our understanding of their distributions. This is particularly important because, while much focus on the exposure of terns to offshore wind energy development has been during the breeding season, we found their exposure to potential development within the Virginia WEA to be highest during the migratory period.

We also accounted for variation in detection, which is important in making comparisons between different species across time (Royle and Dorazio 2008). For example, Northern Gannets are large, white birds that contrast sharply against a deep blue ocean, and thus their detection probability is higher than less conspicuous species like smaller dark scoters. In this study, detection remained relatively consistent among seasons, but had we not accounted for variation in detection between species or across different visibility measures, we would have underestimated abundance and risked erroneous inference in between-species comparisons. Our predicted abundance of Northern Gannets in the winter is close to the known breeding population size (Chardine et al. 2013), which suggests that the Mid-Atlantic is an important overwintering ground. Accounting for species-specific variation in detection results in differences between observed and estimated abundance that vary by species.

After estimating detection and habitat relationships as well as abundance of marine birds in this study, future research should evaluate the types of risk that these populations face, as well as other conditions that were outside the sampling frame of the shipboard survey. For example, additional understanding of nocturnal movements and distributions of marine species under different weather conditions would be useful for informing further risk potential. In using our data to identify areas that may be more or less suitable for development, decision-makers should prioritize further research within areas with high abundance and species richness, as well as areas with target species of concern (e.g., terns) that may be vulnerable even at low numbers.

In summary, species within the seabird community off the coasts of Delaware, Maryland, and Virginia show relatively high variability in their abundance and response to habitat covariates, which we were able to quantify reliably using HCDS. Although it has been suggested that a two-year study can capture much of the spatiotemporal variation in environmental conditions (Kinlan et al. 2012), our study had high variability across seasons from one year to the next. In planning for the potential construction of static structures (wind facilities) in a dynamic environment, it is important to consider that the distribution of hotspots is likely to change over a range of fine to coarse spatiotemporal scales. Considering that the operation of wind facilities can span decades, our study quantifies relatively short-term intra- and inter-annual volatility in the region. Further research is required to provide complementary information on the potential effects of long-term climatological cycles (e.g., North Atlantic Oscillation) or climate change on the exposure of marine animals to offshore energy development. Therefore, two years may provide baseline information on the seasonality of spatial trends, but it is likely not enough to quantify longer-term persistence, volatility, or vulnerability (Bailey et al. 2014).

Literature cited

Bailey, H., Brookes, K., Thompson, P., 2014. Assessing environmental impacts of offshore wind farms: lessons learned and recommendations for the future. Aquatic Biosystems 10, 8.

Bradbury, G., Trinder, M., Furness, B., Banks, A.N., Caldow, R.W.G., Hume, D., 2014. Mapping seabird sensitivity to offshore wind farms. PLoS ONE 9, e106366.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London.

Caldow, C., Monaco, M.E., Pittman, S.J., Kendall, M.S., Goedeke, T.L., Menza, C., Kinlan, B.P., Costa, B.M., 2015. Biogeographic assessments: A framework for information synthesis in marine spatial planning. Marine Policy 51, 423-432.

Camphuysen, C.J., Fox, A.D., Leopold, M.F., Petersen, I.K., 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. Royal Netherlands Institute for Sea Research, Texel.

Chardine, J.W., Rail, J.-F., Wilhelm, S., 2013. Population dynamics of Northern Gannets in North America, 1984–2009. Journal of Field Ornithology 84, 187-192.

Dalyander, P.S., Butman, B., Sherwood, C.R., Signell, R.P., Wilkin, J.L., 2013. Characterizing wave- and current- induced bottom shear stress: U.S. middle Atlantic continental shelf. Continental Shelf Research 52, 73-86.

Davoren, G., Garthe, S., Montevecchi, W., Benvenuti, S., 2010. Influence of prey behaviour and other predators on the foraging activities of a marine avian predator in a Low Arctic ecosystem. Marine Ecology Progress Series 404, 275-287.

Everaert, J., 2014. Collision risk and micro-avoidance rates of birds with wind turbines in Flanders. Bird Study 61, 220-230.

Fauchald, P., Skov, H., Skern-Mauritzen, M., Hausner, V.H., Johns, D., Tveraa, T., 2011. Scale-dependent response diversity of seabirds to prey in the North Sea. Ecology 92, 228-239.

Frank, K.T., Petrie, B., Shackell, N.L., 2007. The ups and downs of trophic control in continental shelf ecosystems. Trends in Ecology & Evolution 22, 236-242.

Gelman, A., Carlin, J.B., Stern, H.S., Dunson, D.B., Vehtari, A., Rubin, D.B., 2014. Bayesian Data Analysis, Third Edition. Taylor & Francis, New York, NY, USA.

Goyert, H.F., 2015. Foraging specificity and prey utilization: evaluating social and memory-based strategies in seabirds. Behaviour, DOI: 10.1163/1568539X-00003260

Kinlan, B.P., Zipkin, E.F., O'Connell, A.F., Chris, C., 2012. 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. OCS Study BOEM 2012-101. NOAA Technical Memorandum NOS NCCOS 158, Herndon, VA.

Langston, R.H.W., 2013. Birds and wind projects across the pond: A UK perspective. Wildlife Society Bulletin 37, 5-18.

Lapeña, B.P., Wijnberg, K.M., Stein, A., Hulscher, S.J.M.H., 2011. Spatial factors affecting statistical power in testing marine fauna displacement. Ecological Applications 21, 2756-2769.

Lascelles, B.G., Langham, G.M., Ronconi, R.A., Reid, J.B., 2012. From hotspots to site protection: Identifying Marine Protected Areas for seabirds around the globe. Biological Conservation 156, 5-14.

Lieske, D.J., Fifield, D.A., Gjerdrum, C., 2014. Maps, models, and marine vulnerability: Assessing the community distribution of seabirds at-sea. Biological Conservation 172, 15-28.

Loring, P.H., Paton, P.W.C., McWilliams, S.R., McKinney, R.A., Oviatt, C.A., 2013. Densities of wintering scoters in relation to benthic prey assemblages in a North Atlantic estuary. Waterbirds 36, 144-155.

Loring, P.H., Paton, P.W.C., Osenkowski, J.E., Gilliland, S.G., Savard, J.-P.L., McWilliams, S.R., 2014. Habitat use and selection of black scoters in southern New England and siting of offshore wind energy facilities. The Journal of Wildlife Management 78, 645-656.

Madon, B., Warton, D.I., Araújo, M.B., 2013. Community-level vs species-specific approaches to model selection. Ecography 36, 1291-1298.

Marques, A.T., Batalha, H., Rodrigues, S., Costa, H., Pereira, M.J.R., Fonseca, C., Mascarenhas, M., Bernardino, J., 2014. Understanding bird collisions at wind farms: An updated review on the causes and possible mitigation strategies. Biological Conservation 179, 40-52.

Plummer, M., 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling, In Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DSC 2003). March, pp. 20-22.

Powers, K.D., Cherry, J., 1983. Loon migrations off the coast of the Northeastern United States. The Wilson Bulletin 95, 125-132.

R Development Core Team, 2013. R: A language and environment for statistical computing, Version 2.15.3. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Robards, M.D., Willson, M.F., Armstrong, R.H., Piatt, J.F., 2000. Sand lance: a review of biology and predator relations and annotated bibliography. USDA Forest Service, Pacific Northwest Research Station, Portland, OR.

Royle, J.A., Dawson, D.K., Bates, S., 2004. Modeling abundance effects in distance sampling. Ecology 85, 1591-1597.

Royle, J.A., Dorazio, R.M., 2008. Hierarchical Modeling and Inference in Ecology: The Analysis of Data from Populations, Metapopulations and Communities. Elsevier Science, Burlington, MA USA.

Santora, J., Veit, R., 2013. Spatio-temporal persistence of top predator hotspots near the Antarctic Peninsula. Marine Ecology Progress Series 487, 287-304.

Schwemmer, P., Mendel, B., Sonntag, N., Dierschke, V., Garthe, S., 2010. Effects of ship traffic on seabirds in offshore waters: implications for marine conservation and spatial planning. Ecological Applications 21, 1851-1860.

Shealer, D.A., 2001. Foraging behavior and food of seabirds, In Biology of Marine Birds. eds E.A. Schreiber, J. Burger, pp. 137-177. CRC Press, New York, NY.

Smith, M.A., Walker, N.J., Free, C.M., Kirchhoff, M.J., Drew, G.S., Warnock, N., Stenhouse, I.J., 2014. Identifying marine Important Bird Areas using at-sea survey data. Biological Conservation 172, 180-189.

Sollmann, R., Gardner, B., Gilbert, A., Williams, K., Veit, R., 2015. A community distance sampling model to investigate the abundance and distribution of seabirds, 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.

Veit, R., Guris, P., 2008. Recent increases in alcid abundance in the New York Bight and New England Waters. New Jersey Birds 34, 83-87.

Veit, R.R., Manne, L.L., 2015. Climate and changing winter distribution of alcids in the Northwest Atlantic. Frontiers in Ecology and Evolution 3.

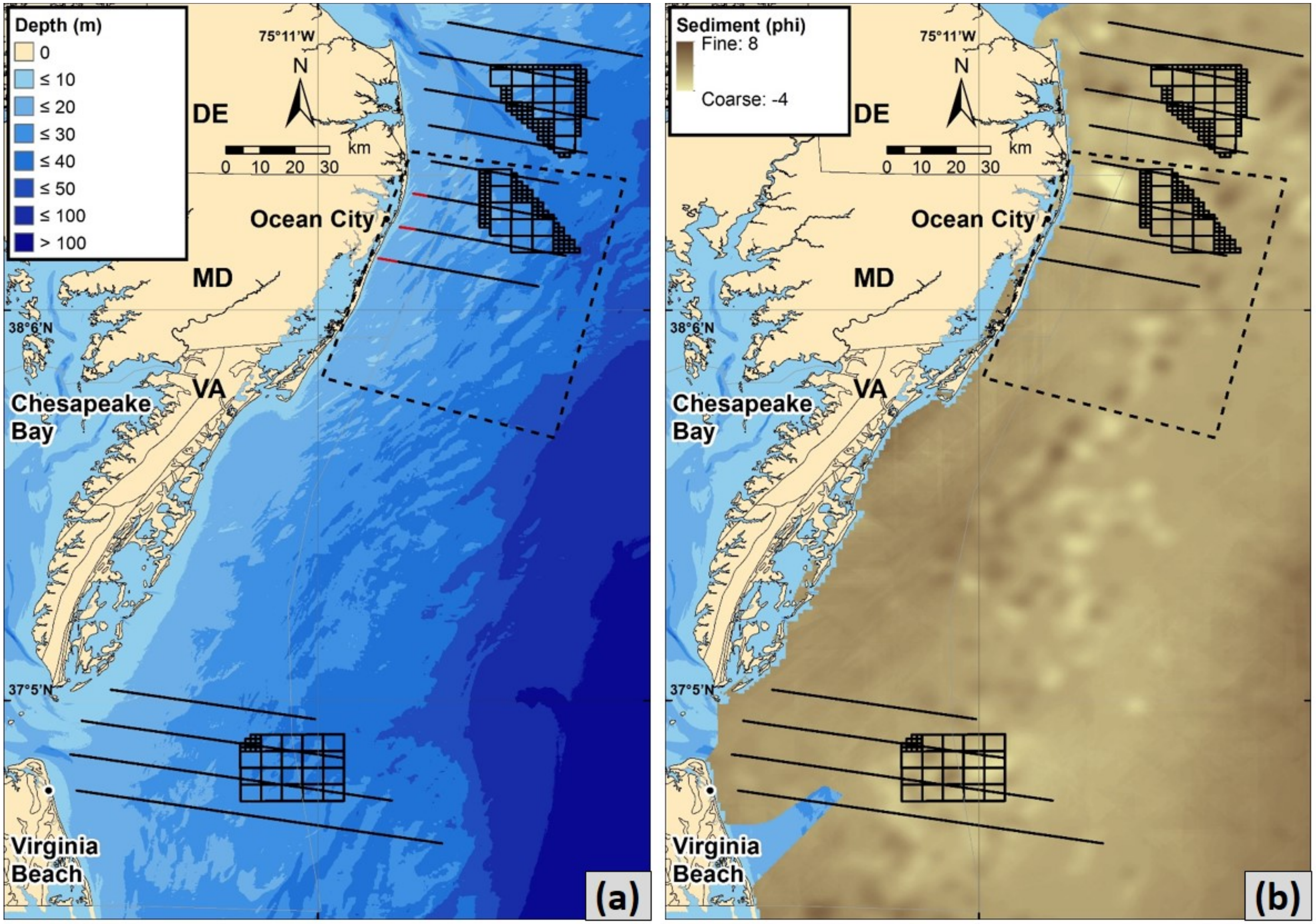
Watson, H., Hiddink, J., Hobbs, M., Brereton, T., Tetley, M., 2013. The utility of relative environmental suitability (RES) modelling for predicting distributions of seabirds in the North Atlantic. Marine Ecology Progress Series 485, 259-273.

Winiarski, K., Miller, D., Paton, P., McWilliams, S., 2013. Spatially explicit model of wintering common loons: conservation implications. Marine Ecology Progress Series 492, 273-283.

Winiarski, K.J., Miller, D.L., Paton, P.W.C., McWilliams, S.R., 2014. A spatial conservation prioritization approach for protecting marine birds given proposed offshore wind energy development. Biological Conservation 169, 79-88.

Zipkin, E.F., Leirness, J.B., Kinlan, B.P., O'Connell, A.F., Silverman, E.D., 2014. Fitting statistical distributions to sea duck count data: Implications for survey design and abundance estimation. Statistical Methodology 17, 67-81.

Figures and tables



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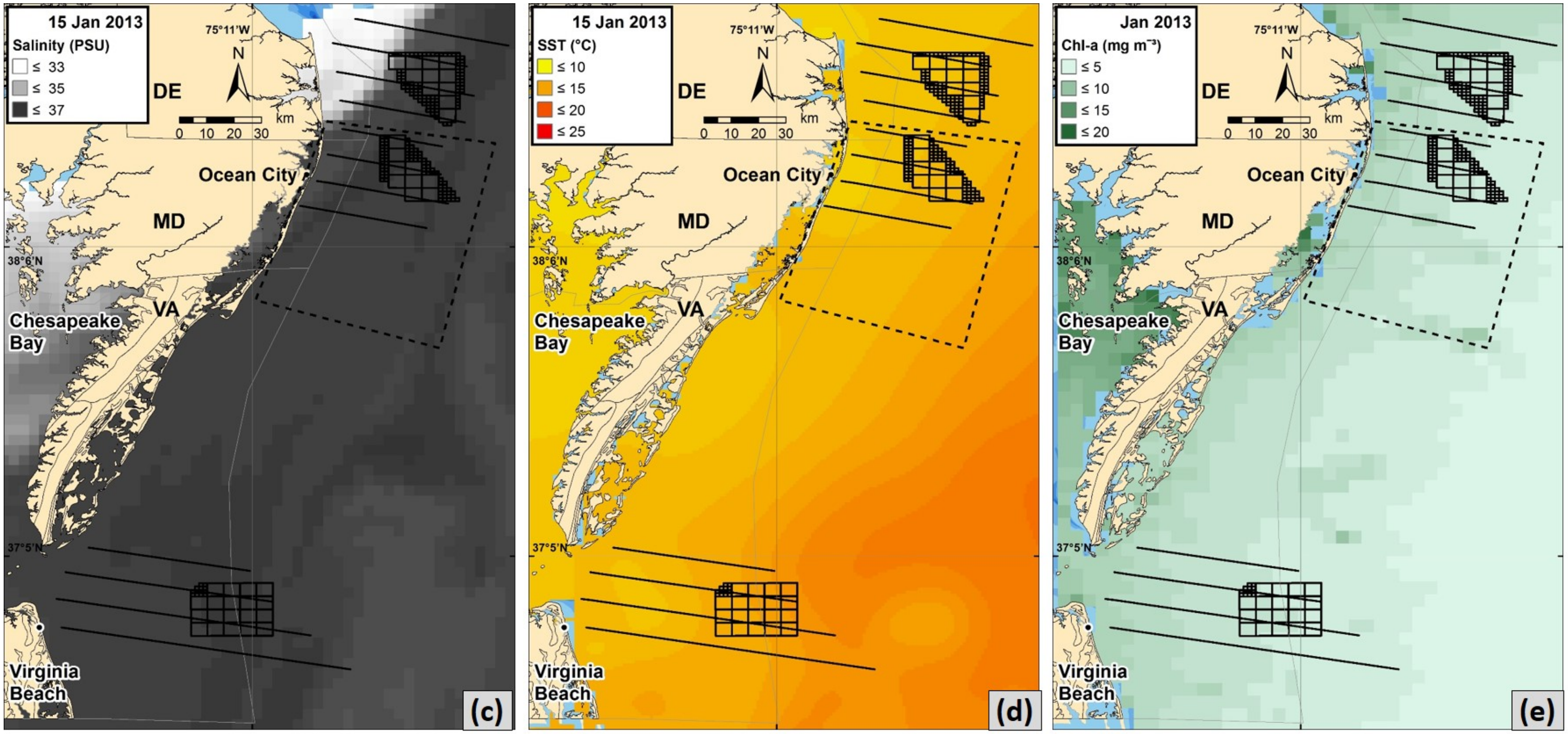
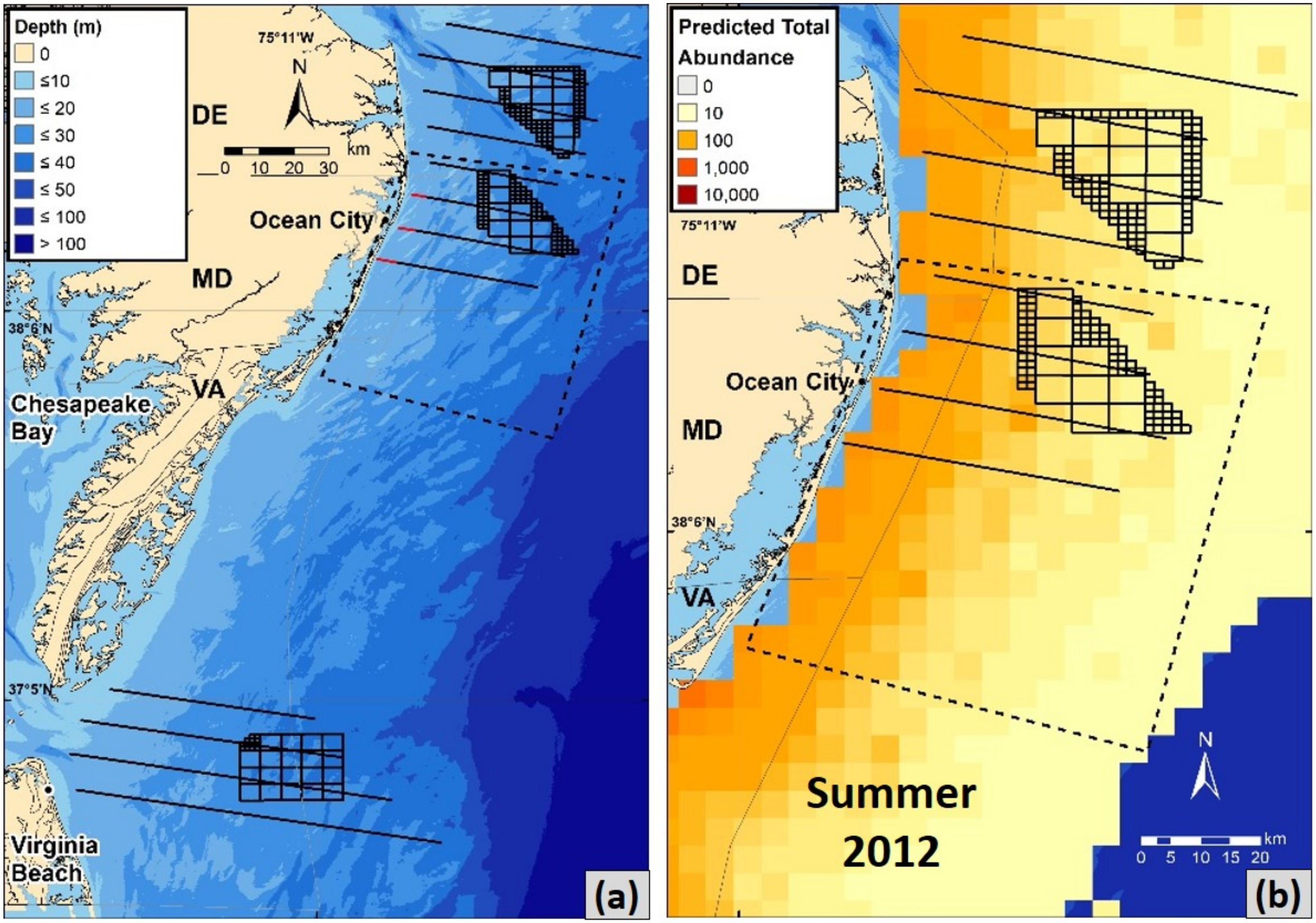


Figure 9-1. Study area and example covariate data. Transects were placed 10 km apart and ran perpendicular to the shoreline, covering federal waters greater than 5 km from the shore and nearshore state waters offshore of Maryland. Transects extended out to a length of approximately 35-90 km. Black lines represent boat transects, black grids represent WEAs, and the MD study area is noted with a dotted black line. Habitat covariates represent (a) bathymetry, distance to shore and slope (red transect segments delineate the MD extensions), (b) sediment grain size (increases in phi units correspond to decreases in size; i.e., coarse to fine sand), (c) 15 Jan 2013 predictive salinity, (d) 15 Jan 2013 predictive sea surface temperature, and (e) Jan 2013 chlorophyll concentration used for model fit and predictions.



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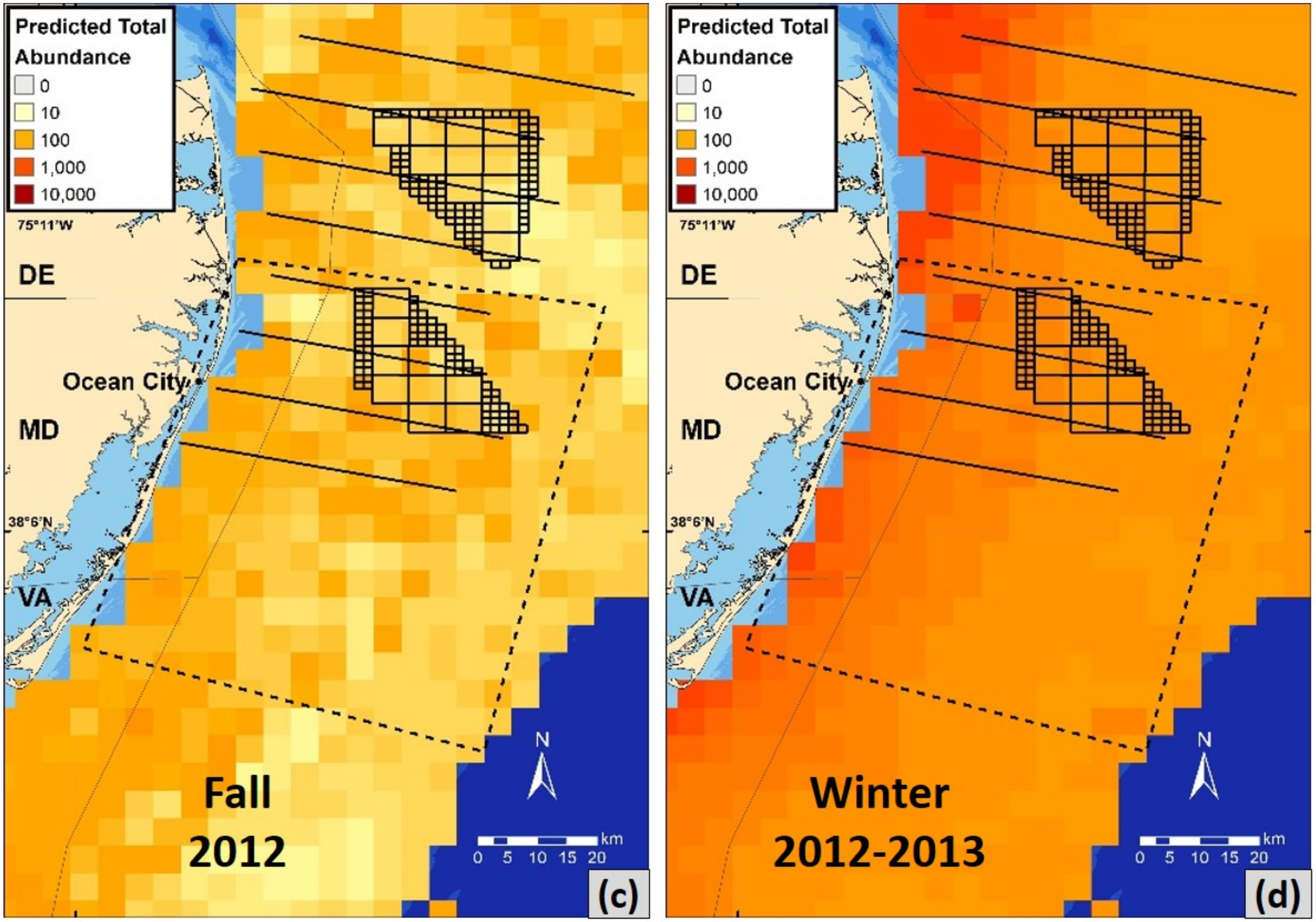

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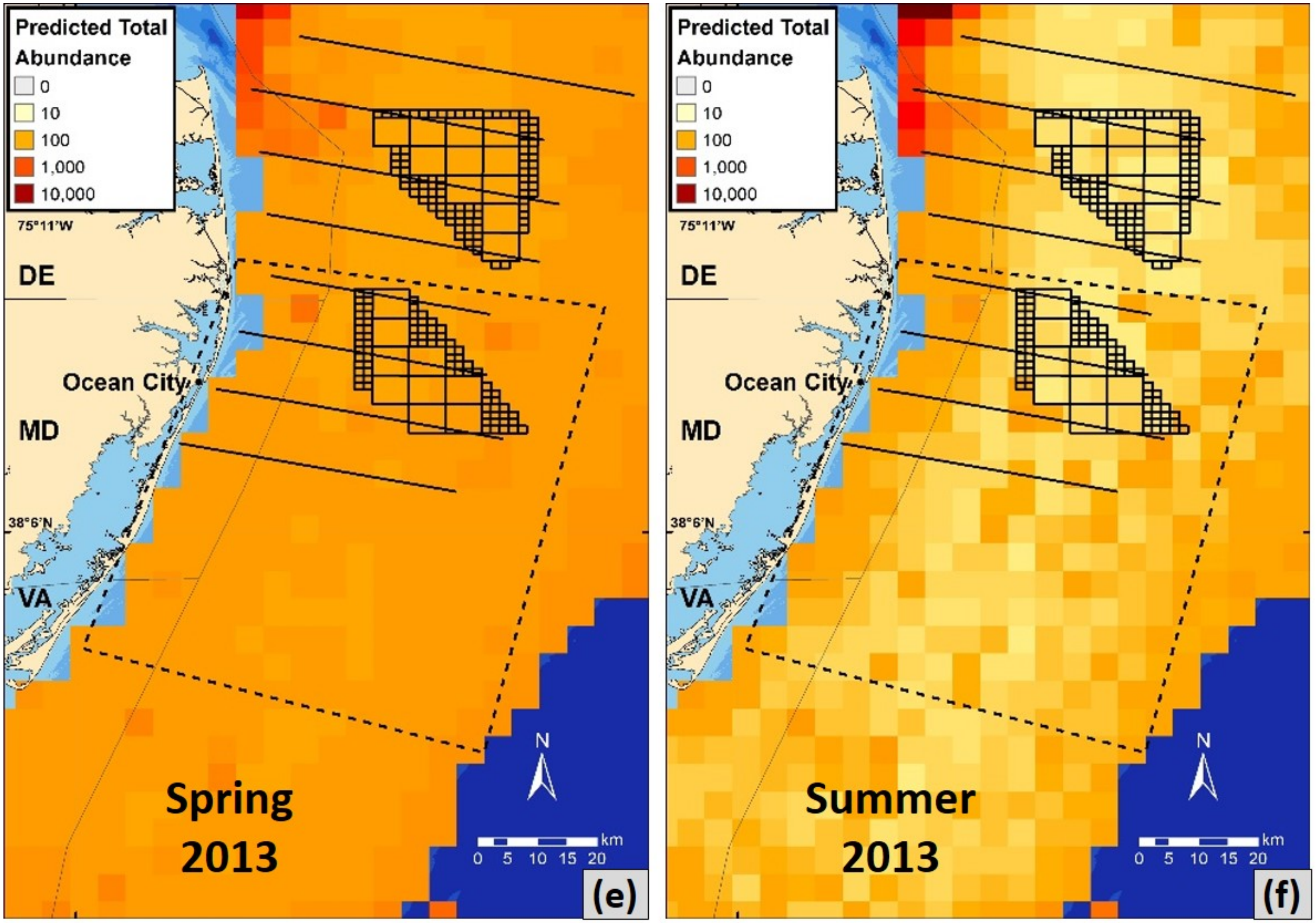

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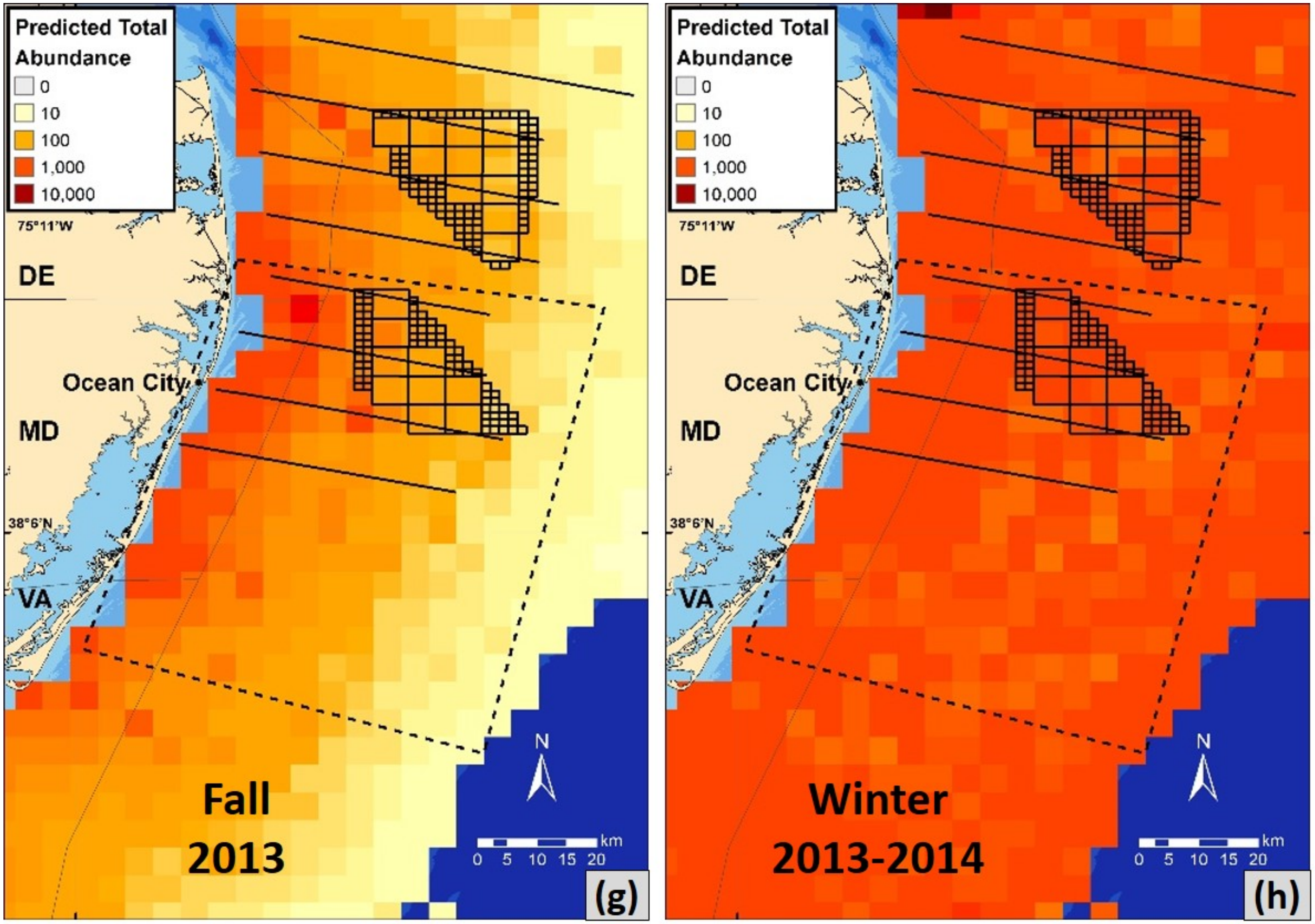
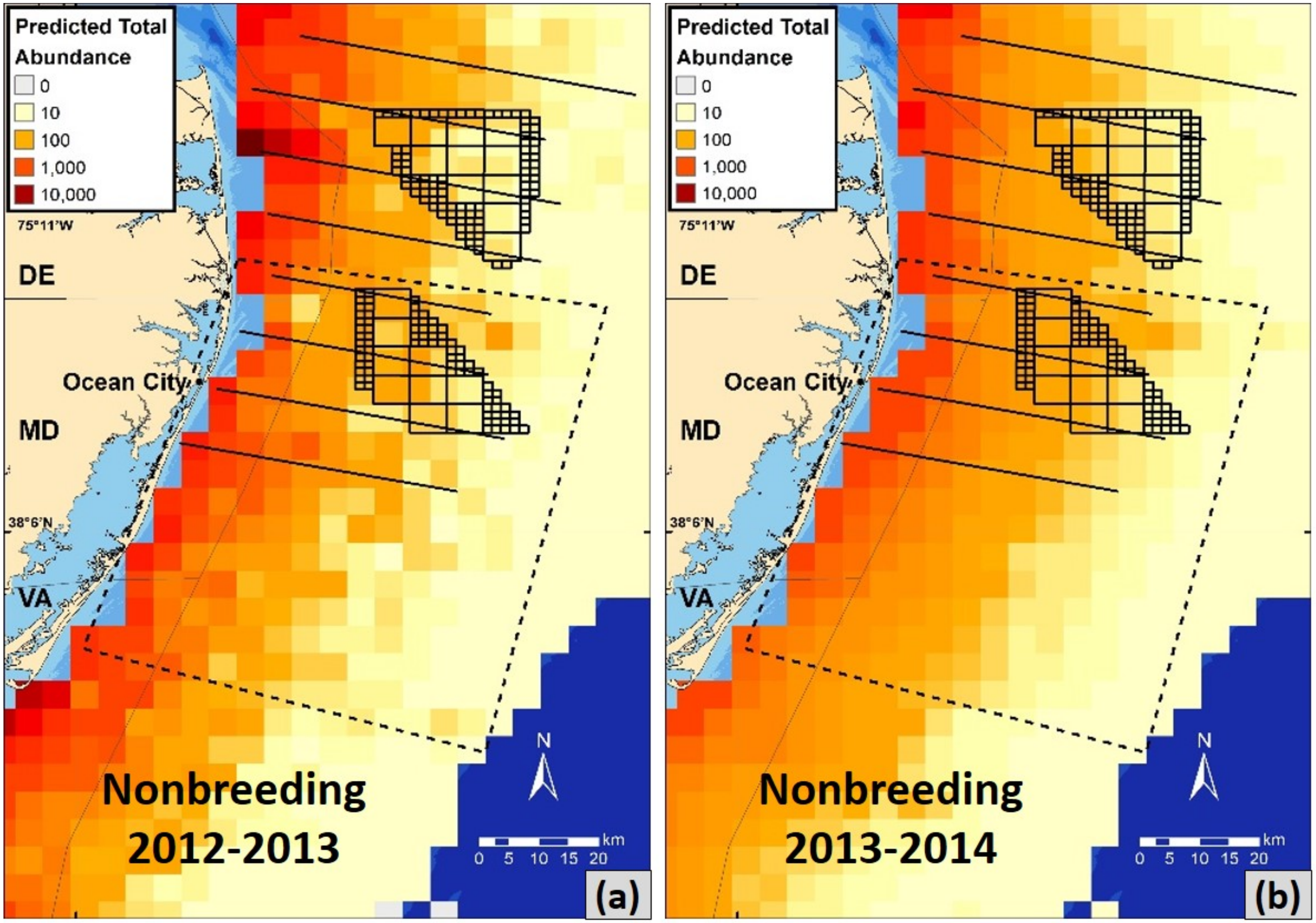


Figure 9-2. Regional study area and Maryland study area (MD area in dotted line) (a) and predicted total abundance maps for the first (b-d) and second (e-h) year in (b, f) summer, (c, g) fall, (d, h) winter, and (e) spring. Abundance maps (b-h) include all species in each seasonal community model (except scoters, which were modeled separately). Each map shows the posterior mean predicted total abundance across the study area: the expected number of flocks multiplied by flock size for each species, then summed across all species. Black lines represent boat transects, red transect segments delineate the MD extensions in (a), black grids represent WEAs.



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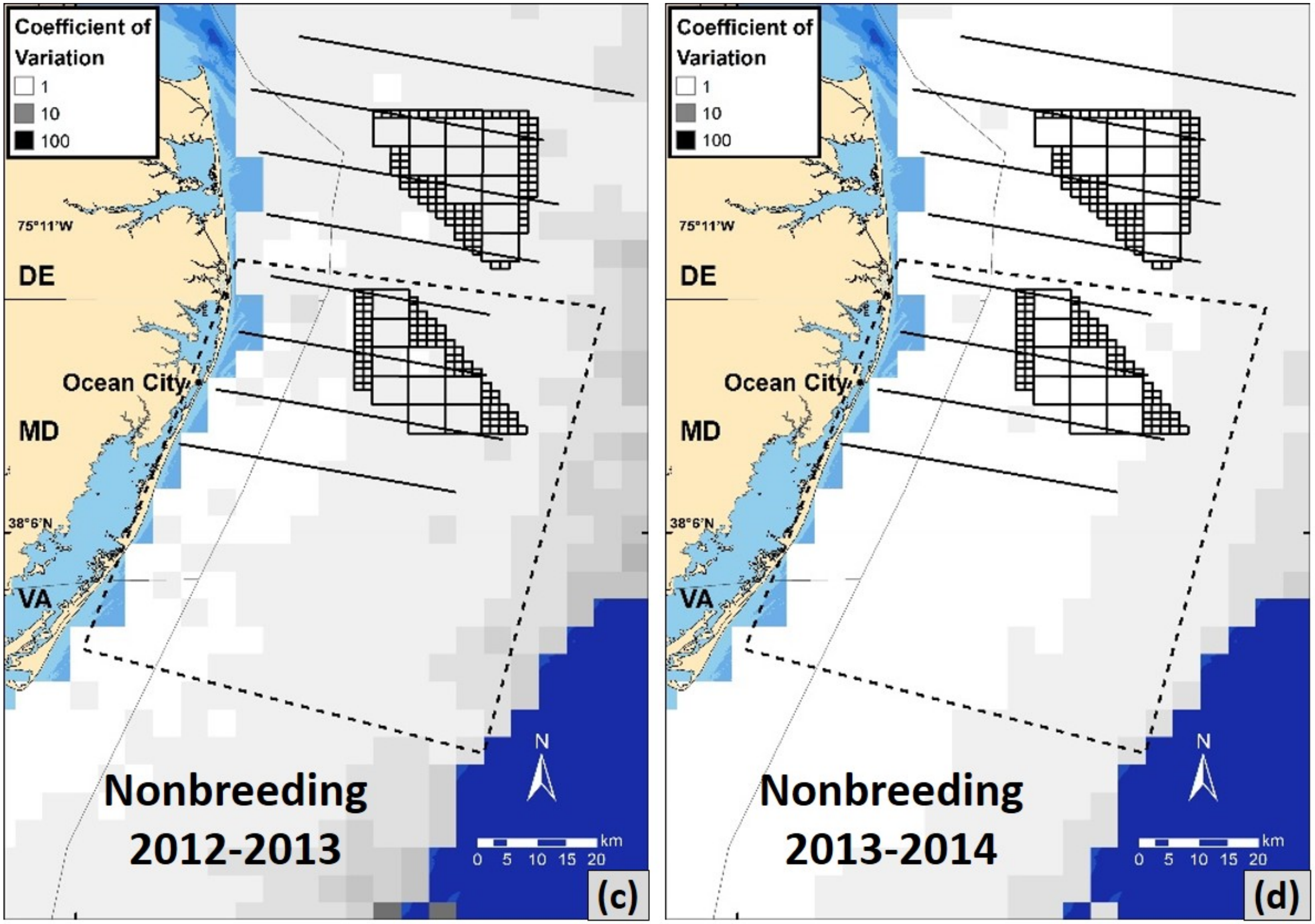
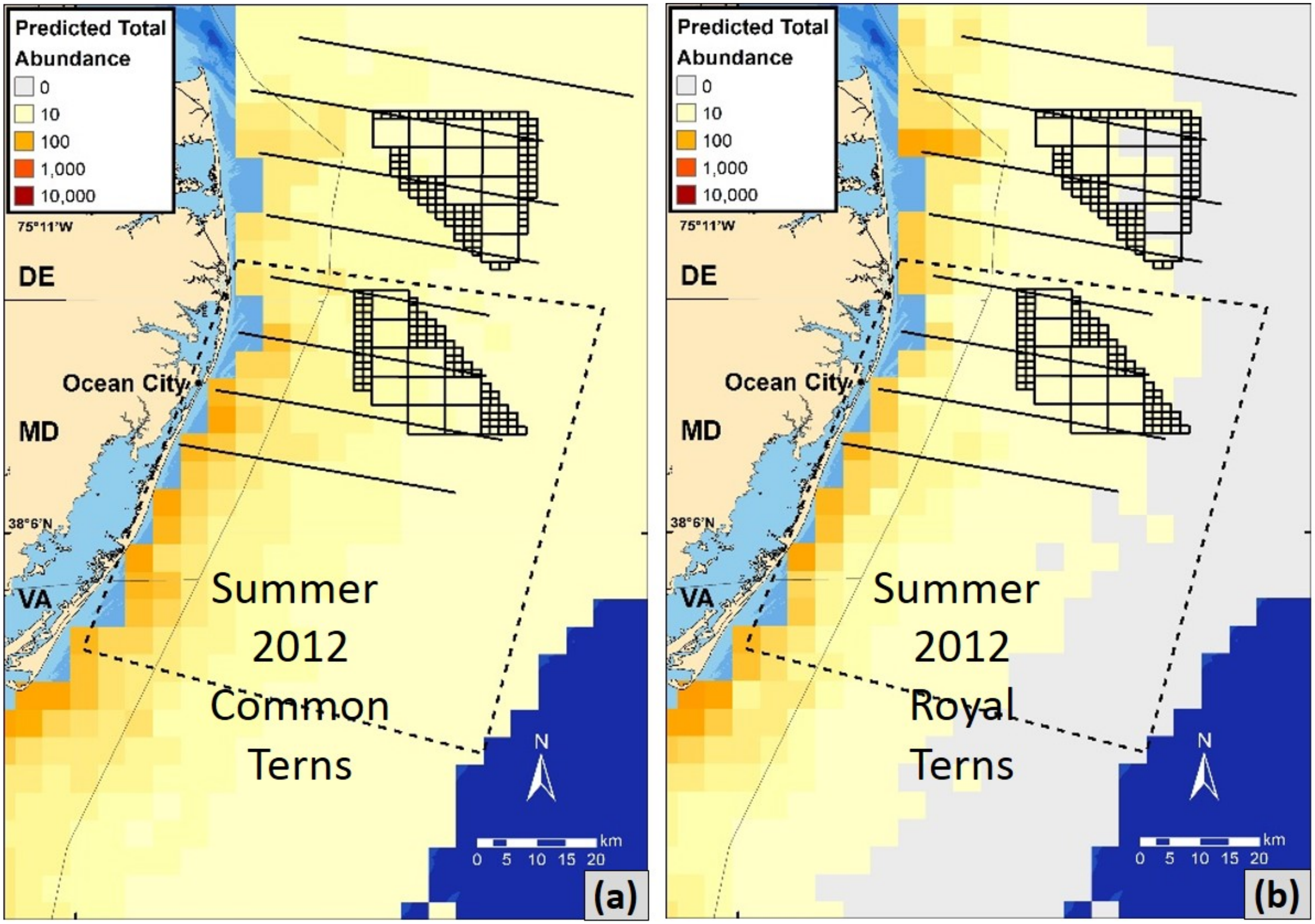


Figure 9-3. Total abundance (a-b) for scoters during the nonbreeding season, predicted to 15 Jan 2013 (first year, left) or 15 Jan 2014 (second year, right). The coefficient of variation (CV) maps (c-d) are derived only for the abundance of flocks, not total abundance. The higher CV towards the edge of the Outer Continental Shelf coincided with sparse data and estimated flock abundances close to zero in the areas farther away from the coastline. Black lines represent boat transects, black grids represent WEAs, and the MD study area is noted with a dotted black line.



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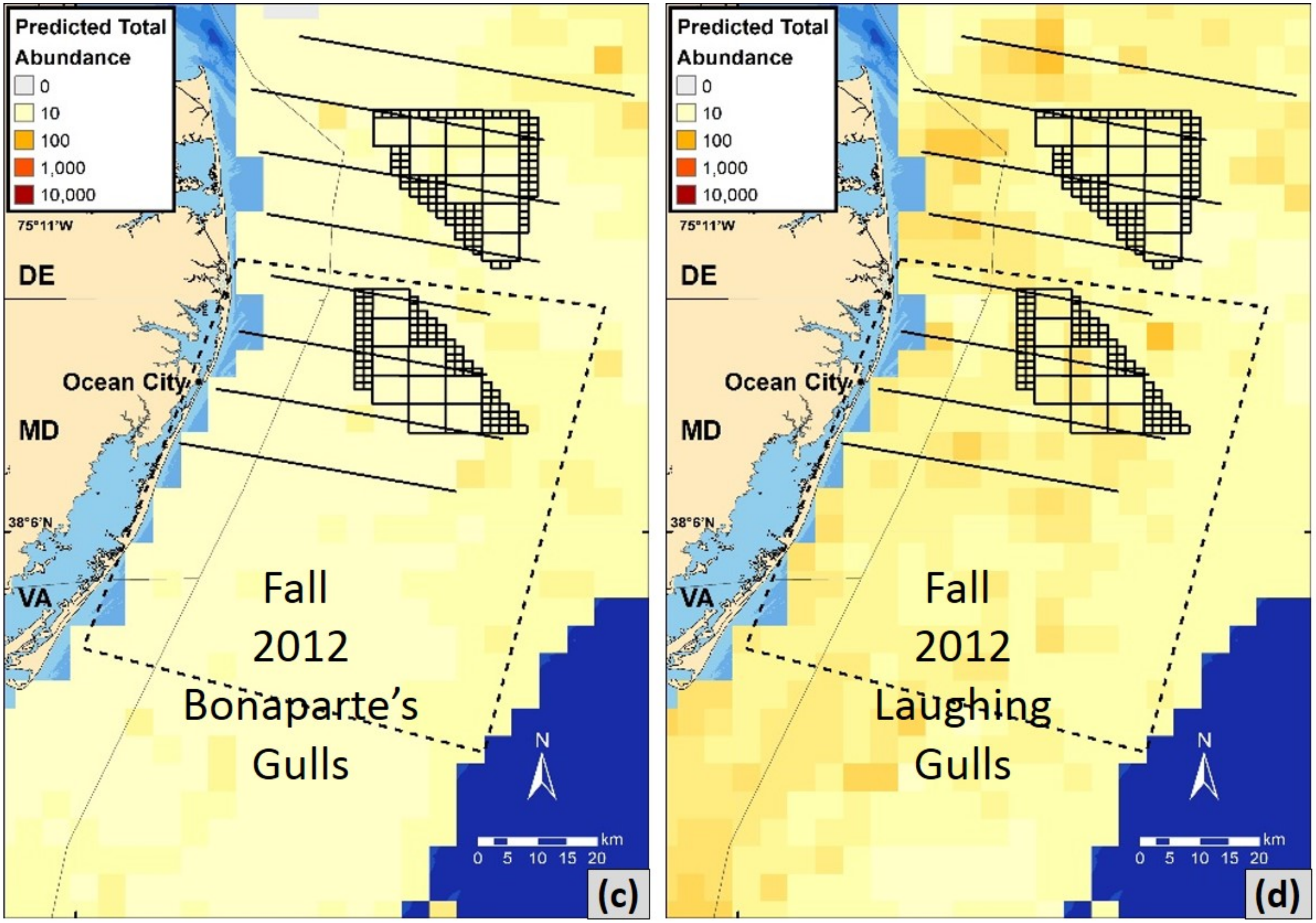

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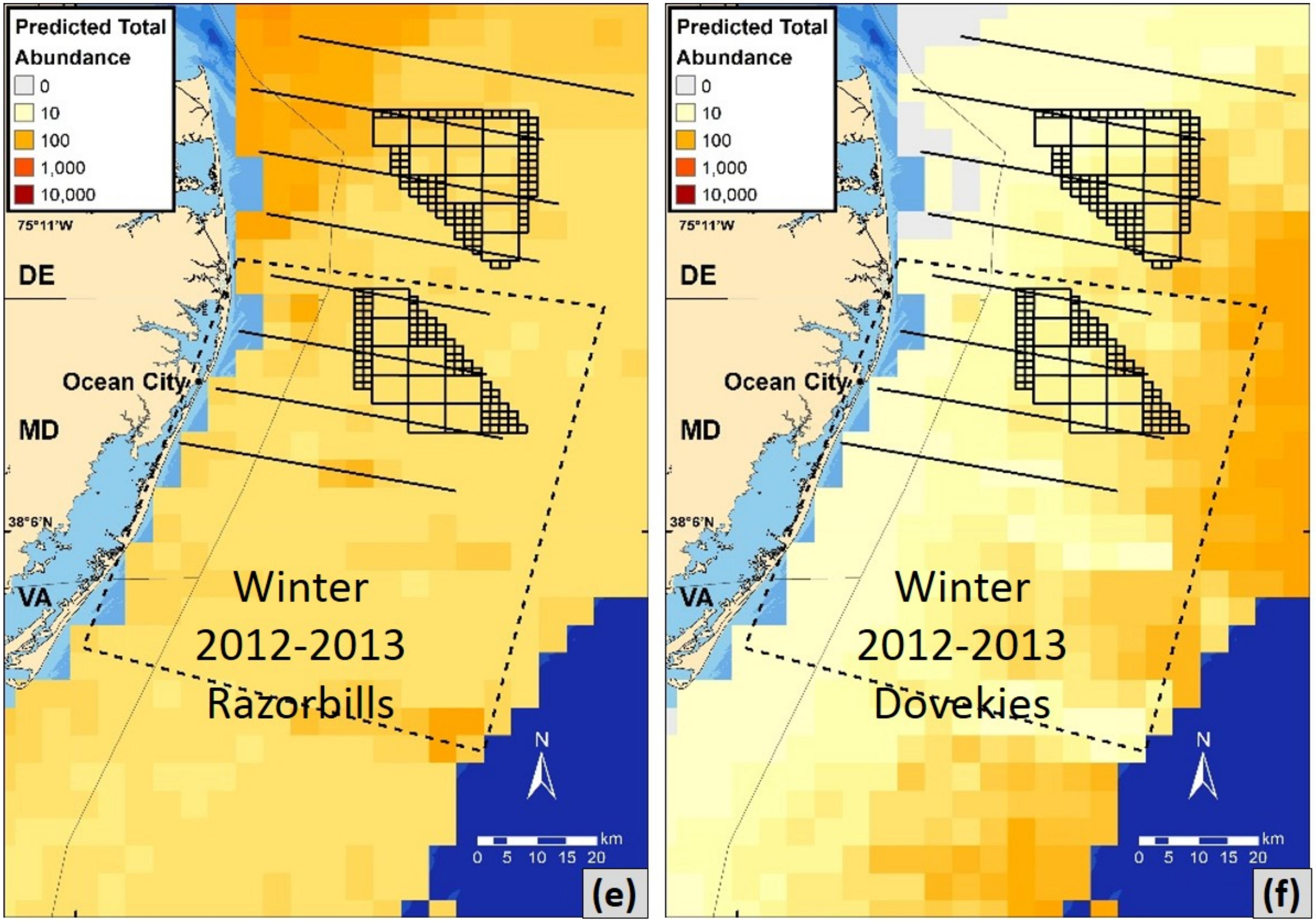

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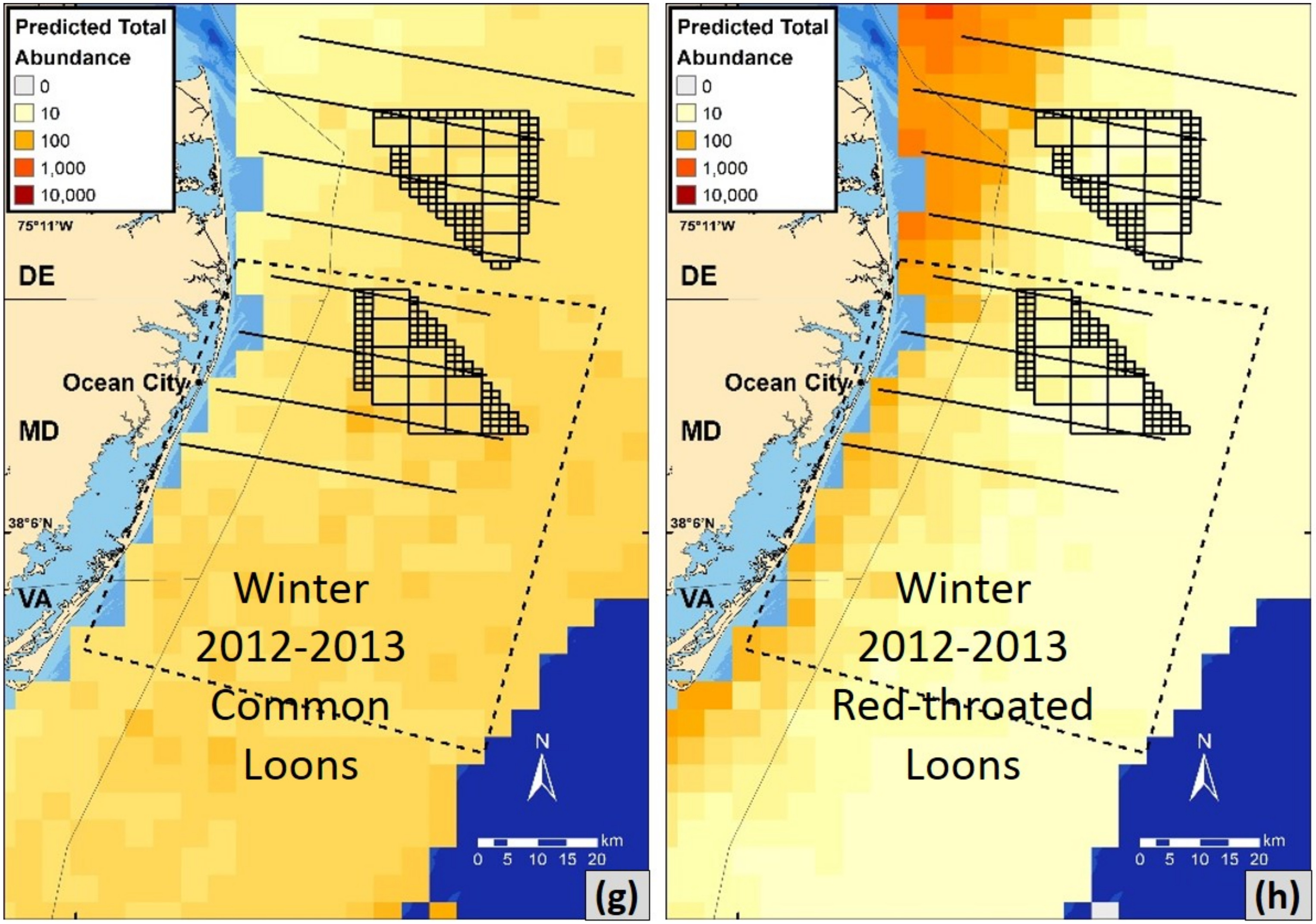

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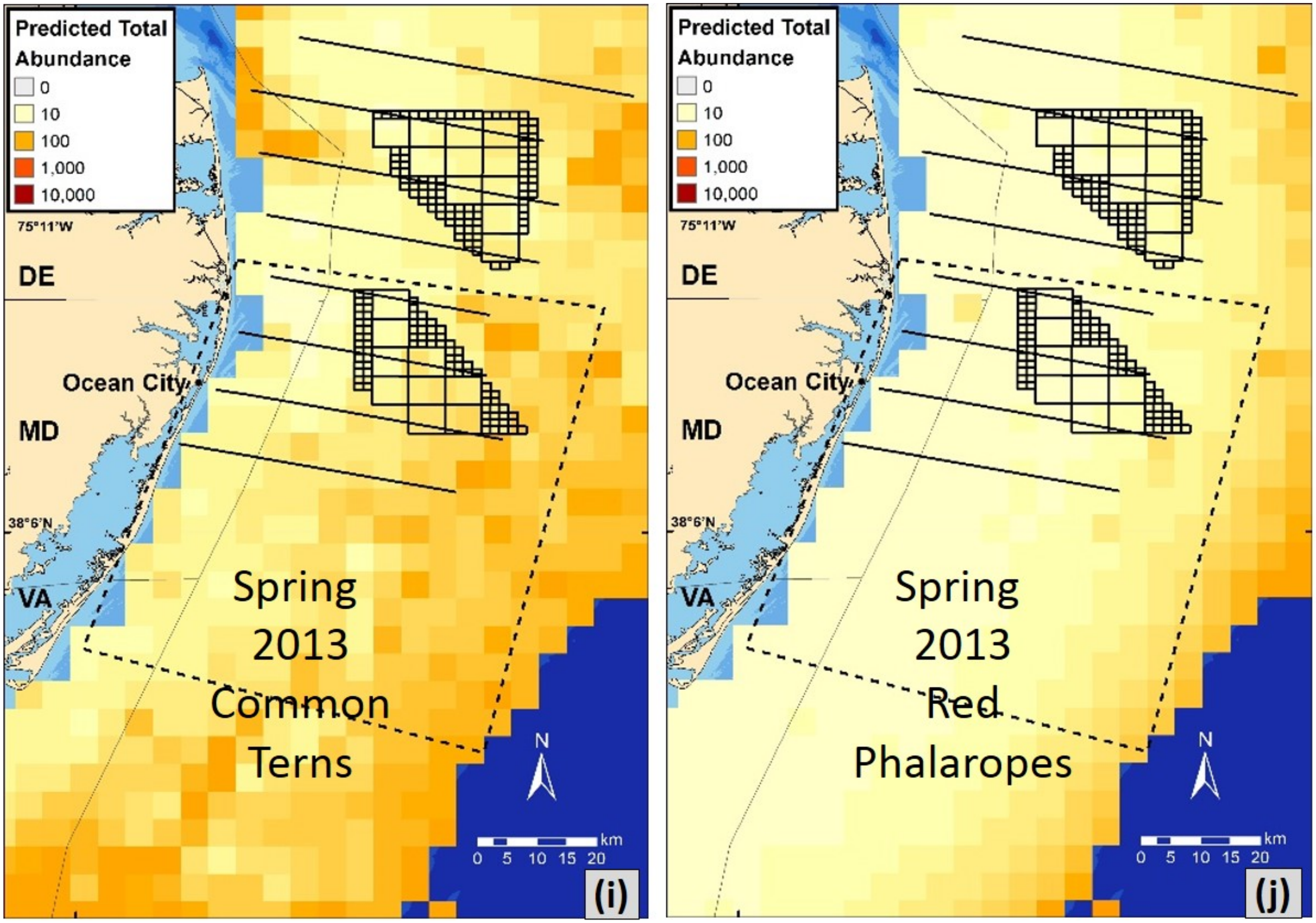

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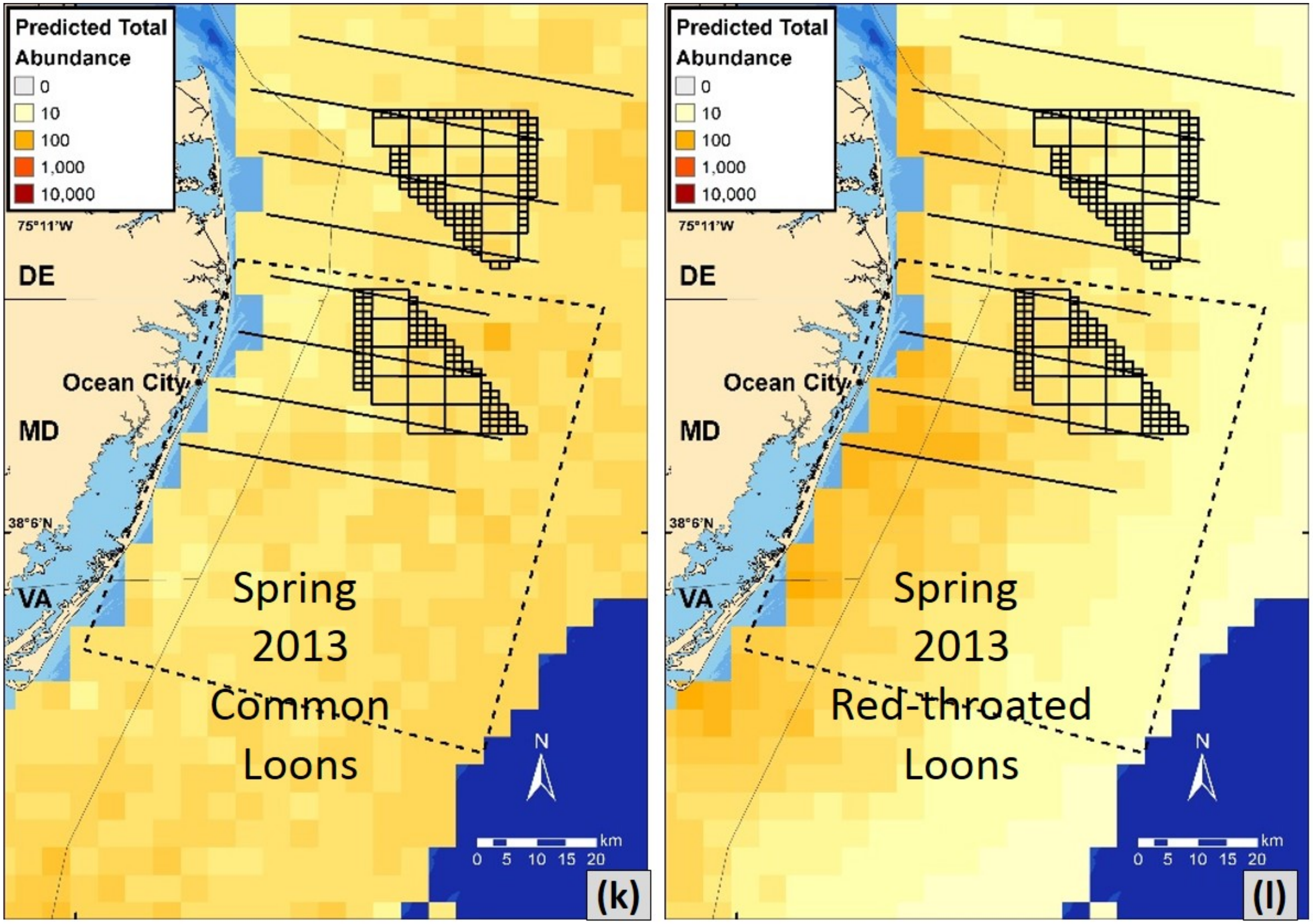

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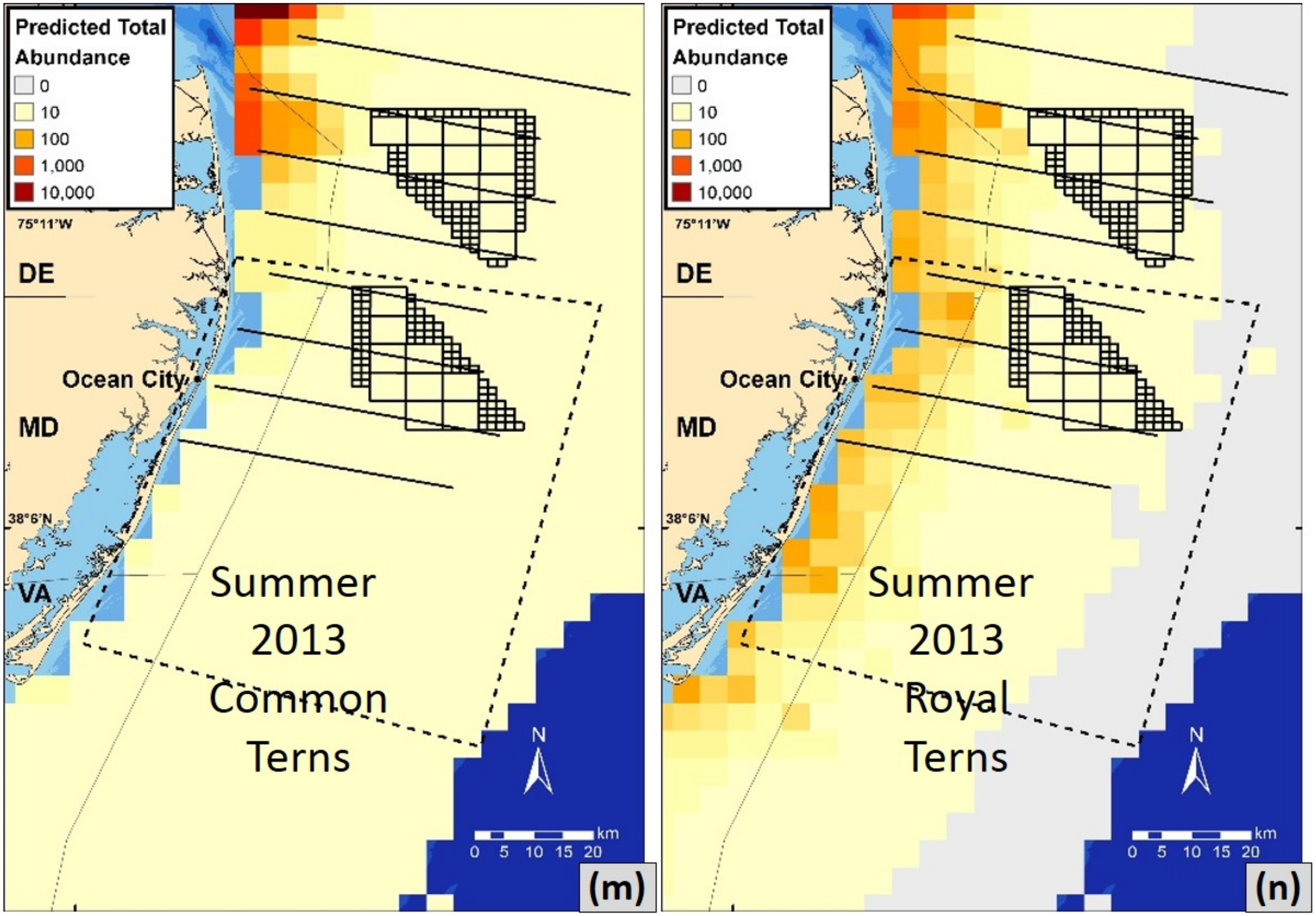

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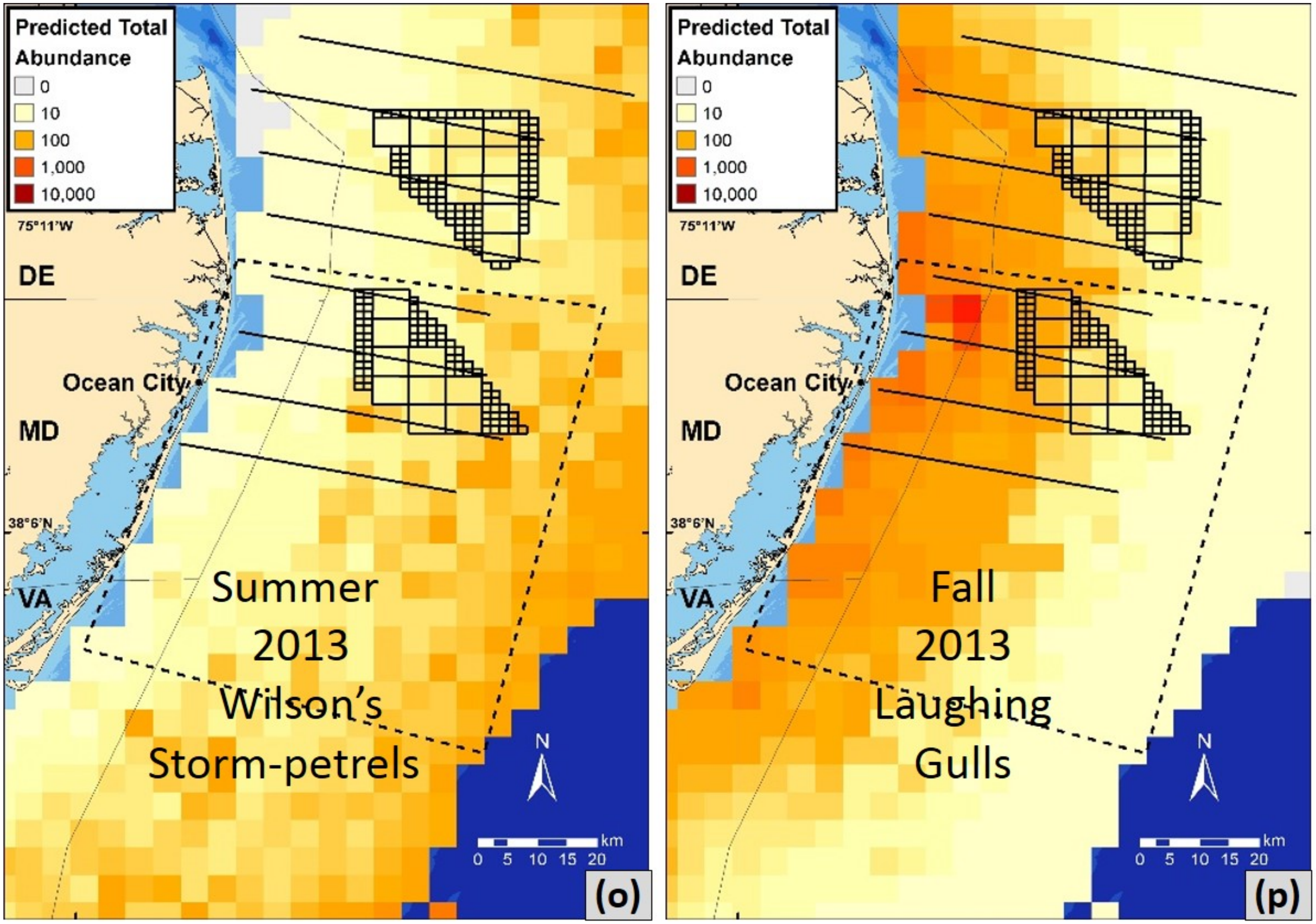

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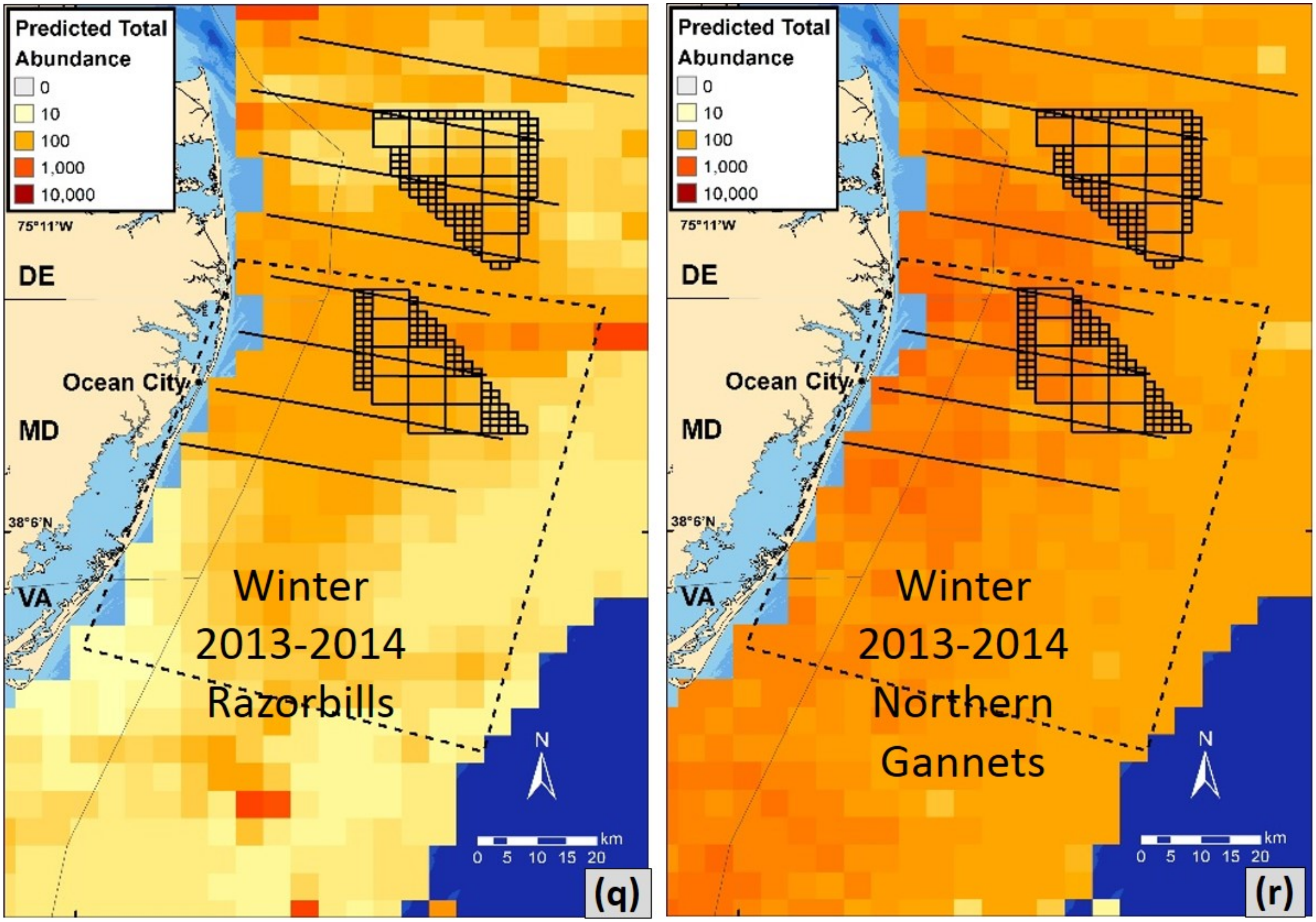


(see figure caption on page 32)

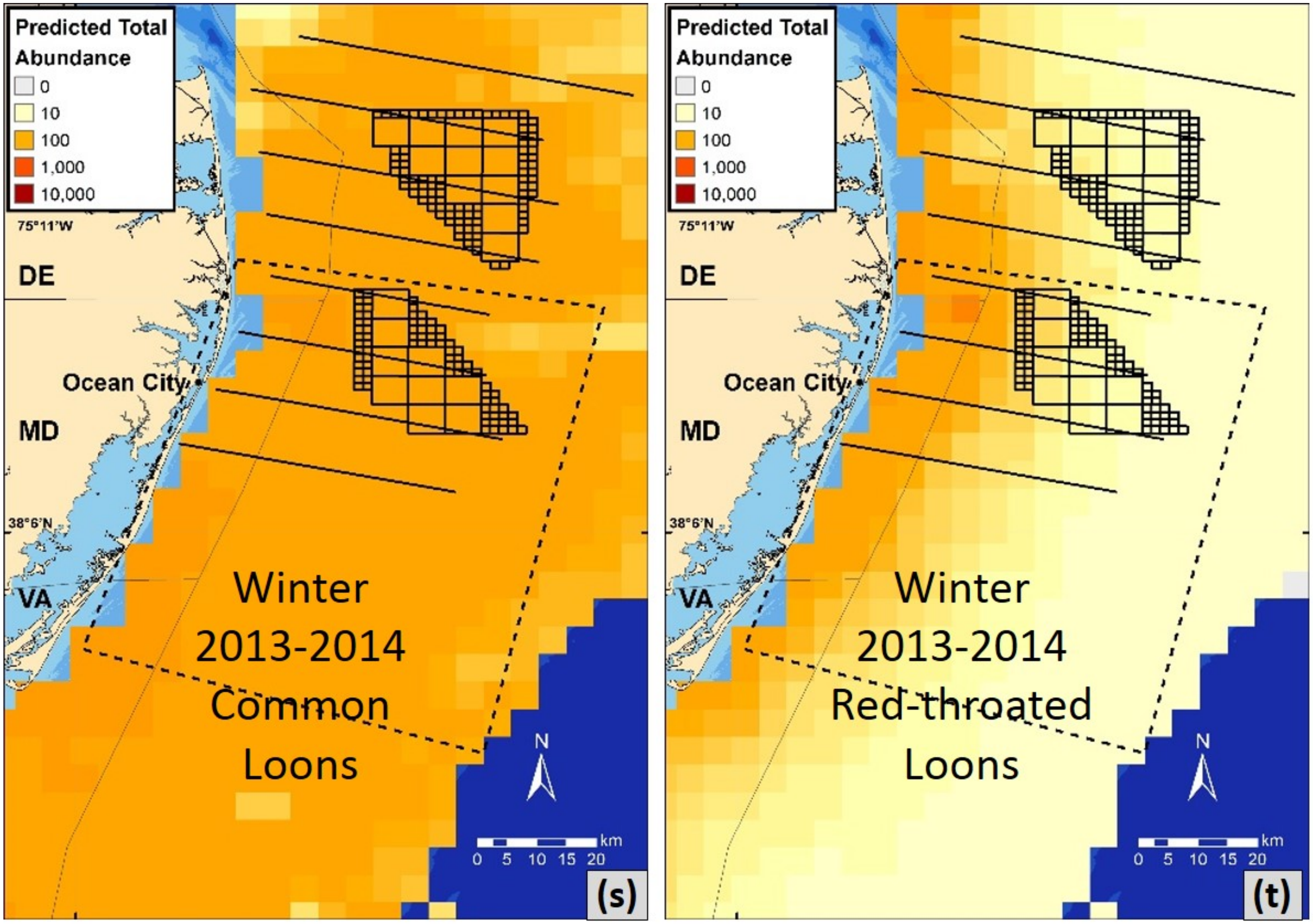
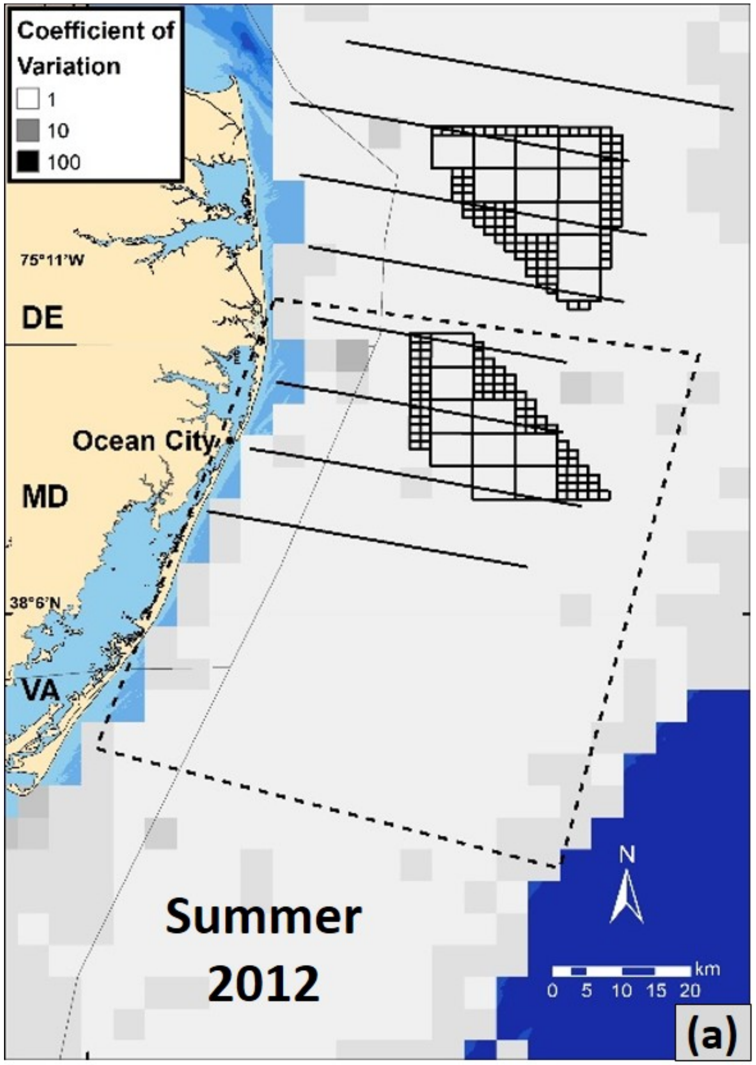
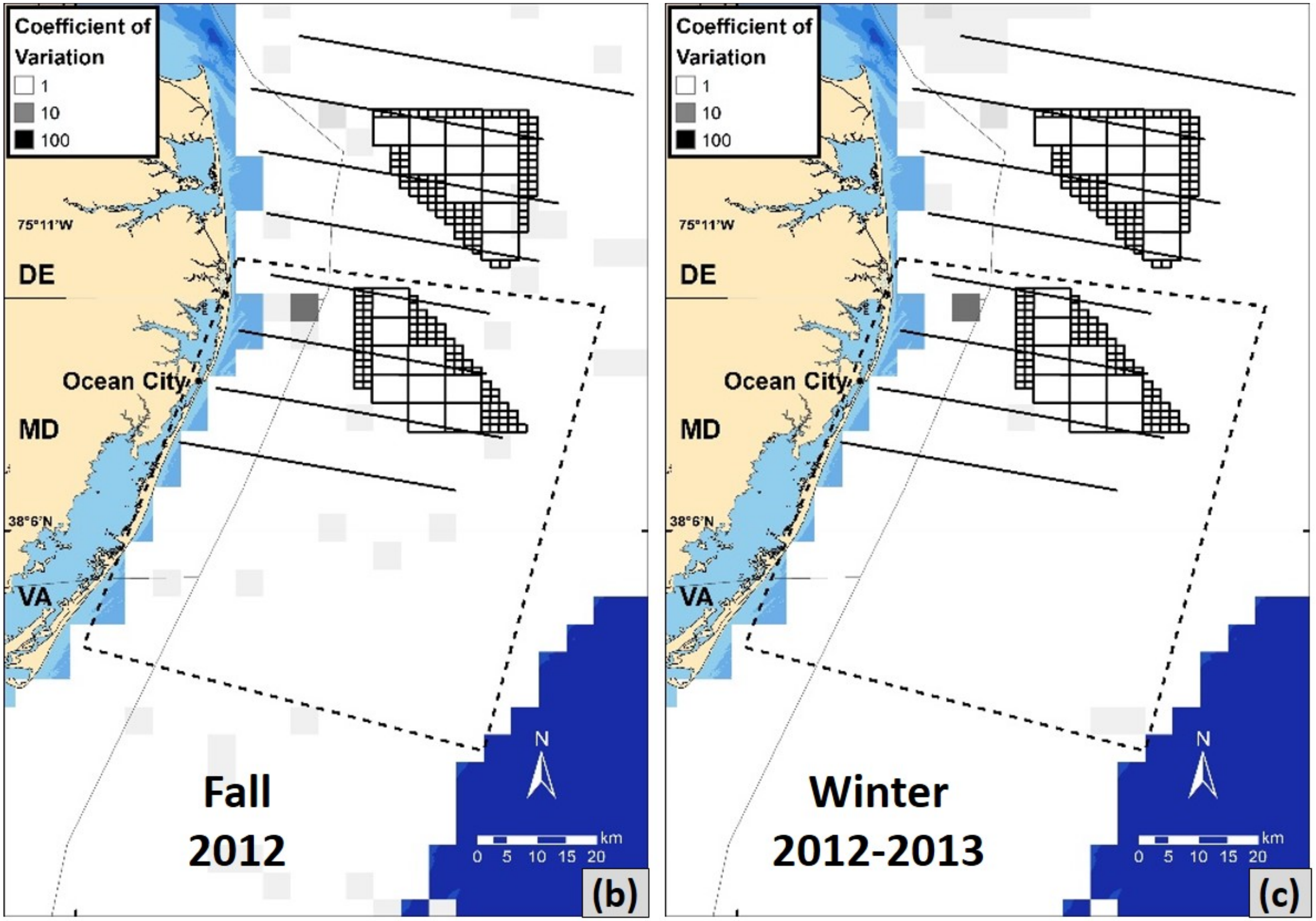


Figure 9-4. Predicted total abundance for selected species per season. The distribution of some of the most abundant species selected from each season, predicted to (a-b) summer 2012 (15 Jul), (c-d) fall 2012 (15 Oct), and (e-h) winter 2013 (15 Jan), as well as (i-l) spring 2013 (15 Apr), (m-o) summer 2013 (15 Jul), (p) fall 2013 (15 Oct), and (q-t) winter 2014 (15 Jan). Selected species include Common Terns (a, i, m), Royal Terns (b, n), Bonaparte's Gulls (c), Razorbills (e, q), Dovekies (f), Common Loons (g, k, s), Red-throated Loons (h, l, t), Red Phalaropes (j), Wilson's Storm-petrels (o), Laughing Gulls (d, p), and Northern Gannets (r).



(see figure caption on page 36)



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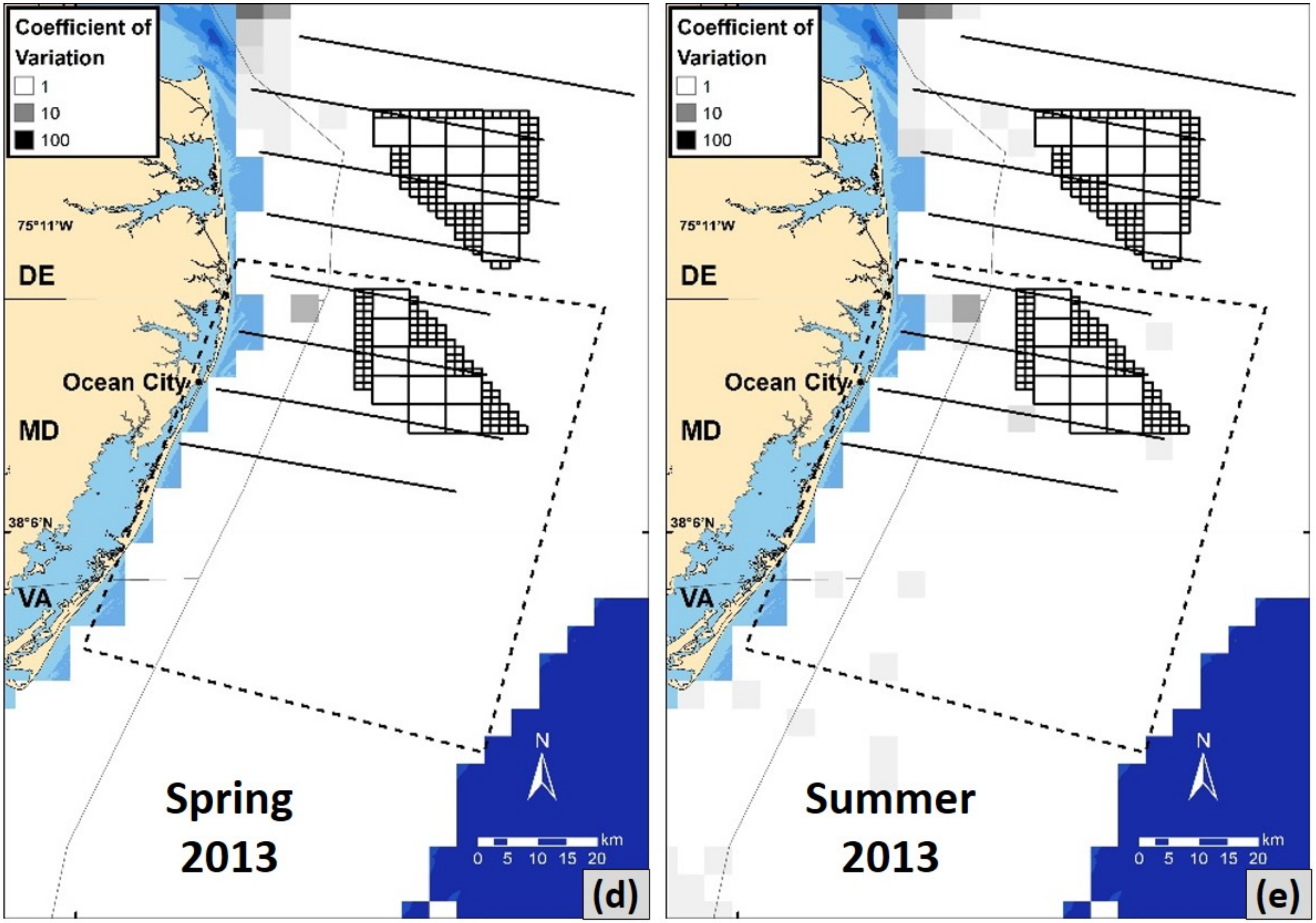


(see figure caption on page 36)

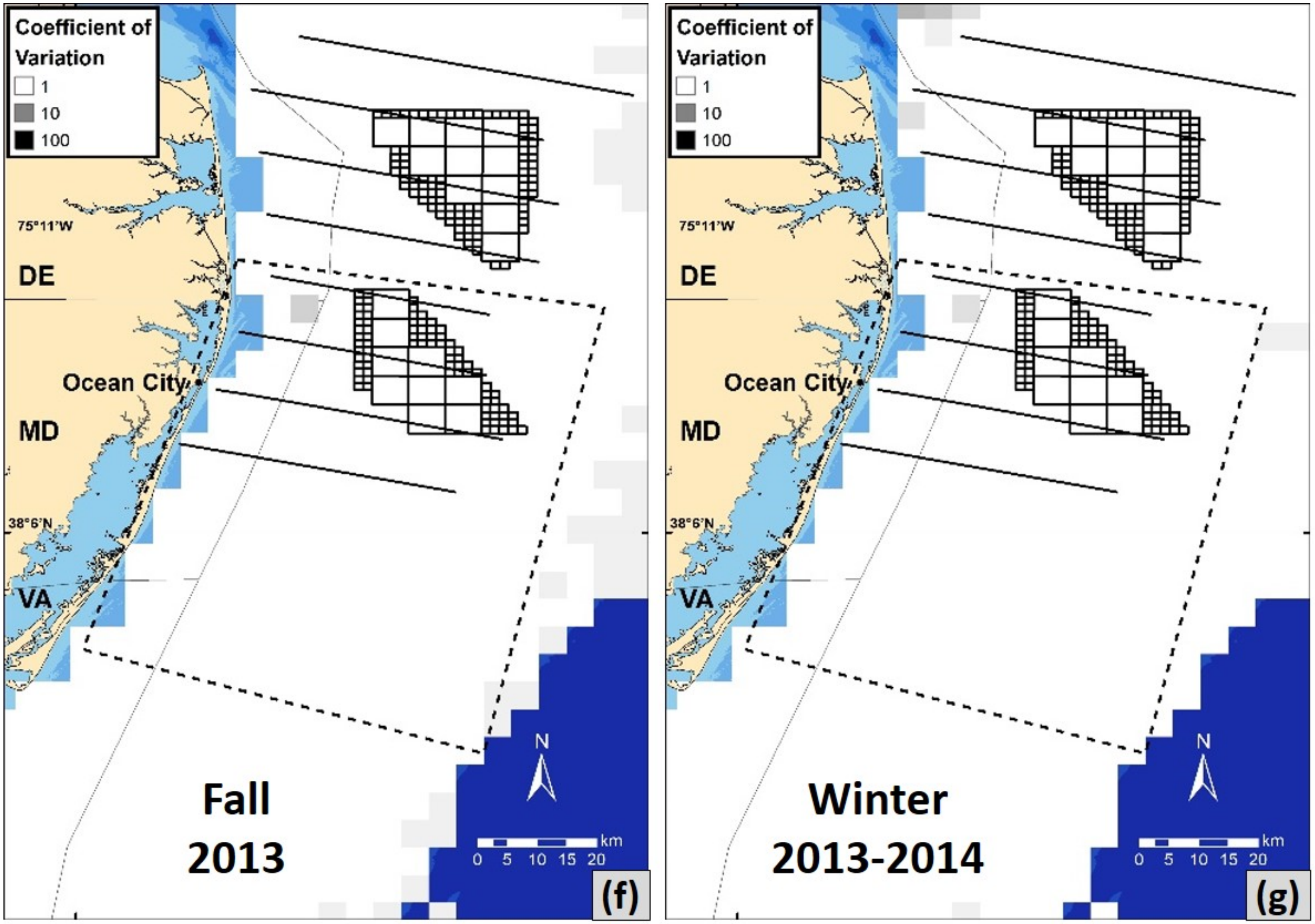
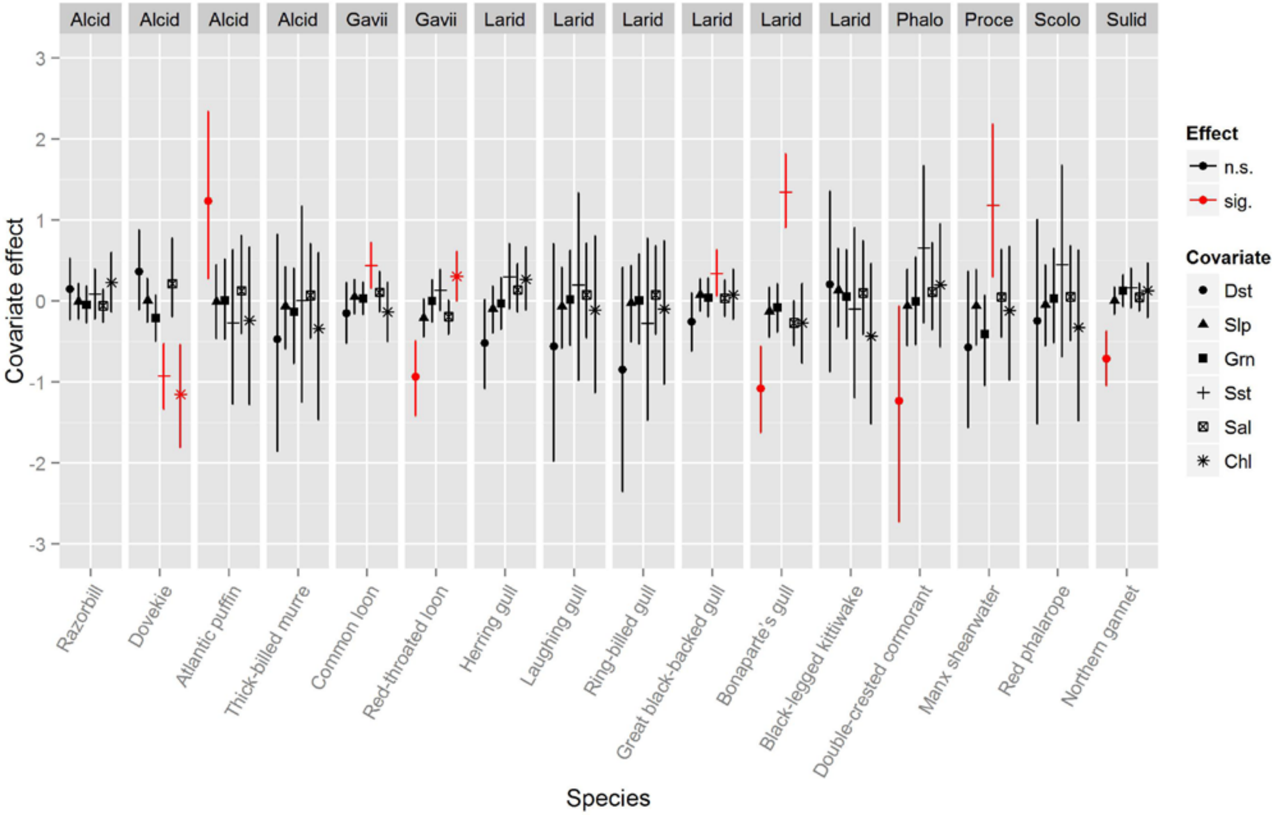
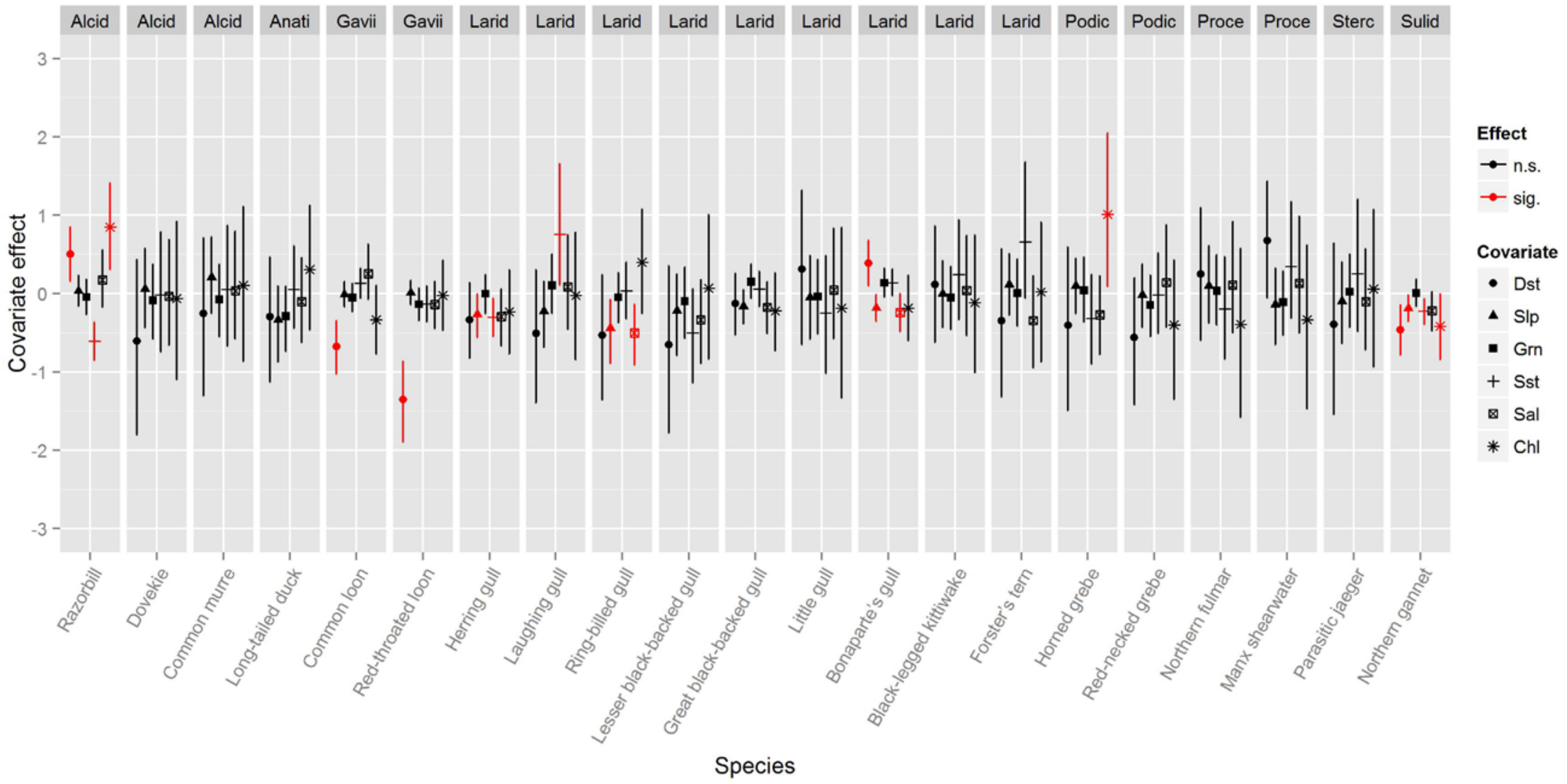


Figure 9-5. Coefficient of variation (CV) maps for abundance of flocks in the first (a-c) and second (d-g) year (a, e) summer, (b, f) fall, (c, g) winter , and (d) spring. These figures include all species in each seasonal community model (to the exclusion of scoters, which were modeled separately) and predicted to the mid-point of the season as described in the text.

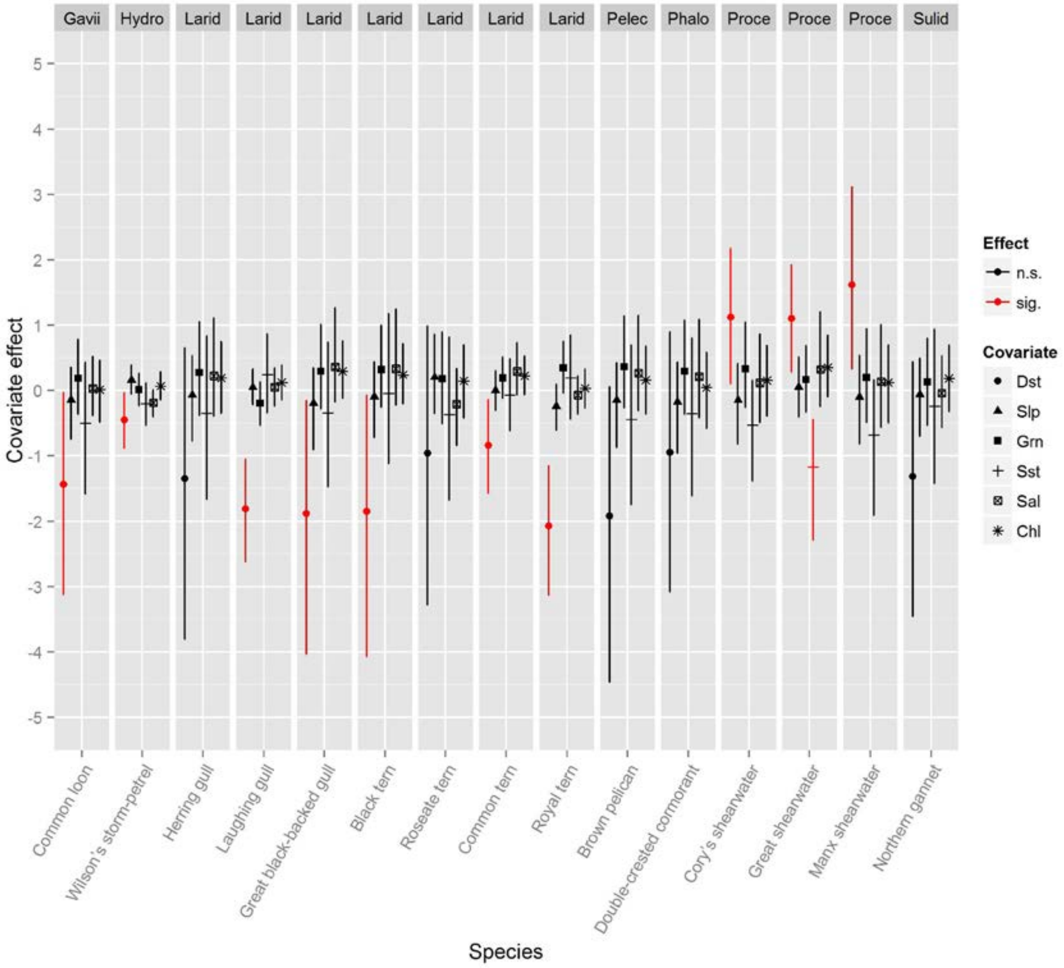

Alcid
Alcid
Alcid
Alcid
Gavii
Gavii
Larid
Larid
Larid
Larid
Larid
Larid
Phalo
Proce
Scolo
Sulid
Covariate effect
3
2
1
0
-1
-2
-3
Razorbill
Dovekie
Atlantic puffin
Thick-billed murre
Common loon
Red-throated loon
Herring gull
Laughing gull
Ring-billed gull
Great black-backed gull
Bonaparte's gull
Black-legged kittiwake
Double-crested cormorant
Manx shearwater
Red phalarope
Northern gannet
Species
Effect
n.s.
sig.
Covariate
Dst
Slp
Grn
Sst
Sal
Chl

(a)

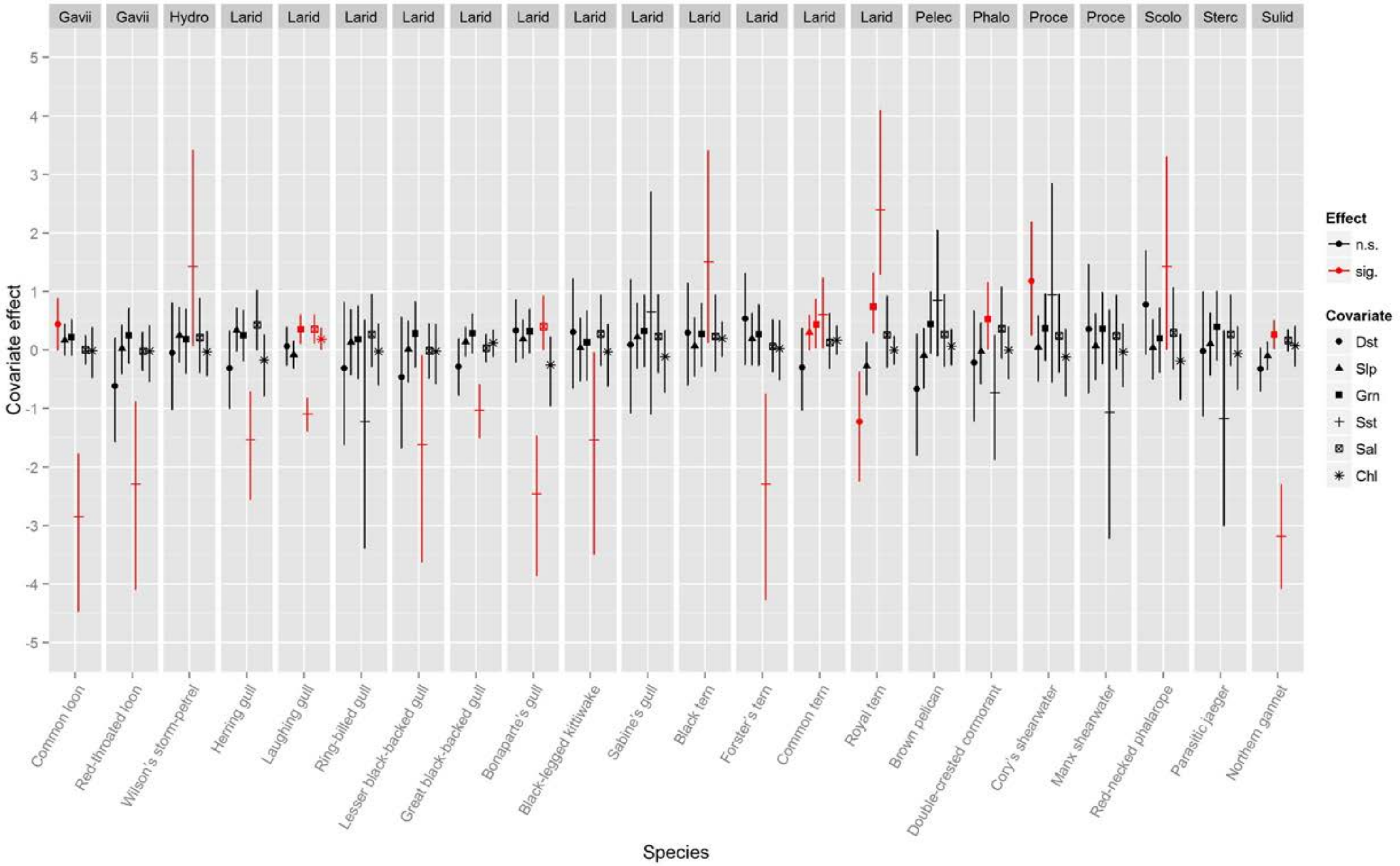


(b)

Figure 9-6. First (a) and second (b) year effects of habitat covariates on each species in the winter community model (excluding scoters). Error bars (Bayesian credible intervals) in red indicate which parameter estimates (on the log scale) were significantly different from zero; n.s. = not significant, sig. = significant, Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Chl = chlorophyll anomaly. Species are ordered by family (see Table 9-1 for abbreviations). Covariate effects are relative to study-specific habitat values, where negative responses indicate associations with proximity to shore, gradual slope, coarse sediment grain size, cold water, low salinity, and low primary productivity; positive responses indicate dependence on distance away from shore, steep slope, fine sediment grain size, warm water, high salinity, and high primary productivity.


Gavii
Hydro
Larid
Larid
Larid
Larid
Larid
Larid
Larid
Pelec
Phalo
Proce
Proce
Proce
Sulid
5
4
3
2
1
0
-1
-2
-3
-4
-5
Covariate effect
Common loon
Wilson's storm-petrel
Herring gull
Laughing gull
Great black-backed gull
Black tern
Roseate tern
Common tern
Royal tern
Brown pelican
Double-crested cormorant
Cory's shearwater
Great shearwater
Manx shearwater
Northern gannet
Species
Effect
n.s.
sig.
Covariate
Dst
Slp
Grn
Sst
Sal
Chl

(a)


Gavii
Gavii
Hydro
Larid
Larid
Larid
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Larid
Larid
Larid
Larid
Larid
Larid
Larid
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Pelec
Phalo
Proce
Proce
Scolo
Sterc
Sulid
5
4
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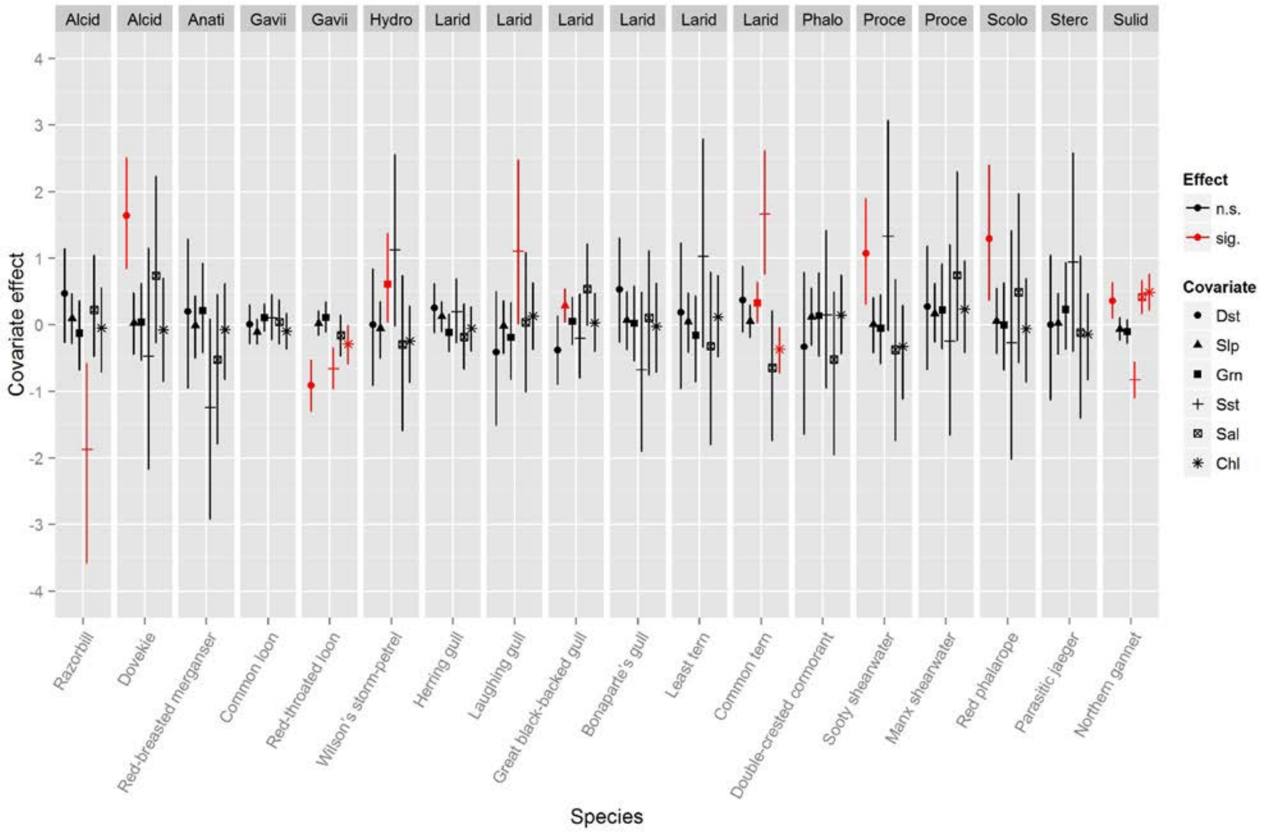
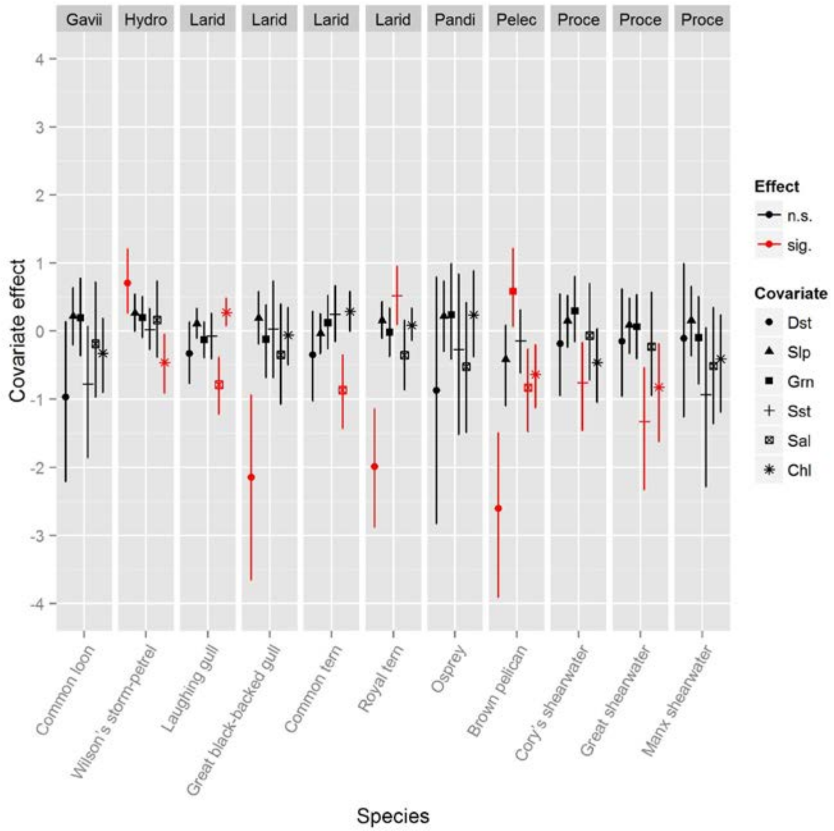
-1
-2
-3
-4
-5
Covariate effect
Common loon
Red-throated loon
Wilson's storm-petrel
Herring gull
Laughing gull
Ring-billed gull
Lesser black-backed gull
Great black-backed gull
Bonaparte's gull
Black-legged kittiwake
Sabine's gull
Black tern
Forster's tern
Common tern
Royal tern
Brown pelican
Double-crested cormorant
Cory's shearwater
Manx shearwater
Red-necked phalarope
Parasitic jaeger
Northern gannet
Species
Effect
n.s.
sig.
Covariate
Dst
Slp
Grn
Sst
Sal
Chl

(b)


Alcid
Alcid
Anati
Gavii
Gavii
Hydro
Larid
Larid
Larid
Larid
Larid
Larid
Phalo
Proce
Proce
Scolo
Sterc
Sulid
Covariate effect
4
3
2
1
0
-1
-2
-3
-4
Razorbill
Dovekie
Red-breasted merganser
Common loon
Red-throated loon
Wilson's storm-petrel
Herring gull
Laughing gull
Great black-backed gull
Bonaparte's gull
Least tern
Common tern
Double-crested comorant
Sooty shearwater
Manx shearwater
Red phalarope
Parasitic jaeger
Northern gannet
Species
Effect
n.s.
sig.
Covariate
Dst
Slp
Grn
Sst
Sal
Chl

(c)


Gavii
Hydro
Larid
Larid
Larid
Larid
Pandi
Pelec
Proce
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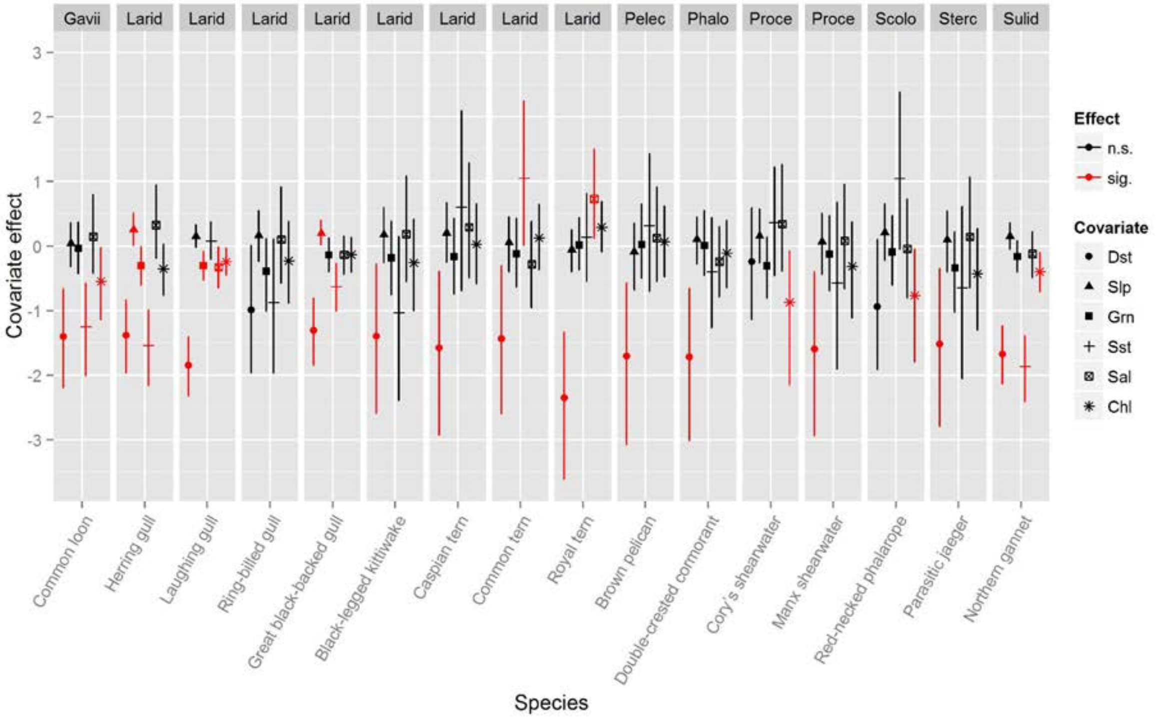
-1
-2
-3
-4
Covariate effect
Common loon
Wilson's storm-petrel
Laughing gull
Great black-backed gull
Common tern
Royal tern
Osprey
Brown pelican
Cory's shearwater
Great shearwater
Manx shearwater
Species
Effect
n.s.
sig.
Covariate
Dst
Slp
Grn
Sst
Sal
Chl

(d)



(e)

Figure 9-7. First year summer (a) and fall (b), and second year spring (c), summer (d) and fall (e) effects of habitat covariates on each species in the community models. Error bars (Bayesian credible intervals) in red indicate which parameter estimates (on the log scale) were significantly different from zero; n.s. = not significant, sig. = significant, Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Chl = chlorophyll anomaly. Species are ordered by family (see Table 9-1 for abbreviations). Covariate effects are relative to study-specific habitat values, where negative responses indicate associations with proximity to shore, gradual slope, coarse sediment grain size, cold water, low salinity, and low primary productivity; positive responses indicate dependence on distance away from shore, steep slope, fine sediment grain size, warm water, high salinity, and high primary productivity.

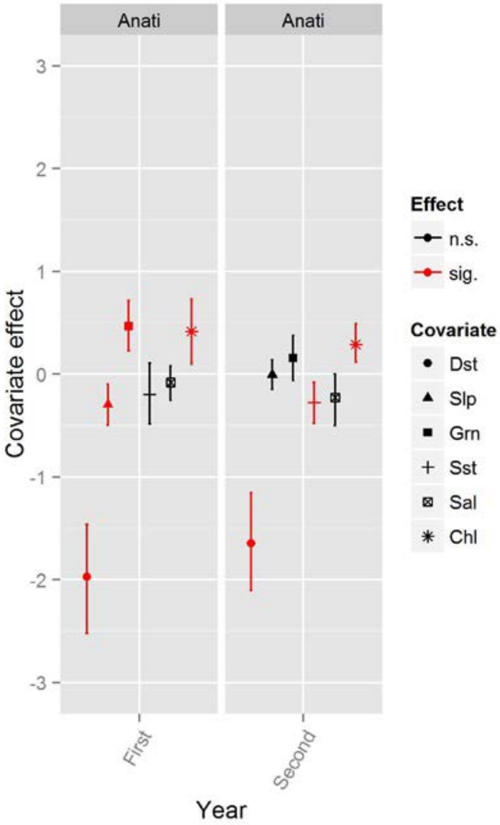


Figure 9-8. Habitat effects for scoters during the nonbreeding season (Nov 2012 - Mar 2013, and Oct 2013 – Apr 2014). Error bars (Bayesian credible intervals) in red indicate which parameter estimates (on the log scale) were significantly different from zero; n.s. = not significant, sig. = significant, Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Chl = chlorophyll anomaly, Anati = anatid family. Covariate effects are relative to study-specific habitat values, where negative responses indicate associations with proximity to shore, gradual slope, coarse sediment grain size, cold water, low salinity, and low primary productivity; positive responses indicate dependence on distance away from shore, steep slope, fine sediment grain size, warm water, high salinity, and high primary productivity.

Table 9-1. Seasonal flock size for each species in the community models, including Latin names and taxonomic family. "Observed" and "estimated" refer to the sampled area along transects, by season (across two surveys), where "Obs." is the mean of the observed flock sizes, and "Estim." is the estimated posterior mean for flock size.

			2012 Summer		2012 Fall		2012-13 Winter		2013 Spring		2013 Summer		2013 Fall		2013-14 Winter	
Common Name	**Latin Name**	**Family**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**
Razorbill	*Alca torda*	Alcidae					2.5	2.5	2.1	2.1					3.1	3.2
Dovekie	*Alle alle*	Alcidae					1.9	2.0	1.0	1.0					1.0	1.2
Atlantic Puffin	*Fratercula arctica*	Alcidae					1.8	1.8								
Common Murre	*Uria aalge*	Alcidae													1.3	1.4
Thick-billed Murre	*Uria lomvia*	Alcidae					1.0	1.6								
Long-tailed Duck	*Clangula hyemalis*	Anatidae													2.7	2.7
Red-breasted Merganser	*Mergus serrator*	Anatidae							8.0	7.8						
Common Loon	*Gavia immer*	Gaviidae	1.0	1.2	2.0	2.1	1.5	1.5	1.5	1.5	2.0	2.0	1.2	1.5	5.0	5.4
Red-throated Loon	*Gavia stellata*	Gaviidae			1.5	1.5	1.3	1.3	1.3	1.3					1.6	1.6
Wilson's Storm-petrel	*Oceanites oceanicus*	Hydrobatidae	1.8	2.1	1.0	1.1			1.0	1.0	1.6	1.7				
Herring Gull	*Larus argentatus*	Laridae	1.0	2.0	1.1	1.1	1.2	1.3	1.5	1.6			1.7	1.8	2.4	2.5
Laughing Gull	*Leucophaeus atricilla*	Laridae	1.4	1.5	1.3	1.3	1.0	1.6	1.3	1.3	1.6	1.7	3.5	3.5	1.3	1.4
Ring-billed Gull	*Larus delawarensis*	Laridae			1.0	1.2	1.0	1.4					1.0	1.0	1.6	1.6
Lesser Black-backed Gull	*Larus fuscus*	Laridae			1.0	1.1									1.3	1.4
Great Black-backed Gull	*Larus marinus*	Laridae	1.2	1.4	1.2	1.2	1.3	1.3	1.5	1.5	1.1	1.2	1.5	1.5	1.4	1.4
Little Gull	*Hydrocoloeus minutus*	Laridae													1.0	1.2
Bonaparte's Gull	*Chroicocephalus philadelphia*	Laridae			9.1	8.6	3.0	2.9	1.0	1.0					15.4	14.9
Black-legged Kittiwake	*Rissa tridactyla*	Laridae			1.0	1.1	1.0	1.3					1.0	1.0	1.4	1.4
Sabine's Gull	*Xema sabini*	Laridae			1.0	1.2										
Black Tern	*Chlidonias niger*	Laridae	1.5	1.8	1.2	1.2										
Least Tern	*Sternula antillarum*	Laridae							1.3	1.4						
Caspian Tern	*Hydroprogne caspia*	Laridae											1.5	1.5		
Roseate Tern	*Sterna dougallii*	Laridae	1.0	2.0												
Forster's Tern	*Sterna forsteri*	Laridae			3.7	3.6									7.4	7.1
Common Tern	*Sterna hirundo*	Laridae	4.7	5.5	3.6	3.7			4.3	4.4	1.9	2.0	6.0	6.0		
Royal Tern	*Thalasseus maximus*	Laridae	1.5	1.6	2.0	2.0					1.3	1.4	1.6	1.7		
Osprey	*Pandion haliaetus*	Pandionidae									1.0	1.5				
Brown Pelican	*Pelecanus occidentalis*	Pelecanidae	2.0	2.5	2.0	2.0					2.0	2.1	1.5	1.5		
Double-crested Cormorant	*Phalacrocorax auritus*	Phalacrocoracidae	5.0	6.0	24.4	23.1	1.0	1.3	53.7	52.2			88.6	87.6		
Horned Grebe	*Podiceps auritus*	Podicipedidae													1.1	1.1
Red-necked Grebe	*Podiceps grisegena*	Podicipedidae													1.1	1.1
Northern Fulmar	*Fulmarus glacialis*	Procellariidae													1.4	1.4
Cory's Shearwater	*Calonectris diomedea*	Procellariidae	1.0	1.2	1.3	1.4					1.5	1.6	1.0	1.0		

			2012 Summer		2012 Fall		2012-13 Winter		2013 Spring		2013 Summer		2013 Fall		2013-14 Winter	
Common Name	**Latin Name**	**Family**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**	**Obs.**	**Estim.**
Great Shearwater	*Puffinus gravis*	Procellariidae	1.1	1.2							1.1	1.2				
Sooty Shearwater	*Puffinus griseus*	Procellariidae							6.0	6.0						
Manx Shearwater	*Puffinus puffinus*	Procellariidae	1.0	1.5	1.0	1.2	2.3	2.2	1.0	1.0	1.6	1.7	1.0	1.0	2.3	2.3
Red Phalarope	*Phalaropus fulicaria*	Scolopacidae					3.0	2.4	74.7	72.7						
Red-necked Phalarope	*Phalaropus lobatus*	Scolopacidae			2.2	2.2							2.3	2.3		
Parasitic Jaeger	*Stercorarius parasiticus*	Stercorariidae			1.0	1.1			1.0	1.0			1.0	1.0	1.0	1.2
Northern Gannet	*Morus bassanus*	Sulidae	1.0	1.5	2.8	2.9	3.6	3.7	1.9	2.0			2.8	2.9	7.4	7.5

Table 9-2. First and second year abundance of scoters during the nonbreeding season (8 surveys) within the regional study area. “Observed” and “estimated” refer to the sampled area along transects, by season (across four surveys), where “Obs.” is the raw count of individuals, and “Estim.” is the estimated posterior mean for total abundance. “Predict.” is the posterior mean for the total abundance predicted to the 15 Jan 2013 (first year) or 15 Jan 2014 (second year), over the entire study area (including unsampled areas). Three species make up the ‘scoter’ group: White-winged Scoters *Melanitta. fusca*, Black Scoters *M. nigra,* and Surf Scoters *M. perspicillata*.

Scoters	Nonbreeding abund.			Flock size	
	Obs.	Estim.	Predict.	Obs.	Estim.
First year (Nov 2012 – Mar 2013)	11990	90545.3	706723.8	24.4	24.7
Second year (Oct 2013 – Apr 2014)	4906	36572.1	305488.7	14.6	14.9

Table 9-3. Seasonal abundance for each species in the community models (excluding scoters) within the regional study area. "Observed" and "estimated" refer to the sampled area along transects, by season (across two surveys), where "Obs." is the raw count of individuals, and "Estim." is the estimated posterior mean for total abundance. "Predict." is the posterior mean for total abundance predicted to a single day at the midpoint of each season, over the entire study area (including unsampled areas; see text for more details). Species are listed in order of decreasing total mean estimated abundance, averaged across the seven seasons. The five most abundant (estimated) species in each season are in bold. In the second year, there were at least 5 species with a single detection in each season (observed number of flocks = 1), which we removed to avoid problems with model convergence related to sparse observations.

Species	**2012 Summer**			**2012 Fall**			**2012-13 Winter**			**2013 Spring**			**2013 Summer**			**2013 Fall**			**2014 Winter**		
	Obs.	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**
Northern Gannet	2	8.6	274.4	1227	**5728.1**	6308.5	2790	12503.9	**213891.6**	1041	**5768.1**	24305.9	NA	NA	NA	678	**3998.3**	47755.1	4148	**21795.7**	383298.0
Bonaparte's Gull	NA	NA	NA	372	**2200.1**	11285.2	282	1458.2	44000.0	6	65.2	798.1	NA	NA	NA	NA	NA	NA	5471	**38203.7**	704669.7
Common Loon	6	49.1	599.8	208	**1550.2**	3805.0	421	2520.1	**62373.2**	313	**3205.9**	57157.5	16	132.8	1134.6	27	142.2	2485.9	1586	**10688.2**	152887.8
Laughing Gull	106	**394.4**	11549.0	292	**2264.1**	26044.9	1	15.0	496.6	10	191.0	2518.2	289	**1847.5**	87989.4	804	**5862.7**	77448.1	20	176.8	1591.7
Double-crested Cormorant	5	62.5	1564.5	122	705.8	12127.5	4	31.1	921.5	161	2067.2	48545.5	NA	NA	NA	797	**5761.1**	84029.7	NA	NA	NA
Razorbill	NA	NA	NA	NA	NA	NA	375	3839.4	**63221.3**	23	530.9	1509.4	NA	NA	NA	NA	NA	NA	494	**3141.5**	89158.5
Common Tern	252	**1042.1**	19105.0	76	**852.9**	13205.1	NA	NA	NA	376	**3835.1**	105664.4	93	**797.9**	134278.6	36	469.7	2591.6	NA	NA	NA
Red-throated Loon	NA	NA	NA	19	147.7	484.1	277	1792.9	**34540.6**	259	**2541.1**	31648.4	NA	NA	NA	NA	NA	NA	404	**2461.2**	37633.2
Great Black-backed Gull	6	75.5	1715.0	71	516.5	4961.8	243	1641.3	33454.0	58	727.8	5260.7	14	100.4	1965.3	148	**1207.2**	18366.8	179	1263.7	20451.3
Wilson's Storm-petrel	319	**2041.4**	20385.2	5	63.3	699.9	NA	NA	NA	9	135.5	4027.9	290	**3120.8**	115828.5	NA	NA	NA	NA	NA	NA
Herring Gull	1	12.3	557.0	20	173.7	1668.6	73	592.5	10446.9	104	1106.2	25948.1	NA	NA	NA	101	**941.2**	12227.5	235	1707.9	30256.5
Red Phalarope	NA	NA	NA	NA	NA	NA	3	46.0	1023.9	224	**3559.0**	79819.2	NA	NA	NA	NA	NA	NA	NA	NA	NA
Dovekie	NA	NA	NA	NA	NA	NA	204	2681.1	**38556.3**	9	117.2	1860.9	NA	NA	NA	NA	NA	NA	2	19.6	400.8
Royal Tern	86	**422.6**	17971.6	86	502.5	4260.0	NA	NA	NA	NA	NA	NA	85	**730.2**	18995.6	57	384.1	2948.4	NA	NA	NA
Ring-billed Gull	NA	NA	NA	1	13.9	181.3	2	23.4	461.6	NA	NA	NA	NA	NA	NA	6	81.7	1375.1	62	612.3	12388.2
Sooty Shearwater	NA	NA	NA	NA	NA	NA	NA	NA	NA	60	642.1	45266.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
Brown Pelican	4	34.2	1024.6	14	92.1	1402.2	NA	NA	NA	NA	NA	NA	79	**472.4**	11108.1	6	39.7	435.3	NA	NA	NA
Forster's Tern	NA	NA	NA	26	200.5	1035.8	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	52	381.2	3465.8
Manx Shearwater	2	13.4	488.8	1	15.8	311.6	16	163.9	5136.0	4	52.3	380.2	8	63.3	429.2	2	30.6	449.7	21	186.5	5783.7
Cory's Shearwater	5	60.7	1561.8	4	55.9	1946.4	NA	NA	NA	NA	NA	NA	29	245.8	2313.3	11	101.4	1004.8	NA	NA	NA
Red-necked Phalarope	NA	NA	NA	11	157.4	3104.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	14	205.7	1198.5	NA	NA	NA
Red-breasted Merganser	NA	NA	NA	NA	NA	NA	NA	NA	NA	16	255.6	3383.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
Long-tailed Duck	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	35	246.9	3902.5
Great Shearwater	20	**92.3**	377.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	21	101.9	431.7	NA	NA	NA	NA	NA	NA
Black-legged Kittiwake	NA	NA	NA	3	3NA	342.4	3	32.3	996.3	NA	NA	NA	NA	NA	NA	3	24.8	361.2	14	100.8	1751.9
Black Tern	6	52.7	3289.2	6	58.0	617.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Species	2012 Summer			2012 Fall			2012-13 Winter			2013 Spring			2013 Summer			2013 Fall			2014 Winter		
	Obs.	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**	**Obs.**	**Estim.**	**Predict.**
Parasitic Jaeger	NA	NA	NA	2	17.6	266.9	NA	NA	NA	3	44.3	1071.5	NA	NA	NA	2	24.7	478.9	2	20.4	361.6
Red-necked Grebe	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	14	101.9	1615.3
Lesser Black-backed Gull	NA	NA	NA	3	29.0	211.7	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	8	66.7	1610.3
Atlantic Puffin	NA	NA	NA	NA	NA	NA	14	94.6	3006.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Least Tern	NA	NA	NA	NA	NA	NA	NA	NA	NA	4	75.8	1871.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
Horned Grebe	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	11	73.7	11049.9
Northern Fulmar	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	7	58.2	1446.8
Caspian Tern	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	3	38.8	289.0	NA	NA	NA
Common Murre	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	4	36.2	652.5
Osprey	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	21.7	50046.9	NA	NA	NA	NA	NA	NA
Little Gull	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	2	18.1	507.7
Thick-billed Murre	NA	NA	NA	NA	NA	NA	1	14.7	458.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sabine's Gull	NA	NA	NA	1	13.4	320.6	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Roseate Tern	1	5.7	194.1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 9-4. First and second year posterior summaries for the community-level parameters by season. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Chl = chlorophyll anomaly, NB overdisp. is the Negative Binomial overdispersion parameter, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). Parameters are presented on the log scale, and the posterior mean for covariates where the 95% Bayesian credible interval does not overlap zero are in bold italics; all SD terms (shaded) are greater than zero by necessity.

		2012 Summer		**2012 Fall**		**2012-13 Winter**		**2013 Spring**		**2013 Summer**		**2013 Fall**		**2013-14 Winter**	
Component	**Term**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Abundance	**Intercept**; $\mu_{\alpha 0}$	***-4.8***	0.7	***-4.1***	0.5	***-2.6***	0.7	***-3.0***	0.6	***-3.2***	0.6	***-3.7***	0.5	***-2.5***	0.5
	Intercept SD; $\sigma_{\alpha 0}$	2.3	0.6	1.7	0.4	2.6	0.6	2.1	0.4	1.8	0.5	1.7	0.4	2.0	0.4
	Dst, mean; $\mu_{\alpha 1}$	-0.9	0.5	0.0	0.2	-0.4	0.3	0.3	0.2	-0.8	0.4	***-1.4***	0.3	-0.3	0.2
	Dst, SD; $\sigma_{\alpha 1}$	1.5	0.4	0.7	0.2	0.8	0.2	0.8	0.2	1.2	0.4	0.7	0.2	0.6	0.2
	Slp, mean; $\mu_{\alpha 2}$	-0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	-0.1	0.1
	Slp, SD; $\sigma_{\alpha 2}$	0.3	0.1	0.3	0.1	0.2	0.1	0.2	0.1	0.3	0.1	0.2	0.1	0.3	0.1
	Grn, mean; $\mu_{\alpha 3}$	0.2	0.2	***0.3***	0.1	0.0	0.1	0.1	0.1	0.1	0.2	-0.2	0.1	0.0	0.1
	Grn, SD; $\sigma_{\alpha 3}$	0.3	0.1	0.3	0.1	0.3	0.1	0.3	0.1	0.4	0.1	0.3	0.1	0.2	0.1
	Sst, mean; $\mu_{\alpha 4}$	-0.3	0.3	-0.6	0.4	0.2	0.2	0.1	0.3	-0.3	0.3	-0.3	0.3	0.0	0.1
	Sst, SD; $\sigma_{\alpha 4}$	0.6	0.2	1.8	0.4	0.7	0.2	1.2	0.3	0.7	0.3	1.0	0.3	0.5	0.1
	Sal, mean; $\mu_{\alpha 5}$	0.1	0.2	0.2	0.1	0.0	0.1	0.0	0.2	-0.4	0.2	0.1	0.2	-0.1	0.1
	Sal, SD; $\sigma_{\alpha 5}$	0.4	0.2	0.3	0.1	0.3	0.1	0.6	0.3	0.5	0.2	0.4	0.2	0.3	0.1
	Chl, mean; $\mu_{\alpha 6}$	0.2	0.1	0.0	0.1	-0.1	0.2	0.0	0.1	-0.2	0.2	-0.3	0.2	0.0	0.2
	Chl, SD; $\sigma_{\alpha 6}$	0.3	0.1	0.3	0.1	0.5	0.2	0.4	0.1	0.5	0.2	0.4	0.2	0.6	0.2
	NB overdisp.; r_N	***0.5***	0.1	***0.6***	0.1	***0.6***	0.0	***0.9***	0.1	***0.5***	0.1	***1.0***	0.1	***0.9***	0.1
Detection	**Intercept**; $\mu_{\beta 0}$	***5.1***	0.2	***5.0***	0.1	***4.9***	0.1	***4.5***	0.1	***5.0***	0.1	***4.9***	0.2	***5.2***	0.1
	Intercept SD; $\sigma_{\beta 0}$	0.5	0.2	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.1	0.4	0.2	0.2	0.1
	Beaufort 3-6; β_1	***-0.5***	0.1	***-0.3***	0.1	***-0.2***	0.0	***-0.1***	0.1	***-0.3***	0.1	-0.1	0.1	***-0.4***	0.0

Table 9-5. First and second year Bayesian p-values for the abundance and detection components of the models. Values close to 0.5 indicate good model fit. Value in bold indicate which detection function we selected to model abundance. Highlighted values are being updated and may change slightly (likely by no more than 0.01). In the case of the second-year spring and fall, the low fit statistic was due to our fitting a Poisson distribution to the flock size of two species with sparse data (< 20 observations) that had large variance-to-mean ratios: Double-crested Cormorants (fall, spring), Common Terns (fall) and Red Phalaropes (spring). We recalculated the fit statistic without those species, to evaluate the impact of just a few species with few observations, and found that this improved the Bayesian p-value (from the reported 0.0 to a value of 0.3, which is closer to the ideal of 0.5). HN = Half Normal, NE = Negative Exponential functions.

Year	Model	Abundance	Detection		Flock
			HN	NE	size
First	Community summer	0.50	**0.49**	0.37	0.52
	Community fall	0.51	0.89	**0.51**	0.11
	Community winter	0.50	0.92	**0.39**	0.61
	Scoter nonbreeding	0.49	0.89	**0.48**	0.75
Second	Community spring	0.52	0.72	**0.34**	0.01
	Community summer	0.50	0.73	**0.42**	0.44
	Community fall	0.48	0.93	**0.49**	0.00
	Community winter	0.49	0.90	**0.32**	0.60
	Scoter nonbreeding	0.51	0.78	**0.47**	0.63

Supplementary material

Appendix 9A. Supplementary information on methods

Covariate data collection

We considered eight habitat covariates as explanatory variables for variation in abundance. Five of the habitat covariates were static: distance to shore, bathymetry, and three seafloor features. We calculated distance to shore (km) as the distance to the nearest Delmarva shoreline (North or South regions[2]). We extracted a bathymetry data layer[3] from the National Oceanic and Atmospheric Administration's (NOAA) National Geophysical Data Center (NGDC) Coastal Relief Model (3-second, or 30-m resolution), using the spatial extent -76.1°W, 36.5°N to -74.4°W, 38.9°N. Seafloor feature characteristics were derived by NOAA/NOS National Centers for Coastal Ocean Science (NCCOS, Kinlan et al. 2013) at a 370-m resolution and included: (1) seafloor slope (% rise) (2) predicted surficial sediment mean grain size ($\phi = -\log2$[mean grain diameter in mm]), and (3) predicted surficial sediment percent sand (%). On rare occasions (<0.01% of sites), sediment data contained missing values, which we imputed using the average from neighboring sites.

We used three dynamic habitat covariates: daily SST and salinity, and monthly chlorophyll. We downloaded the two daily data layers (1) one km SST (°C) from the Group for High-Resolution Sea Surface Temperature (GHRSST)[4], and (2) three km salinity (Practical Salinity Units, PSU) from the Global Navy Coastal Ocean Model (NCOM)[5]. We downloaded monthly composites of 4-km chlorophyll concentration (mg/cubic m) from the Marine Geospatial Ecology Tools (Roberts et al. 2010) in ArcGIS 10.2, which accesses the OceanColor Level 3 Standard Mapped Image, via the National Aeronautics and Space Administration's (NASA) Goddard Space Flight Center (GSFC) Aqua satellite. We used monthly chlorophyll data because coastal satellite interference produced too many missing chlorophyll values at finer temporal resolution. Instead of using chlorophyll concentration, we calculated chlorophyll anomaly, by centering on the monthly mean of all sites, or effectively standardizing this covariate to a mean = 0 and a standard deviation < 2.

We conducted a preliminary analysis to select which covariates, at what spatiotemporal scale, were needed to quantify habitat suitability. This involved a tradeoff in selecting enough covariates to maximize variation, yet minimize overparameterization and co-linearity (Dormann et al. 2013). We evaluated co-linearity of these eight covariates by calculating Pearson's correlation coefficients and generalized variance inflation factors (GVIF, Zuur et al. 2010). As a result, this reduced our parameter space to include six covariates: three static (distance to shore, seafloor slope, sediment grain size) and three dynamic (SST, salinity, chlorophyll anomaly).

Due to slight survey-specific variation in the course-made-true (e.g., at the ends of each transect), we included the length of each segment (including MD extensions) as an offset in the model to standardize

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[2] pubs.usgs.gov/of/2010/1119/data_catalog.html

[3] maps.ngdc.noaa.gov/viewers/wcs-client/

[4] coastwatch.pfeg.noaa.gov/erddap/griddap/jplG1SST.html

[5] http://edac-dap3.northerngulfinstitute.org/erddap/griddap/US_East_3D_agg.html

abundance by effort for each of the 1206 transect segments (each of which was considered an individual 'site' in the model). Eight of the 15 surveys (from March 2013 to February 2014) also included extensions of three transects farther west into Maryland state waters, with a total additional transect length of approximately 12 km per survey. Where track line segments (sites) crossed over multiple values of each habitat covariate, we calculated the mean value per segment. Therefore, we modeled seabird observations in each 4-km segment by fitting them to the corresponding segment-level mean SST and salinity value on their day of observation, and mean chlorophyll from their month of observation (e.g., Figure 9-1).

Modeling

Some seabird groups were only present during two surveys (e.g., during the summer or winter), which is one of the reasons why we analyzed each season separately in the community models; there were at least 5 species with a single detection in each season of the second year (observed number of flocks = 1), which we removed to avoid problems with model convergence related to lack of data. Scoters, on the other hand, were present for the four surveys that comprised the nonbreeding season for Northern Hemisphere breeders. Therefore, the scoter models included the same surveys from the two winter seasons in the community models (Dec-Feb), but also included an adjacent survey from either shoulder season (fall and spring). We separated scoters from the community models for three reasons: (1) of all observations not identified to species in the dataset, > 90% were scoters, and 75% of all scoter observations were identified to the scoter genus, *Melanitta* spp., or to "non-White-winged Scoter", but not to species; (2) their flock sizes were larger than any other species in the community; (3) they are benthivores, whereas the rest of the community is composed primarily of surface-feeding piscivores and planktivores. Analyzing scoters separately allowed for estimates of their flock sizes and habitat responses to remain independent of the surface-feeding community, and avoid influences acting upon or arising from other species.

We follow the model developed in Sollmann et al. 2015. The sampling unit of analysis was an observation of a seabird 'flock', consisting of one or more individuals. First, we used observed distances to a flock to estimate the detection function that describes decline in detection probability with distance from the transect. To do so, we binned the observed distances into $k=$ 10 distance categories of $w = 100$ m each, where **b** corresponds to the break points (we truncated the data at a maximum perpendicular distance of 1 km from the boat). Let p_{ijk} be the detection probability of species i at site j in distance bin k. Then, under a Gaussian (or half-normal) detection function,

$$p_{ijk} = \frac{\int_{b_k}^{b_{k+1}} \exp\left(-\frac{x^2}{2\sigma_{ij}^2}\right) dx}{w}.$$

We allowed the scale parameter σ_{ij} in the detection function to vary by species i and a binary indicator of sea state at site j. We classified Beaufort state as a 0 if the mean Beaufort state was 0-2 for a segment (calm seas), and as a 1 if mean Beaufort state was 3-6 for a segment (rough seas) . For example, a sea state of 6 represents wind velocities that reach up to 27 knots (38 mph or 14 m/s), thus the weather conditions were variable during sampling. These high wind periods also fall within the range at which offshore wind turbines can operate at maximum rated power (Jonkman et al. 2009). Accounting for sea state accommodated reduced visibility due to increased wave height and occasions when observers switched platforms between calm and rough seas, following equipment safety protocol (Chapter 6).

We modeled the observed number of flock detections of species i at site j, n_{ij}, as an outcome of a Binomial random variable where N_{ij} is the true abundance of species i at site j, and $p.t_{ij}$ is the total detection probability ($p.t_{ij} = \sum_k p_{ijk}$) such that:

$$n_{ij} \sim Binomial\left(N_{ij}, p.t_{ij}\right)$$

See Methods for further details on estimating flock abundance as a function of covariates. To model observed flock sizes, $\boldsymbol{F}_i$ (a matrix of $\sum_j N_{ij}$ by i flock sizes for each species i) we used a Poisson – Negative Binomial mixture model to accommodate overdispersion, but with limits due to small sample sizes. Through data exploration, we found that there was overdispersion of flock sizes for many species; however, there were also often very small sample sizes. Therefore, we set the threshold of the mixture to be 20 observed detections for each species in each season, and we fitted flock sizes to a Poisson distribution when those detections fell below this threshold, or a Negative Binomial distribution otherwise.

$$\boldsymbol{F}_i \sim \begin{cases} zt\ Poisson(\mu_i) & < 20 \text{ detections} \\ zt\ Negative\ Binomial(\mu_i, \rho_i) & \geq 20 \text{ detections} \end{cases}$$

Note that $\boldsymbol{F}_i$ is partially observed for each species, i.e., known for observed clusters and unknown for $\sum_j (N_{ij} - n_{ij})$ unobserved clusters of species i. We implemented a hyperparameter on mean flock size and on the dispersion parameter for all seasons except the summer of the first year, when flocks were more consistent in size.

Using the package “rjags” (Plummer 2014) in program R version 2.15.3 (R Development Core Team 2013), we ran the software JAGS. We standardized the covariates for analysis to center them on a mean = 0, with a variance close to 1. We initialized three parallel Markov chains at different values and ran them for 30,000 iterations following a burn-in of 1,000 iterations. We checked for chain convergence visually (posterior density and trace plots), and quantitatively using the Gelman-Rubin statistic; this ‘R-hat’ statistic indicated that chains converged as a measure of among-chain versus between-chain variance (R-hat < 1.1; Gelman et al. 2014).

Literature cited in Appendix 9A

Dormann, C.F., Elith, J., Bacher, S., Buchmann, C., Carl, G., Carré, G., Marquéz, J.R.G., Gruber, B., Lafourcade, B., Leitão, P.J., Münkemüller, T., McClean, C., Osborne, P.E., Reineking, B., Schröder, B., Skidmore, A.K., Zurell, D., Lautenbach, S., 2013. Collinearity: a review of methods to deal with it and a simulation study evaluating their performance. Ecography 36, 27-46.

Gelman, A., Carlin, J.B., Stern, H.S., Dunson, D.B., Vehtari, A., Rubin, D.B., 2014. Bayesian Data Analysis, Third Edition. Taylor & Francis, New York, NY, USA.

Jonkman, J.M., Butterfield, S., Musial, W., Scott, G., 2009. Definition of a 5-MW reference wind turbine for offshore system development. National Renewable Energy Laboratory, Golden, CO.

Kinlan, B.P., Poti, M., Drohan, A., Packer, D.B., Nizinski, M., Dorfman, D., Caldow, C., 2013. Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch. Released August 2013. Available at: http://coastalscience.noaa.gov/projects/detail?key=35.

Plummer, M., 2014. rjags: Bayesian graphical models using MCMC, R package version 3-13.

R Development Core Team, 2013. R: A language and environment for statistical computing, Version 2.15.3. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Roberts, J., Best, B., Dunn, D., Treml, E., Halpin, P., 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. http://mgel.env.duke.edu/mget

Sollmann, R., Gardner, B., Gilbert, A., Williams, K., Veit, R., 2015. A community distance sampling model to investigate the abundance and distribution of seabirds, 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.

Zuur, A.F., Leno, E.N., Elphick, C.S., 2010. A protocol for data exploration to avoid common statistical problems. Methods in Ecology and Evolution 1, 3-14.

Appendix 9B. Supplementary information on results

High levels of spatiotemporal variability were observed between species, for both detection and abundance. Highly conspicuous Northern Gannets, for example, had a higher detection probability than scoters (in rough seas during the first year winter/nonbreeding season, detection probability, $p = 0.33 \pm 0.012$ SD for Northern Gannets and $p = 0.23 \pm 0.015$ for scoters). Seasonal patterns of distribution and abundance by season are described in further detail below; winter patterns are described in the main text.

Spring

In the spring (2013, Figure 9-7c), Northern Gannets showed consistency with the second year winter associations (2013-14), as they were likely to be observed over high primary productivity, high salinity, and cold water areas, and were more likely to venture farther away from shore than in other seasons. With respect to alcids, Dovekies were observed far away from shore, and Razorbills associated with cold water, as in the second year winter. As for gaviids, Red-throated Loons were likely to be close to shore (as in the winter), over low primary productivity (unlike the first year winter) and cold water (unlike Common Loons in the first year winter). The procellarids and hydrobatids we observed during the spring were southern ocean breeders: Sooty Shearwaters were likely to stay far from shore, while Wilson's Storm-petrels associated with warm water and fine grain size. Red Phalaropes were observed away from the coast. Common Terns are larids that migrate northerly during the spring, and they were predicted to have higher abundances in low primary productivity and high SST (as in other offshore studies, Amorim et al. 2009; Goyert et al. 2014), as well as to fine sediment grain size (see discussion).

Summer

During the summer (2012-2013, Figure 9-7a, d), SST was significantly warmer than the other seasons. Warm water positively influenced the distribution of Royal Terns (Year 2), and negatively affected Great Shearwaters (both years) and Cory's Shearwaters (Year 2).The procellarids and hydrobatids we observed were likely to be far from shore (Year 1), and included southern breeders (Wilson's Storm-petrel, Great Shearwater), northern breeders (Manx Shearwater), and East Atlantic breeders (Cory's Shearwater). In the second year, Wilson's Storm-petrels were again far from shore, and associated with steep slope and low primary productivity. Low primary productivity also had a strong effect on Great Shearwaters (Year 2). Terns adhered closely to the shoreline, particularly Common Terns (Year 1), which are northern breeders, and Royal Terns (both years), which are local breeders. In the second year, Common Terns additionally associated with high primary productivity (similarly to a northerly nearshore study, Goyert 2014) and low salinity. Laughing Gulls were likely to be observed close to shore (Year 1), over high primary productivity (Year 2) and low salinity (Year 2), which led to high density predictions around the Delaware Bay. Brown Pelicans, which breed locally, were likely to be close to shore, over low primary productivity, low salinity, and fine sediment.

Fall

During the fall (Figure 9-7b, e) of the first year (2012), the surface-feeding community as a whole were positively associated with fine sediment grain size (Table 9-4), which was driven by Royal Terns, Common Terns, Laughing Gulls, Northern Gannets, and Double-crested Cormorants. In the second year (2013), the entire community was likely to be close to shore, driven by 13 of the 16 species (Figure

9-7e); distance to shore had no strong effect on Cory's Shearwater, which was the only species to respond differently from the rest of their community (its Bayesian credible interval did not overlap the community mean effect). Cory's Shearwaters and Common Loons were likely to be observed far from shore in the first year fall. In addition to their response to fine sediment, Royal Terns associated with proximity to shore (both years), high salinity (Year 2), and warm water (Year 2). In the first year, SST strongly affected many species in the community both positively and negatively. Wilson's Storm-petrels, Common Terns and Black Terns associated with warm water. Across both years, the species that associated with cold water were Northern Gannets (as in the winter and spring), Common Loons (unlike in the first year winter), Herring Gulls and Great Black-backed Gulls. Other larids and gaviids that associated with cold water in the first year were: Laughing Gulls, Black-legged Kittiwakes, Lesser Black-backed Gulls, Bonaparte's Gulls, Forster's Terns, and Red-throated Loons. In the second year fall, several species associated with low primary productivity: Northern Gannets (unlike in the spring), Laughing Gulls, Common Loons (like Red-throated Loons in the spring), Red-necked Phalaropes, and Cory's Shearwaters. Gaviid abundances were negatively related to low primary productivity, specifically Common Loons in the second year fall and Red-throated Loons in the spring (in contrast to the first year winter, when they associated with higher primary productivity). Primary productivity was lowest in the summer and second year fall.

Literature cited in Appendix 9B

Amorim, P., Figueiredo, M., Machete, M., Morato, T., Martins, A., Serrão Santos, R., 2009. Spatial variability of seabird distribution associated with environmental factors: a case study of marine Important Bird Areas in the Azores. ICES Journal of Marine Science 66, 29-40.

Goyert, H.F., 2014. Relationship among prey availability, habitat, and the foraging behavior, distribution, and abundance of common terns *Sterna hirundo* and roseate terns *S. dougallii*. Marine Ecology Progress Series 506, 291-302.

Goyert, H.F., Manne, L.L., Veit, R.R., 2014. Facilitative interactions among the pelagic community of temperate migratory terns, tunas and dolphins. Oikos 123, 1400-1408.

Introduction to Part IV
Integrating data across survey methods

Report structure

The chapters in this report represent a broad range of study efforts focused on understanding wildlife population distributions in Atlantic waters offshore of Maryland (and elsewhere in the Mid-Atlantic United States). Some chapters are purely methodological in nature, while others present a variety of analyses and results (Figure I). Part I of this report (the Executive Summary and Chapters 1-2) summarizes and synthesizes project results. The 12 subsequent chapters and their relationships to each other are shown in Figure I. In Parts II (Chapters 3-5) and III (Chapters 6-9), we describe methods and results for high resolution digital video aerial surveys and boat-based surveys, respectively. Part IV of this report (Chapters 10-14) combines data from both survey approaches to develop a comprehensive understanding of marine wildlife populations that use the Mid-Atlantic study area.

Part IV: Integrating data across survey methods

High resolution digital video aerial surveys are a relatively new method for collecting distribution and abundance data on animals (Thaxter and Burton 2009, Buckland et al. 2012). The technology used in this study, one of several digital aerial survey methodologies, was developed by HiDef Aerial Surveying, Ltd., in the U.K. Digital aerial survey approaches have largely replaced visual aerial surveys for offshore wind energy research in Europe, as their greater aircraft speed and much higher flight altitude makes them safer to conduct than visual aerial surveys, and reduces or eliminates disturbance to wildlife as compared to visual aerial or boat survey approaches (Buckland et al. 2012). They also produce archivable data, which allow for a robust quality assurance and audit process. However, as they are a relatively new technology, methodological and analytical processes for collecting and analyzing these data are still being addressed in the scientific literature.

Standardized boat-based surveys with distance estimation are a widely used and well-established method of obtaining density data for birds, sea turtles, and marine mammals. This survey method allows for the development of more detailed behavioral data than is possible with digital aerial approaches, and also provides excellent identification rates for most species (though identifications are generally not verified, either during or after the fact, which can be problematic in certain cases; Hobbs and Waite 2010, Conn et al. 2013). Detection bias is a known issue for boat-based surveys, but it is also an issue that is relatively well understood, and can be addressed in part with established analytical approaches (Buckland et al. 2001).

There are five chapters in Part IV of this report, focused on the comparison and integration of data from boat surveys and digital video aerial surveys to examine wildlife distributions and relative abundance offshore of Maryland, as well as within the broader Mid-Atlantic region:

Chapter 10.	A general comparison of results from boat surveys and digital video aerial surveys in the Mid-Atlantic (2012-2014).
Chapter 11.	Integrating data across survey methods: persistent hotspots and temporal changes in observed abundance.
Chapter 12.	Density modeling with environmental covariates for marine mammals and turtles.
Chapter 13.	Comparison of boat and aerial models of abundance with environmental covariates for seabirds.
Chapter 14.	Integrating aerial and boat data with environmental covariates to develop joint predictions of abundance for seabirds.

Several chapters focus on contrasting boat and digital video aerial survey approaches (Chapters 10, 13). In some cases, data from one survey approach are used independently to analyze wildlife distributions and relative abundance (e.g., in the case of sea turtles, Chapters 11-12, or Bottlenose Dolphins, *Tursiops truncatus*, Chapter 12). In other cases, digital video aerial survey data and boat survey data are used jointly (Chapters 11 and 14) to describe distributions and abundance of animals across the study area.

Comparisons of the two survey approaches

Project collaborators pursued several methods of comparing and contrasting the two survey datasets (Williams et al. 2015; Chapter 14). Species identification rates, as well as detection rates, varied considerably between methods for some taxa. Aquatic species, such as sea turtles, rays, sharks, and fishes, were observed in much higher numbers in the aerial data than the boat data. While some of these animals were also observed in the boat survey, the aerial surveys appeared to provide an excellent platform for detecting and identifying animals within the upper reaches of the water column. A similar efficiency in detecting and identifying sea turtles and marine mammals from high resolution digital aerial platforms (as compared to visual aerial or boat surveys) has also been observed elsewhere (Normandeau Associates Inc. 2013).

In contrast, boat survey observers detected larger numbers of more species of birds than the aerial survey, which may be partially due to differences in detectability between the two survey types. Northern Gannets and larger gulls, for example, were visible at great distances from the boat survey, as observers could look from the vessel all the way to the horizon. Reviewers of aerial survey data could only see animals present in the narrow strip of the transect onscreen, and aerial survey speed was roughly 13.5 times that of the boat, potentially limiting onscreen appearances by highly mobile animals (Williams et al. 2015; Figure II). Rates of identification of animals to species were also lower for many taxa in digital video aerial surveys than boat surveys. The limitation of many aerial identifications to the family or genus level is likely due in part to the detailed and exhaustive quality assurance process applied to digital video aerial survey data (Chapter 4), but it is also likely due in part to image quality. This issue may be ameliorated with technological advances in the field, as the current generation of cameras being used in Europe have much higher resolution and color rendition than the cameras used in this study, with better identification rates as a result (A. Webb pers. comm).

In addition to these general comparisons of survey results, project collaborators compared the estimated effects of habitat on seabird abundance using the boat and digital video aerial datasets. Chapter 13 presents an analysis of data from four seabird groups (terns, gannets, loons, and alcids), in which remotely-collected environmental data were incorporated into the models. Data were analyzed similarly to Chapters 9 and 12, but with slightly different formulations of models to facilitate comparison between the two survey approaches. 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 a joint analysis. Boat vs. aerial survey data did indicate some differences in species-habitat relationships, which suggested that joint modeling approaches that incorporated both sources of data could prove fruitful for describing species distributions, relative abundance, and habitat use throughout the study area.

Integrated analyses of boat and digital video aerial survey data

The best methodological approach for surveys of offshore wildlife will depend on the specific characteristics of each study area and on project goals (Camphuysen et al. 2004), and may involve a combination of complementary survey methods. It is important to understand how to successfully integrate data from different survey platforms, in order to ensure compatibility among studies, maintain a continuous historical record, and enable the assessment of long-term changes in wildlife distributions and abundance. The differences in detectability, species identification, field of view, and species-habitat relationships between survey approaches provides an opportunity to create higher-quality end products, by incorporating complementary data streams from both survey approaches. In addition, there is a need to further the development of analytical approaches for digital aerial surveys. Because the cameras are pointed down towards the water's surface (Figure II), digital aerial surveys avoid the common problem of distance bias; but, to date, other types of detection bias have not been addressed for digital aerial surveys. Collecting these data alongside traditional boat survey data provides an opportunity to explore new approaches for understanding and analyzing digital video aerial survey data for wildlife.

On a small scale, this has 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; Chapter 11). 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 "persistent hotspots," or geographic areas with consistently high numbers of animals or species through time (Chapter 11). These persistent hotspots of abundance and species richness could indicate important habitat use areas (Santora and

Veit 2013). Temporal patterns of observations of different species and groups within the study area can also be used to determine potential exposure to offshore development activities at different times of year (Chapter 11).

A broader geographic and temporal scale of analysis may be required to fully assess exposure to wildlife from proposed development projects, however, including the examination of locations which were not directly surveyed. The incorporation of environmental covariates into modeling efforts allowed for the prediction of relative densities across the study area for many taxa (Chapters 9 and 12-14), 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, digital aerial surveys for sea turtles; Chapter 12), while in other cases, the two datasets could be combined using recently developed joint modeling frameworks. In Chapter 14, 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). Building on Chapters 9 and 13, Chapter 14 incorporated remotely collected environmental covariate data into the hierarchical modeling structure and produced a single prediction of abundance and distribution across the study area that utilized data from both survey approaches. Integrated models for the four taxa examined (terns, alcids, loons, and gannets) predicted taxon-specific hotspots that generally concurred with the results from Chapters 9 and 13, and in some cases performed better than models developed using data from a single survey approach. While additional exploration and model development is needed, these results indicate that joint modeling approaches may be a fruitful avenue of continued research.

Implications

Our application of these methods in the Mid-Atlantic, and specifically offshore of Maryland, is expected to be useful for understanding wildlife populations and minimizing impacts to those populations from offshore wind energy development in several ways:

- First, this study has explored technological advancements and statistical approaches that could be used in future monitoring efforts. Comparisons of high resolution digital video aerial surveys to boat-based surveys allow us to better understand the potential uses of high resolution digital video aerial surveys in relation to offshore development in U.S. waters, and to understand when and where each survey approach may be best suited to meet the monitoring needs of regulators, resource managers, and developers. We also explore statistical models aimed at improving our utilization of digital video aerial survey data, particularly in combination with boat data, to understand wildlife patterns.
- Second, we identify species that are likely to be exposed to offshore wind energy development activities in the Mid-Atlantic study area, along with their important habitat use or aggregation areas and temporal variation in distribution patterns. By combining data from two quite different survey approaches, we can develop a better view of wildlife populations and distribution patterns than either survey method could provide alone. This information can be helpful for informing the siting, permitting, and mitigation of future offshore development projects offshore of Maryland.

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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.

Literature cited

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas (2001). Introduction to Distance Sampling: Estimating abundance of Biological Populations. Oxford University Press, Oxford, UK.

Buckland, S. T., M. L. Burt, E. A. Rexstad, M. Mellor, A. E. Williams, and R. Woodward (2012). Aerial surveys of seabirds: the advent of digital methods. Journal of Applied Ecology 49:960–967. doi: 10.1111/j.1365-2664.2012.02150.x

Camphuysen, K. C. J., T. A. D. Fox, M. M. F. Leopold, and I. K. Petersen (2004). Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. *COWRIE - BAM - 02-2002*.

Conn, P. B., B. T. McClintock, M. F. Cameron, D. S. Johnson, E. E. Moreland, and P. L. Boveng (2013). Accommodating species identification errors in transect surveys. Ecology 94:2607–2618. doi: 10.1890/12-2124.1

Hatch, S. K., E. E. Connelly, T. J. Divoll, I. J. Stenhouse, and K. A. Williams (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

Hobbs, R. C., and J. M. Waite (2010). Abundance of harbor porpoise (Phocoena phocoena) in three Alaskan regions, corrected for observer errors due to perception bias and species misidentification, and corrected for animals submerged from view. Fishery Bulletin 108:251–267.

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*.

Santora, J. A., and R. R. Veit (2013). Spatio-temporal persistence of top predator hotspots near the Antarctic Peninsula. Marine Ecology Progress Series 487:287–304. doi: 10.3354/meps10350

Thaxter, C. B., and N. H. K. Burton (2009). High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols. *Report commissioned by COWRIE Ltd*.

Williams, K., I. Stenhouse, E. Adams, E. Connelly, A. Gilbert, and M. Duron (2015). 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*.

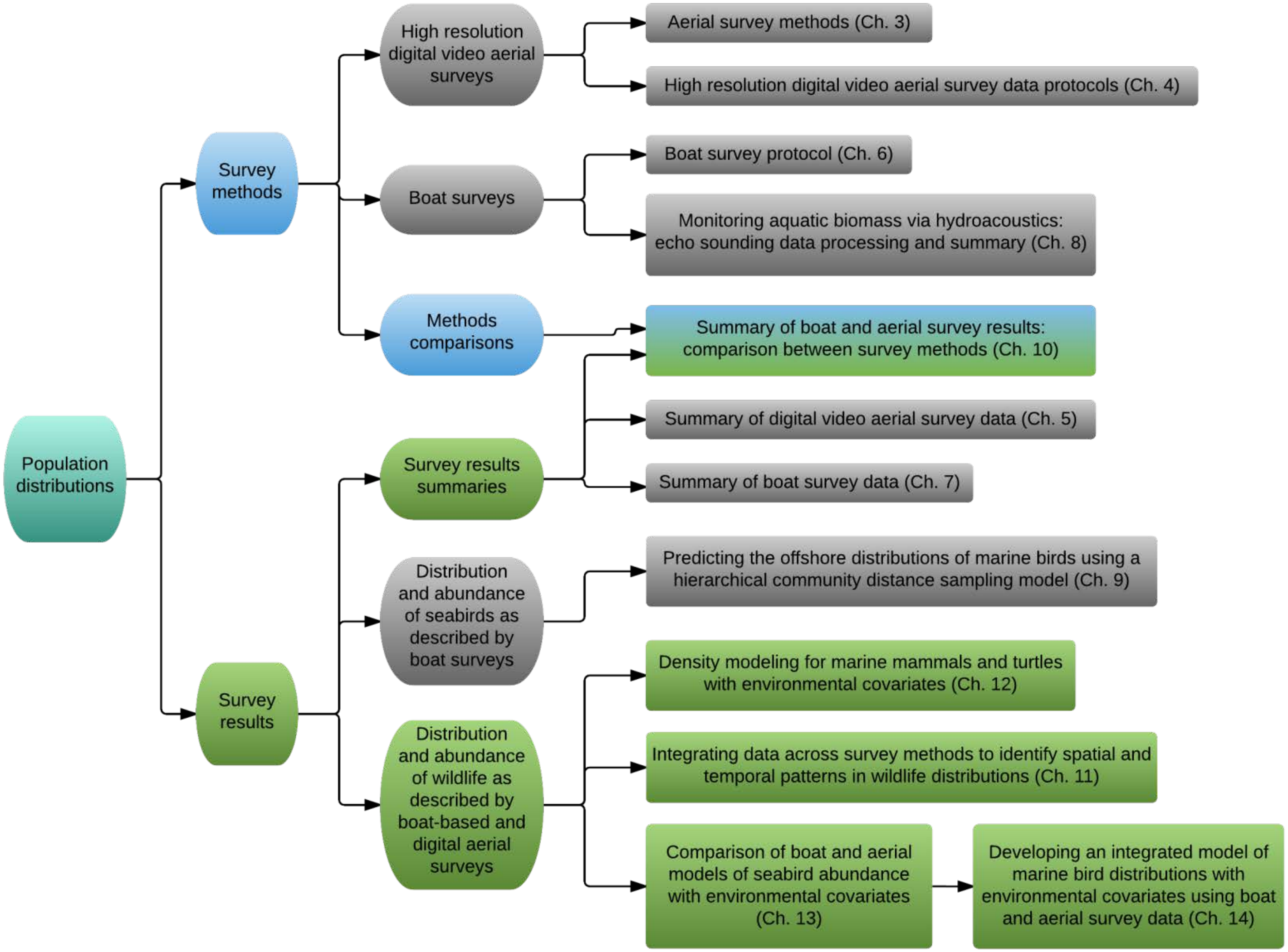

Figure I. Organization of chapters within this final report.

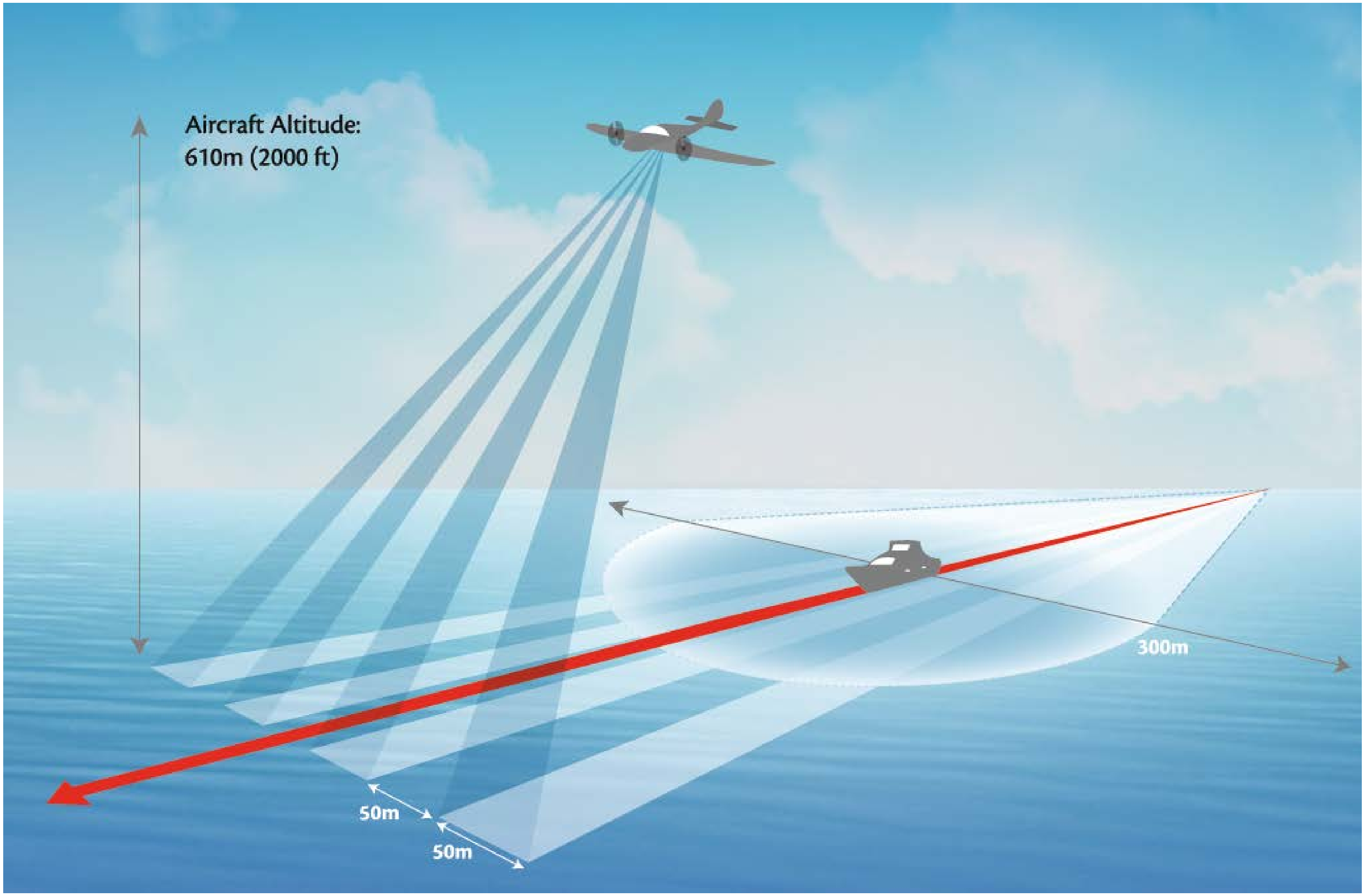

Figure II. Fields of view for boat-based and digital video aerial surveys. Combined strip width for the four video cameras was 200m; the boat had an intended minimum strip width of 300m, though observations of animals were made up to 1,000m away. Apart from an experimental comparison conducted in 2013 (Williams et al. 2015), boat and plane followed different transects (see study area maps elsewhere in this report).

Chapter 10: Summary of boat and aerial datasets: comparison between survey methods

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

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Chapter 10 Highlights

Examining differences in observations and species identifications between the boat-based and digital video aerial survey datasets.

Context[1]

Digital video aerial surveys and boat surveys were both used to collect data on marine animal abundances and distributions in the Maryland Project and Mid-Atlantic Baseline Studies project areas, and the results from each survey method provide complimentary information about the ecology of the region. Digital video aerial surveys are described in detail in Part II, with information on the methods used to collect and analyze the survey data (Chapters 3 - 4), and the results of the surveys (Chapter 5). Part III describes the boat surveys, with methods outlined in the protocol (Chapter 6), and a summary of the results (Chapter 7). Chapter 9 analyzes the boat survey data in greater detail using statistical models.

Part IV of this report examines ways to integrate the two survey datasets, using a variety of methods. This chapter compares the overall results of the boat and digital video aerial study methods across the two years of surveys to increase our understanding of how each of the methods can best be used to examine the marine environment. Subsequent chapters in Part IV use the two datasets together to develop more integrated views of wildlife distributions and abundance (Chapters 11-14).

Study goal/objectives addressed in this chapter

Examine the differences between data collected during two years (2012-2014) of boat-based and digital video aerial surveys conducted offshore of Maryland and elsewhere in the mid-Atlantic.

Highlights for the Maryland study area

- More birds and more bird species were observed in the boat surveys, and birds made up a higher proportion of boat observations (97%) compared to digital video aerial surveys (27%).
- Gulls and terns were the most abundant avian group observed using both study methods.
- Rays were the most abundant animal observed in the digital video aerial surveys, but were rarely observed in the boat study.
- More sea turtles were observed in the digital video aerial surveys, with more species observed; in both methods, turtles were most abundant in warmer months (spring through fall).

Implications

Both survey methods have distinct strengths and weaknesses, though they showed similar overall patterns for avian species. Digital video aerial surveys appear to be particularly good for observing sea turtles and other aquatic animals, while boat surveys generally had higher rates of species identification.

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[1] For more detailed context for this chapter, please see the introduction to Part IV of this report.

Abstract

High resolution digital video aerial surveys are a relatively novel method for collecting information on marine wildlife distributions and abundances, particularly in North America. In contrast, standardized boat based surveys are widely used to collect information on marine animals, and biases inherent to this survey approach are well understood. Our study focused on using both methodologies to collect marine bird, mammal, and sea turtle data within the Maryland Project and Mid-Atlantic Baseline Studies project areas in 2012-2014. More birds, and more species of birds, were observed in the boat surveys, while much higher numbers of aquatic animals were observed in the digital video aerial surveys; birds made up a much higher proportion of the animals observed in boat surveys as compared to digital video aerial surveys. Similar avian species were found to be abundant in the study area according to both methods, but digital video aerial surveys observed more rays and turtles than the boat surveys, where the most abundant aquatic animals were toothed whales. Identification rates were notably different between study methods, with higher rates of animals identified to species on the boat surveys. Sea turtles provided an interesting case study for comparing the study methods. Taken together, the two methodologies provide complementary information on marine animal abundances and distributions offshore of Maryland.

Introduction

The Mid-Atlantic region is an extremely important area for a broad range of marine wildlife species throughout the year. This is largely due to a relatively high level of productivity as compared with the rest of the western North Atlantic, and to the region’s geographic location on the eastern edge of the continent (Chapter 1). The Mid-Atlantic area supports large populations of marine wildlife in the summer; some breed along the coastline west of the project study area, including some tern species, while others visit from the southern hemisphere in their non-breeding season, such as shearwaters. In the fall, many of the summer residents migrate south and are replaced by species that have travelled from their northern breeding grounds to winter in the Mid-Atlantic. Additionally, many pelagic, coastal, and terrestrial species make annual migrations up and down the eastern seaboard and travel directly through the region in spring and fall. Thus, many species use or funnel through the Mid-Atlantic region each year, resulting in a complex ecosystem where the community composition is constantly shifting and the temporal and geographic patterns are highly variable.

In this study, we aimed to produce the data that will inform siting and permitting processes for offshore wind energy development in the Mid-Atlantic. We collected information on bird, sea turtle, and marine mammal abundances and movements over a two-year period (2012-2014) using a variety of technologies and methods to examine spatial patterns and trends, while simultaneously testing a new technology for the first time in the United States, high resolution digital video aerial surveys (hereafter digital video aerial surveys or digital aerial surveys). Digital video aerial surveys are a relatively new method for collecting distribution and abundance data on animals in the marine ecosystem (Thaxter and Burton, 2009). Although digital aerial surveys have become common practice for offshore wind energy planning and monitoring in Europe, these baseline wildlife studies in the Mid-Atlantic (funded by the Department of Energy and the state of Maryland) are the first projects to use these methods on a large scale in the United States. We also conducted boat surveys for wildlife within the study area on the

Outer Continental Shelf to accompany and compare with the data from the digital aerial surveys. Standardized boat-based surveys are a widely used method of obtaining density data for birds, sea turtles, and marine mammals (Camphuysen et al., 2004; Gjerdrum et al., 2012; Tasker et al., 1984). A focused comparison study of the two methods was conducted in March of 2013 (Williams et al., 2015), but we present a more general examination of the full datasets here, to provide details on a broader range of animals observed by boat and digital aerial surveys throughout the Maryland Project and Mid-Atlantic study areas over the two-year survey period. While the experimental comparison study was focused on comparing the results of the two survey methodologies from the same location and time period, the diversity and number of animals observed during this experimental comparison was limited, and comparing the two full datasets can provide further insight into the relative utility and strengths of the two survey methodologies.

The broader Mid-Atlantic Baseline Studies (MABS) study area encompasses the continental shelf from Delaware to Virginia, extending from 3 nautical miles from the coastline (the boundary between state and federal waters) out to either the 30 m isobath or the eastern extent of the Wind Energy Areas (WEAs; Figure 10-1). In 2013, the state of Maryland funded an expansion of this survey effort, extending the original Department of Energy-funded aerial and boat survey transects west and south to include more of the state and federal waters offshore of Maryland (Figure 10-2). For this report, we consider data from both the MABS and Maryland Projects.

We examine the differences in observations and identification rates between the two study methods, with a particular focus on sea turtles. All five species of sea turtle present in the Mid-Atlantic study area are listed as threatened or endangered under the Endangered Species Act. Fisheries bycatch affects Loggerhead Sea Turtles (*Caretta caretta*) and Leatherback Sea Turtles (*Dermochelys coriacea*) in the Mid-Atlantic and directly negatively impacts their populations' survival (Murray and Orphanides, 2013). Turtles are also vulnerable to vessel collisions, particularly at higher ship speeds (Hazel et al., 2007). Relatively little is known about sea turtle hearing capabilities, or the effects of noise on these species, but the hearing range of the Leatherback overlaps with all noise-generating activities conducted during offshore wind development (Dow Piniak et al., 2012), and the noise generated during offshore wind construction is thought to be a potential concern for this taxon (Michel, 2013).

Methods

Data collection

Details on data collection methods used in both the aerial and the boat surveys can be found in Chapters 3, 4, and 6. Between March 2012 and May 2014, 15 digital video aerial surveys and 16 boat surveys were conducted in the Mid-Atlantic study area (Figure 10-1). In the second year of surveys (March 2013 – May 2014), funding from the state of Maryland led to the addition of 747 km of high density aerial survey transects to the west and south of the Maryland WEA in the aerial surveys, and a total of approximately 12.5 km of additional boat survey transect at the western edges of three existing transect lines off of Maryland (Figure 10-2). Seven of the aerial surveys encompassed the MABS area (March 2012-February 2013), seven included the MABS area and the Maryland Project (March 2013-May 2014), and one survey (August 2013) included only the Maryland Project and the Maryland WEA (see Chapter 5 for information on specific flight timing). Analyses below include either the entire dataset from both studies, or data specifically for the Maryland study area (shown in Figure 10-2), which includes transects funded by the DOE as well as the state of Maryland.

Aerial observers indicated a degree of certainty for each object identified (Chapter 3). For the summaries below, all aerial identifications were taken at face value (e.g., an identified "possible Black Scoter [*Melanitta americana*]" was considered to be a Black Scoter, rather than an "Unidentified Scoter"; see Chapter 4 for additional information on certainty levels and identification criteria).

Observation rates

Digital aerial survey data were easily effort-corrected to present observations per square kilometer surveyed, as aerial transects had a defined strip width (Chapter 3). For purposes of comparison with boat survey data, aerial count data were taken at face value, and were not corrected for distance bias or other potential biasing factors, apart from variation in survey effort (Buckland et al., 2012; Williams et al., 2015). Boat surveys were designed to have a strip width of at least 300 m, but the *effective* strip width varied by taxon (Chapter 7). Detection of objects in boat surveys is known to vary with distance from the observer (Thomas et al., 2010), and thus species that were readily detected large distances away from the boat had a larger surveyed area, or effective strip width, than species that were generally only detectable near the boat. We calculated effective strip half widths for the entire MABS/Maryland dataset for the four avian taxa where data were sufficient to parameterize a null distance model in package 'unmarked' in the R Statistical Computing Environment (R Core Team, 2014). These groups included Sulidae (gannets), Laridae (gulls and terns), Gaviidae (loons), and Anatidae (scoters, ducks, and geese; Figure 10-3). Effective strip width was calculated in 'unmarked' by applying distance-based detection functions (half-normal distributions) to species groups during distance modeling, and integrating the area underneath the distance curve. Because of specific properties of distance detection curves, this number is equal to the distance at which there is a 50% chance of detecting an object (Royle et al., 2004). Because we surveyed on both sides of the ship, this effective strip half-width was multiplied by two to obtain the full effective strip width for each species group. This value was multiplied by the total linear distance of the survey to estimate the effective boat survey area for each species group. For species groups with insufficient boat observations to fit a distance curve, we used the median observation distance as a proxy for the effective half strip width, as the two values appeared to be comparable for the species where we could calculate both values.

Identification rates

We used the naïve counts from each of the Maryland study area surveys to calculate identification rates for the data collected on the two survey platforms. Within each of the most commonly observed family groups, including Anatidae, Sulidae, Laridae, Gaviidae, Alcidae (alcids, including puffins, murres, and others), Procellariidae (shearwaters and fulmars), Odontoceti (toothed whales, including dolphins and porpoises); Testudines (sea turtles); and Mysticeti and Cetacea (baleen and other large unidentified whales), the proportion of observations in which animals were identified to the species level vs. the group level (e.g., Common Tern, *Sterna hirundo,* vs. "Unidentified Tern") was compared between survey methods.

Results

Our assessments of the boat-based and aerial survey data indicated that the two methods differed in their abilities to detect and identify certain taxa. We discuss these results in detail below.

Observation rates

Within the combined MABS and Maryland Project datasets, boat survey observers detected larger numbers of birds per unit effort and more species of birds than the digital video aerial survey observers (Figure 10-4), while the digital aerial surveys appeared to be better at detecting certain aquatic animals (Figure 10-5, Table 10-1). In the Maryland study area alone, birds made up a very large proportion of the animals observed on the boat survey (97%) compared to the digital video aerial survey (27%). Gulls and terns were the most abundant avian group observed in both boat (33% of birds) and digital video aerial surveys (20% of birds) in the Maryland study area, with anatids the next most abundant group in each (25% boat and 19% aerial, Figure 10-6). This is different from the pattern seen in the broader MABS area, where scoters comprised the highest percentage of birds observed. A similar percentage of gannets were observed in the Maryland boat data (18%) compared to the Maryland aerial data (17%), while loons made a larger percentage of the digital video aerial data than the boat data, in both Maryland and the MABS areas (Figure 10-6).

Digital aerial surveys detected many aquatic animals compared to boat surveys, including turtles, sharks, fish, and rays; the same patterns were observed offshore of Maryland and the broader MABS area (Figure 10-7, Table 10-1). The aerial surveys provided an excellent platform for detecting and identifying animals within the upper reaches of the water column. In particular, higher counts and species diversity of sea turtles and mammals were detected on the aerial surveys (Figure 10-5; Chapter 4) than from the boat. Of the non-avian digital video aerial observations, the bulk of detections were rays (61% of the Maryland study area data), with many fish (7%), toothed whales (6%), and some turtles (2%) observed as well; in contrast, the most commonly observed aquatic species group in the boat data (both in the Maryland study area and overall) was toothed whales (dolphins and porpoises; Figure 10-7). Major migrations of Cownose rays (*Rhinoptera bonasus*) were observed in the aerial study but went undetected in the boat surveys; almost 48,000 rays were observed in aerial surveys in all, and 200 times as many rays were observed from the aerial surveys as from the boat surveys (Figure 10-8; Chapter 4). Many schools of baitfish were observed in the aerial data, some spanning hundreds of meters, with peak observations occurring in July-September 2013. Schools of small fish were not measured nor individuals enumerated, but in the MABS area a total of 7,501 schools of fish of varying sizes were observed on the aerial surveys, while 50 were counted on the boat surveys. Baitfish schools were observed primarily in nearshore areas, and many were observed in the high-density transect extension offshore of Maryland in the second year of surveys, as well as in western extents of the sawtooth transects; the bulk of the baitfish observations occurred within the Maryland study area (74%, Figure 10-8).

Identification rates

There appeared to be differences in observers' ability to identify animals between the aerial and boat-based surveys in some cases, and the patterns observed in the Maryland study area were similar to those seen in the entire MABS area (Figure 10-9; see Connelly et al., 2015 for MABS identification rates). Twice as many bird species were definitively identified in the Maryland study area boat surveys than from the air (Table 10-1), with many more digital video aerial observations limited to the family or genus level of identifications. Gulls and terns, loons, and alcids all had much higher identification rates to the species level from the boat surveys than from the aerial surveys (Figure 10-9). Aerial observers were slightly better at identifying scoters, ducks, and geese (Anatidae) to species, which was likely due to boat observers having difficulty differentiating large flocks of Black Scoters (*Melanitta nigra*) and Surf Scoters (*M. perspicillata*) at a distance (Figure 10-9; see Williams et al., 2015 for a more detailed discussion). Observers from both survey types had similarly high identification rates of shearwaters (Procellariidae).

As fish were not a focal taxon for research in this study, neither platform identified fish to species, aside from Ocean Sunfish (*Mola mola*); in the Maryland study area, the aerial observers detected 46 sunfish, while the boat observers did not detect any. Identification rates of toothed whales (Odontoceti) were higher on boat surveys, but baleen whales (Mysticeti) had higher rates of identification from aerial surveys (Figure 10-10), and each method observed a few species that were missed by the other (Chapters 5 and 7).

Case study: sea turtles

Much higher counts and species diversity of sea turtles were detected on the aerial surveys than on the boat surveys in the MABS area (Figure 10-11) and in the Maryland study area (Chapters 4 and 7). While there were higher identification rates of turtles on the boat survey (Figure 10-10), only two species of turtles were identified (Loggerhead and Leatherback Sea Turtles) were identified from the boat. Despite difficulties with differentiating some subsurface turtles in the aerial footage, video observers were able to identify three additional species of turtles (Kemp's Ridley, *Lepidochelys kempii*; Hawksbill, *Eretmochelys imbricata*; and Green, *Chelonia mydas*) in both the Maryland and MABS areas.

Turtle distributions shift according to temperature, as they are poikilotherms and are limited to certain water temperature ranges (Gardner et al., 2008). There were times of year when turtles were far less abundant in the study area; as shown in Chapter 12 and the figures below, sea turtles had highest abundances from May through October. Overall, turtles were more abundant in the southerly survey transects, especially near the Virginia WEA (Figure 10-12 - Figure 10-14). Seasonal distributions varied between species groups, however. In the spring, Loggerhead Sea Turtles were found predominantly off the coast of Virginia, with a few individuals observed on the sawtooth transects further up the coast (Figure 10-12). One Leatherback and a few Green Sea Turtles were seen in Virginia and Maryland further offshore, and Kemp's Ridley Sea Turtles were seen mostly in the south (Figure 10-12). More Leatherbacks were observed in the summer compared to the other seasons, and while observations occurred mostly in the south, some were seen as far north as Delaware (Figure 10-13). Loggerheads were found further north in the summer as well, but all Kemp's Ridley and Green Sea Turtle observations were made off of Virginia (Figure 10-13). Turtles were much more evenly distributed up the coast in the fall than during earlier seasons; all five species were observed in the Virginia and Maryland WEAs during fall surveys. The only sightings of Hawksbill Sea Turtles occurred in the fall, in the Virginia and Maryland WEAs (Figure 10-14). There were only two turtle sightings in winter, one Kemp's Ridley and one unidentified to the species level, both located off of Virginia. All species of turtle were observed in the Maryland study area, with the highest number of observations and highest diversity in fall. Turtles were relatively evenly distributed in spring in the Maryland study area, with a more offshore distribution in summer and fall, unlike many other taxa observed in this study (Chapter 11).

Discussion

Overall, there were substantial similarities between the species groups detected via the two study methods offshore of Maryland. Gulls and terns were the most abundant bird group detected in both studies, with anatids observed in high numbers from both platforms as well. Both platforms detected similar species within these broader taxonomic groups. Chapters 13-14 continue to explore these similarities, with the goal of developing an integrated model that uses data from both survey platforms to yield more information about the study area than would have been possible through the use of either survey method alone.

However, there were notable differences in observation and identification rates between the two survey methods as well, which point towards differing strengths and weaknesses of the two methods (Figure 10-15). For example, there were more birds and more species of birds observed in the boat surveys, while aerial surveys detected many more aquatic animals. A similar efficiency in detecting and identifying sea turtles and marine mammals from high resolution digital aerial platforms (as compared to visual aerial or boat surveys) has also been observed elsewhere (Normandeau Associates Inc., 2013). Some of the discrepancies in observations point towards potential differences in detectability between the two survey types; for example, Northern Gannets (*Morus bassanus*) and larger gulls were visible at great distances from the boat survey, as observers could look from the vessel all the way to the horizon. Reviewers of aerial survey data, in contrast, could only see animals present in the narrow strip of the transect onscreen, and aerial survey speed was roughly 13.5 times that of the boat, potentially limiting onscreen appearances by highly mobile animals (Williams et al., 2015). Boat surveys are also known to affect animal behavior, and possibly detections as a result. Gulls are often attracted to boats as potential sources of food, while scoters are sensitive to disturbance by boats (Schwemmer et al., 2014), which we found to be the case in the focused comparison of the boat and aerial methods in the MABS study (Williams et al., 2015). Marine mammals are known to be attracted to or disturbed by boats (Mattson et al., 2005), and our boat survey counts of these species were potentially biased by the influence of the vessel's presence.

Differences in identification abilities between survey methods may have also played a role in explaining lower detections for many avian taxa. Low rates of aerial species identification were not altogether surprising for alcids and terns, given their small size and subtle differences between species. However, higher identification rates had been expected for loons based on results from European studies. Aerial video reviewers faced difficulties in differentiating the two loon species that use the Mid-Atlantic during the non-breeding season, due to the high degree of suspected size overlap (particularly for birds sitting at the water's surface) in this time period and region of the U.S. (Gray et al., 2014).

Additionally, the aerial results were analyzed using defined confidence level criteria, and were audited following an exhaustive quality assurance protocol. Both of these processes increase the amount of scrutiny given to identifications, which could result in lower identification rates. In contrast, boat observations are generally unverifiable and unable to be audited. The quality assurance and quality control protocol followed during analysis of digital video aerial survey data recognizes the inherent uncertainty in the identification process, which is generally under-recognized in visual surveys, as it is difficult to measure. At the same time, some of the lower identification rates in aerial surveys were, in the opinion of reviewers, clearly due to image quality, and this issue limits the utility of the digital video aerial surveys for describing the distributions of some taxa. Within the Maryland study area, a large percentage of digital video aerial observations of birds were recorded as Unidentified Bird due to poor image quality (6% overall, 21% of birds; Figure 10-6; Chapter 5). The next generation of cameras being used in Europe have higher resolution and color rendition than the cameras used in this study, however, with increased identification rates as a result (A. Webb pers. comm.), so technological advances in the field may largely ameliorate this issue.

We examined sea turtles more closely to compare observers' abilities to detect and identify aquatic animals using the two study methods, and found the digital video aerial surveys to be particularly good for observing and identifying sea turtles in the Mid-Atlantic. High resolution digital aerial survey platforms have previously been shown to be particularly efficient means to detect sea turtles as compared to visual aerial or boat survey platforms (Normandeau Associates Inc., 2013). Looking directly down on the surface of the water likely allows for clearer views of submerged or partially submerged animals, and video capture allows for in-depth examination of the animals for key characteristics. The animals are also not disturbed in the same way that they would be by a boat or a low-flying airplane (Hazel et al., 2007; Normandeau Associates Inc., 2013). Given that all species of sea turtle in Maryland and the Mid-Atlantic are federally listed and are of conservation concern, more accurate counts and distribution data for these species (even if many of the observations are recorded as simply non-Leatherback "unidentified turtles"), are still extremely useful for resource managers. As mentioned above, cameras used in this study have already been replaced by better models in Europe, and continued technological improvements are likely to dramatically increase identification rates for this key taxon.

Given the seasonal distribution patterns found for sea turtles, it is clear that there is overlap between these species' observed distributions and the locations of planned offshore wind energy development (WEAs), in part because sea turtles in the mid-Atlantic display a generally more offshore distribution pattern (thus placing them in areas of potential exposure to development activities in federal waters; Chapter 12). Offshore wind construction is the development period with the most risk to sea turtles, due to noise from pile driving and other activities, as sea turtles can detect and react to low-frequency sounds of the same frequencies as those emitted by seismic airguns, offshore drilling, sonar, pile driving, ships, and operational wind turbines (Chapter 12; Dow Piniak et al., 2012; Lenhardt et al., 1983; Read, 2013) Sea turtles are also vulnerable to collisions with ships, particularly those moving at higher speeds (Hazel et al., 2007). Turtles can be displaced from operating offshore wind facilities due to turbine or vessel noise, or artificial reef effects could lead to turtles aggregating around turbine foundations (Read, 2013). It may be possible to minimize potential effects of offshore wind energy development on sea turtles in the mid-Atlantic by planning offshore wind energy construction activities for periods in which turtles are not present (e.g., winter), though conducting construction activities during winter can be difficult or impossible. Since it is likely that turtle presence and construction will overlap, the development of techniques to avoid or reduce interactions between sea turtles and development activities should be a priority (Chapter 12). Restricting vessel speeds within areas and times of year when turtles are present could also help prevent negative impacts and/or mortalities of sea turtles (Hazel et al., 2007). Aerial video surveys appear to be an effective means to document sea turtle distributions, and we would suggest that future studies of sea turtles strongly consider digital aerial survey methodologies in order to obtain the best possible data for conservation and mitigation purposes.

Literature cited

Buckland, S.T., Burt, M.L., Rexstad, E.A., Mellor, M., Williams, A.E., Woodward, R., 2012. Aerial surveys of seabirds: The advent of digital methods. J. Appl. Ecol. 49, 960–967. doi:10.1111/j.1365-2664.2012.02150.x

Camphuysen, K.C.J., Fox, T.A.D., Leopold, M.M.F., Petersen, I.K., 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K., COWRIE - BAM - 02-2002. Royal Netherlands Institute for Sea Research, Texel, Netherlands.

Connelly, E., Williams, K., Duron, M., Johnson, S., Stenhouse, I., 2015. Summary of boat and aerial datasets: comparison between survey methods, 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.

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.

Gardner, B., Sullivan, P.J., Epperly, S., Morreale, S.J., 2008. Hierarchical modeling of bycatch rates of sea turtles in the western North Atlantic. Endanger. Species Res. 5, 279–289. doi:10.3354/esr00105

Gjerdrum, C., Fifield, D.A., Wilhelm, S.I., 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms, Canadian Wilidlife Service Technical Report Series No. 515. Atlantic Region. vi + 37 pp.

Gray, C.E., Paruk, J.D., DeSorbo, C.R., Savoy, L.J., Yates, D.E., Chickering, M.D., Gray, R.B., Taylor, K.M., Long, D., Schoch, N., Hanson, W., Cooley, J., Evers, D.C., 2014. Body Mass in Common Loons (Gavia immer) Strongly Associated with Migration Distance. Waterbirds 37, 64–75. doi:10.1675/063.037.sp109

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.

Lenhardt, M.L., Bellmund, S., Byles, R.A., Harkins, S.W., Musick, J.A., 1983. Marine turtle reception of bone-conducted sound. J. Aud. Res. 23, 119–125.

Mattson, M.C., Thomas, J.A., St. Aubin, D., 2005. Effects of Boat Activity on the Behavior of Bottlenose Dolphins (Tursiops truncatus) in Waters Surrounding Hilton Head Island, South Carolina. Aquat. Mamm. 31, 133–140. doi:10.1578/AM.31.1.2005.133

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.

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

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.

R Core Team, 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.r-project.org.

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.

Royle, J.A., Dawson, D.K., Bates, S., 2004. Modeling Abundance Effects in Distance Sampling. Ecology 85, 1591–1597.

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.

Tasker, M., Jones, P.H., Dixon, T., Blake, B.F., 1984. Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardized aproach. Auk 101, 11. doi:10.2307/4086610

Thaxter, C.B., Burton, N.H.K., 2009. High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols, Report commissioned by COWRIE Ltd.

Thomas, L., Buckland, S.T., Rexstad, E.A., Laake, J.L., Strindberg, S., Hedley, S.L., Bishop, J.R.B., Marques, T.A., Burnham, K.P., 2010. Distance software: Design and analysis of distance sampling surveys for estimating population size. J. Appl. Ecol. 47, 5–14. doi:10.1111/j.1365-2664.2009.01737.x

Williams, K., Stenhouse, I., Adams, E., Connelly, E., Gilbert, A., Duron, M., 2015. 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.

Figures and tables

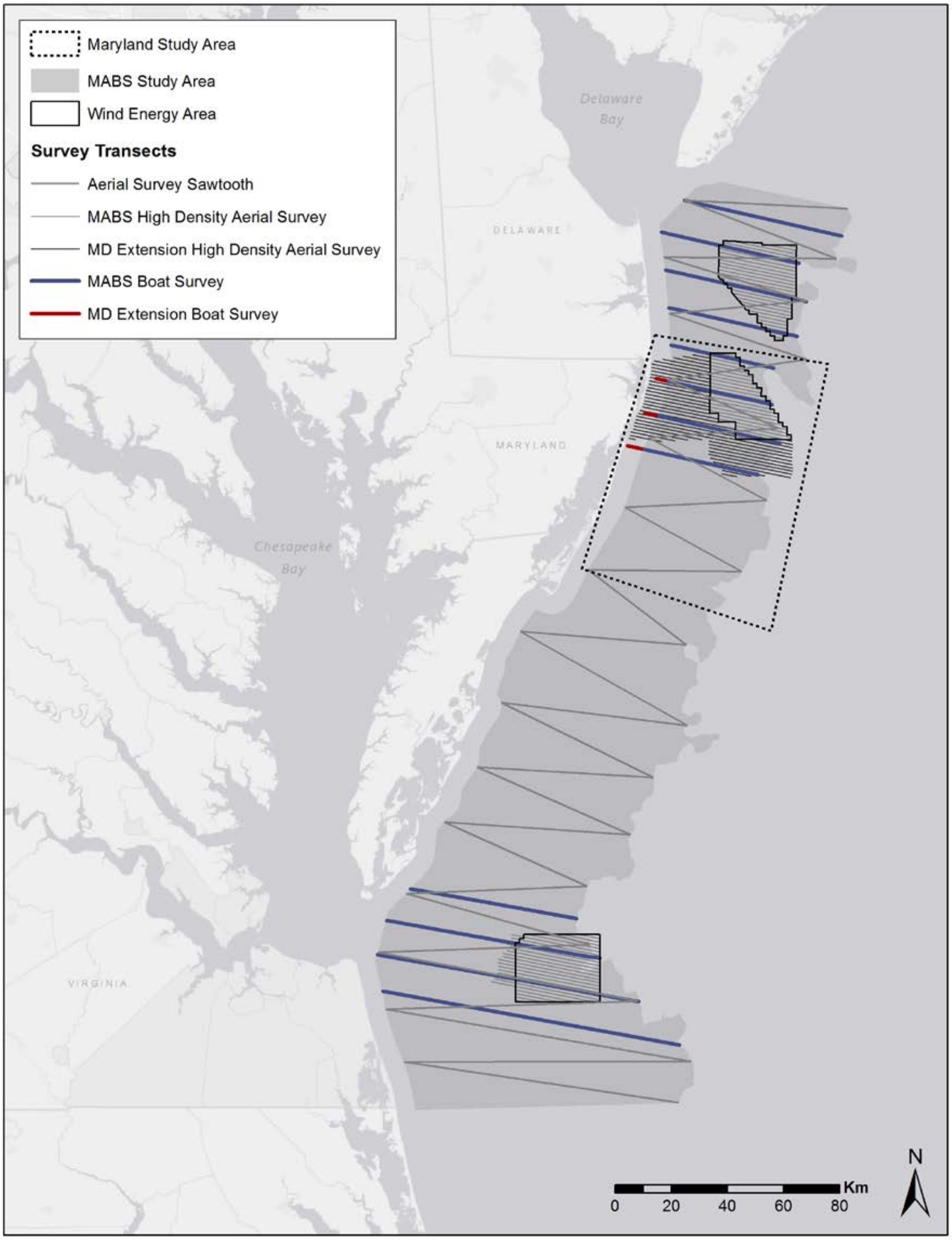


Figure 10-1. Map of digital video aerial survey transects and boat survey transects for the Maryland-funded Maryland Project (2013-2014) and the DOE-funded Mid-Atlantic Baseline Studies Project (2012-2014). MABS boat transects are shown in dark blue and Maryland Project boat transects are shown in red. MABS aerial transects are shown in light grey and Maryland Project aerial transects are shown in dark grey.

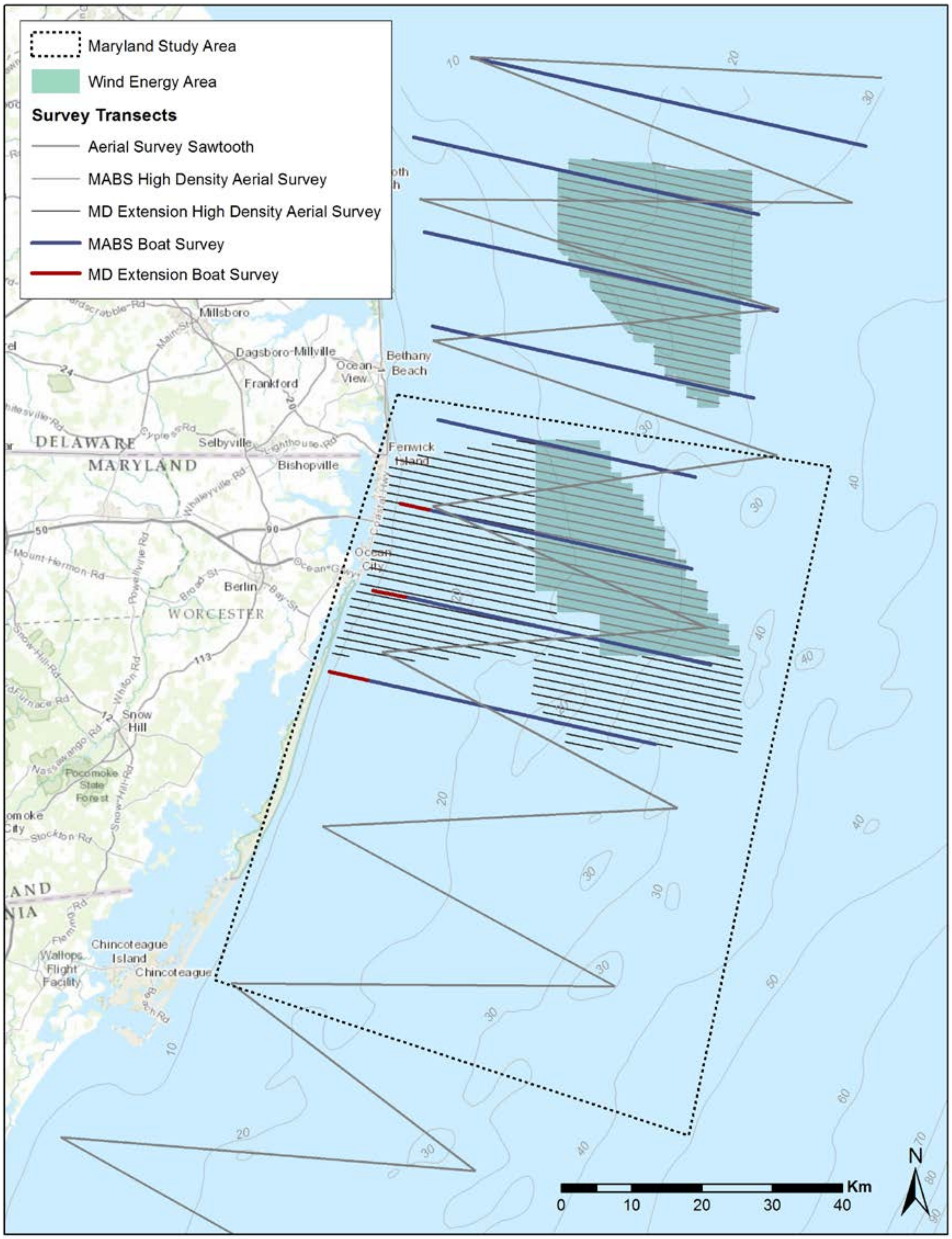


Figure 10-2. Detailed map of aerial survey transects focused on the digital video aerial surveys and boat surveys for the Maryland-funded Maryland Project (2013-2014) along with the adjacent DOE-funded Mid-Atlantic Baseline Studies Project (2012-2014). The “Maryland Study Area” includes all boat and aerial survey transects in waters offshore of Maryland (both DOE and Maryland-funded surveys) The Maryland Project surveys are a subset of the surveys within the Maryland study area that were specifically funded by the state of Maryland in 2013-2014. These extension surveys included boat survey extensions into state waters (red bars), aerial survey high-density transect extensions west and south of MD WEA (dark grey lines), and a 15th aerial survey of the Maryland WEA and Maryland Project high-density transects in 2013. Surrounding transect lines for the MABS study are also shown.

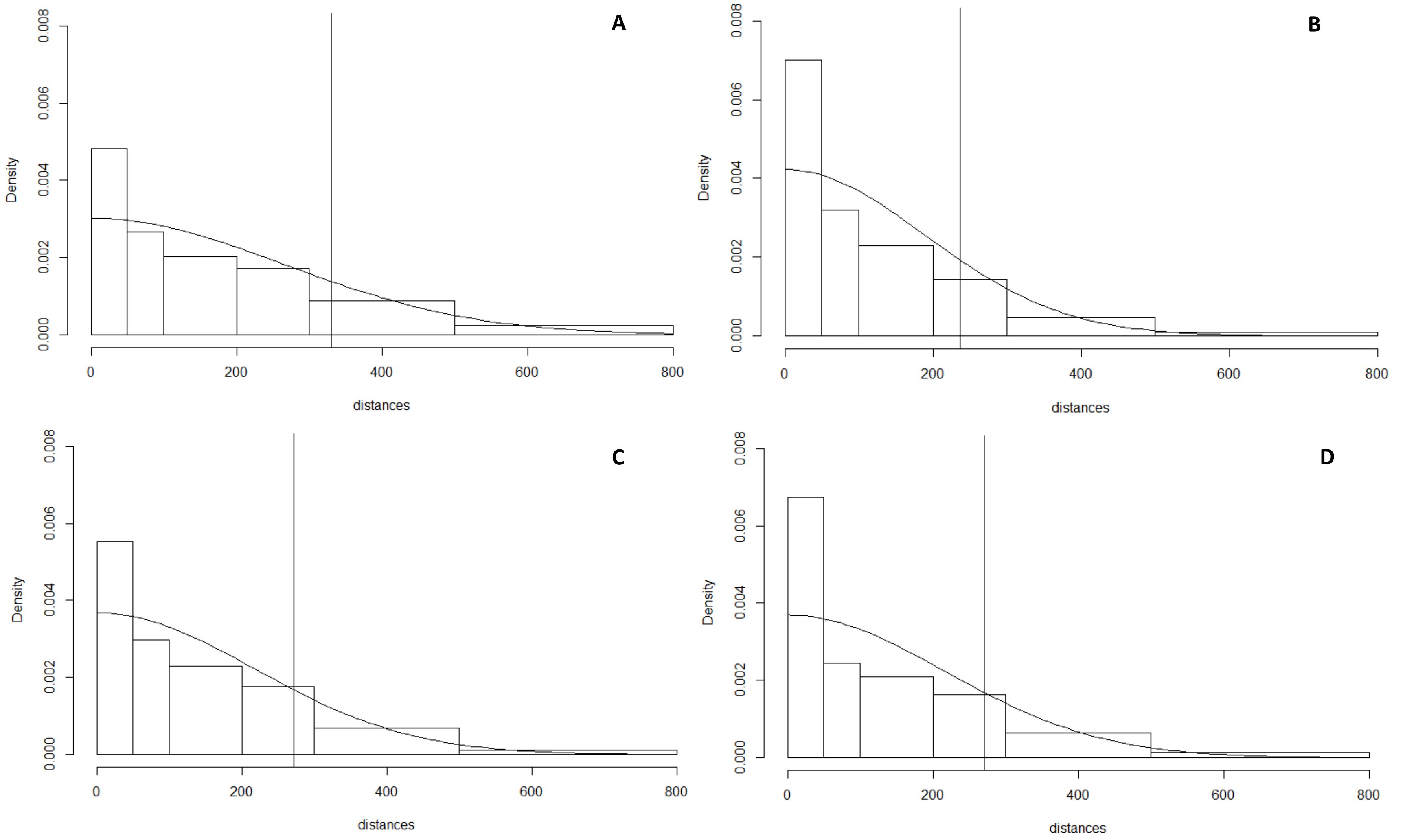


Figure 10-3. Distance functions for a) Sulidae, b) Laridae, c) Gaviidae, and D) Anatidae from the combined MABS and Maryland Project boat survey data. Effective strip half-widths, or the distance from the boat at which there is average detection probability, are indicated by the vertical line in each chart (330m for Sulidae, 236m for Laridae, 272m for Gaviidae, and 271m for Anatidae).

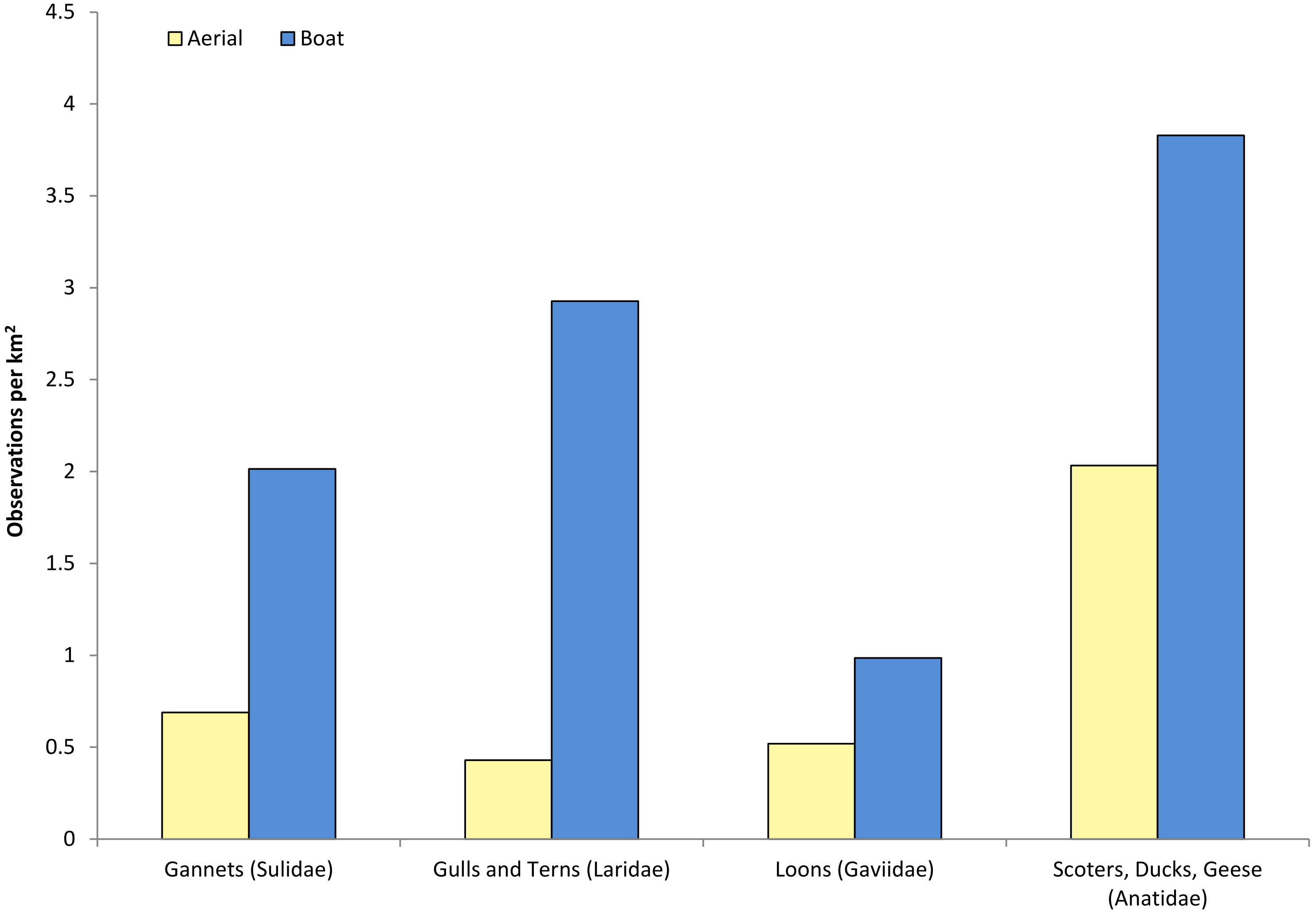


Figure 10-4. Comparison of total effort-corrected boat and aerial survey counts by taxon for the combined MABS and Maryland Project study area. Densities are calculated by the total number of counts divided by the total surveyed area. Aerial data have transect widths of either 200 or 300 meters (Chapter 3). Effective boat transect strip widths were calculated for each group based on the effective half strip width (see Figure 10-3).

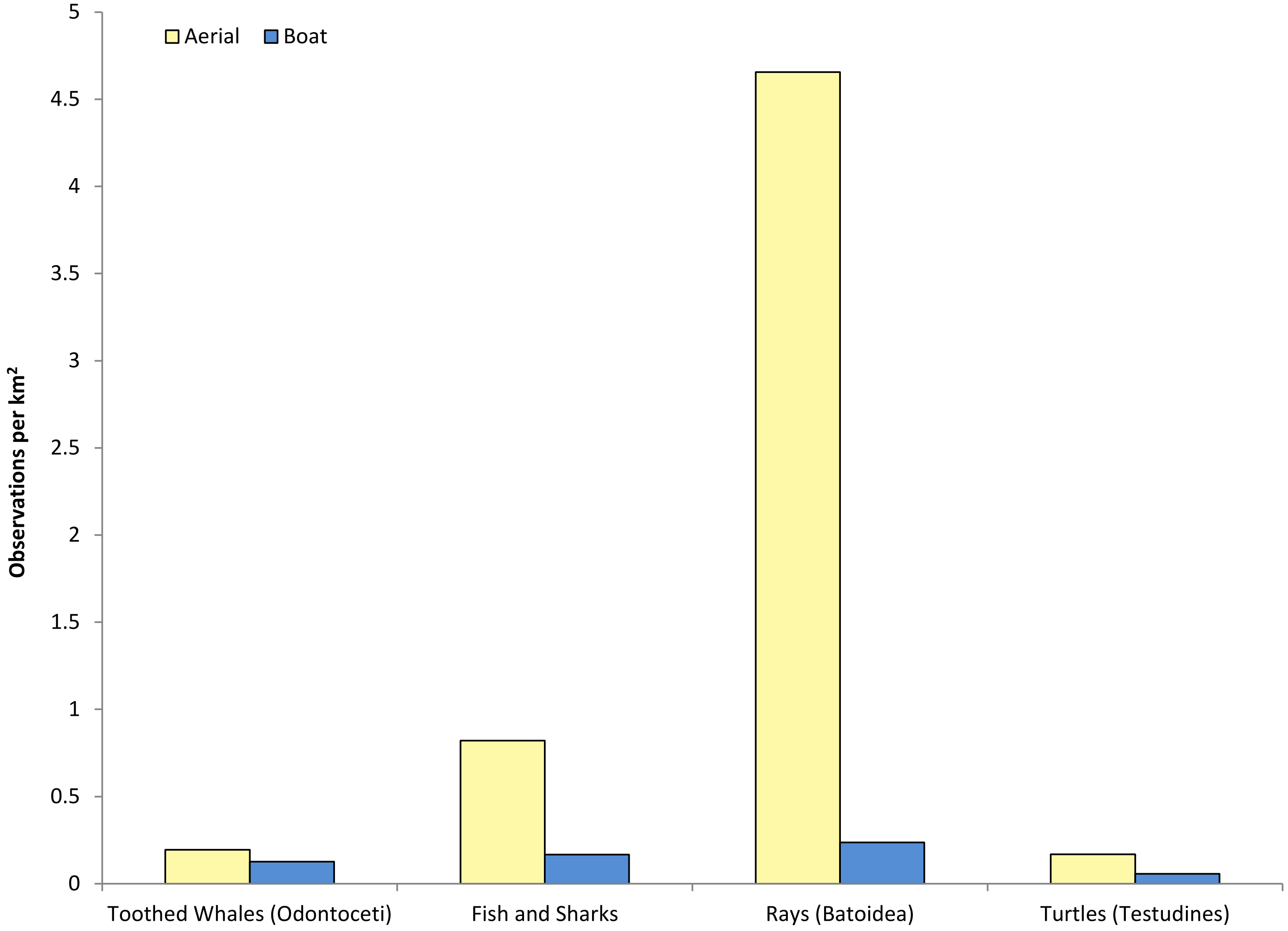


Figure 10-5. Comparison of total effort-corrected boat and aerial survey counts by taxon for the combined MABS and Maryland Project study area. Densities are calculated by the total number of counts divided by the total survey area. Aerial data have transect widths of 200 or 300 meters (see Chapter 3). Boat data transect widths were based on the median distance of observations from the boat, in meters (Odontoceti, 300 m; Fish/Sharks, 50 m; Batoidea, 7.5 m; Testudines, 100 m). Observations of groups that were not individually counted or identified (e.g., bait balls, ray schools) are excluded from this figure (see Chapter 5 for more information).

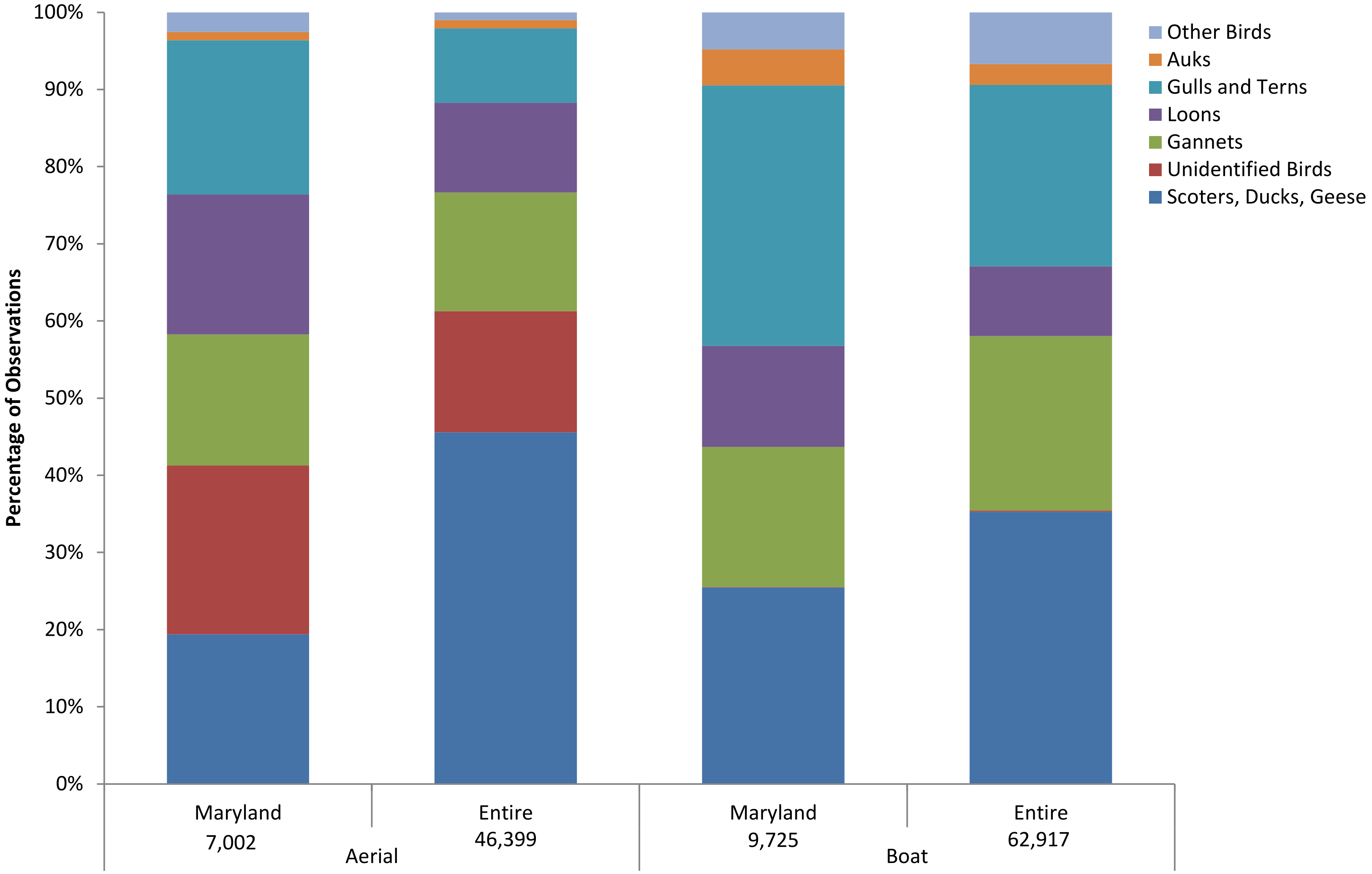


Figure 10-6. Bird groups observed in the digital video aerial and boat surveys in the Maryland study area (Maryland) and the combined MABS area and Maryland Project study area (Entire). The sample size for each group is given in the x-axis. Animals shown are scoters, ducks, and geese (Anatidae); unidentified birds (birds not identified to lower taxonomic levels); Northern Gannets (Sulidae); loons (Gaviidae); gulls and terns (Laridae); auks (Alcidae); and other birds (additional less common animal groups, see Chapters 5 and 7 for animals observed).

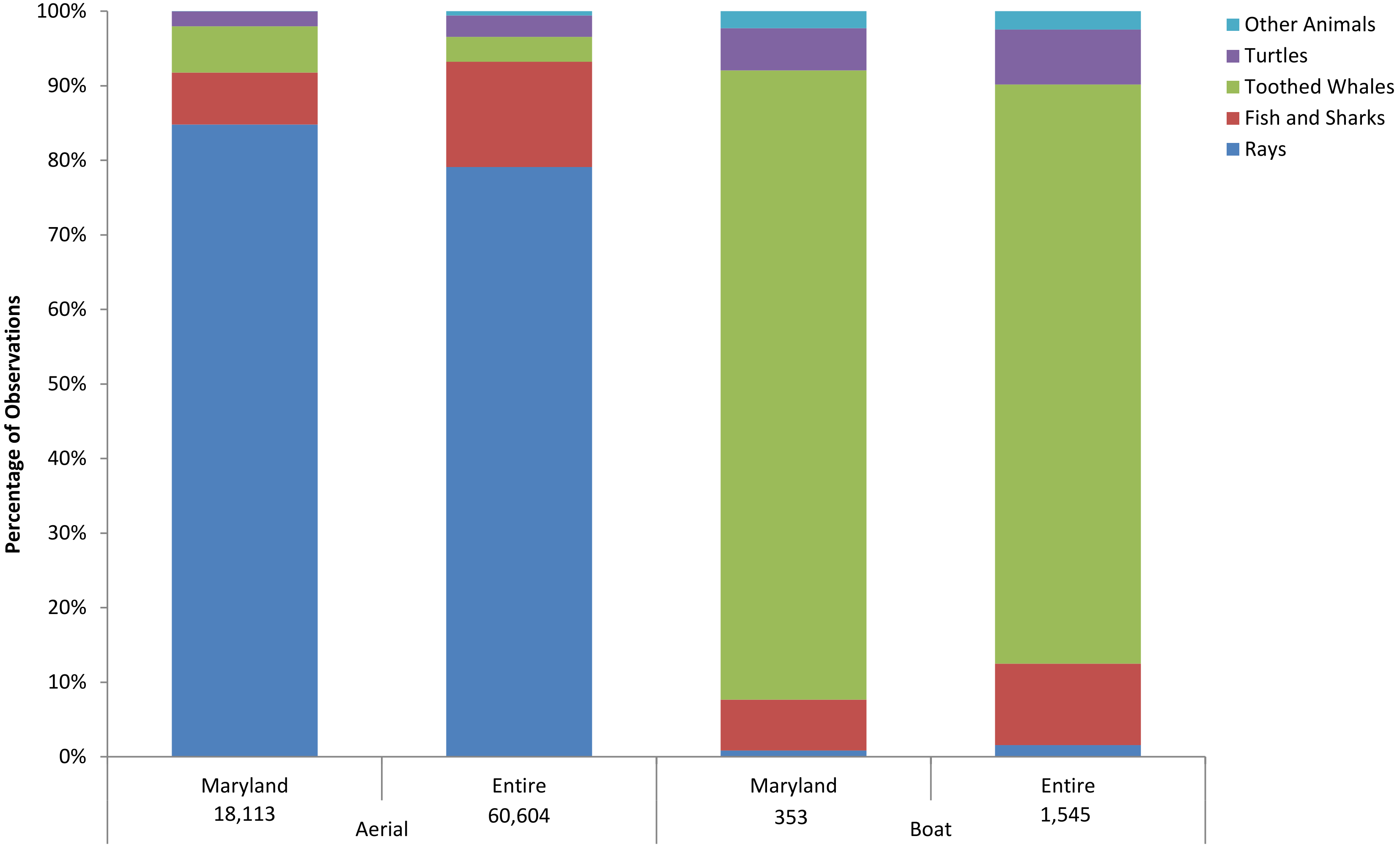


Figure 10-7. Non-avian animals observed in the digital video aerial and boat surveys in the Maryland study area (Maryland) and the combined MABS area and Maryland Project study area (Entire). The sample size for each group is given in the x-axis. Animals shown are rays (Batoidea); fish and sharks (Chordata); toothed whales (Odontoceti, including dolphins and porpoises); turtles (Testudines); and other animals (additional less common animal groups, see Chapters 5 and 7 for animals observed).

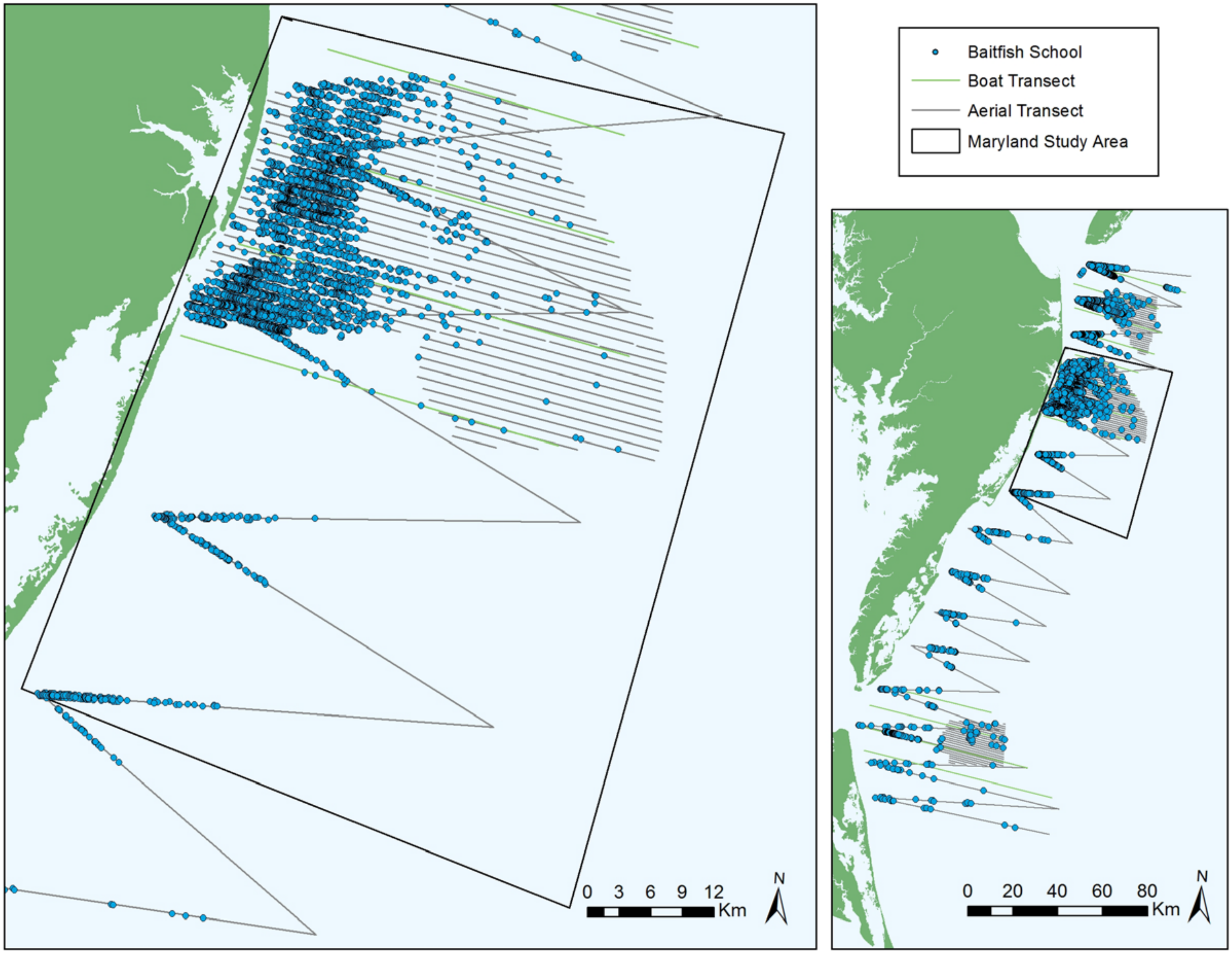


Figure 10-8. Schools of baitfish (forage fish) observed in Maryland boat and digital video aerial surveys. The inset map shows the broader project area.

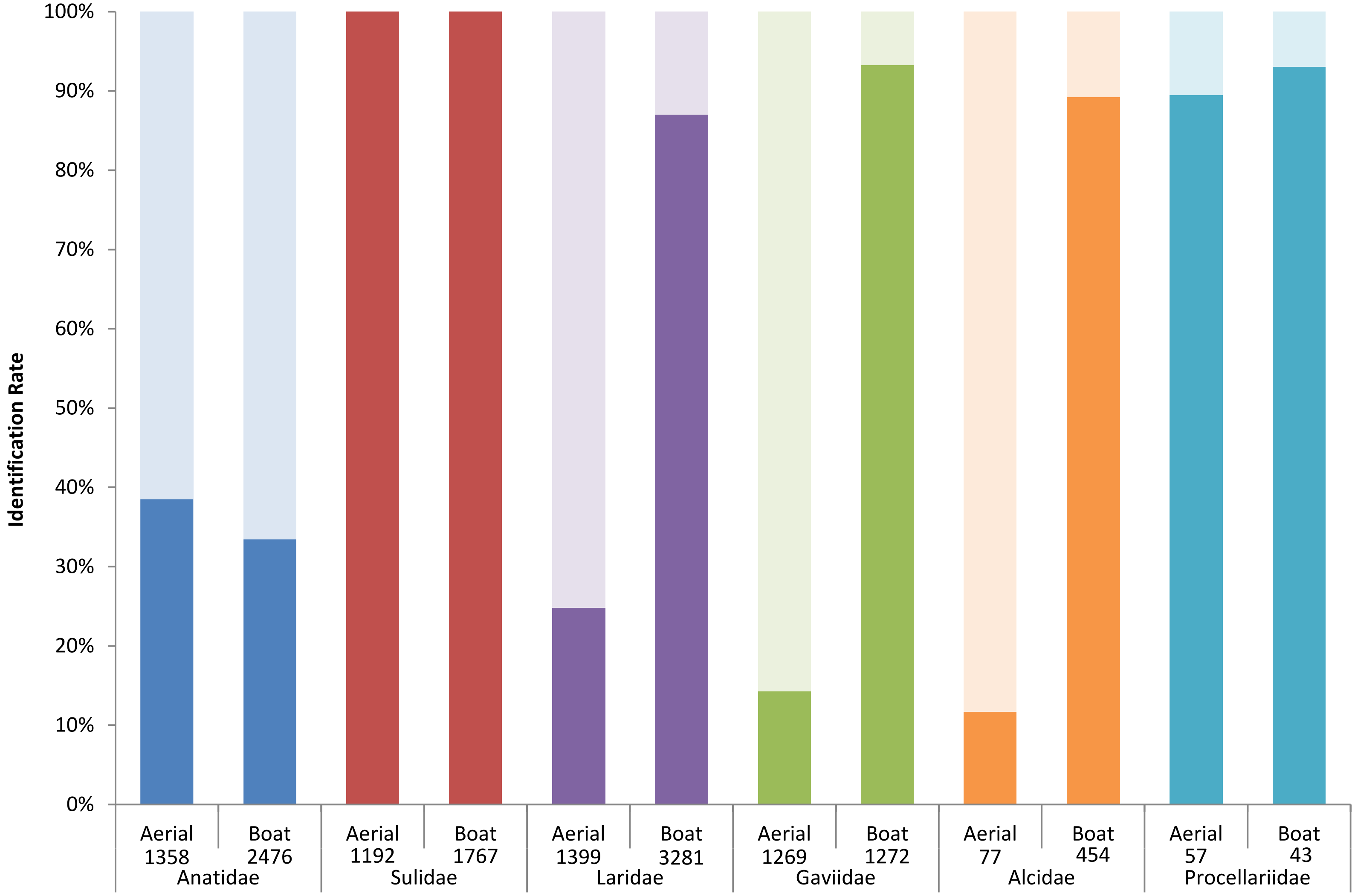


Figure 10-9. Identification rates for common bird taxa observed during boat-based and digital video aerial surveys in the Maryland study area, in order of abundance. Darker colors indicate animals identified to species, and lighter colors indicate animals identified to higher taxonomic levels. Sample sizes are noted in the x-axis. Details on species sighted within each taxonomic group can be found in Chapters 5 and 7. The most common avian families observed in surveys were scoters, ducks, and geese (Anatidae); Northern Gannets (Sulidae); gulls and terns (Laridae); loons (Gaviidae); auks (Alcidae); and fulmars and shearwaters (Procellariidae).

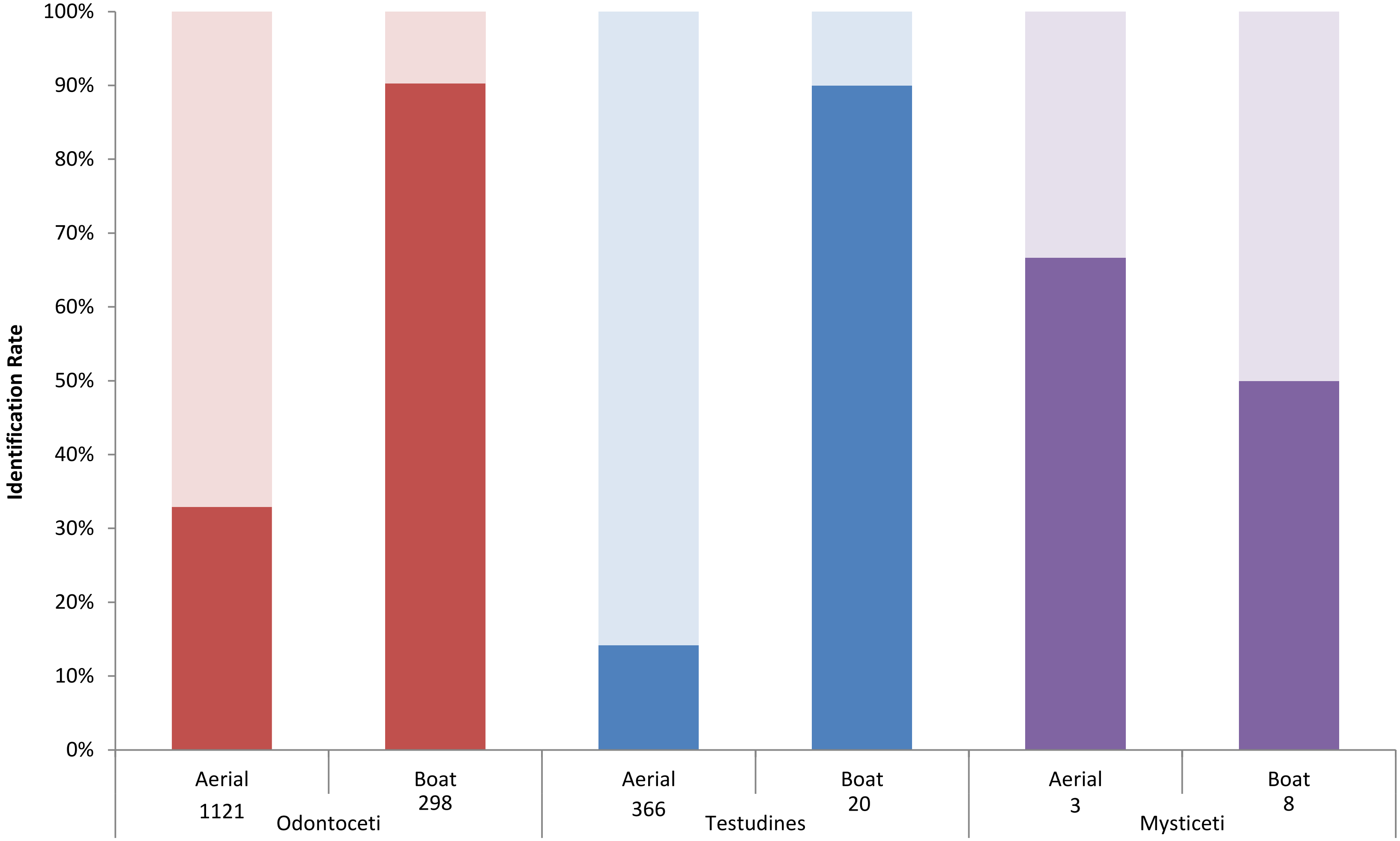


Figure 10-10. Identification rates of mammals and turtles observed on during boat-based and digital video aerial surveys in the Maryland study area. Darker colors indicate animals identified to species, and lighter colors indicate animals identified to higher taxonomic levels. Sample sizes are noted in the x-axis. Details on species included within each taxonomic group can be found in Chapters 5 and 7. Groups are toothed whales (Odontoceti, including dolphins and porpoises); sea turtles (Testudines); and baleen whales (Mysticeti).

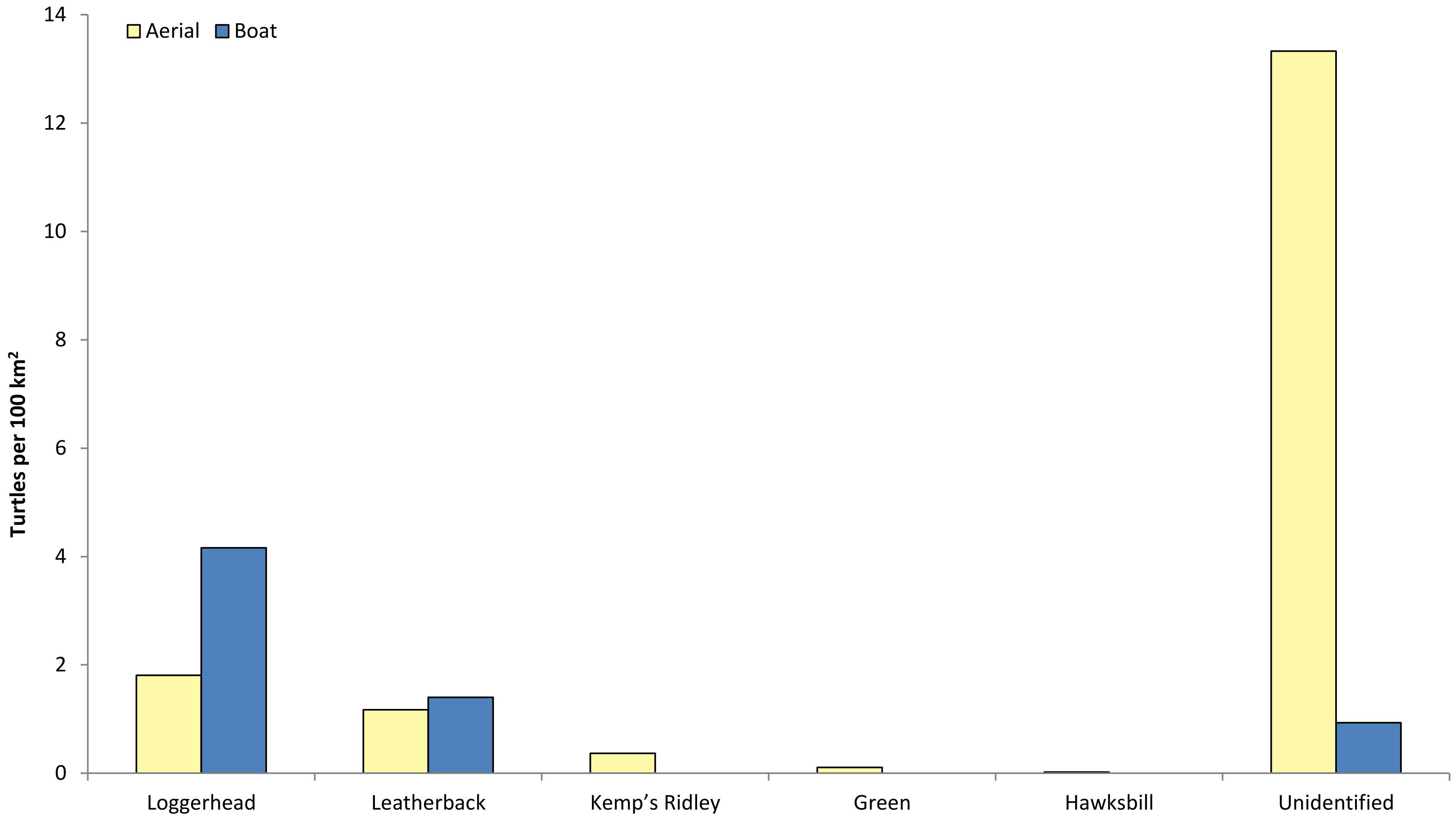


Figure 10-11. Comparison of total effort-corrected boat and aerial survey counts of sea turtles for the combined MABS and Maryland Project study areas. Densities were calculated by the total number of counts divided by the total survey area across all surveys, and standardized to 100 square km. Aerial surveys had transect strip widths of 200 or 300 m (Chapter 3). Boat transect strip widths were based on the median distance of observations from the boat, in meters (Loggerhead 100, Leatherback 50, Unidentified 50 m), and multiplied by two to account for observations made on both sides of the boat.

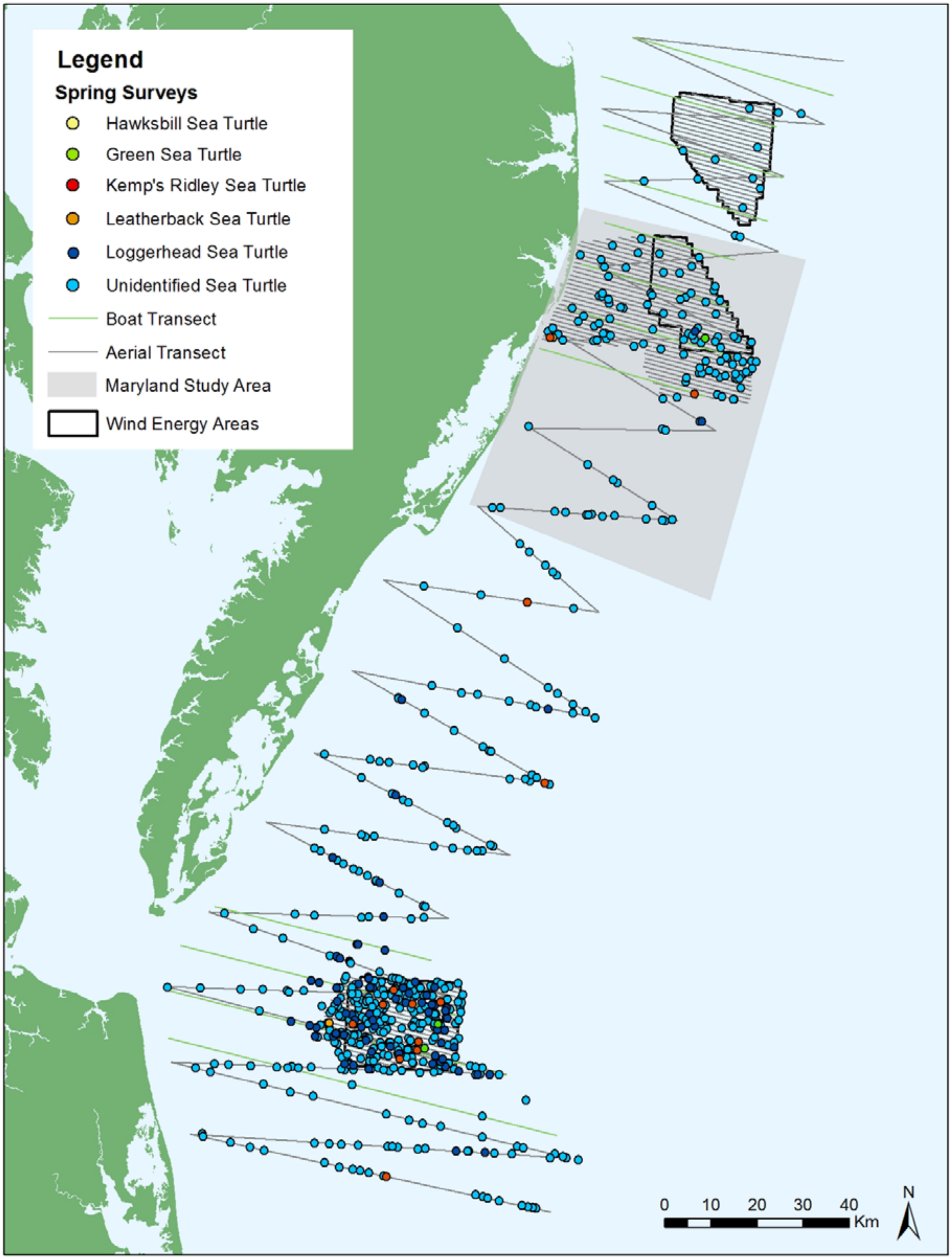


Figure 10-12. Turtles observed in the spring (Mar-May 2012-2014) in boat and high resolution video aerial surveys. Unidentified sea turtles are any turtles not identified to species, and could represent any of the four smaller turtle species present in the study area (excluding Leatherback Sea Turtles).

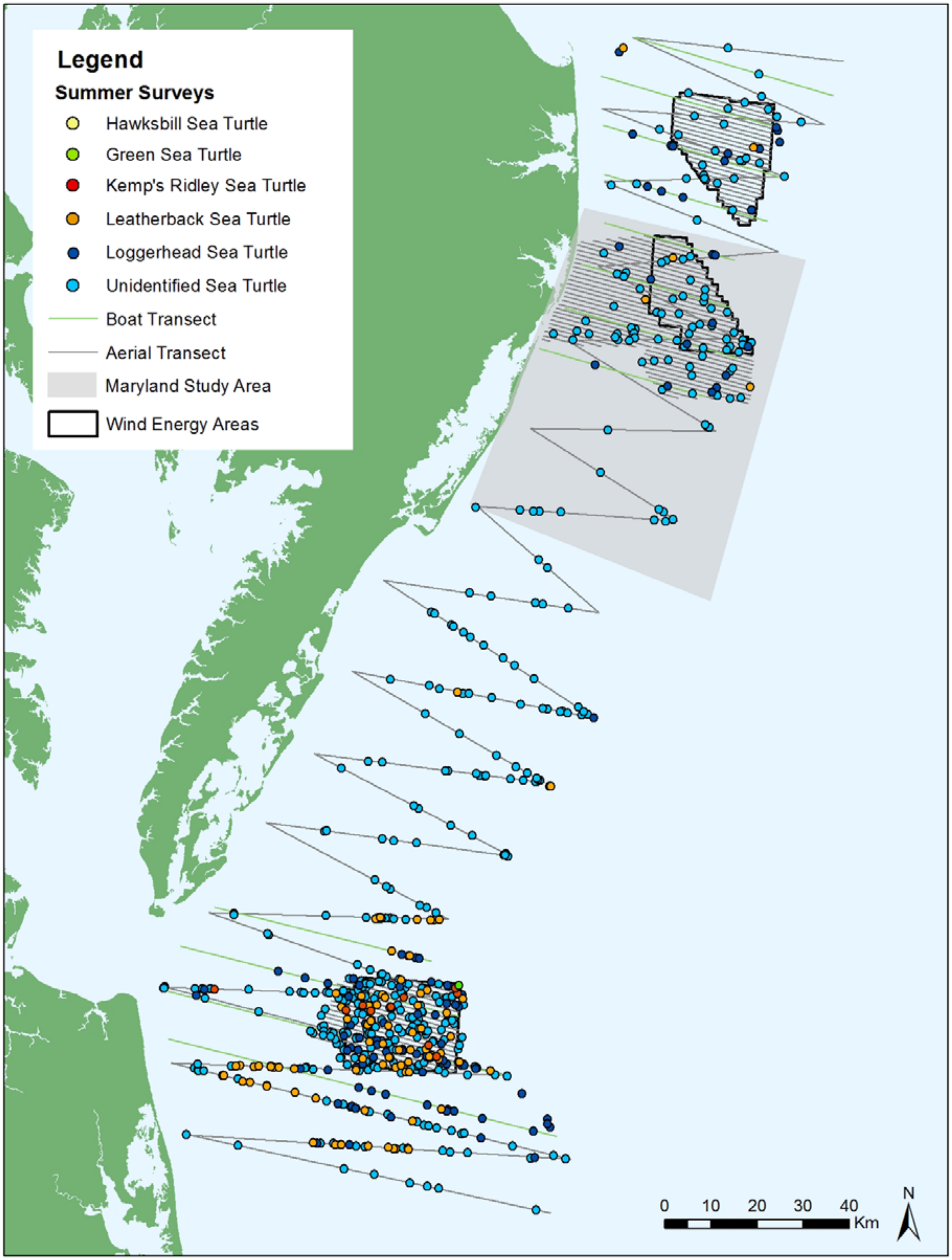


Figure 10-13. Turtles observed in the summer (Jun.-Aug. 2012-2013) in boat and high resolution video aerial surveys. Unidentified sea turtles are any turtles not identified to species, and could represent any of the four smaller turtle species present in the study area (excluding Leatherback Sea Turtles).

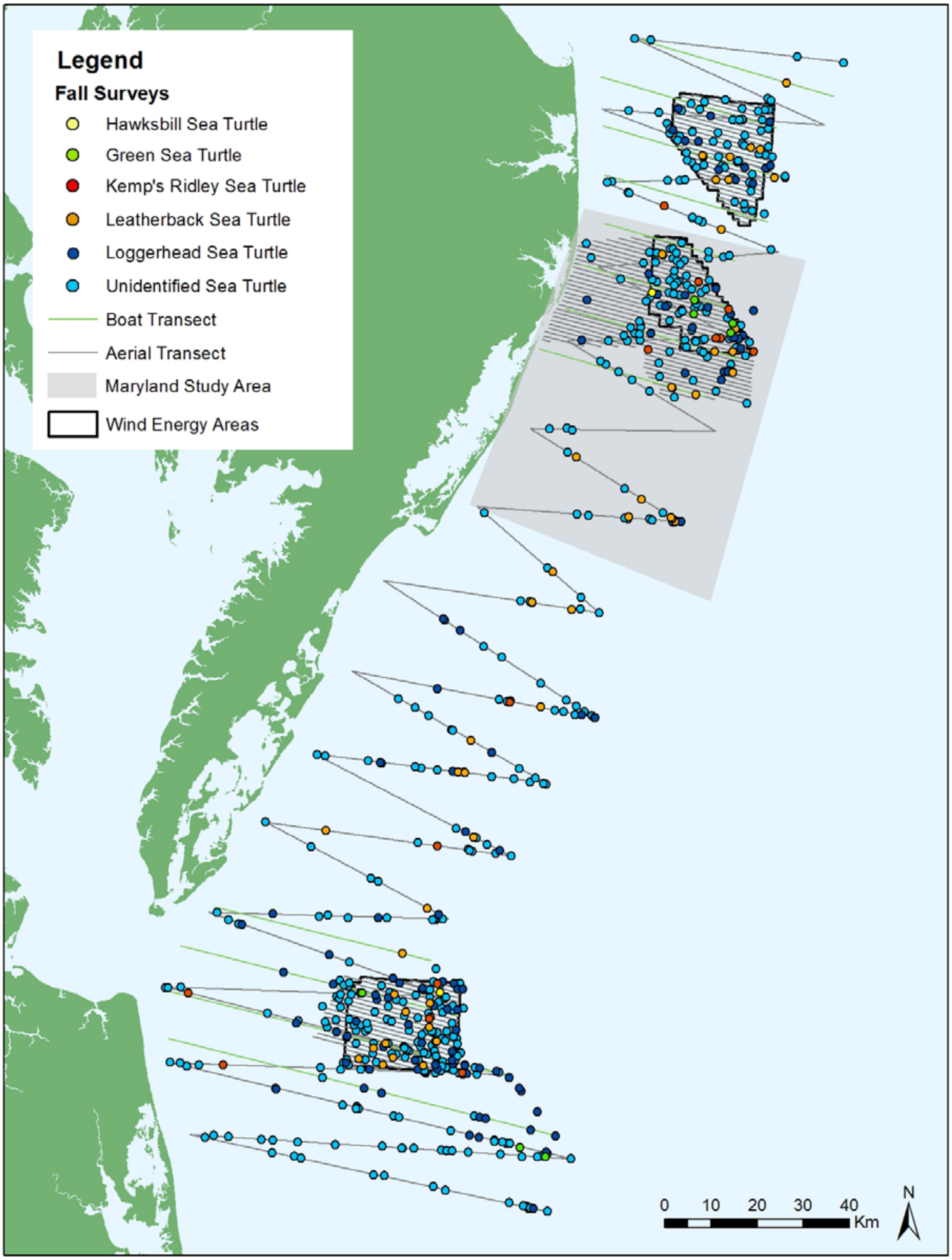
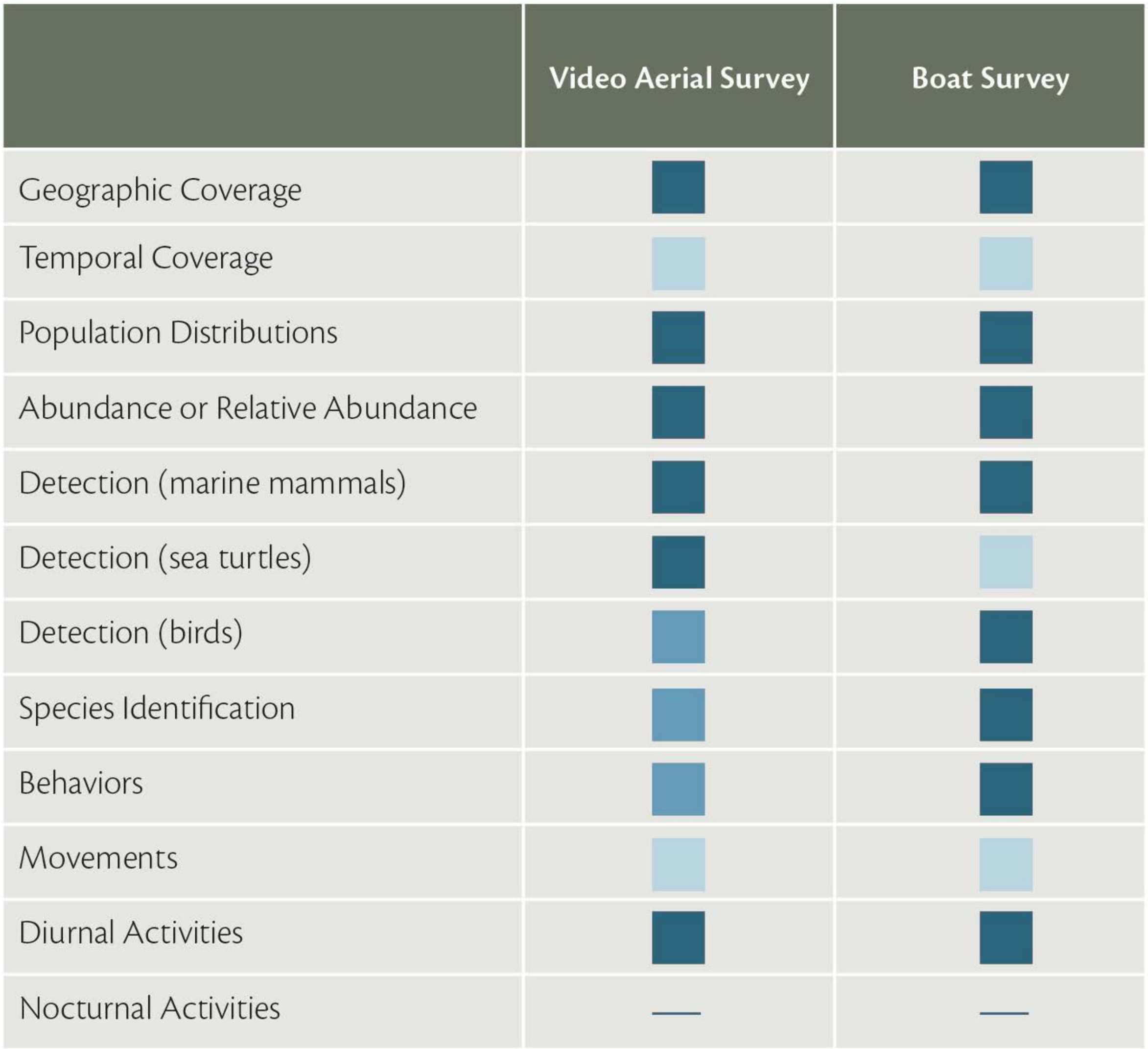


Figure 10-14. Turtles observed in the fall (Sep.-Nov. 2012-2013) in boat and high resolution video aerial surveys. Unidentified sea turtles are any turtles not identified to species, and could represent any of the four smaller turtle species present in the study area (excluding Leatherback Sea Turtles).



	Video Aerial Survey	Boat Survey
Geographic Coverage	■	■
Temporal Coverage	□	□
Population Distributions	■	■
Abundance or Relative Abundance	■	■
Detection (marine mammals)	■	■
Detection (sea turtles)	■	□
Detection (birds)	▨	■
Species Identification	▨	■
Behaviors	▨	■
Movements	□	□
Diurnal Activities	■	■
Nocturnal Activities	—	—

Figure 10-15. Methods for surveying offshore wildlife in this study. Relative strengths and weaknesses of video aerial and boat surveys in this study are indicated by depth of color (dark blue = good, medium blue = fair, light blue = poor). A dash indicates that data are not available from this survey method. Values are subjective; for example, while detection bias was not quantified for aerial surveys, detection of avian species in our boat surveys appeared to be better than digital video aerial surveys in many cases, at least after correction for distance bias in boat data. Thus, boat surveys were categorized as "good" for this type of data, while digital video aerial surveys were considered "fair".

Table 10-1. Total number of individuals observed, species observed, and survey effort for the boat-based and high resolution digital video aerial surveys for the entire study area (MABS and the Maryland Project transects) and the Maryland study area (2012-2014, Figure 10-1). Aerial transect width was 200 meters, with the partial exception of the first three surveys (when the sawtooth transect width was 300 meters). Boat data were collected at varying distances from the transect line depending on the taxon, but the effective transect width for the survey likely fell between 300 and 500 meters for most taxa (and these two numbers are used to present an approximate range of total area covered by the boat surveys in the table below. See Chapters 2 and 6 for more details on data collection methods.

Survey	**Study Area**	**Avian Animals**		**Non-Avian Animals**		**Effort**	
		Number observed	Species	Number observed	Species	Linear km	Area (km^2)
Aerial	Entire	46,399	47	60,604	19	49,576	10,403
	MD	7,002	30	18,113	15	15,698	3,223
Boat	Entire	59,336	94	1,439	12	10,698	3,209 - 5,349
	MD	9,725	61	353	6	2,606	782 - 1,303

Chapter 11: Integrating data across survey methods to identify spatial and temporal patterns in wildlife distributions

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

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Chapter 11 Highlights

Identifying spatial and temporal patterns of species abundance and species richness by combining data from boat-based and digital video aerial surveys

Context[1]

Part IV of this report focuses on the comparison and integration of data from boat surveys and digital video aerial surveys to examine wildlife distributions in the Mid-Atlantic and specifically offshore of Maryland. This chapter uses both datasets to identify temporal and spatial patterns of species presence and relative abundance in the Mid-Atlantic Baseline Studies and Maryland Project study areas, including the identification of "persistent hotspots," or geographic areas with consistently high numbers of animals or species through time, which may indicate important habitat use areas. Temporal patterns of observations of different species and groups within the study area are also presented in this chapter, and can be used to determine potential exposure to offshore development activities at different times of year.

While this chapter examines patterns in areas that were directly surveyed, several other chapters in Part IV incorporate environmental covariates into modeling efforts, in order to identify environment drivers of these distributions and predict relative densities of wildlife across the region (Chapters 12-14). In some instances, one survey method was used to predict abundance of specific taxa (e.g., Chapter 12), while in other cases, the two datasets could be combined using an integrated modeling framework (Chapter 14). Additional chapters in Part IV compare boat and aerial survey methodologies (Chapter 10), highlighting the strengths and weaknesses of the two methods, and provide context for results presented in this chapter.

Study goal/objectives

Identify persistent hotspots of relative abundance and species richness, as well as temporal patterns of species abundance within both boat survey and digital video aerial survey datasets.

Highlights

- To identify persistent hotspots, boat and digital video aerial survey data were combined for locations with sufficient sample sizes where both datasets were available.
- For most taxa, hotspots were most consistently observed in areas within approximately 30-40 km from shore, particularly offshore of the mouths of Chesapeake Bay and Delaware Bay, and in northern Maryland.
- The presence and relative abundance of different species varied widely by time of year.

Implications

Combining data from two different survey approaches can provide a better view of wildlife populations and distribution patterns than either survey method could provide alone. These results may be helpful for informing the siting and permitting processes for future development projects, and for informing mitigation efforts and construction and operations plans.

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[1] For more detailed context for this chapter, please see the introduction to Part IV of this report.

Abstract

Data on the abundance of marine birds, mammals, and turtles were collected over a two-year period (2012-2014) as part of the Mid-Atlantic Baseline Studies and Maryland Projects to inform siting and permitting processes for offshore wind energy development. We employed two methods: (1) traditional boat-based surveys, and (2) high resolution digital video aerial surveys. We combined data from both survey methods to examine spatial and temporal patterns of wildlife abundance by calculating persistent hotspots of abundance across all surveys. "Hotspots," or areas with atypically high effort-corrected counts of a taxon from a given survey, were summed across all surveys to calculate relative persistence. Boat and aerial survey data were combined for locations with sufficient sample sizes where both datasets were available. We also used boat and aerial survey data from both studies to summarize temporal patterns in species observations throughout the annual cycle and compare results between survey methods.

For most taxa, hotspots were most consistently observed in areas within approximately 30-40 km of shore, particularly offshore of the mouths of Chesapeake Bay and Delaware Bay and in northern Maryland. Exceptions to this general rule included sea turtles (Testudines spp.), Common Dolphins (*Delphinus delphis*), Common Loons (*Gavia immer*), and alcids (Alcidae spp.), all of which tended to have persistent hotspots located farther offshore. The presence and relative abundance of species varied widely by time of year, however, with different species and groups using the Mid-Atlantic region, and areas offshore of Maryland in particular, during non-breeding (summer or winter), breeding, and migratory periods.

Introduction

The Mid-Atlantic region is an important area for a broad range of marine wildlife species throughout the year. This is due to relatively high levels of productivity, fed in part by nutrient inputs from Chesapeake Bay and Delaware Bay, as well as the region's central location on the eastern edge of the continent and in the middle of an important migratory flyway (Chapter 1; Schofield et al., 2008; Smith and Kemp, 1995). During this study, our main goal was to gather the baseline information on abundance and movements of marine birds, mammals, and turtles required to inform siting and permitting processes for offshore wind energy development in the Mid-Atlantic, as part of the Mid-Atlantic Baseline Studies (MABS) Project and the Maryland Project.

We collected data on bird, sea turtle, and marine mammal abundances and movements over a two-year time period (2012-2014) using a variety of technologies and methods to examine spatial patterns and trends, while simultaneously testing a new technology for the first time in the United States (high resolution digital video aerial surveys; hereafter video aerial surveys). Video aerial surveys are a relatively new method for collecting distribution and abundance data on animals in the marine environment (Thaxter and Burton, 2009). Although they have become a common method of collecting baseline data on marine bird and mammal distribution and abundance for offshore wind energy planning and monitoring in Europe, the U.S. still relies almost exclusively on boat-based and standard (visual observer) aerial survey methods. The MABS and Maryland Projects together are the largest application of video aerial surveys in the U.S. to date. We also conducted boat-based surveys within the study areas to accompany the video aerial surveys; standardized boat-based surveys are a well-established and widely used method of obtaining density data for birds, sea turtles, and marine mammals (Gjerdrum et al., 2012; Tasker et al., 1984).

Boat and video aerial surveys produced markedly different results for some taxa (Chapter 10), which can present a challenge when interpreting and/or integrating data obtained from the two survey methodologies. These differences also present an opportunity, however, in that the two surveys can provide complementary data that, in tandem, may be used to provide a better overall view of wildlife distributions and relative abundance in the Maryland and MABS study areas. The challenge was to integrate these data in a meaningful way that adds to our understanding of wildlife distributions. Two such integrative efforts are discussed below: the identification of geographic hotspots of persistent abundance, as well as the identification of temporal patterns of persistence and relative abundance of species within the study area.

Both abiotic components (e.g., climatic conditions) and biotic components (e.g., prey and predator distributions) of marine ecosystems can be highly variable in space and time (Kappes et al., 2010; Lehodey et al., 2006; Murphy et al., 1998). Thus, identifying key habitat use areas or locations of high wildlife abundance in the marine environment can be difficult, as such locations may be ephemeral. Several previous studies have attempted to identify hotspots of wildlife abundance in the marine ecosystem; while each study defined hotspots slightly differently, all of these definitions contain an element of temporal as well as spatial persistence. For example, Piatt et al. (2006) define a hotspot for the Short-tailed Albatross (*Phoebastria albatrus*) as a ‘relatively small area in which we expect to find animal aggregations repeatedly’, while Davoren (2007) defines hotspots of seabirds as ‘areas where high abundance of species overlap in space and time’. Suryan et al. (2012) define hotspots of marine predators as ‘regions of consistently high abundance of predators relative to the surrounding area in the open ocean’. Other studies have used varying mathematical definitions to identify hotspots. Zipkin et al. (2015) identifies hotspots as locations with 3x the mean abundance for the study region. Santora and Veit (2013) define hotspots as ‘locations with anomalies that exceed the mean for the entire study region by 1 standard deviation in a given survey’. Likewise, in this study, we apply a quantitative definition to identify hotspots in a consistent, repeatable way across species and surveys. While most similar to the approach taken by Santora and Veit (2013), our exact definition of hotspots also varies slightly from those above, in order to account for highly non-normal distributions of animal counts across our study area, and with a goal of identifying those hotspots that are most consistent throughout the two years of surveys.

Persistent hotspots thus highlight locations where individuals within a species or species group have been consistently observed in greater than average numbers over time, and may indicate the locations of important habitat (Gende and Sigler, 2006; Santora et al., 2010; Sydeman et al., 2006). In this study, we examined spatial patterns of persistent abundance for a wide range of taxa, including seabirds, marine mammals, sea turtles, rays, and bait fish, which were present within the study area for varying amounts of time or in variable numbers depending on each group’s life history traits. Temporal bar charts summarize the temporal patterns of species and species groups within the study area, and allow for comparison of effort-corrected count data for species and species groups through time and between survey methods. Identification of persistent hotspots, paired with temporal bar charts for taxa of interest, can be used in: (1) marine spatial planning efforts; (2) understanding when and where animals may be affected by anthropogenic activities; and (3) identifying species or taxa in particular need of additional study. These data can be used during permitting processes for future development, as well as for siting projects and designing development plans to minimize wildlife impacts on the Mid-Atlantic Outer Continental Shelf. By pairing persistent hotspot maps with temporal bar charts for species and taxonomic groups of interest, we hope to develop a comprehensive picture of geographic and temporal patterns of wildlife within the study area.

Methods

Between March 2012 and May 2014, we conducted 16 large-scale boat-based visual surveys and 15 large-scale high-resolution digital video aerial surveys within the Maryland and MABS study areas, with additional survey effort within the Maryland study area during Year Two of the study. The broader MABS study area encompasses the coastal area from Delaware to Virginia, extending from 3 nautical miles from the coastline (the boundary between state and federal waters) out to the 30 m isobath or the eastern extent of the Wind Energy Areas (WEAs; Figure 11-1). The Maryland Project funded an expansion of the original Department of Energy (DOE)-funded aerial and boat survey transects to include more of the federal and state waters offshore of Maryland (Figure 11-1). Seven aerial surveys and eight boat surveys of the entire MABS project area were conducted each year. In the second year of surveys (March 2013-May 2014), the Maryland Project extension transects were surveyed along with the broader MABS surveys. An additional aerial survey of just the extension transects and the Maryland WEA transect lines was flown in August of 2013. Further details on the study area and data collection methods can be found in Chapter 3 and Chapter 6.

Several taxa observed during boat and video aerial surveys had insufficient data to calculate persistent hotspots or conduct other spatial analyses, and simple point maps of raw data for several of these taxa are briefly discussed. For taxa with more robust datasets from the boat survey, video aerial survey, or both, additional analyses were conducted. All analyses described below include data collected from both the Maryland Project and the broader MABS study areas.

Persistent hotspot analysis

We adapted the methods of Santora and Veit (2013) to quantify the variance and anomaly persistence of counts for a single species or species group within grid cells across the study area. Aerial and boat survey transects and species observations were binned by Bureau of Ocean Energy Management (BOEM) Outer Continental Shelf (OCS) lease blocks (a 23.0 km^2 grid, where each cell is 4.8 x 4.8 km) using ArcGIS version 10.2.2 (ESRI, Redlands, CA). The BOEM lease grid was extended west of the Submerged Lands Act boundary (generally 5.6 km from shore) to include the entire Mid-Atlantic Baseline Studies and Maryland Project study area. Binning survey data by grid cell allowed us to standardize for spatial variation in survey effort within each survey, and combine the resulting hotspot determinations from all 31 surveys (including both survey methods) in a unified hotspot persistence analysis.

We limited our analysis to the most commonly observed species or species groups, defined by having a minimum of 700 total observations from a survey method over the entire study period (including both MABS and Maryland study areas). This cut-off point was found to be high enough to show ecologically relevant patterns for most species or groups examined, while eliminating most complications caused by low sample size. The exception to this criterion was cormorants (Phalacrocoracidae spp.) observed by boat; although over 700 individuals were observed, over half of these individuals were recorded in three single observations, which prevented the identification of persistent hotspots according to the criteria used in this chapter. Data were grouped and analyzed by family, instead of by individual species, provided that either (1) most observations within a family likely represented a single species (e.g., unidentified storm-petrels and Wilson's Storm-Petrels [*Oceanites oceanicus*] were mapped together as storm-petrels, Hydrobatidae), or (2) sample sizes for single species were too small to analyze separately, but large enough to be analyzed when aggregated by family (e.g., alcids).

Defining a hotspot

Boat and video aerial survey data were analyzed independently for hotspot analysis. First, an effort-corrected count was calculated for the species or group of interest per grid cell for each survey. For boat surveys, this was done by dividing the number of individuals observed by the total transect length (km) within each grid cell for each survey. For video aerial surveys, the number of individuals observed was divided by the total surveyed area (km^2) within each grid cell per survey. As resulting data were highly non-normal, a gamma distribution was fitted to non-zero effort-corrected counts for each grid cell in a given survey using 'fitdistrplus' package (Delignette-Muller and Dutang, 2015) in the R Statistical Environment (version 1.1-7, R Core Team 2014), and used to assign a probability to each grid cell's value depending on where it fell within the distribution curve for that survey. Fitting a gamma distribution to non-zero effort-corrected counts allowed us to identify cells with high abundance relative to other cells where the taxa was present, on a survey by survey basis. We considered grid cells within the top quartile (>75th percentile in the survey's gamma distribution) of effort-corrected values for a given survey as hotspots for that survey.

Determining persistence

After identifying hotspots for each survey, data were combined in order to index hotspot persistence, or the percentage of time each grid cell was a hotspot across all surveys (within a given survey method). Grid cells that had been surveyed fewer than eight times (i.e., in fewer than half of the surveys) within a survey method were excluded from further analysis. Using these criteria, 168 grid cells were included in further analyses when only boat survey data were analyzed, 410 grid cells were included when only aerial data were analyzed, and a total of 450 cells were included when both boat and aerial data were analyzed and combined in a unified hotspot persistence map for a given species or taxon. In these combined maps, 128 grid cells were surveyed by both methods, 40 cells were surveyed only by boat, and 282 cells were surveyed only by aerial methods (Figure 11-2).

Where only boat or aerial data were analyzed for a given species, the number of times each cell represented a hotspot (hotspot sum) was divided by the number of times the cell was surveyed (survey sum), to calculate persistence as the percentage of surveys in which a cell represented a hotspot for the species or group of interest. For grid cells surveyed by both boat and video aerial survey methods, data were combined. Due to presumed differences in detection and/or identification rates between these two survey methods, we often observed notably different counts of species between the two datasets (Chapter 10). To account for these differences, we weighted the data by effort-corrected total abundance for each dataset before calculating persistence as described above. Effort-corrected total abundance was calculated by dividing total abundance across all surveys by total area surveyed (km^2) across all surveys. Effective strip width for boat survey transects was approximated by multiplying the total transect length by the median distance at which the species/group was observed from the boat, then multiplying by two (to account for the fact that observers surveyed both sides of the boat simultaneously). The resulting ratio of boat to aerial effort-corrected abundance was used to weight data using the following equation:

$$Persistence = \frac{(Hsum_a \times R_a) + (Hsum_b \times R_b)}{(Ssum_a \times R_a) + (Ssum_b \times R_b)}$$

where R_a:R_b is the ratio of aerial to boat effort-corrected abundance, *Hsum* is number of times a cell was identified as a hotspot by survey method (*a,* aerial; *b*, boat), and *Ssum* is the number of times a cell was surveyed by each method.

Mapping hotspot persistence

Persistence values were broken into four distinct classes for mapping purposes, based on breaks at the 75th, 85th, and 95th percentiles of persistence values for cells that were a hotspot in at least one survey. We presented percentiles of persistence values (rather than the persistence values themselves) in order to facilitate comparison between species with different life histories, which may be present in the study area for varying amounts of time throughout the year.

Special case: Common Loons and Red-throated Loons

Loon abundance data collected by video aerial surveys presented a unique challenge, as only 14% of aerial loon observations were identified to species; the remaining 86% were categorized as unidentified loons, which contained an unknown proportion of either Common Loons or Red-throated Loons (*Gavia stellata*). We used the species identification model with environmental covariates developed as part of the MABS project (Hostetter et al., 2015) to predict the proportions of Red-throated and Common Loons in each grid cell for four aerial surveys (May2012, December 2012, March 2013, and December 2013). These surveys had high loon abundance, and also had a boat survey conducted within two weeks of the aerial survey (Hostetter et al., 2015). For these four aerial surveys, we summed the predicted counts of Red-throated Loons and Common Loons with the identified counts for each species to calculate hotspot persistence in video aerial data. In remaining aerial surveys, only the identified counts (e.g., birds identified as either Common Loons or Red-throated Loons, but not unidentified loons) were used in determining hotspots for the two species.

Special case: Species Richness

Species richness hotspots were identified using the same analysis methods described above, with two modifications. First, for each grid cell and survey, the datum of interest was considered to be the total count of species observed within the grid cell, rather than the effort-corrected count of an individual taxon observed within the grid cell. The relationship between survey effort and the number of species observed is not linear, so we did not effort-correct species counts within each grid cell, in order to avoid over-estimating counts in cells with very low effort (Gotelli and Colwell, 2010). However, in order to identify hotspots within datasets with similar effort per grid cell, we separated the sawtooth aerial survey transects from the high density aerial survey transects, which were located in the WEAs and offshore of Maryland (see study area map in Executive Summary and other chapters throughout this report). We independently identified hotspots within the sawtooth aerial data, high density aerial data, and boat data, and species richness hotspots identified from each dataset were weighted equally when combined to map hotspot persistence.

Temporal bar charts

We generated temporal bar charts of effort-corrected count data for boat and video aerial survey data independently, because detection and geographic coverage varied between survey methods (Chapters 5, 7, and 10). The total count of individuals was summed for each species and species group by two-month time period. Thus, each time period included data from two to four surveys over the two-year study. The two-month length of these time periods was found to best serve for data visualization purposes, as it displayed variation in the data presented while also controlling somewhat for variation in effort between periods (see Chapters 5 and 7).

Bar charts were created in Microsoft Excel (Redmond, WA) for all individual species and species groups that were observed more than 10 times within a survey method over the course of the study. Species and group counts were standardized for survey effort for each survey method (boat-based and digital video aerial surveys), using linear kilometers surveyed over each two-month time period. Effective transect strip width varied greatly by taxon for boat survey data, and using linear kilometers rather than total area surveyed allowed for direct comparisons between the two study methods. Percentiles were calculated for all effort-corrected survey data from both survey types for species groups (Table 11-1) and individual species (Table 11-3). Boat and aerial percentile values, represented by bars of increasing height and greater color intensity, are presented adjacent to one another to allow for comparison between the two study methods.

Results

Persistent hotspots were identified primarily for groups of species, rather than for individual species, due to sample size limitations and/or difficulties with species identification. Whenever possible, boat and video aerial survey data were combined to develop joint maps of persistent hotspots of abundance for taxa of interest. Insufficient data from one of the two survey methods, however, led to hotspots being estimated with data from a single survey method for some species groups. Thus, some hotspot maps below include data only from boat surveys (for example, for storm-petrels); some hotspots were calculated solely from video aerial surveys (such as sea turtles and rays); and many others used data from both survey methodologies, weighted by the ratio of effort-corrected counts between the two survey types. Temporal bar charts provide context for the maps of hotspots, illustrating the changes in relative abundance of counts and in species composition for both survey types over time.

Scoters

Scoters, a genus of sea ducks that in the Mid-Atlantic includes Black Scoter (*Melanitta americana*), White-winged Scoter (*M. fusca*), and Surf Scoter (*M. perspicillata*), were observed in 61% of surveys, primarily between September and May (Table 11-2). Though scoters were observed at all longitudes within the Maryland and MABS study areas, observations in the east tended to be sporadic and to involve small numbers of individuals. Scoter flocks, or rafts, were most consistently located in areas within about 30 km of shore, particularly near the mouths of Chesapeake Bay and Delaware Bay (Figure 11-3). Hotspots were also present, though slightly less persistent, in nearshore waters within the Maryland study area. The persistent hotspots of scoter abundance identified in Figure 11-3 were some of the largest and most consistent of any species group examined. Surf Scoters (Figure 11-4) and Black Scoters (Figure 11-5) showed strikingly similar patterns of hotspot persistence to each other and to the family as a whole. Additional information on Surf Scoter movements and habitat use in the Mid-Atlantic is presented in Meattey et al. (2015).

Loons

Loons, including Common Loons and Red-throated Loons, were present in 90% of surveys, with greatest numbers present in the broader study area between November and May (Table 11-2, Table 11-4). Loons do not form large rafts like many sea duck species, and were more likely to be observed individually or in small groups. Hotspots of loon abundance were less persistent between surveys than for scoters, and showed distinctly different patterns between species (particularly when the species identification model using environmental covariates was used to incorporate unidentified loons into hotspot datasets; Hostetter et al., 2015). Red-throated Loons showed highest hotspot persistence close to shore along the length of the MABS and Maryland study areas (Figure 11-6). Common Loon hotspots were scattered across the width of the Outer Continental Shelf, though many of the most persistent Common Loon hotspots were located offshore of the mouth of Chesapeake Bay (Figure 11-7). Additional information on Red-throated Loon movements and habitat use in the Mid-Atlantic is presented in Gray et al. (2015).

Storm-petrels

Storm-petrels were not identified frequently enough from the aerial data to allow mapping persistent hotspots of abundance using those data, but hotspots estimated from boat data for this taxon (primarily Wilson's Storm-petrels), are presented in Figure 11-8. Storm-petrels were observed in 50% of boat surveys, and almost exclusively in summer (Table 11-2). Identified hotspots of relative abundance included both nearshore and offshore locations across the MABS and Maryland study areas (Figure 11-8). Storm-petrels were generally observed individually, rather than in groups, and were abundant for only a few months each year; this led to lease blocks only being considered a hotspot in one out of 16 (6.25%) or two out of 16 (12.5%) boat surveys (that is, 12.5% or 25% of surveys in which the taxon was present in the study area), so persistence classes were consolidated into two categories to display the data for this species group.

Northern Gannets

Northern Gannets (*Morus bassanus*) were observed in 81% of all surveys (13 out of 16 boat surveys and 12 out of 15 video aerial surveys). The species was widely distributed across the MABS and Maryland study areas. The most persistent abundance hotspots for gannets contained large aggregations between

36% and 54% of the time that the species was present in the region, but the majority of grid cells (70%) were identified as an abundance hotspot during at least one survey (Figure 11-9), indicating that Northern Gannet distribution and abundance patterns varied widely between surveys. The most persistent hotspots in the Maryland study area (as well as across the broader MABS study area) tended to be located within about 30-40 km of the shoreline (Figure 11-9). Northern Gannets were consistently observed in high numbers from September to April for both boat and video aerial surveys, with low numbers in July and August (Table 11-2). The two survey methods showed very similar temporal variation for Northern Gannets, indicating that detection rates for this species may have been relatively similar between survey methods. Additional information on Northern Gannet movements and habitat use in the Mid-Atlantic is presented in Adams et al., 2015 and Stenhouse et al., 2015.

Alcids

Family Alcidae, which in the Mid-Atlantic generally includes Dovekies (*Alle alle*), Razorbills (*Alca torda*), Atlantic Puffins (*Fratercula arctica*), and both murres (*Uria* spp.), were not identified frequently enough from the aerial data to allow mapping persistent hotspots of abundance. Hotspots estimated from boat data for this taxon are presented in Figure 11-10. Alcids were present almost exclusively in winter (Table 11-2). Identified hotspots of relative abundance included both nearshore and offshore locations throughout the MABS study area, with relatively few occurring within the Maryland study area. The largest and most persistent aggregations seemed to occur in the part of the study area located farthest from the shoreline (between about 60-85 km from the coast of southern Virginia; Figure 11-10). Alcids were seldom observed in groups, and the most persistent hotspots for this species were identified in about 30% of the seven boat surveys for which the taxon was present in the study area (2 out of 16 surveys in total).

Gulls and terns

Gulls and terns (Laridae) were observed in all surveys. This is a fairly disparate group in terms of behaviors across species, with some species breeding near the study area, others using this region purely in the non-breeding season, and still others present year-round. Bonaparte's Gull (*Chroicocephalus philadelphia*) and Ring-billed Gull (*Larus delawarensis*), for example, are present primarily in winter, while other gulls are present during fall, winter, and spring (e.g., Laughing Gull, *Leucophaeus atricilla*), and several tern species are present in spring, summer, and fall (Common Tern, *Sterna hirundo*, and Royal Tern, *Thalasseus maximus*). Several gull species use the study area year-round (Herring Gull, *Larus argentatus*, Great Black-backed Gull, *L. marinus*, and Lesser Black-backed Gull, *L. fuscus*; Table 11-4). Likewise, species distributions across the study area vary based on when each species is present. We calculated persistent hotspots for the entire family, as 23% of these aerial observations were not differentiated to subfamily (Chapter 5). But due to the life history and distributional differences between species, we also analyzed data separately for the two main subfamilies (terns, Sterninae; and gulls, Larinae), as well as for the most abundant individual species in our datasets (Bonaparte's Gull, Laughing Gull, Herring Gull, Great Black-backed Gull, and Common Tern).

For the entire family, abundance hotspots were widely distributed throughout the Maryland and MABS study areas, though the most persistent of these were located in the western half of the study area, and particularly in three locations: the northern shore of Maryland, the mouth of Chesapeake Bay, and the mouth of Delaware Bay (Figure 11-11).

The same patterns of the most persistent hotspots are present in both the gull-specific (Figure 11-12) and tern-specific (Figure 11-13) maps. A comparison of Figure 11-11 to Figure 11-13, however, indicates that the less persistent hotspots located in many offshore areas in the eastern part of the study area were largely driven by gull distributions, with many fewer tern hotspots in areas >20 km from shore.

Examining hotspot persistence of individual species allowed us to further parse patterns shown in the subfamily maps. Hotspot persistence for both Herring Gulls and Great Black-backed Gulls was most similar to hotspot persistence for the gull subfamily; hotspots occurred across the MABS and Maryland study areas, and were most persistent along the north shore of Maryland and at the mouth of the Chesapeake Bay (Figure 11-14; Figure 11-15). Laughing Gull hotspots were also most persistent in nearshore areas, primarily off the coast of Maryland (Figure 11-16). In contrast, Bonaparte's Gull hotspots were notably less persistent within the Maryland study area, as this species was more persistently observed in large numbers in the southern half of the MABS study area, and at a broad range of distances from shore (Figure 11-17).

Common Terns were the only tern species abundant enough to conduct a species-specific hotspot analysis, and they were only observed in large numbers by boat (only one Common Tern was definitively identified over the course of the study in digital video aerial surveys). Common Tern hotspots occurred across the Outer Continental Shelf within the MABS study area, and were most persistent near the mouth of Delaware Bay (Figure 11-18). This differed from the pattern of hotspot persistence observed for terns as a group, which additionally showed high hotspot persistence in Maryland state waters and at the mouth of Chesapeake Bay (Figure 11-13). These differences were likely driven in part by Royal Terns observed from the boat, as well as unidentified terns in both boat and video aerial data (which represented a diverse group of at least six species; Table 11-4) that are mapped in aggregate in Figure 11-13.

Rays

Rays (Batoidea), primarily Cownose Rays (*Rhinoptera bonasus*), were mostly observed in summer and early fall, and were much more frequently observed in video aerial surveys than from the boat (Table 11-2). They were not identified frequently enough from the boat data to allow mapping persistent hotspots of abundance, so only the aerial data are presented in Figure 11-19. Cownose Rays occur in the coastal waters of the western Atlantic Ocean from the northeastern US to Brazil, and migrate seasonally along the Atlantic coast of the US (Goodman et al., 2011). Large and persistent aggregations of rays were commonly observed at the mouth of Chesapeake Bay, the mouth of Delaware Bay, and within about 20-40 km from the coast of Maryland and the north shore of Virginia (Figure 11-19). Further discussion regarding observed Cownose Ray distributions is presented in Chapter 5.

Sea turtles

Sea turtles, including Green (*Chelonia mydas*), Kemp's Ridley (Lepidochelys kempii), Loggerhead (*Caretta caretta*), Hawksbill (*Eretmochelys imbricata*), and Leatherback (*Dermochelys coriacea*) turtles, were mostly observed in warmer months (Table 11-2). They were also much more frequently observed in video aerial surveys than from the boat (Chapter 10), a phenomenon that has been seen for digital aerial surveys elsewhere (Normandeau Associates Inc., 2013). They were not observed frequently enough from boat-based surveys to allow mapping persistent hotspots of abundance, so only the video aerial data are presented in Figure 11-20. Sea turtle species were observed in 80% of video aerial surveys, and were most persistently abundant south of the Maryland study area and farther from shore (Figure 11-20). Further examination of seasonal distribution patterns and possible environmental drivers for this taxon are presented in Chapters 10 and 13.

Dolphins and porpoises

Odontoceti, or toothed whales, were observed throughout the study period, with some summertime increases in observations (Table 11-2). The two survey methods showed similar temporal patterns of relative abundance for toothed whales, indicating that detection rates may have been similar between survey methods (Table 11-2; Chapter 10). Almost all identified observations were either Bottlenose Dolphins (*Tursiops truncatus*) or Common Dolphins. Bottlenose Dolphins were observed primarily in warmer months, were observed across the Maryland and MABS study areas, and made up a higher proportion of the aerial data than the boat data for most time periods (Table 11-4). Bottlenose Dolphins are distributed into coastal and offshore populations in this area of the Atlantic (Kenney, 1990), so we likely saw individuals from both populations represented in these counts. Common Dolphin counts peaked in the winter for both survey types (Table 11-4), and were mostly observed in the eastern part of the study areas. The persistent hotspots identified in Figure 11-21 reflect a combination of these species' distributions. Hotspots for toothed whales within the Maryland study area were most persistent within roughly 40 km of shore, showing a similar pattern to the broader MABS study area. Nearshore hotspots were likely driven by coastal Bottlenose Dolphin populations (Chapter 12), while hotspots located father offshore may represent a combination of offshore Bottlenose Dolphin and Common Dolphin populations. When mapped independently (using boat data only, as there were too few aerial observations), Bottlenose Dolphin hotspots occurred primarily on the western half of the study area, and were most persistent at the mouth of Delaware Bay and in coastal regions within the Maryland study area (Figure 11-22). Further examination of seasonal distribution patterns and possible environmental drivers for Bottlenose Dolphin distributions are presented in Chapter 12.

Bait balls

Shoals of small fishes that were not individually distinguishable or identifiable during boat and video aerial surveys were recorded as 'bait balls', and each shoal was counted as a single observation regardless of group size. These large groups of forage fish were much more frequently observed in video aerial surveys than from the boat, and only the aerial data were used in calculating areas of persistent abundance. Bait balls were most persistently observed in highest densities in the nearshore regions of the Maryland study area, with less persistent hotspots occurring in nearshore regions off the coasts of Delaware and Virginia (Figure 11-23). In cells with the highest hotspot persistence, the area was identified as an abundance hotspot in roughly half of the surveys in which bait balls were observed.

Persistent hotspots of overall abundance and species richness

When calculated in aggregate for all taxa observed in this study, abundance hotspots were most consistently observed in nearshore areas (within about 40 km from shore). This held true within the Maryland study area as well as within the broader MABS study area, where more persistent hotspots were located near the mouth of Chesapeake Bay, the North Shore of Virginia, and near the mouth of Delaware Bay (Figure 11-24). Hotspots of species richness were consistently located in similar areas (Figure 11-24). While the aggregate abundance hotspot patterns may be largely driven by a few common species groups (such as scoters and gannets), species richness hotspots display habitat use areas that are valuable to large numbers of species through time. In grid cells that were identified as species richness hotspots, up to 10 species were observed in a single survey; the most persistent species richness hotspots were identified in 88% of surveys.

Temporal trends in abundance

Overall, late fall to early spring was identified by both boat and digital video aerial surveys as a time of year with high effort-corrected counts of animals in the study area, though many aquatic animals peaked in abundance in the summer (Table 11-2). Scoters, gannets, and gulls all contributed greatly to overall abundance, regardless of survey method; loons made up a large proportion of the boat data, in the early winter surveys in particular, while rays were highly abundant in the video aerial surveys in the summer and early fall (Table 11-2). Some differences in temporal patterns between the two survey types are likely reflective of differences in detection for the two methods; for example, both Common Loons and Red-throated Loons make up higher proportions of the boat data compared to the video aerial data, as most loons in aerial surveys were not identified to species. There were peaks in abundance of some alcid and tern species that went almost entirely undetected in the video aerial data, while the video aerial surveys were able to detect temporal trends in abundance of several aquatic species that weren't detected or abundant in the boat surveys (Table 11-4).

Distributions of uncommonly observed species

Several other taxa observed during boat and video aerial surveys had insufficient data to calculate persistent hotspots or conduct other spatial analyses. Cormorants made up a relatively large proportion of the boat data (1.6% of total observations within the Maryland study area, and 3.2% of observations within the MABS study area), with a total of 2,035 individuals observed in the MABS study area (149 within the Maryland study area). Despite high abundance, there were relatively few sightings; over half of the total individuals observed were reported in three sightings in May and October 2013 at the mouth of Delaware Bay, and only 38 total sightings were reported (Figure 11-25). Within the Maryland study area, a group of 140 cormorants plus two individuals were reported in May 2013, and an additional 7 were reported in a single sighting in October 2013. Nearly all were identified as Double-Crested Cormorants (*Phalacrocorax auritus*). Only 42 Double-Crested Cormorants were observed by video aerial surveys; 26 of these occurred within the Maryland study area (Figure 11-25). Cormorants were most commonly observed by boat in the spring and fall (Table 11-2).

Passerines made up a small proportion of the aerial data compared to the boat data in both the Maryland and MABS study areas. In the MABS study area, 180 passerines were observed by boat and 17 were observed by video aerial survey methods (representing 22 unique identified species; Chapters 5 and 7); of these observations, only 14 individuals were observed by boat and 2 observed by digital video within the Maryland study area. Peak numbers of passerines were observed in the summer and fall (Table 11-2). Songbirds were observed throughout the study areas, particularly where boat surveys were conducted (Figure 11-26). Swallows (Hirundinidae) were the most frequently observed passerine both in the MABS and Maryland study areas, and were particularly abundant in the coastal waters off of Virginia. Warblers (Parulidae) were most commonly observed in the Maryland and Delaware offshore areas. Only Purple Martins (*Progne subis*) and Barn Swallows (*Hirundo rustica*) were abundant enough for temporal persistence charts, with peaks of observed counts in July-August and March-April, respectively (Table 11-4). Additional discussion of passerine migration (which largely occurs nocturnally) may be found in Adams et al. (2015).

Shorebirds (Charadriiformes) were also observed primarily on boat-based surveys within both study areas; within the broader MABS study area, there were 587 observations of at least 15 species reported by boat, as compared to 74 observations reported in the aerial data. In the Maryland study area, 29 observations of at least 6 species were reported by boat and 46 individuals were observed by digital video (Chapters 5 and 7). Shorebird observations were distributed broadly across both study areas (Figure 11-27). Dunlin (*Calidris alpina*) and Red Phalarope (*Phalaropus fulicarius*) observations peaked in March-April, while Red-necked Phalaropes (*P. lobatus*) were observed primarily in September-October (Table 11-4). Only eight plovers were observed over the course of the study (five Wilson's Plover [*Charadrius wilsonia*], and three Semipalmated Plover [*C. semipalmatus*]), all observed during boat surveys. No identified Red Knots (*Calidris canutus*) were observed, though individuals could have been included among the unidentified shorebirds or unidentified scolopacids (Chapters 5 and 7).

Observations of shearwaters and fulmars (Procellariidae) were more consistent across survey platforms, with 43 individuals of 5 species observed by boat and 57 individuals of 4 species observed by digital video within the Maryland study area (Chapters 5 and 7). Within the broader MABS study area, 325 individuals of six species were observed during boat surveys, and 112 individuals from at least five species were observed during video aerial surveys. Great Shearwaters (*Puffinus gravis*) and Cory's Shearwaters (*Calonectris diomedea*) were most commonly observed in both study areas, typically in the eastern part of the study areas (Figure 11-28). Manx Shearwaters (*Puffinus puffinus*) were mostly observed on boat surveys, and showed a relatively inshore distribution in the Maryland study area. Shearwaters were observed primarily in the spring and fall, while Northern Fulmars (*Fulmaris glacialis*) were observed primarily in winter (Table 11-4).

Eleven large whales were observed within the Maryland study area, out of a total of 51 that were observed within the broader MABS study area during boat and video aerial surveys (Figure 11-29). Humpback Whales (*Megaptera novaeangliae*), Minke Whales (*Balaenoptera acutorostrata*), and unidentified whales were all observed in the Maryland study area. While North Atlantic Right Whales (*Eubalaena glacialis*) were not detected within the Maryland study area, 8 sightings were made by video aerial surveys within the Virginia WEA and on the sawtooth transects between Maryland and Virginia WEAs; an additional Right Whale was observed east of the Virginia WEA during a boat survey. All sightings were reported to NOAA and the New England Aquarium. Additionally, Fin Whales

(*Balaenoptera physalus*) were generally observed across the MABS study area, but none were observed within the Maryland study area (Figure 11-29). More than half of the large whale sightings within the Maryland and MABS study areas occurred during winter months (Chapter 12).

One Eastern Red Bat (*Lasiurus borealis*) was observed within the Maryland study area by video aerial surveys, in September 2013. Across the broader MABS study area, 17 bats were observed altogether, including two during boat surveys and 15 in video aerial surveys, in September of 2012 (Hatch et al. 2013) and September of 2013. Bats were observed between approximately 16 and 70 km from shore (Figure 11-30), during morning daylight hours (Hatch et al., 2013). Video aerial survey methods allowed for altitude estimation for several of these bats at >200 m above sea level.

Discussion

The presence and relative abundance of species within the MABS and Maryland study areas varied widely by time of year, with different species and groups using the study area during non-breeding (summer or winter), breeding, and migratory periods. We obtained insufficient observations for some taxa to develop useful distribution patterns; however, other useful information can be drawn from the raw data on its own. For example, our nine observations of North Atlantic Right Whales, the most critically endangered large whale along the Atlantic coast of North America, provide an important contribution to our collective knowledge of this species given their small population size and our general lack of detailed data on their movements and habitat use in the Mid-Atlantic. Additionally, raw observation data for bats provides insight into their offshore migration patterns. In 2012, bats were observed during a period with relatively strong tailwinds and average barometric pressure, suggesting that their presence offshore may have been facultative (e.g., taking advantage of favorable migratory conditions), rather than because storms or other factors pushed them offshore. Direction of movement was noted to be southwest in 10 out of the 15 video aerial observations, further suggesting migratory movements. Little is known about the migration and movements of tree bat species in North America, but anecdotal observations of migrating bats over the Atlantic Ocean (particularly during fall migration periods) have been reported since at least the 1890s (Hatch et al., 2013). The observations from this study provide new evidence of bat movements offshore, and offer insight into their flight heights above sea level and the times of day at which such migrations may occur.

For species or groups with sufficient data, we developed products to visualize both temporal and spatial variation in distribution and relative abundance. Calculating persistent abundance hotspots provides a means for identifying locations where individuals of a species or species group are most often found in large aggregations relative to their typical distribution patterns. These areas likely provide important habitat for foraging, roosting, and/or other activities (Gende and Sigler, 2006; Santora and Veit, 2013; Santora et al., 2010; Sydeman et al., 2006). Calculating persistent abundance hotspots can be particularly useful for highly mobile marine wildlife, because this analysis identifies patterns of high abundance that persist over time. For example, while hotspots of Northern Gannet abundance occurred across the study area and throughout the year, the majority of the most consistent hotspots during our surveys occurred at the mouth of Chesapeake Bay. This pattern only emerged when data were aggregated across repeated surveys. Similarly, summarizing aggregated data across survey methods and across years allowed us to examine temporal patterns of abundance for many species present within the study area. Identifying such patterns may provide useful insight to future siting and permitting processes within the region.

Species of interest were widely distributed across the study area, but for many taxa, larger aggregations were more consistently observed in the western part of the study area, and particularly offshore of the mouths of Chesapeake Bay and Delaware Bay, and in northern Maryland (Figure 17-23). Some exceptions to this general rule included sea turtles, Common Dolphins, Common Loons, and alcids, which were more evenly distributed across the Outer Continental Shelf or were more commonly observed in areas farther from shore. The area offshore of northern Maryland, while likely a real hotspot for many species such as gulls and terns, 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 inshore state waters (e.g., within three 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). While high numbers of some species may be consistently present in other nearshore areas as well, similar surveys were not conducted in nearshore or state waters elsewhere during this study.

In some instances, our analyses revealed unexpected patterns of hotspot persistence that may contribute new information about the distribution and relative abundance of a taxon. For example, large and persistent aggregations of rays (primarily Cownose Rays) were observed at the mouth of the Chesapeake Bay, and it is likely that many of the rays observed in our study area moved into the Chesapeake Bay and its tributaries in the summer months, as found in previous studies (Blaylock, 1993; Fisher, 2010). However, our analyses also reveal persistent hotspots at the mouth of Delaware Bay, and within about 20-40 km from the coast of Maryland and the north shore of Virginia, suggesting that this population may also use Delaware Bay and possibly other locations during the summer. Considering that Cownose Rays are thought to summer exclusively in bays and estuaries (Grusha, 2005), and have been particularly well studied in the Chesapeake Bay (e.g., Smith and Merriner 1985; Smith and Merriner 1987), the hotspots calculated from video aerial survey data in this study include areas much farther north and father offshore than might have been expected.

Caveats for persistent hotspot analyses

Several characteristics or limitations of persistent abundance hotspot maps should be noted, and carefully considered when using these maps for management or planning purposes. These maps do not indicate a species' full range of habitat use within the study area; rather, grid cells that were never identified as a hotspot simply never had abundance levels 'above the norm' for a particular species and survey. Quite often, blocks that were never identified as a hotspot still consistently hosted individuals of the species of interest. It is also important to note that persistent hotspot maps are intended to identify persistent geographic patterns at a regional scale; while values are presented by lease block, these individual grid cell 'persistence' values should be interpreted with caution. Minor changes to the display of these data (for example, slightly changing how a hotspot is defined within a survey, or using different persistence categories for mapping) may change individual grid cell values, though overall patterns of animal distributions remained quite robust to such adjustments.

It should also be noted that taxa of interest aggregate to varying degrees. A hotspot for alcids, for example, includes many fewer individuals than does a hotspot for scoters, because alcid species simply do not flock to the same degree within our study area. Likewise, scoter hotspots were much more consistent through time than were hotspots identified for some other species groups. Hotspot persistence calculations in this study were designed to be reasonably comparable between species, but all values presented in maps represent relative, rather than absolute, abundance.

Finally, it is important to consider the number of surveys conducted and the length of our study period when evaluating hotspot persistence. In this study we analyzed data from 31 surveys conducted over a two year period; although our timeframe was relative brief, we conducted a comparable number of surveys to previous studies examining hotspot persistence. Zipkin et al. (2015), for example, used compiled data from 32 data sets collected over a span of 32 years, while Santora and Veit (2013) used data from 14 surveys conducted over 9 years, and Gende and Sigler (2006) used data from 34 surveys conducted over 3 years. Although our study's timeframe is on the lower end of this spectrum, a recent analysis of interannual variation in wildlife distributions suggests that 2-3 years of surveys may be sufficient to capture longer-term (e.g., decadal) levels of variation (Kinlan et al., 2012). There are also several benefits to expending high survey effort over a relatively short time frame. First, this study design provides extensive data within a relatively small study area. Additionally, our study design provides a complete picture of what is happening year round during the course of the study, compared to studies that only survey within a single season (e.g., Santora and Veit, 2013). Combining data from boat-based (16 surveys) and digital video aerial (15 surveys) methodologies also provides a more complete picture of wildlife distributions than a single survey method, by providing complementary data collected during the same time frame in the same location. One drawback to this study design, however, is that trends of persistence may not be accurately captured for species that are present in the study area for short periods of time throughout the year, and thus have fewer opportunities to be sampled. For example, alcids were present almost exclusively in the winter, and the most persistent hotspots for alcids were only hotspots in two out of 16 boat surveys (alcids were not abundant enough in the aerial dataset to conduct persistent hotspot analysis). For these less commonly observed species, we may simply lack the number of sampling events required to adequately characterize lease blocks as hotspots (Zipkin et al., 2015). Data collected from surveys conducted over a greater number of years would provide greater opportunity for sampling of less commonly observed species, and would perhaps capture finer scale patterns of persistence with greater statistical rigor.

Ecology of persistent hotspots

This study focused on identifying the locations and persistence of hotspots offshore of Maryland and elsewhere on the Mid-Atlantic OCS, and did not examine drivers of hotspot occurrence. In some instances, however, we can infer that distinct populations within a taxon may be partial drivers of observed patterns of hotspot persistence. For example, persistent hotspots of Bottlenose Dolphins were generally located in nearshore regions within the study area. As Bottlenose Dolphins are distributed into coastal and offshore populations in this area of the Atlantic, this pattern was likely partially driven by the consistency of locations and numbers for the coastal ecotype of this species, as compared to the more variable and transient populations offshore (Gannon and Waples, 2004; Kenney, 1990).

Patterns of persistent hotspots for various taxa are also likely driven by environmental factors, as previous studies have shown that persistent hotspots likely indicate locations of important habitat for the taxa examined. Piatt et al. (2006) showed that Short-tailed Albatross hotspots in the Aleutian Islands were closely associated with shelf-edge habitats where upwelling and strong vertical mixing occurred, supporting high primary and secondary productivity. Similarly, Suryan et al. (2012) found that persistently high levels of primary productivity (chlorophyll *a*) are a significant predictor of seabird hotspots. Other studies have shown the relationship between hotspots of prey species and hotspots of marine predators (Gende and Sigler, 2006; Santora et al., 2010).

In our study, the most common persistent hotspots tended to occur in nearshore areas, particularly in northern Maryland and areas near and directly south of the mouths of Chesapeake Bay and Delaware Bay. These nearshore regions, particularly those adjacent to the regional bays, contained the most persistent hotspots of overall abundance and species richness, in addition to persistent hotspots for many individual taxa examined. These areas are likely attractive to a wide variety of high trophic level species, such as seabirds and marine mammals, due to their consistently higher primary productivity relative to the broader study area (Chapter 1; Smith and Kemp 1995; Schofield et al. 2008). These areas typically have the highest levels of chlorophyll *a* in the study area due to their close proximity to highly productive estuarine ecosystems, where strong tidal currents and year-round mixing of saline and fresh waters boost productivity. More generally, in shallow coastal waters sunlight is able to penetrate a high proportion of the water column, fueling photosynthetic activity and phytoplankton growth where nutrients are available (Schofield et al., 2008b; Xu et al., 2011). This primary productivity forms the base of the pelagic food chain on which nearly all species observed during this study rely; thus, these areas likely serve as key wildlife habitats within the study area, and the locations of these areas should be considered carefully in relation to any future offshore development activities in the region.

Our results present an opportunity for future studies to explicitly examine the relationship between the location and persistence of hotspots (as determined in this study) and the potential environmental predictors of such hotspots. Of particular note, future studies could explore the relationship between persistent hotspots of bait balls and those of marine predators; as populations of forage fishes that form bait balls likely serve as a prey base for many upper trophic level predators, the distribution of persistent bait ball hotspots has the potential to help explain the similar nearshore distribution observed for many other taxa. There may also be more direct relationships between hotspots of higher trophic level taxa, as the location and persistence of hotspots are likely influenced by competitive and/or facilitative species interactions (Ainley et al., 2009; Camphuysen and Webb, 1999).

Literature cited

Adams, E., Lambert, R., Connelly, E., Gilbert, A., Williams, K., 2015a. 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., Stenhouse, I., Gilbert, A., Williams, K., Montevecchi, W., 2015b. Using state-space models to identify areas of persistent winter activity and their associated environmental covariates in Northern Gannets, 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.

Ainley, D.G., Dugger, K.D., Ford, R.G., Pierce, S.D., Reese, D.C., Brodeur, R.D., Tynan, C.T., Barth, J.A., 2009. Association of predators and prey at frontal features in the California Current: Competition, facilitation, and co-occurrence. Mar. Ecol. Prog. Ser. 389, 271–294. doi:10.3354/meps08153

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

Camphuysen, C.J., Webb, A., 1999. Multi-species feeding associations in north sea seabirds : jointly exploiting a patchy environment. Ardea 87, 177–198.

Davoren, G.K., 2007. Effects of gill-net fishing on marine birds in a biological hotspot in the northwest Atlantic. Conserv. Biol. 21, 1032–1045. doi:10.1111/j.1523-1739.2007.00694.x

Delignette-Muller, M., Dutang, C., 2015. fitdistplus: An R package for fitting distributions. J. Stat. Softw. 64, 1–34.

Fisher, R.A., 2010. Life history, trophic ecology, & prey handling by cownose ray, Rhinoptera bonasus, from Chesapeake Bay, Report to National Oceanic and Atmospheric Administration. Virginia Institute of Marine Science, Virginia Sea Grant, College of William and Mary, Gloucester Point, VA.

Gannon, D.P., Waples, D.M., 2004. Diets of coastal bottlenose dolphins from the U. S. Mid-Atlantic coast differ by habitat. Mar. Mammal Sci. 20, 527–545. doi:10.1111/j.1748-7692.2004.tb01177.x

Gende, S.M., Sigler, M.F., 2006. Persistence of forage fish “hot spots” and its association with foraging Steller sea lions (Eumetopias jubatus) in southeast Alaska. Deep. Res. Part II Top. Stud. Oceanogr. 53, 432–441. doi:10.1016/j.dsr2.2006.01.005

Gjerdrum, C., Fifield, D.A., Wilhelm, S.I., 2012. Eastern Canada Seabirds at Sea (ECSAS) standardized protocol for pelagic seabird surveys from moving and stationary platforms, Canadian Wildlife Service Technical Report Series No. 515. Atlantic Region. vi + 37 pp.

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.

Gotelli, N., Colwell, R., 2010. Estimating species richness, in: Magurran, A.E., McGill, B.J. (Eds.), Biological Diversity: Frontiers in Measurement and Assessment. Oxford, pp. 39–54. doi:10.2307/3547060

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.

Grusha, D.S., 2005. Investigation of the Life History of the Cownose Ray, Rhinoptera Bonasus (Mitchill 1815). College of William and Mary.

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

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.

Kappes, M.A., Shaffer, S.A., Tremblay, Y., Foley, D.G., Palacios, D.M., Robinson, P.W., Bograd, S.J., Costa, D.P., 2010. Hawaiian albatrosses track interannual variability of marine habitats in the North Pacific. Prog. Oceanogr. 86, 246–260. doi:10.1016/j.pocean.2010.04.012

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

Kinlan, B.P., Zipkin, E.F., O'Connell, A.F., Caldow, C., 2012. 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.

Lehodey, P., Alheit, J., Barange, M., Baumgartner, T., Beaugrand, G., Drinkwater, K.F., Fromentin, J.-M., Hare, S.R., Ottersen, G., Perry, R.I., Roy, C., van der Lingen, C.D., Werner, F., Others, 2006. Climate Variability, Fish, and Fisheries. J. Clim. 19, 5009–5030. doi:10.1175/JCLI3898.1

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.

Murphy, E.J., Watkins, J.L., Reid, K., Trathan, P.N., Everson, I., Croxall, J.P., Priddle, J., Brandon, M.A., Brierley, A.S., Hofmann, E., 1998. Interannual variability of the South Georgia marine ecosystem:

biological and physical sources of variation in the abundance of krill. Fish. Oceanogr. 7, 381–390. doi:10.1046/j.1365-2419.1998.00081.x

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.

Piatt, J.F., Wetzel, J., Bell, K., DeGange, A.R., Balogh, G.R., Drew, G.S., Geernaert, T., Ladd, C., Byrd, G.V., 2006. Predictable hotspots and foraging habitat of the endangered short-tailed albatross (Phoebastria albatrus) in the North Pacific: Implications for conservation. Deep. Res. Part II Top. Stud. Oceanogr. 53, 387–398. doi:10.1016/j.dsr2.2006.01.008

R Core Team, 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. http://www.r-project.org.

Santora, J.A., Reiss, C.S., Loeb, V.J., Veit, R.R., 2010. Spatial association between hotspots of baleen whales and demographic patterns of Antarctic krill Euphausia superba suggests size-dependent predation. Mar. Ecol. Prog. Ser. 405, 255–269. doi:10.3354/meps08513

Santora, J.A., Veit, R.R., 2013. Spatio-temporal persistence of top predator hotspots near the Antarctic Peninsula. Mar. Ecol. Prog. Ser. 487, 287–304. doi:10.3354/meps10350

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., 2008a. The Decadal View of the Mid-Atlantic Bight from the COOLroom: Is Our Coastal System Changing? Oceanography 21, 108–117. doi:10.5670/oceanog.2008.08

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., 2008b. The Decadal View of the Mid-Atlantic Bight from the COOLroom: Is Our Coastal System Changing? Oceanography 21, 108–117.

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

Smith, J.W., Merriner, J. V, 1985. Food habits and feeding behavior of the cownose ray, *Rhinoptera bonasus*, in lower Chesapeake Bay. Estuaries 8, 305–310.

Smith, J.W., Merriner, J. V., 1987. Age and growth, movements and distribution of the cownose ray, Rhinoptera bonasus, in Chesapeake Bay. Estuaries 10, 153–164. doi:10.1007/BF02689811

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.

Suryan, R.M., Santora, J.A., Sydeman, W.J., 2012. New approach for using remotely sensed chlorophyll a to identify seabird hotspots. Mar. Ecol. Prog. Ser. 451, 213–225. doi:10.3354/meps09597

Sydeman, W.J., Brodeur, R.D., Grimes, C.B., Bychkov, A.S., McKinnell, S., 2006. Marine habitat “hotspots” and their use by migratory species and top predators in the North Pacific Ocean: Introduction. Deep. Res. Part II Top. Stud. Oceanogr. 53, 247–249. doi:10.1016/j.dsr2.2006.03.001

Tasker, M.L., Jones, P.H., Dixon, T., Blake, B.F., 1984. Counting seabirds at sea from ships: A review of methods employed and a suggestion for a standardized approach. Auk 101, 567–577.

Thaxter, C.B., Burton, N.H.K., 2009. High Definition Imagery for Surveying Seabirds and Marine Mammals: A Review of Recent Trials and Development of Protocols, Report commissioned by COWRIE Ltd.

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

Zipkin, E.F., Kinlan, B.P., Sussman, A., Rypkema, D., Wimer, M., O’Connell, A.F., 2015. Statistical guidelines for assessing marine avian hotspots and coldspots: A case study on wind energy development in the U.S. Atlantic Ocean. Biol. Conserv. 191, 216–223. doi:10.1016/j.biocon.2015.06.035

Figures and tables

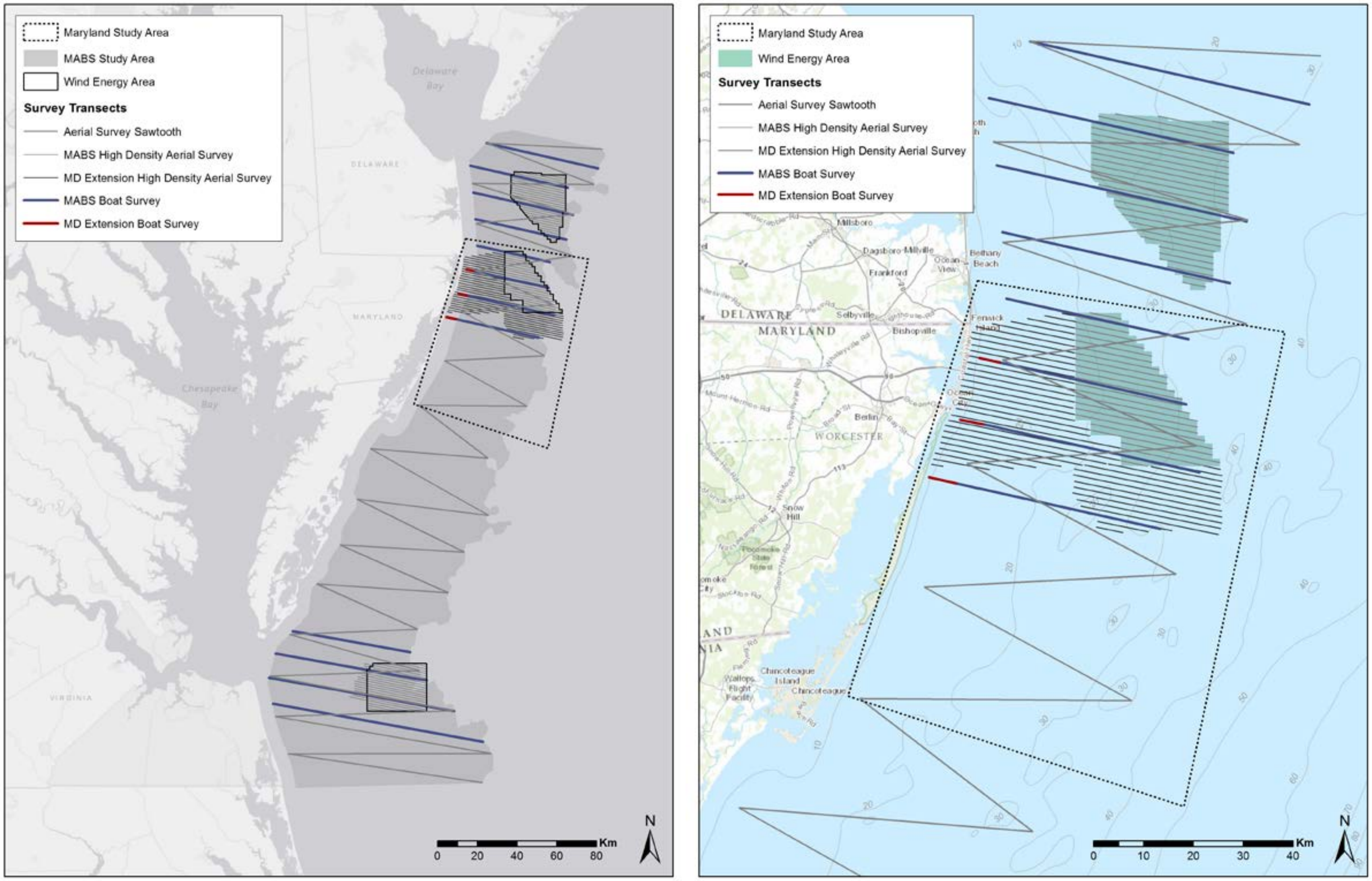


Figure 11-1. Map of boat and aerial survey transects for the Mid-Atlantic Baseline Studies (MABS) and Maryland Projects. The broader Mid-Atlantic study area, or MABS study area (left), includes surveys funded by both DOE and Maryland (2012-2014). The "Maryland study area" (right, black dashed line) includes all boat and aerial survey transects in waters offshore of Maryland (both DOE and Maryland-funded surveys, 2012-2014). The Maryland Project surveys are a subset of the surveys within the Maryland study area that were specifically funded by the state of Maryland in 2013-2014. These surveys included boat survey extensions into state waters (red bars), aerial survey high-density transect extensions west and south of the Maryland WEA (charcoal lines), and a 15th aerial survey of the Maryland WEA and Maryland Project high-density transects in 2013.

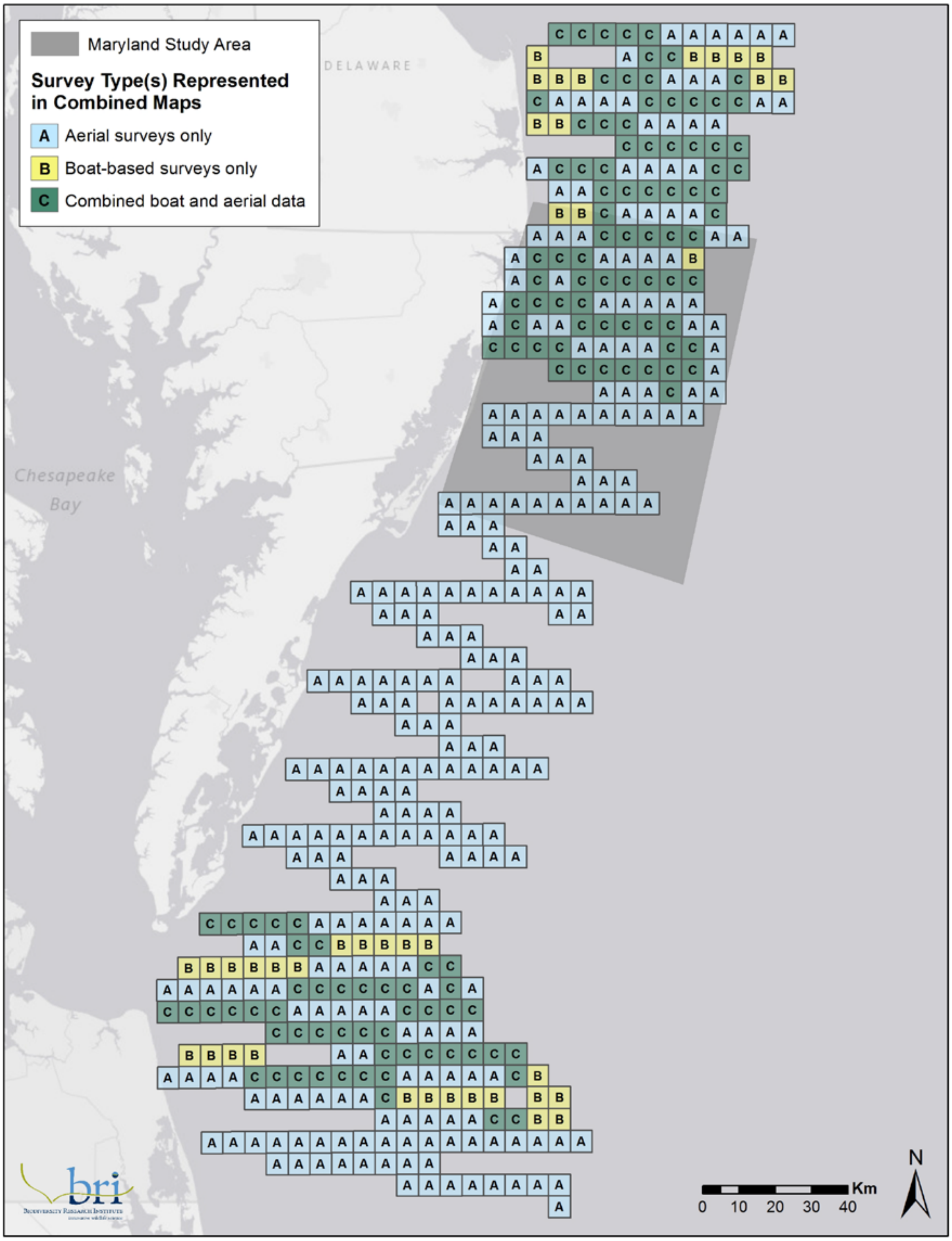
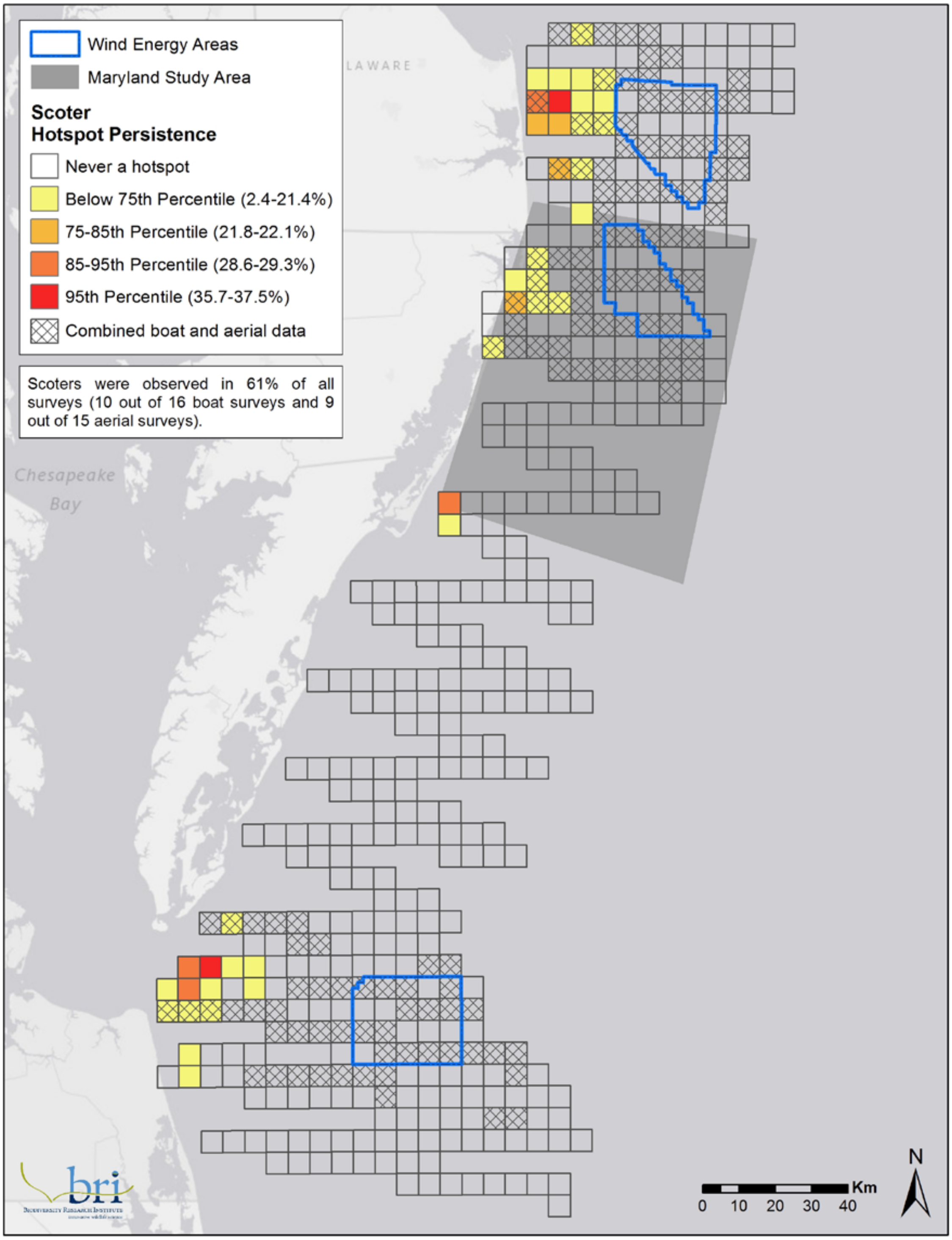


Figure 11-2. Survey method by grid cell for hotspot maps. Sixteen boat-based and 15 video aerial surveys were conducted across the study area, resulting in a total of 450 surveyed grid cells: (A) 262 grid cells surveyed by video aerial surveys only, (B) 40 grid cells surveyed by boat-based surveys only, and (C) 128 grid cells surveyed by both methods.



Scoters were observed in 61% of all surveys (10 out of 16 boat surveys and 9 out of 15 aerial surveys).

Figure 11-3. Classified persistent abundance hotspots for scoters (*Melanitta spp.*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

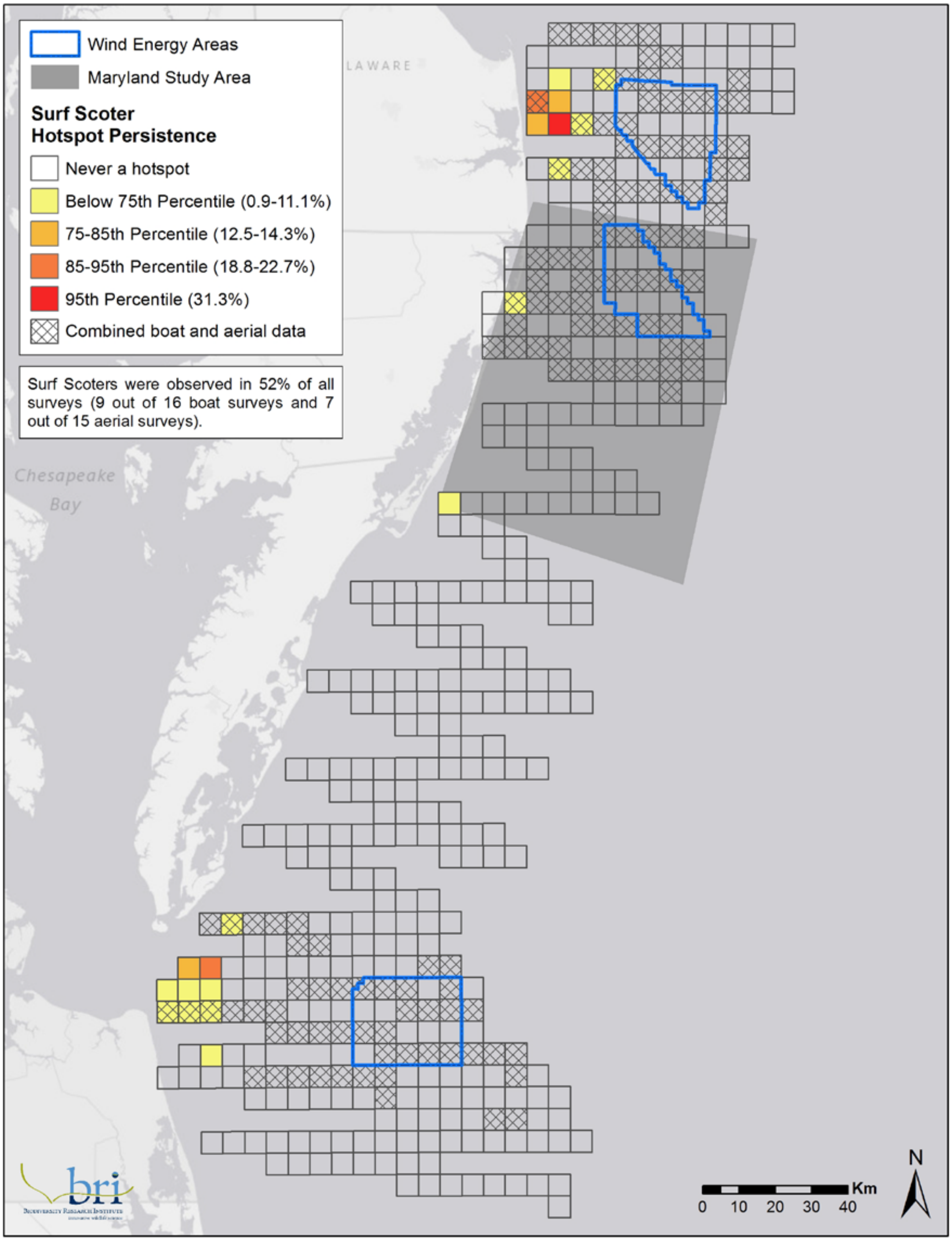


Figure 11-4. Classified persistent abundance hotspots for Surf Scoters (*Melanitta perspicillata*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

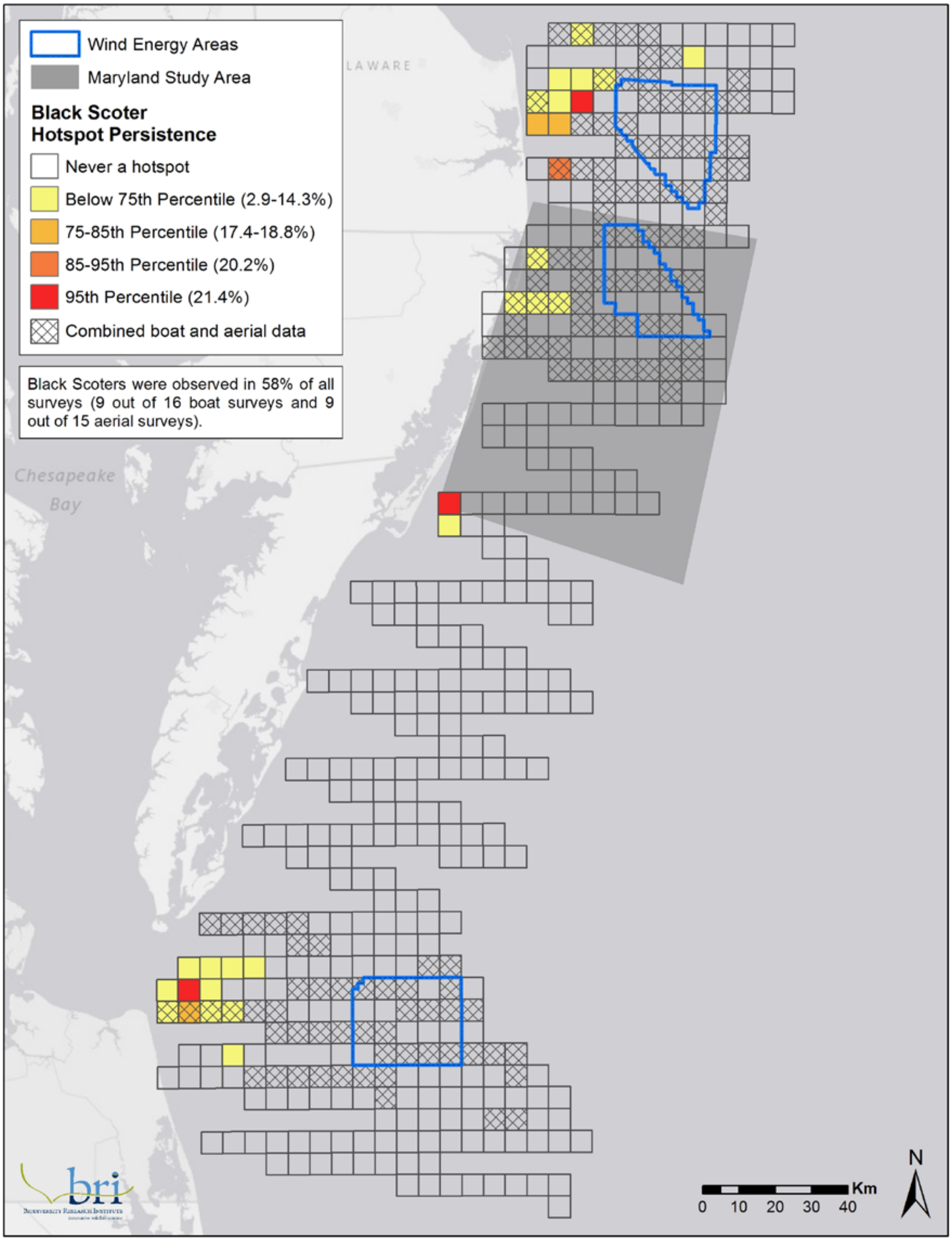


Figure 11-5. Classified persistent abundance hotspots for Black Scoters (*Melanitta americana*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

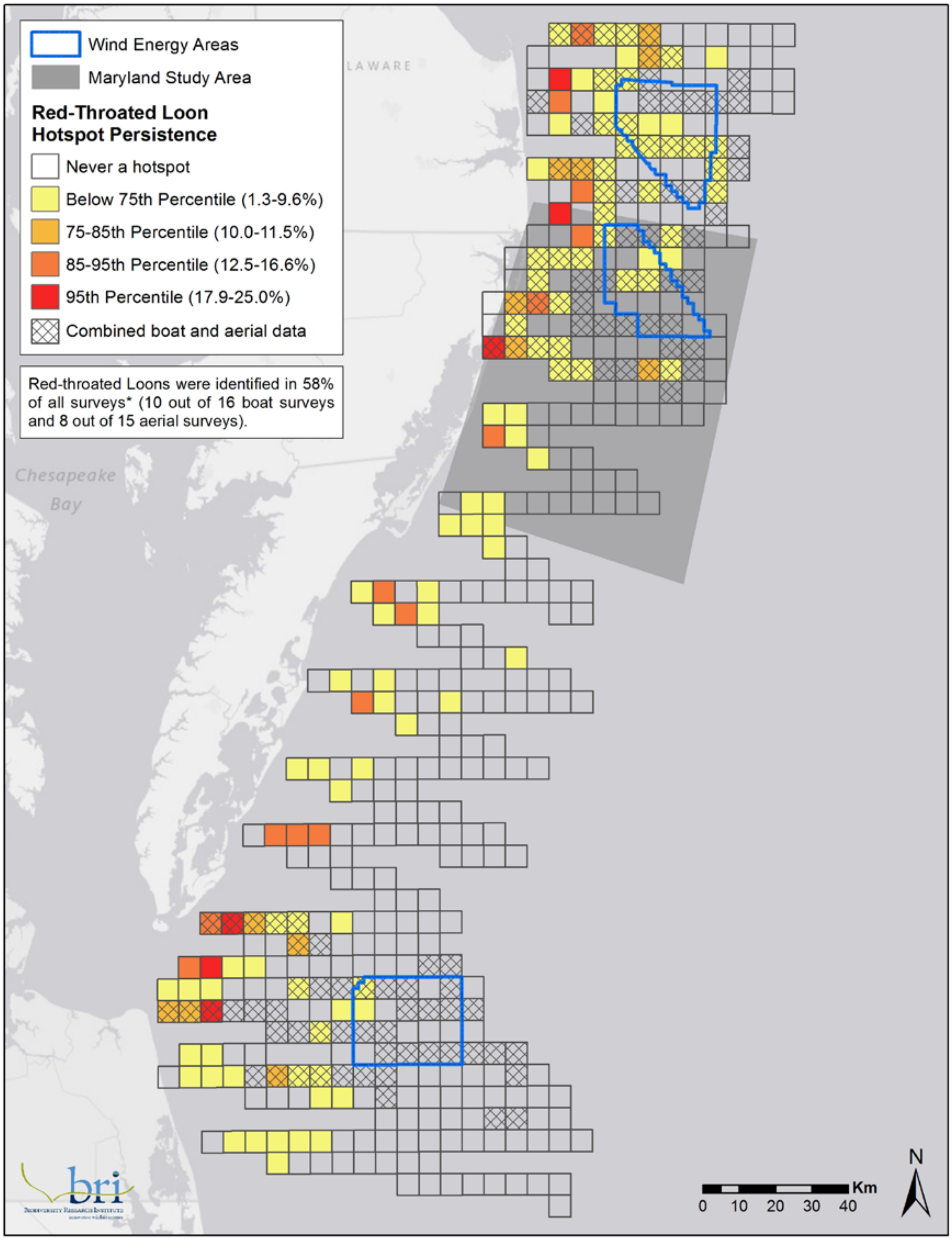


Figure 11-6. Classified persistent abundance hotspots for Red-throated Loons (*Gavia stellata*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. *Red-throated Loons were identified to species in 7 aerial surveys, and were predicted to be present in one additional survey using the species identification model (Hostetter et al., 2015). 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.

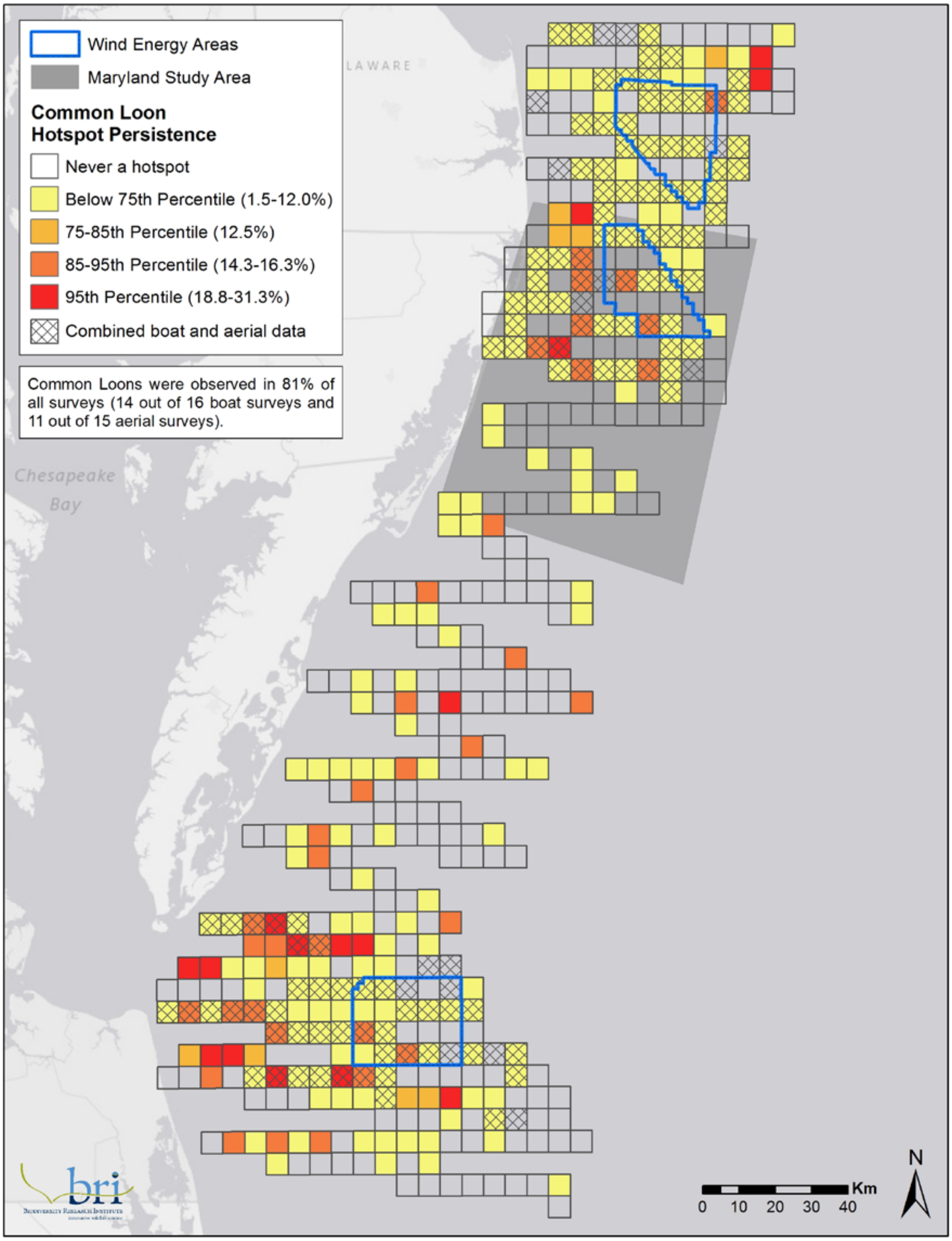


Figure 11-7. Classified persistent abundance hotspots for Common Loons (*Gavia immer*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

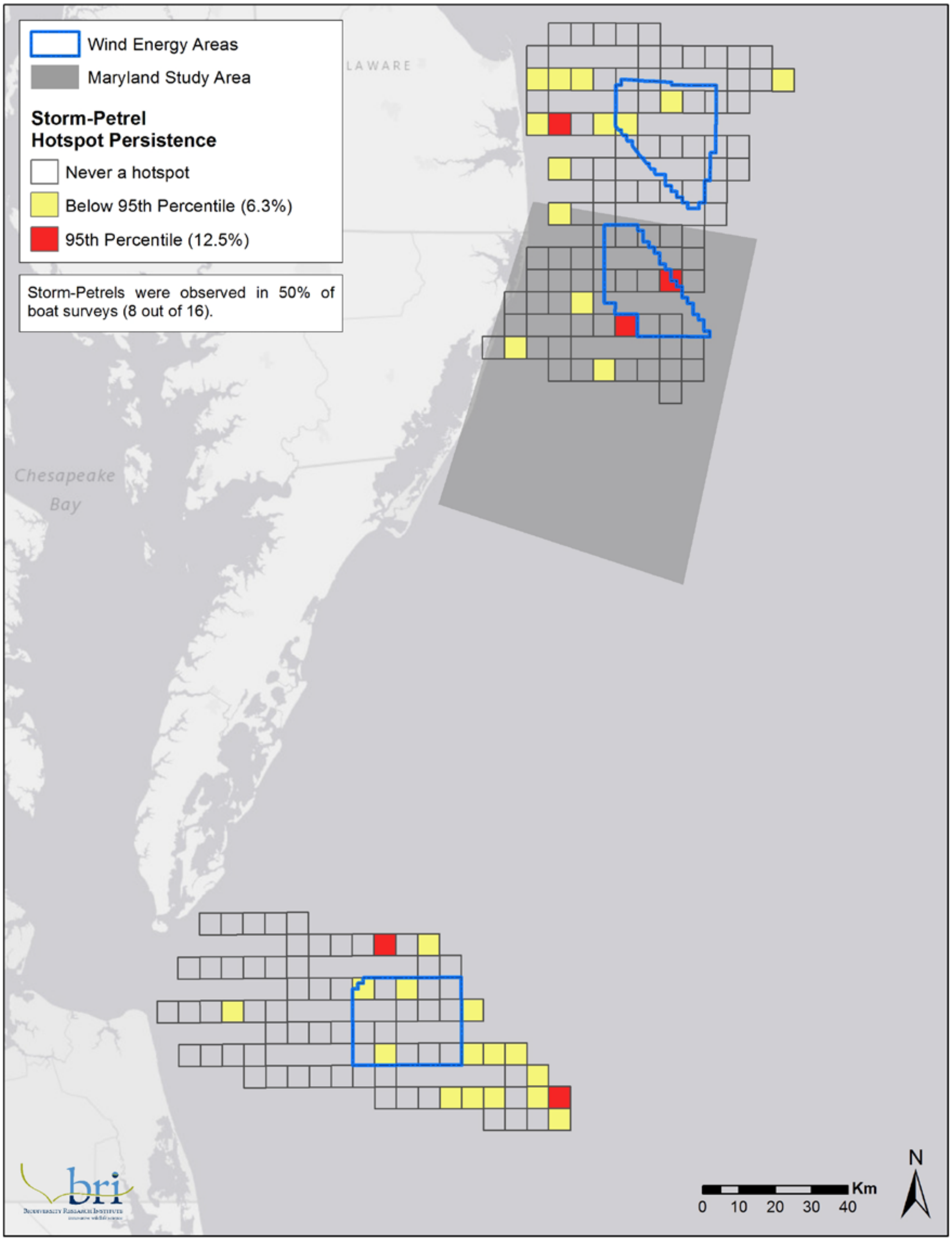


Figure 11-8. Classified persistent abundance hotspots for storm-petrels (Hydrobatidae spp.) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into two persistence classes as only two distinct persistence values were calculated (see text). 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.

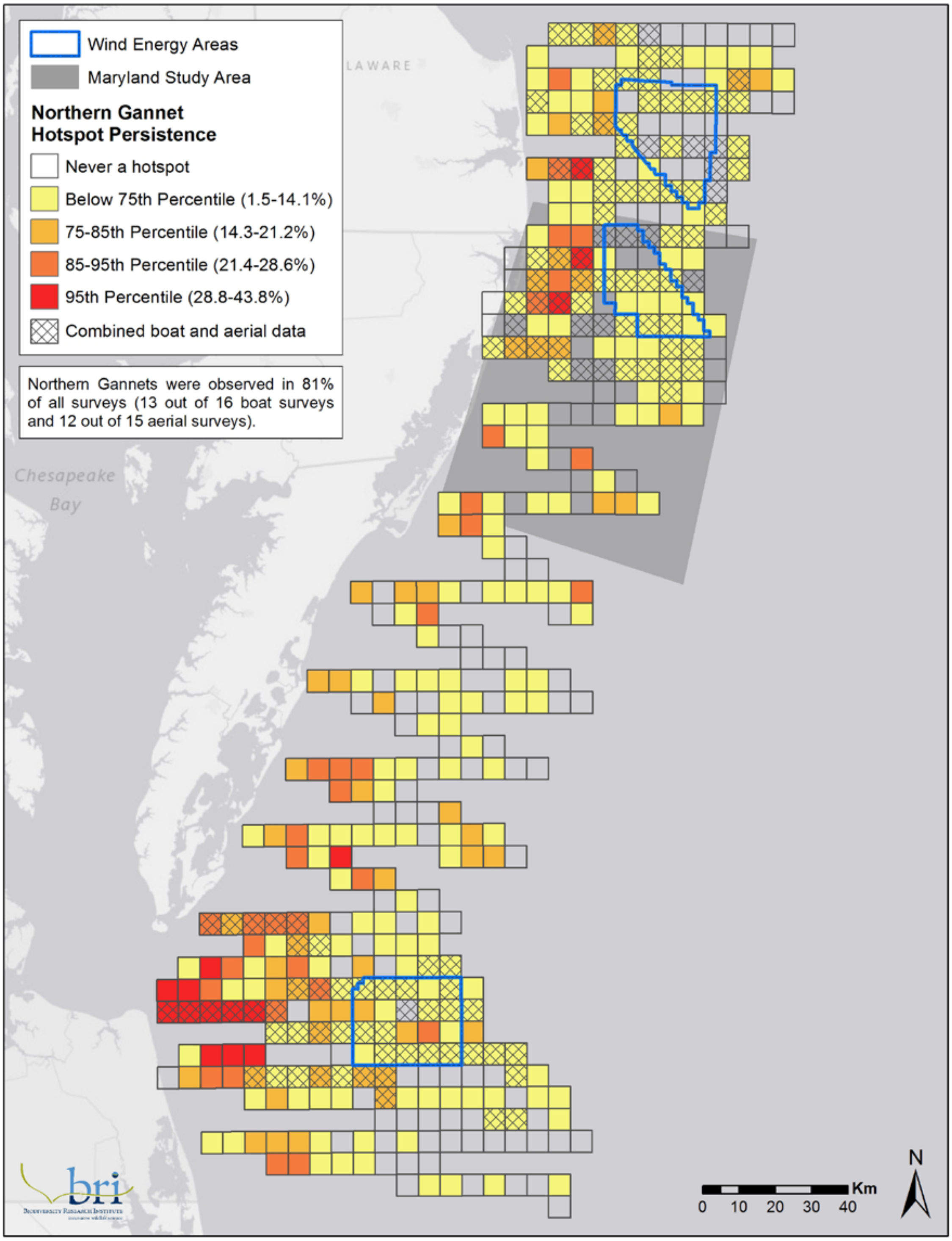


Figure 11-9. Classified persistent abundance hotspots for Northern Gannets (*Morus bassanus*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

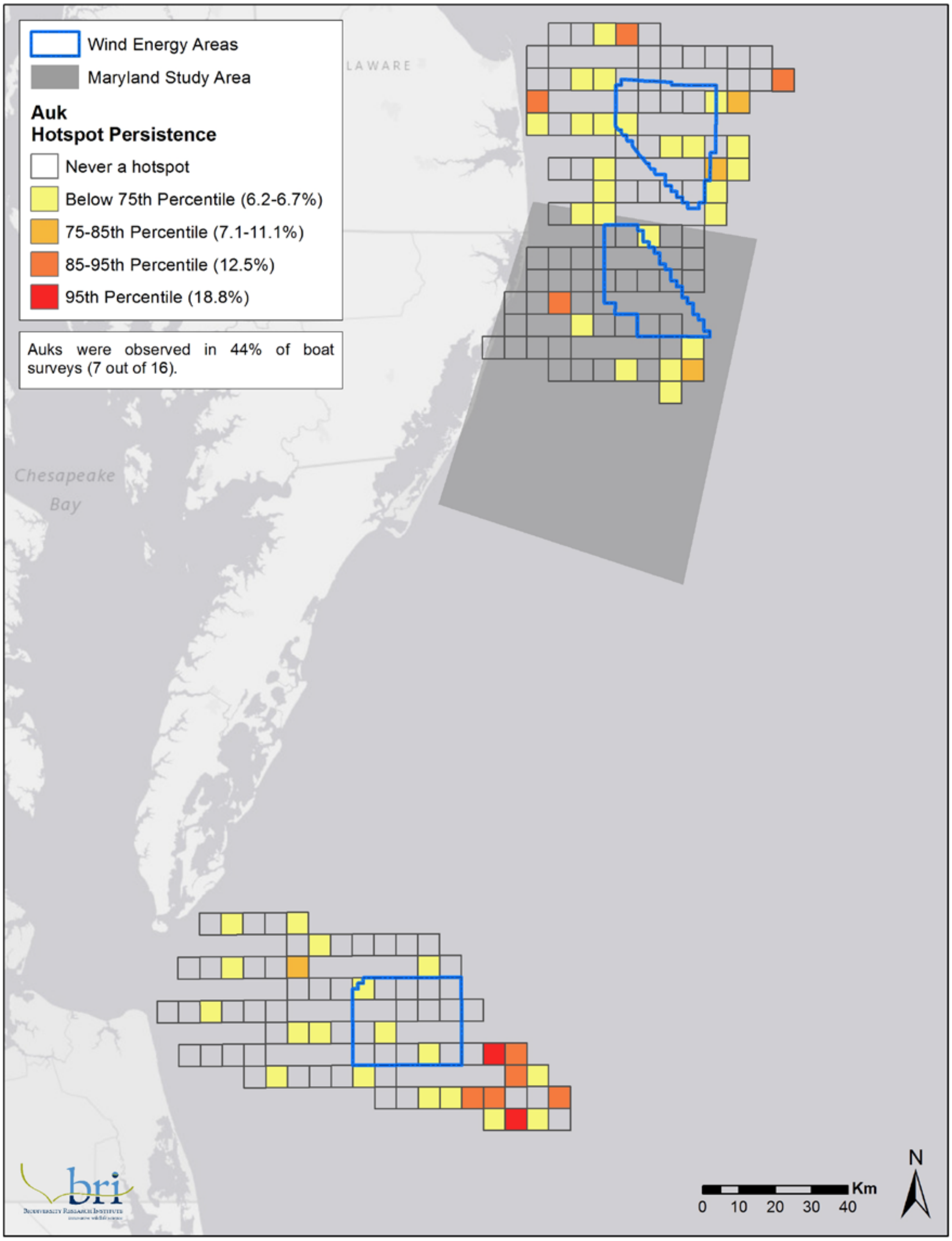


Figure 11-10. Classified persistent abundance hotspots for auks (Alcidae spp.) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. 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.

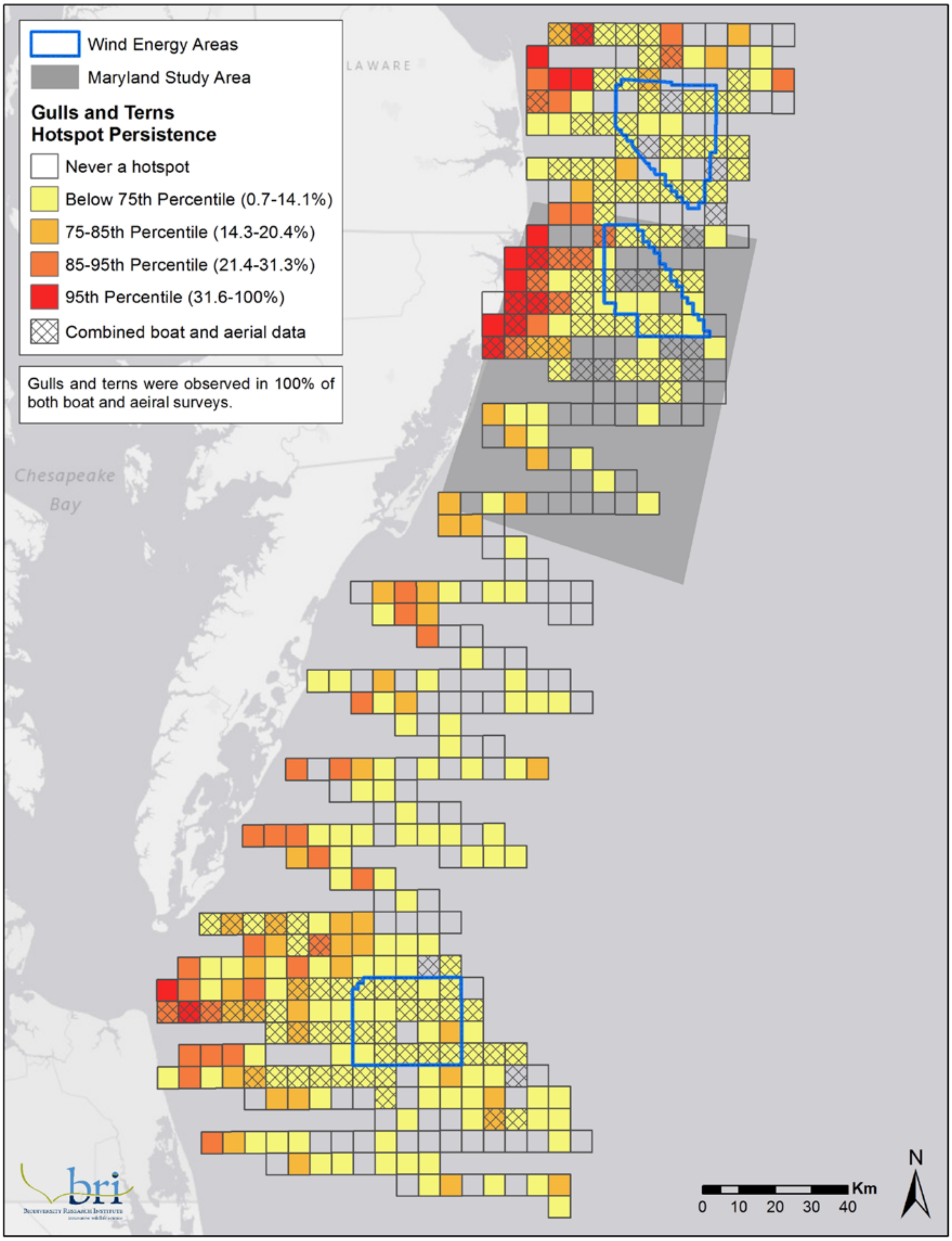


Figure 11-11. Classified persistent abundance hotspots for gulls and terns (Laridae spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

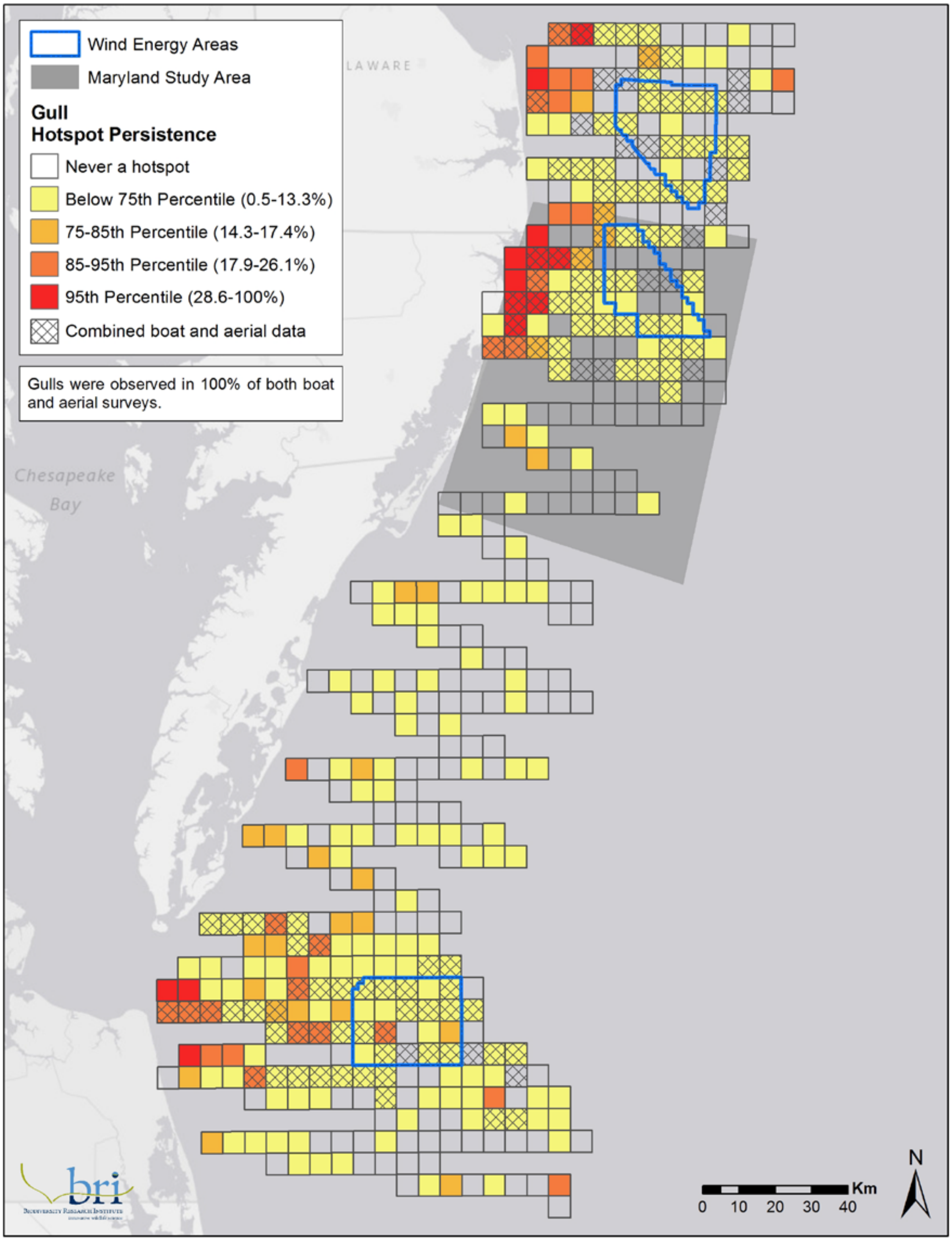


Figure 11-12. Classified persistent abundance hotspots for gulls (Larinae spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

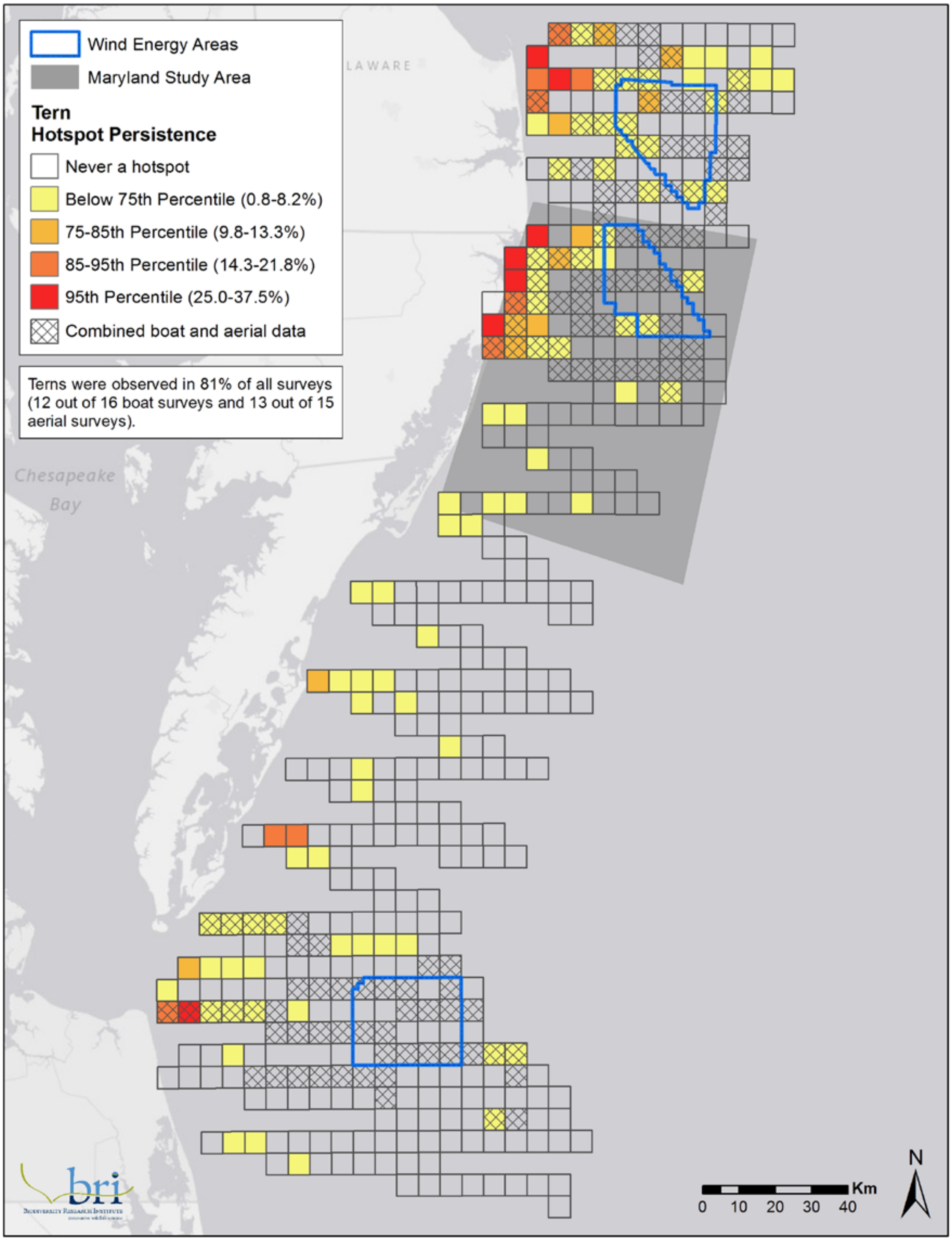


Figure 11-13. Classified persistent abundance hotspots for terns (Sterninae spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

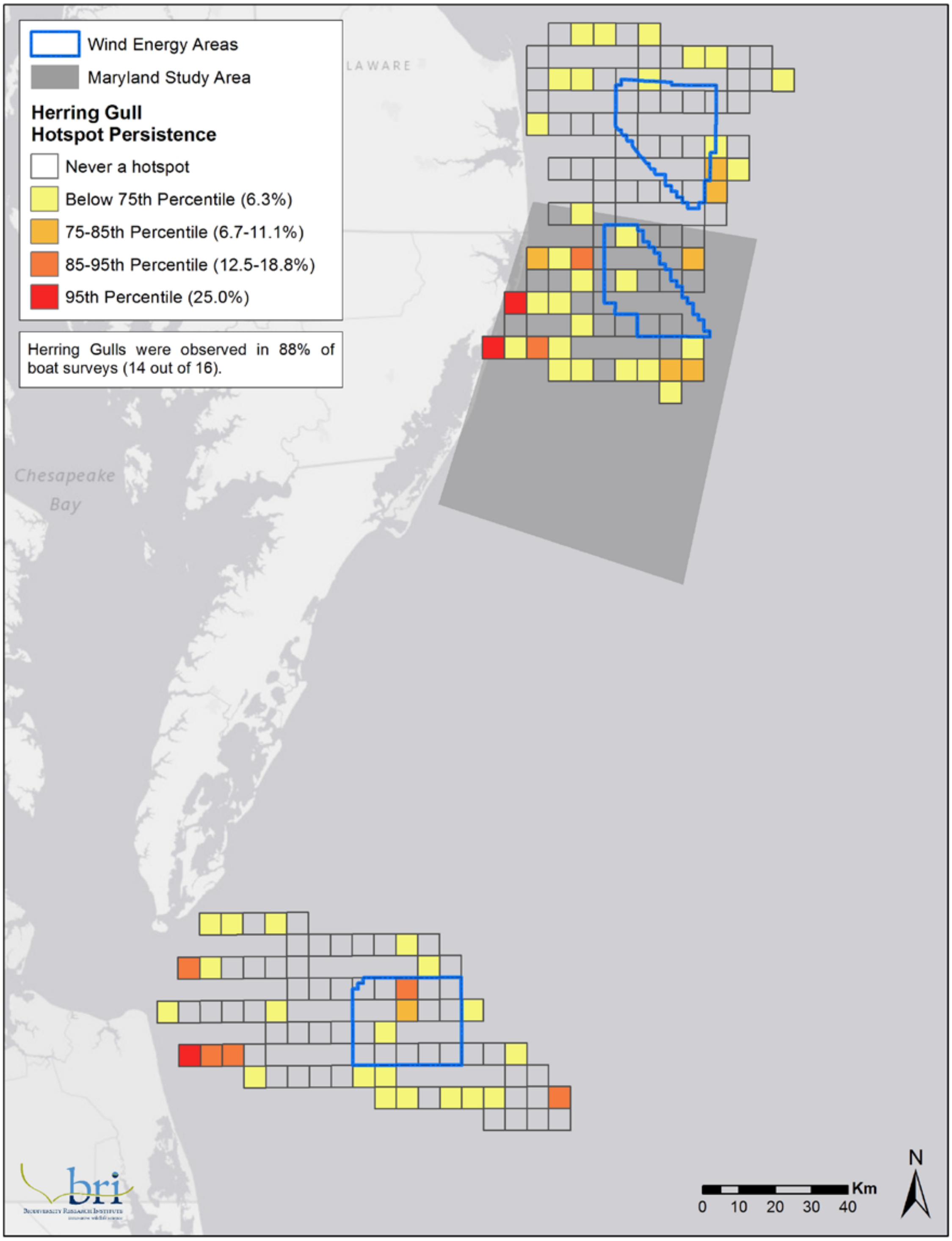


Figure 11-14. Classified persistent abundance hotspots for Herring Gulls (*Larus argentatus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. 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.

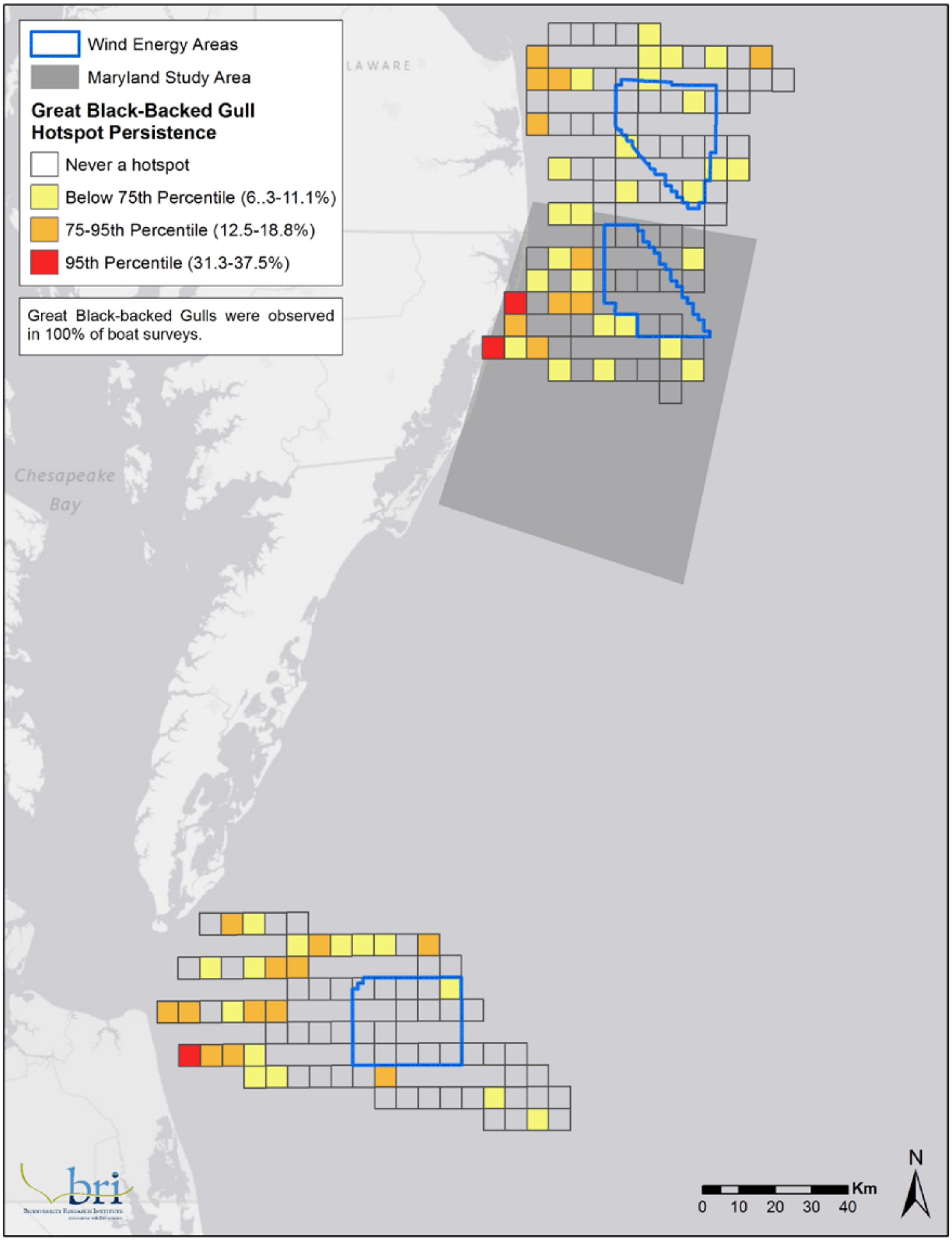


Figure 11-15. Classified persistent abundance hotspots for Great Black-backed Gulls (*Larus marinus*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value (12.5%). 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.

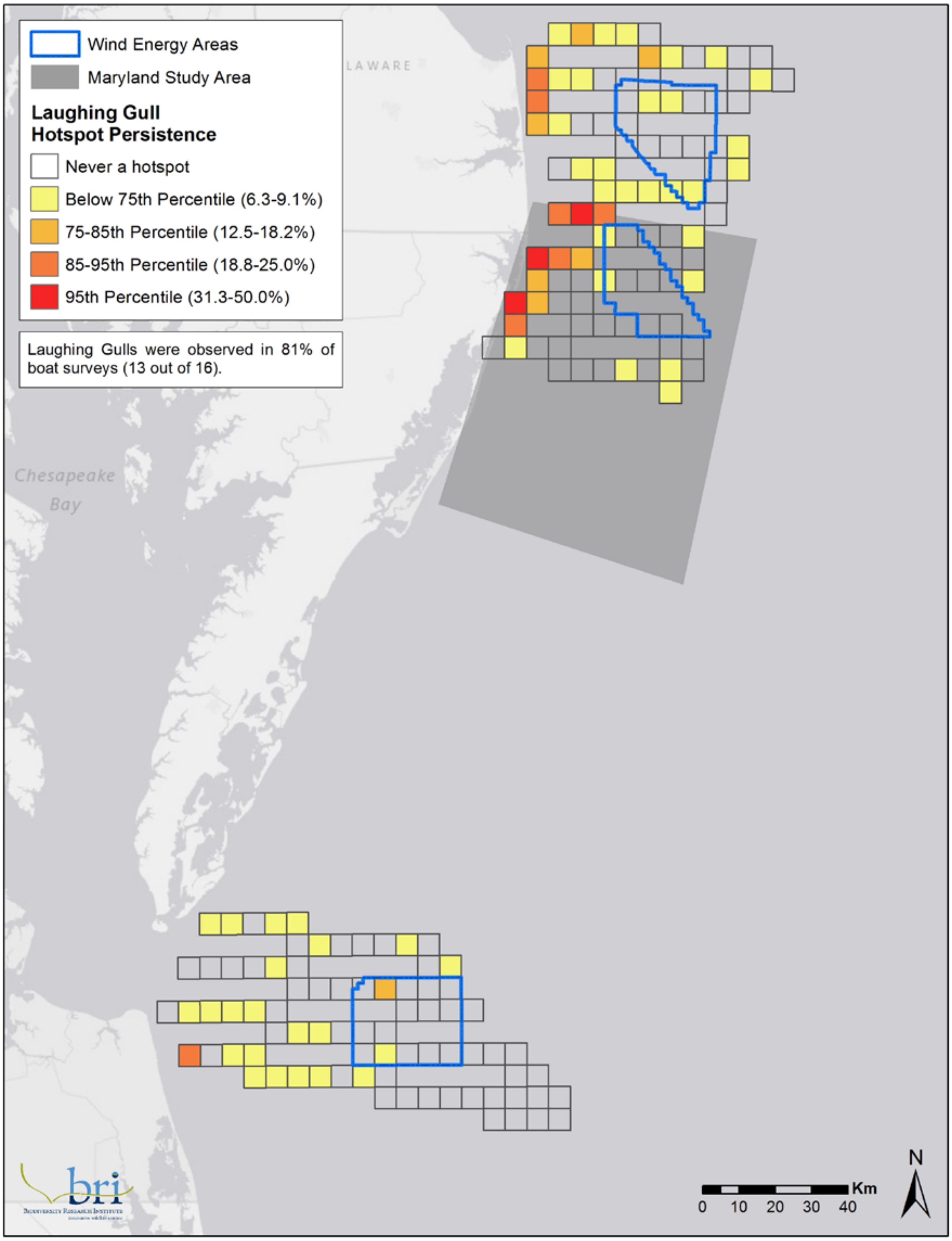


Figure 11-16. Classified persistent abundance hotspots for Laughing Gulls (*Leucophaeus atricilla*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. 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.

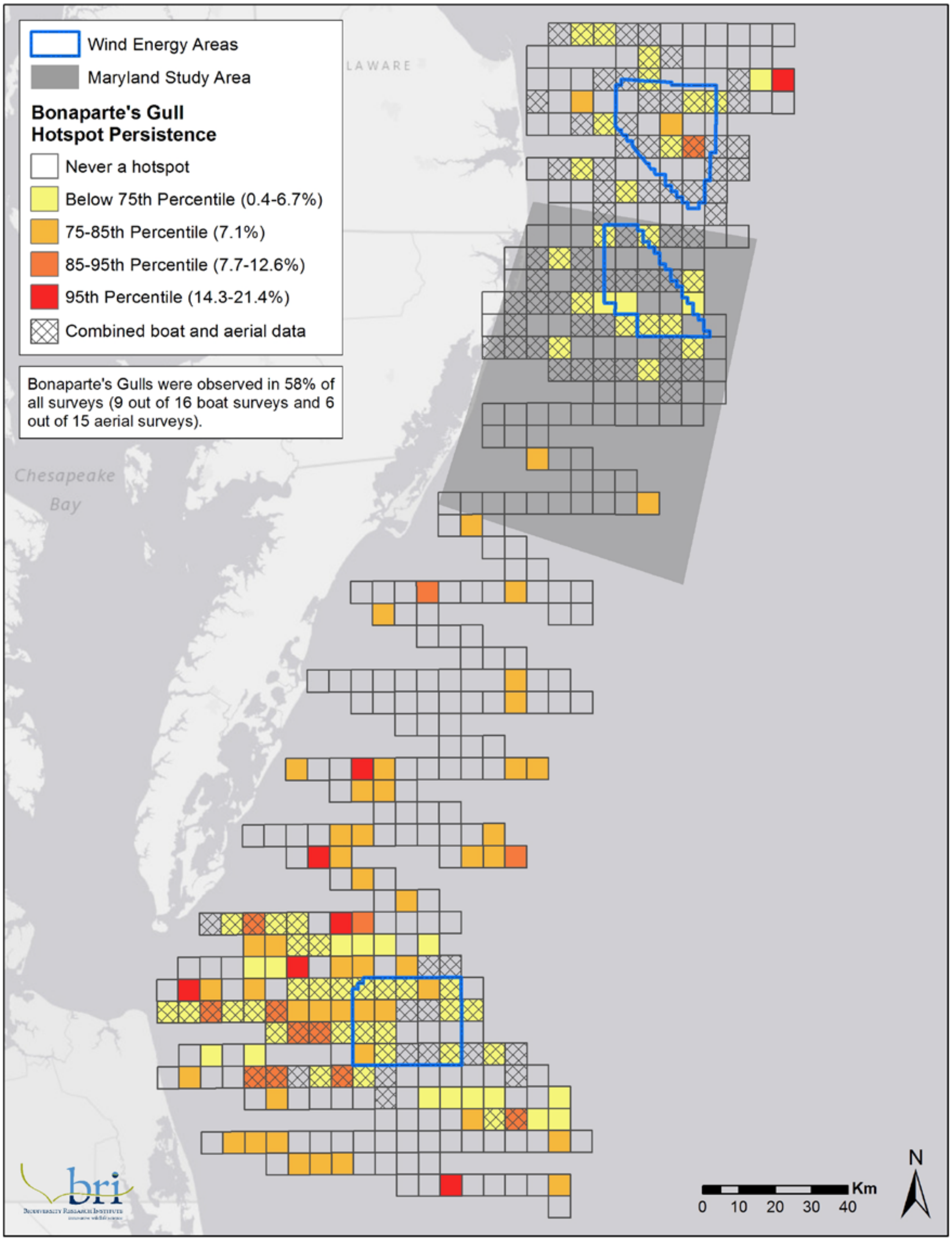


Figure 11-17. Classified persistent abundance hotspots for Bonaparte's Gulls (*Chroicocephalus philadelphia*) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

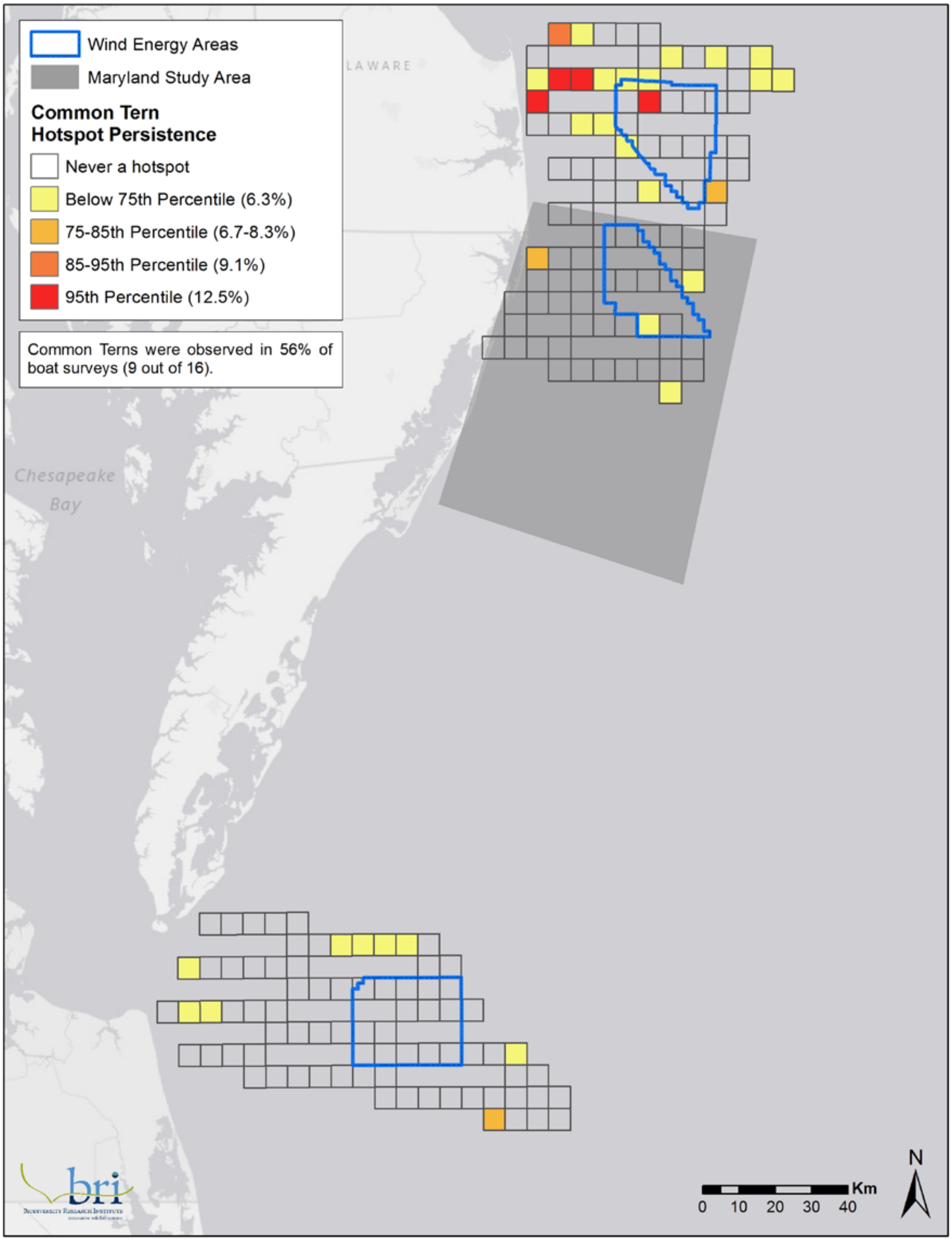


Figure 11-18. Classified persistent abundance hotspots for Common Terns (*Sterna hirundo*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. 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.

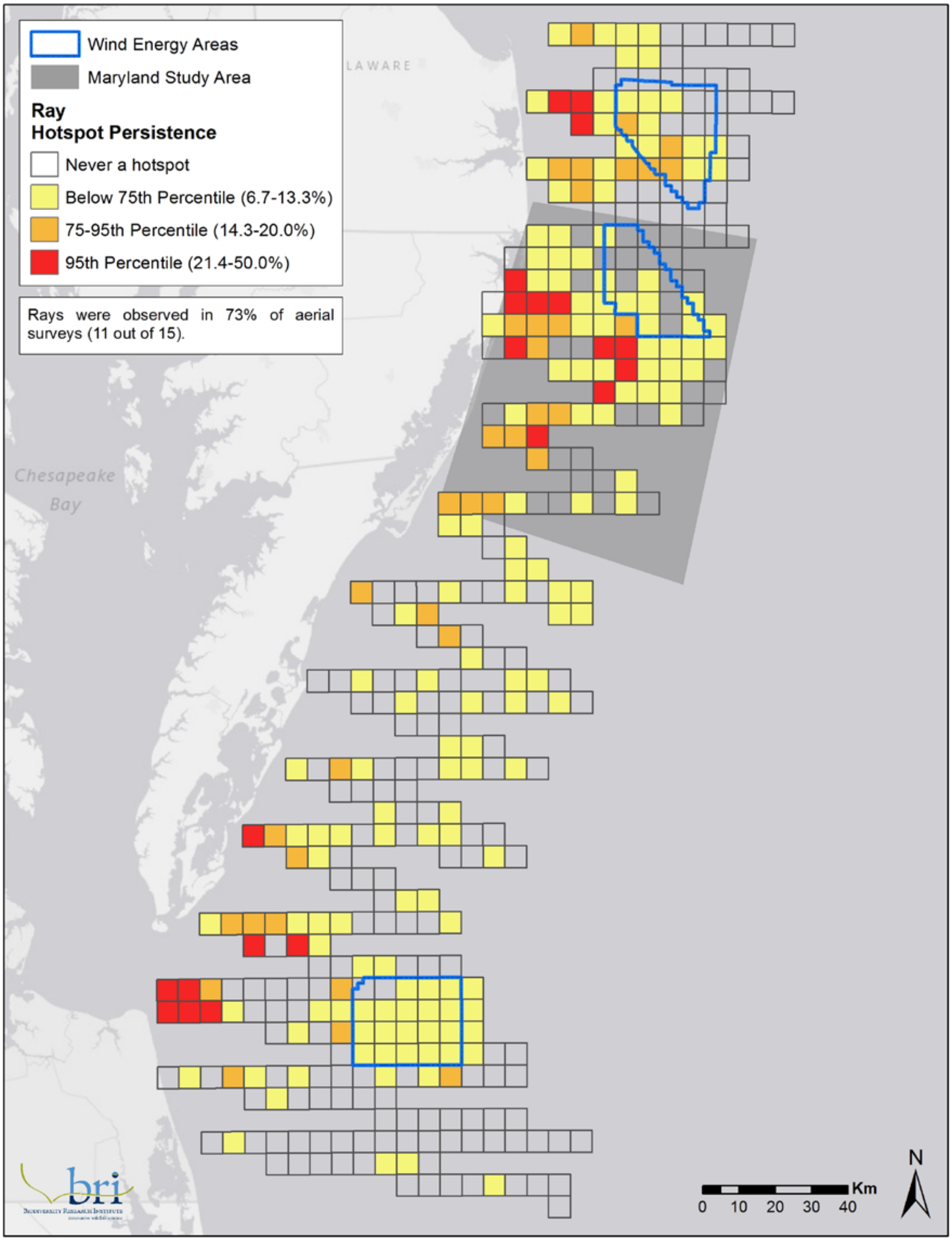


Figure 11-19. Classified persistent abundance hotspots for rays (Batoidea spp.) observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value (14.3%). Blank cells never had high enough abundance to be considered a hotspot. 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.

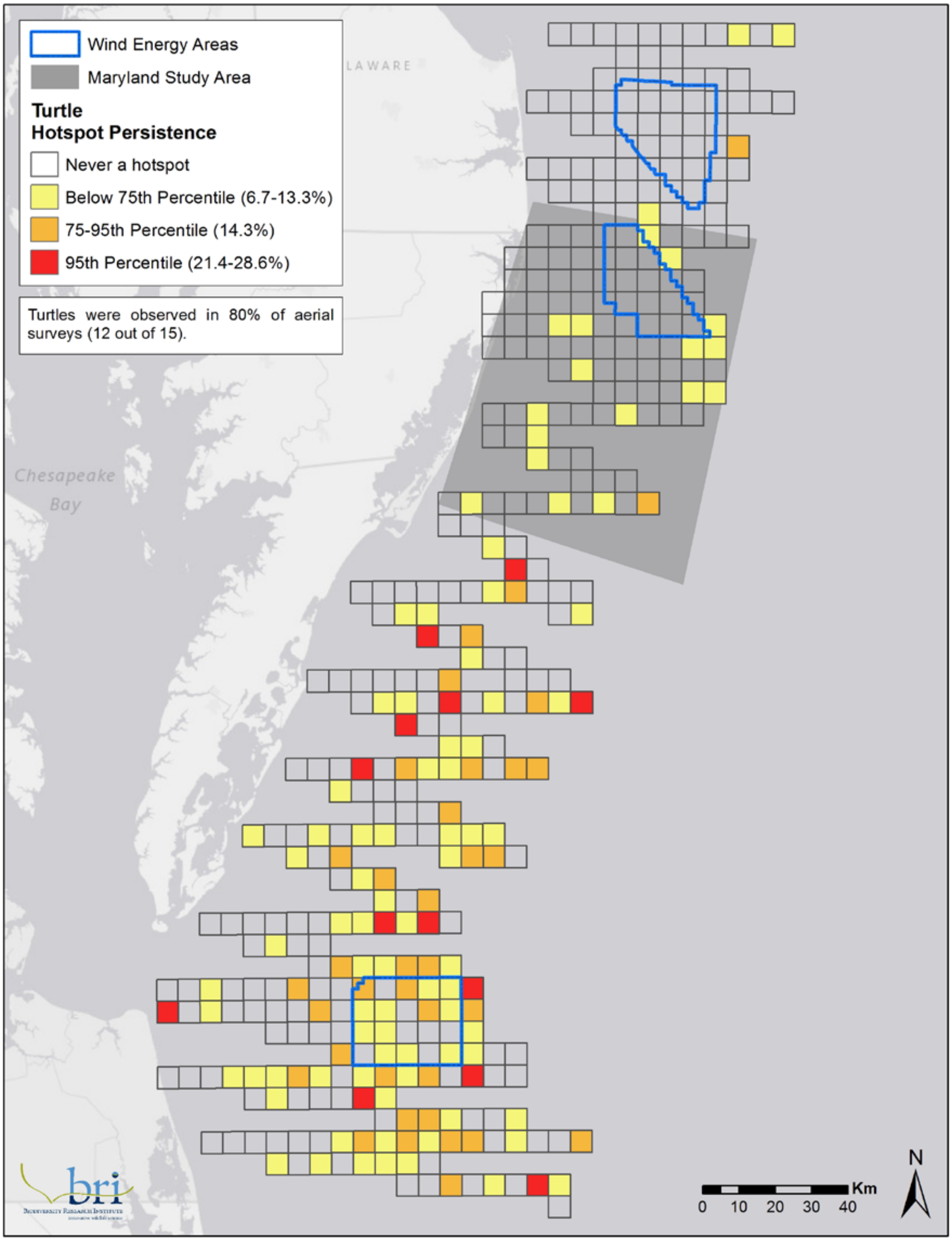


Figure 11-20. Classified persistent abundance hotspots for turtles (Testudines spp.) observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value (14.3%). 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.

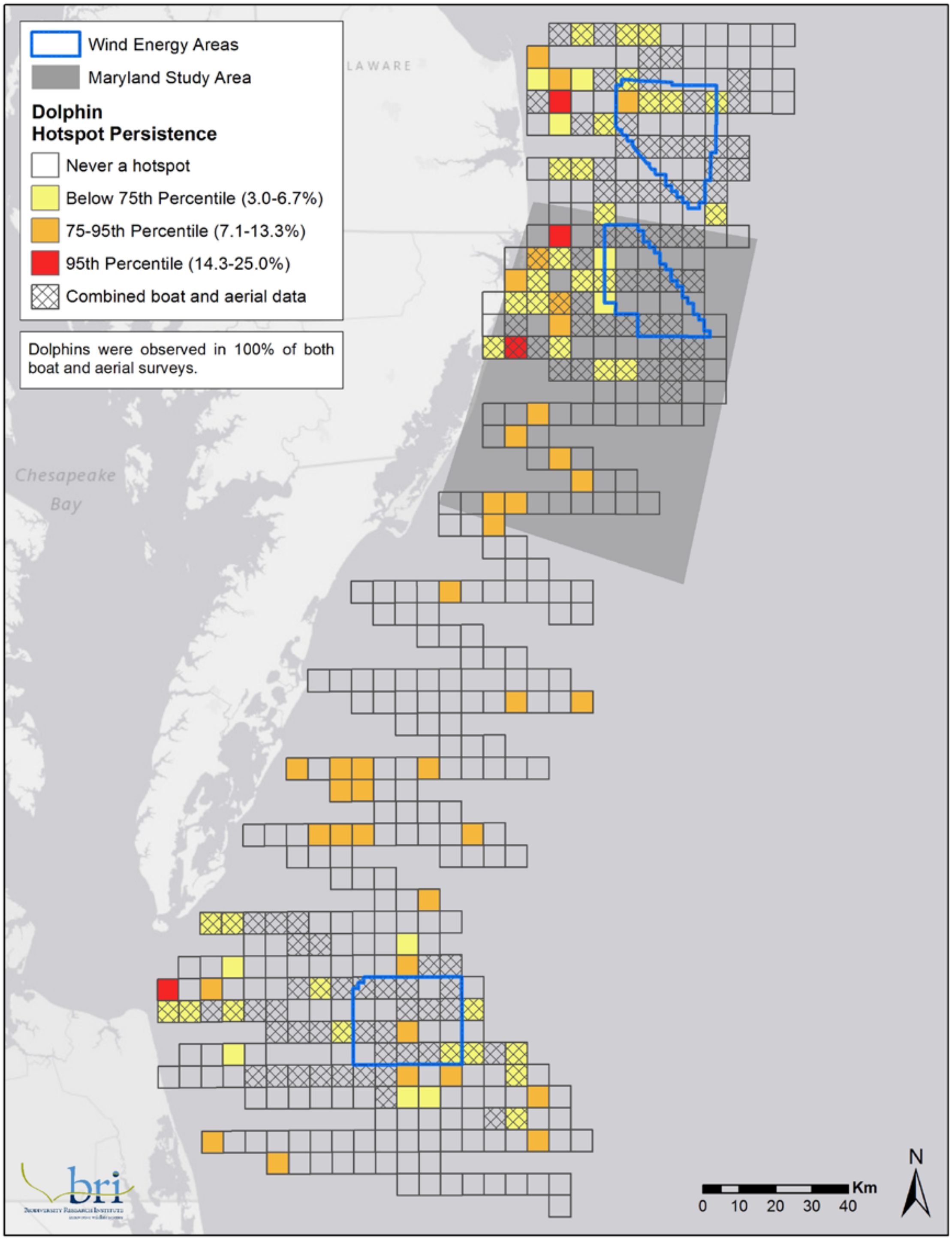


Figure 11-21. Classified persistent abundance hotspots for dolphin (Odontoceti spp.) observed in boat and video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Crosshatched cells integrate data from both boat and video aerial survey methods. Data are split into only three persistence classes as the 75th and 85th percentile of persistence values fell at the same value (7.1%). 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.

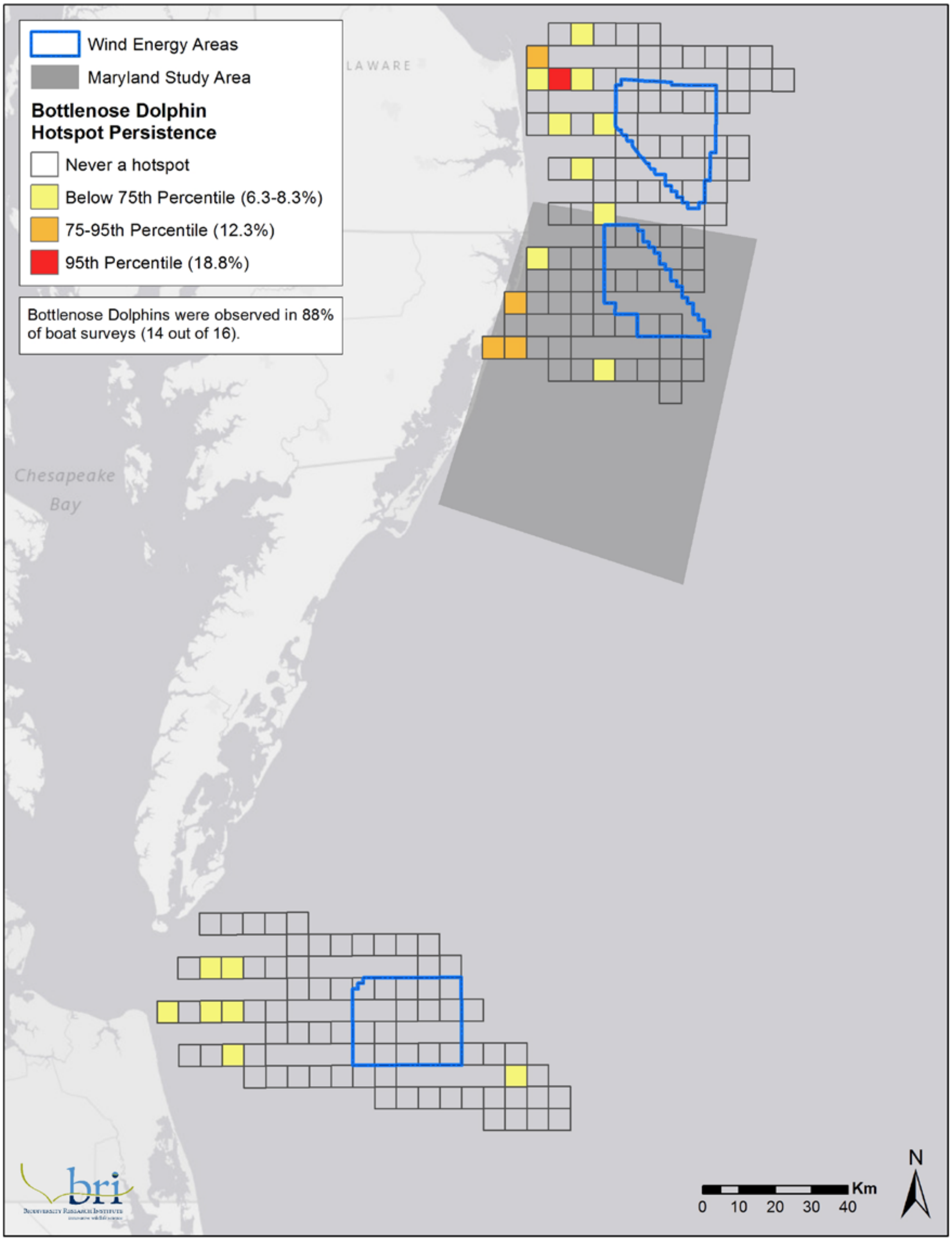


Figure 11-22. Classified persistent abundance hotspots for Bottlenose Dolphins (*Tursiops truncates*) observed in boat surveys, April 2012 – April 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. Data are split into only three persistence classes as the 75th and 85th percentile of persistence values fell at the same value (12.3%). 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.

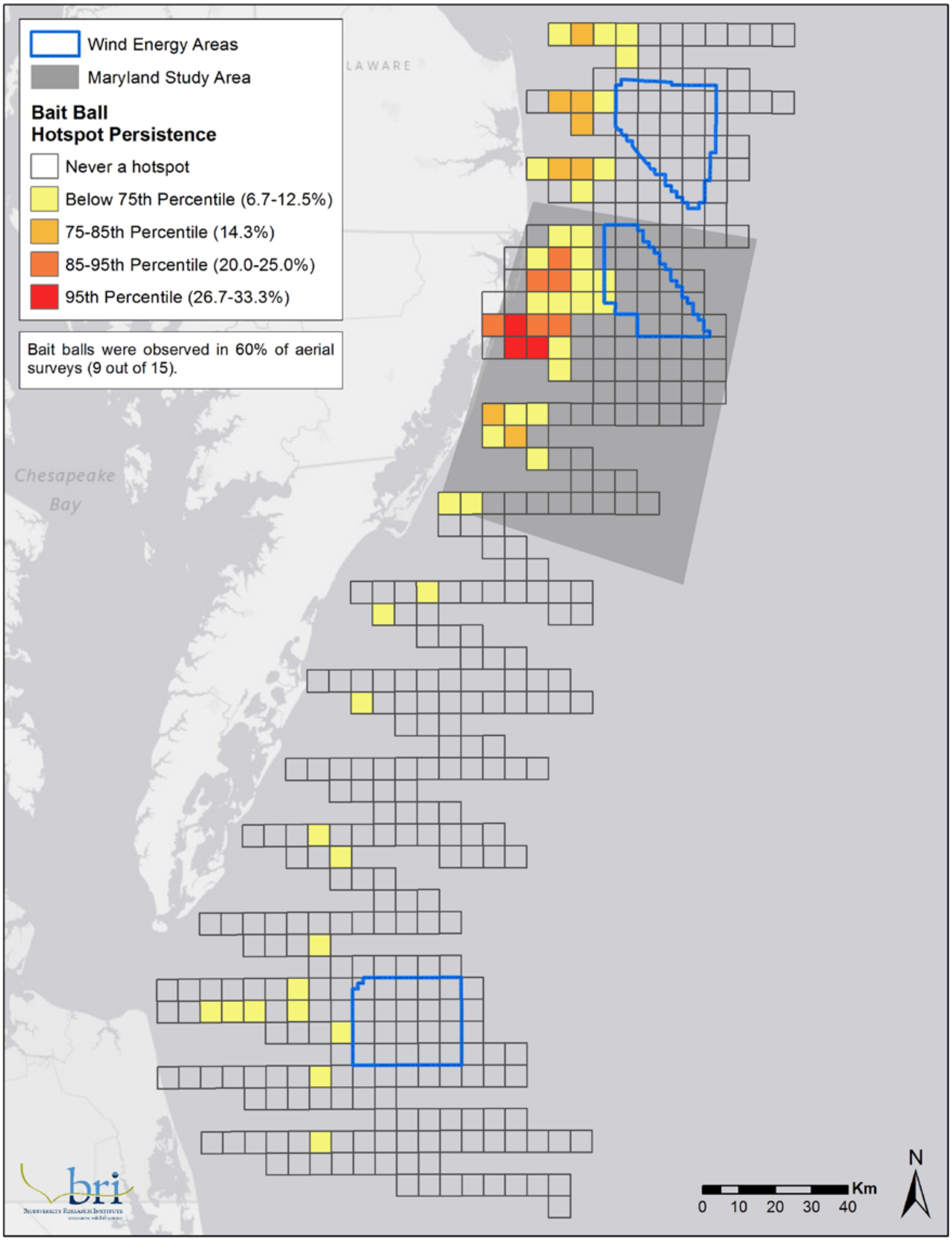


Figure 11-23. Classified persistent abundance hotspots for bait balls observed in video aerial surveys, March 2012 – May 2014. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance to be considered a hotspot. 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.

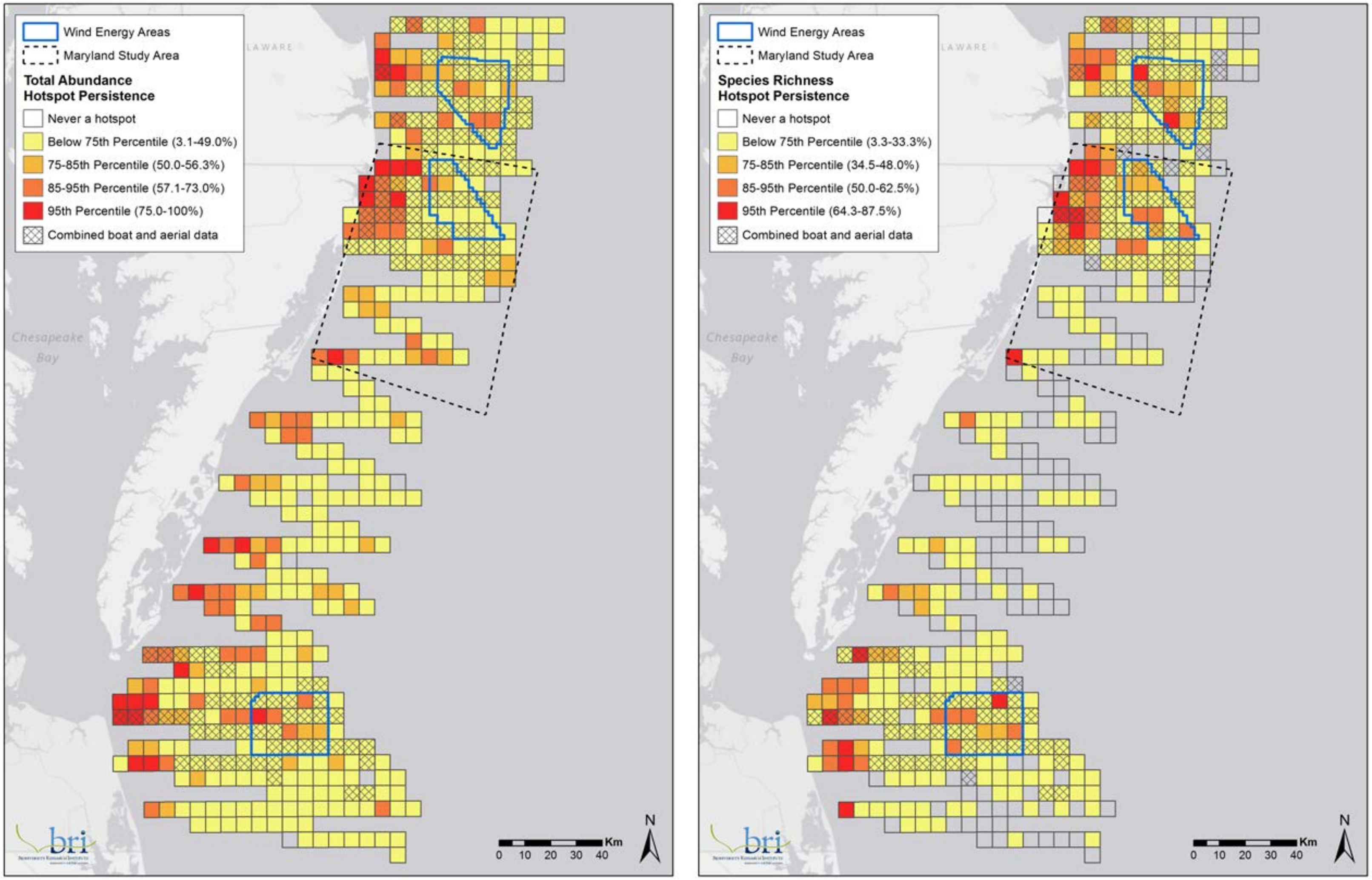


Figure 11-24. Persistent abundance hotspots identified across all taxa (left) and persistent species richness hotspots (right). These maps highlight areas where the greatest numbers of individuals across all taxa (left) and the greatest numbers of species (right) were consistently observed over the course of the study. For each percentile category shown in the legend, the corresponding percentage of time a cell was a hotspot (including all surveys) is shown parenthetically. Blank cells never had high enough abundance or high enough species counts to be considered a hotspot. Crosshatched cells integrate data from both boat and video 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.

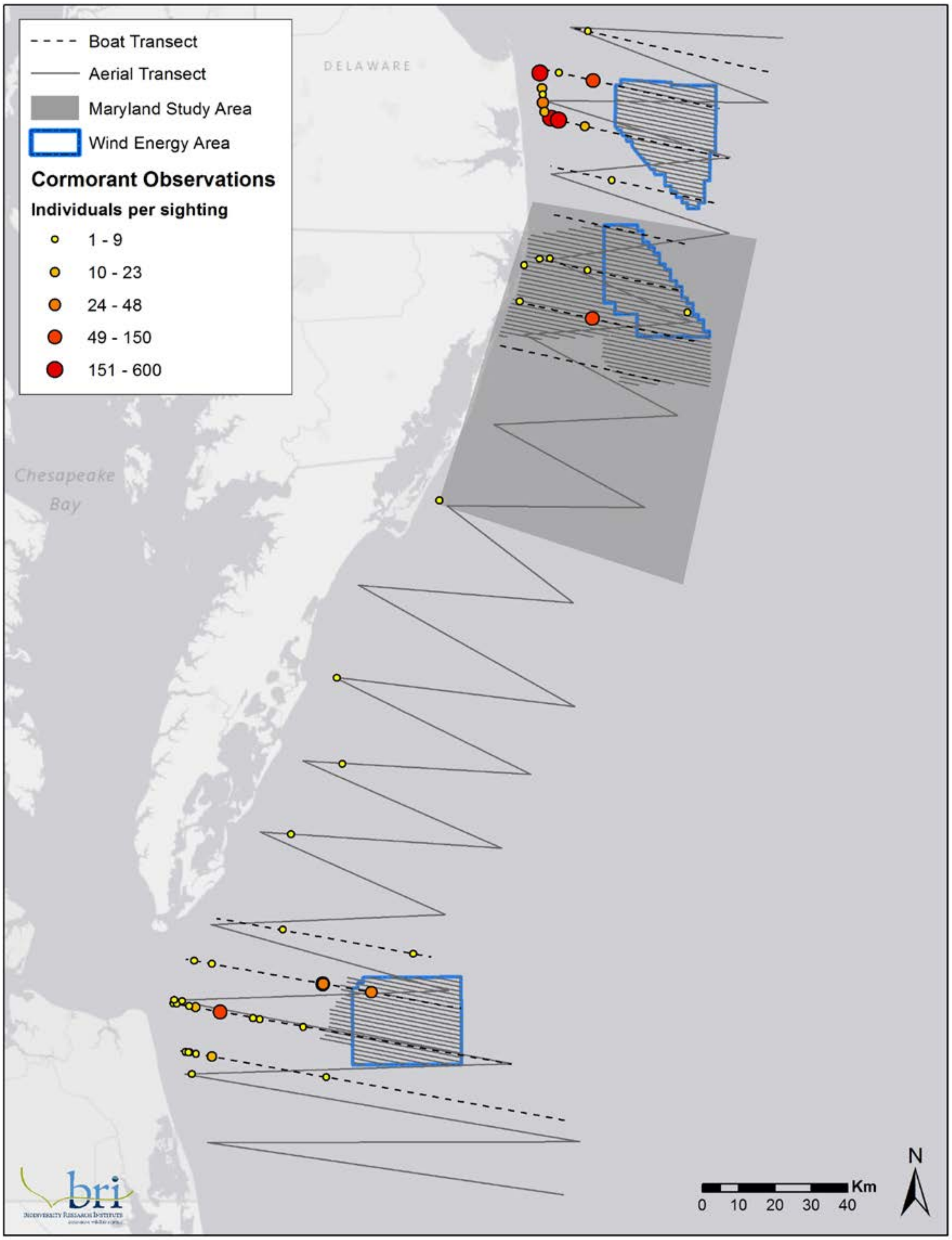


Figure 11-25. Cormorants (Phalacrocoracidae) observed by boat and video aerial surveys. A total of 2,077 cormorants were observed (2,035 by boat; 42 by aerial) over the course of the study, March 2012 – May 2014. Over half of these individuals were observed in three sightings by boat surveys near the mouth of Delaware Bay.

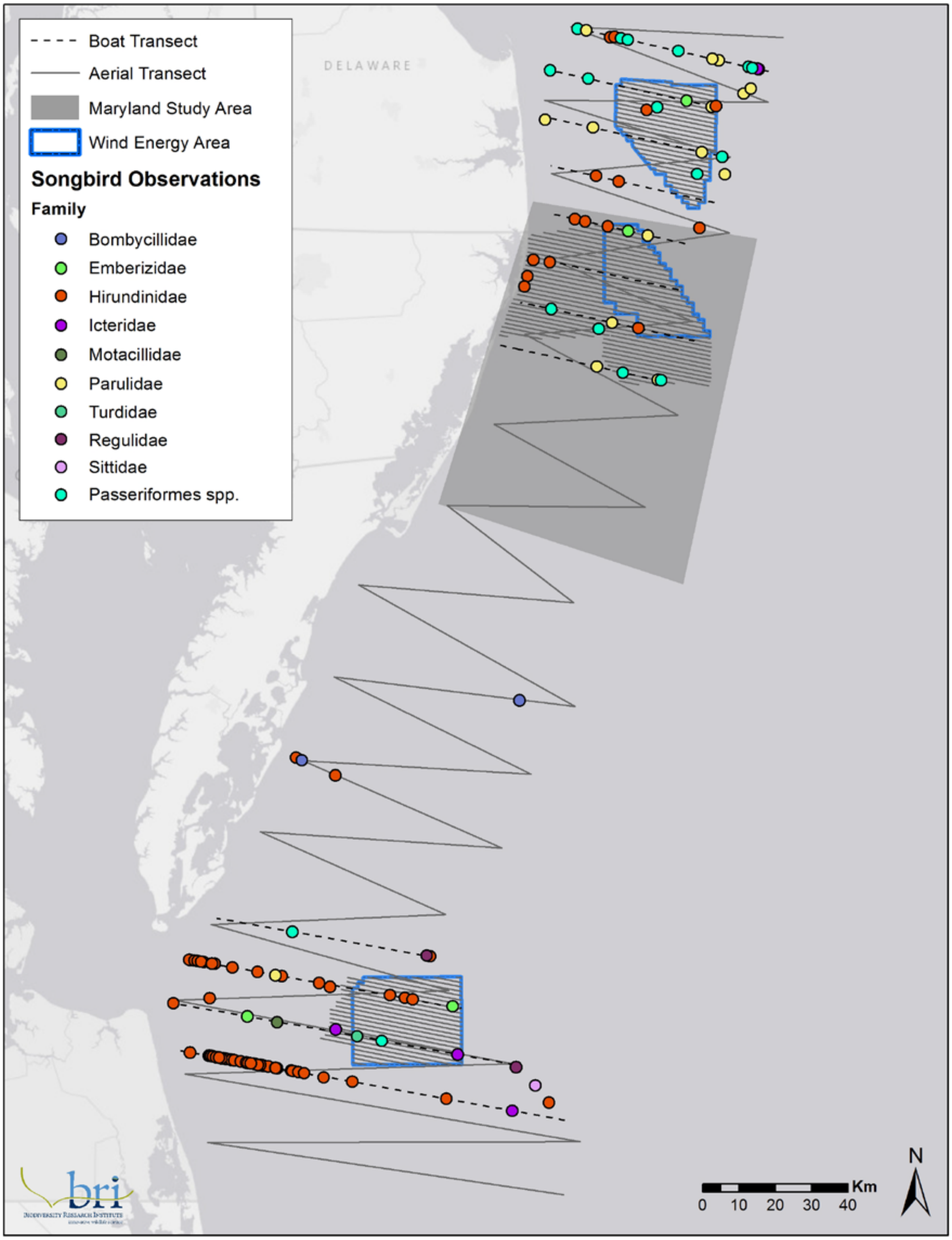


Figure 11-26. Songbirds observed in the boat and video aerial surveys displayed by family. Families include waxwings (Bombycilldae), sparrows (Emberizidae), swallows (Hirundinidae), blackbirds and cowbirds (Icteridae), pipits (Motacillidae), warblers (Parulidae), kinglets (Regulidae), nuthatches (Sittidae), robins (Turdidae), and unidentified passerines (Passeriformes).

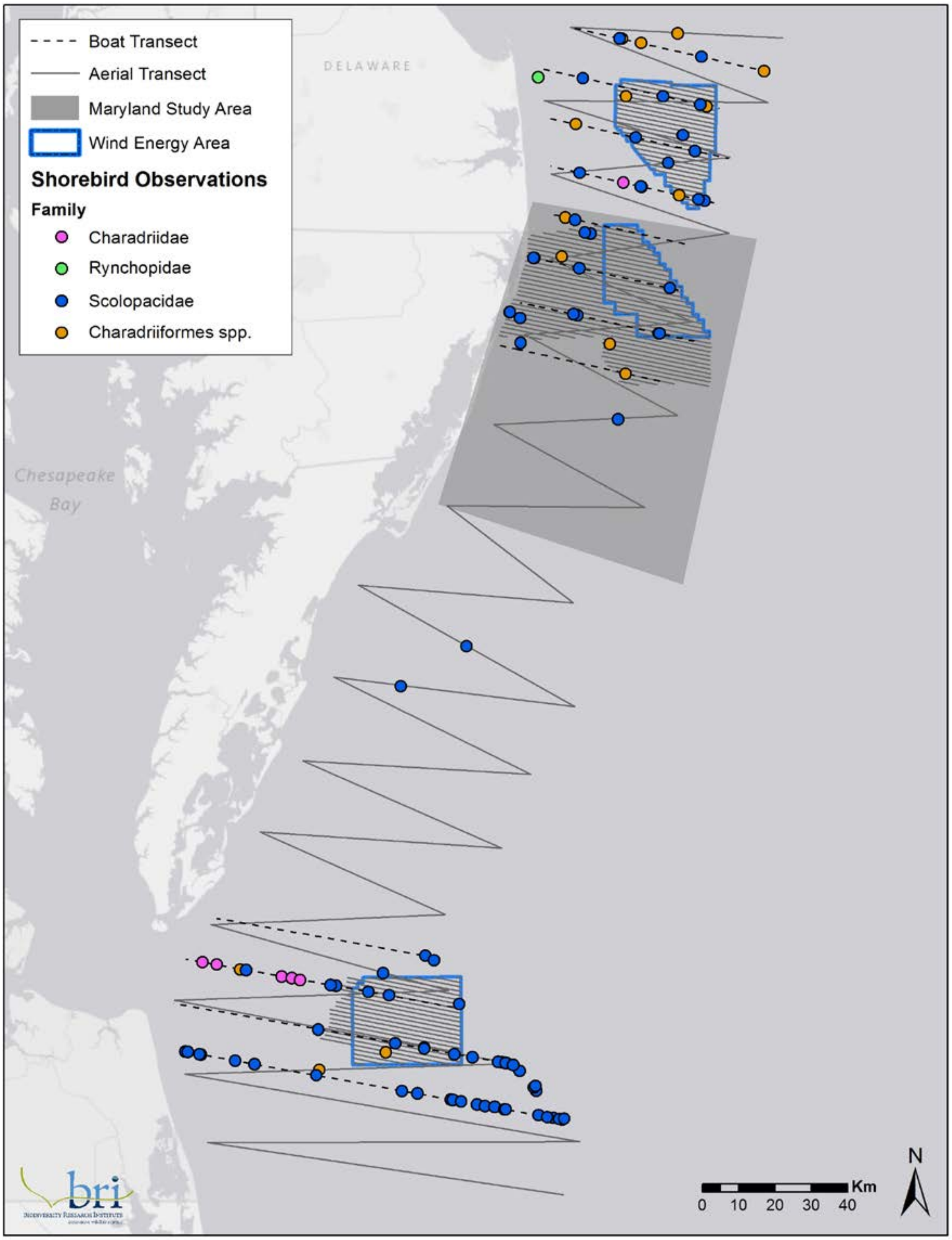


Figure 11-27. Shorebirds observed in the boat and video aerial surveys, displayed by family. Families include plovers (Charadriidae); skimmers (Rynochopidae); sandpipers, phalaropes, and other shorebirds (Scolopacidae); and unidentified shorebirds (Charadriiformes).

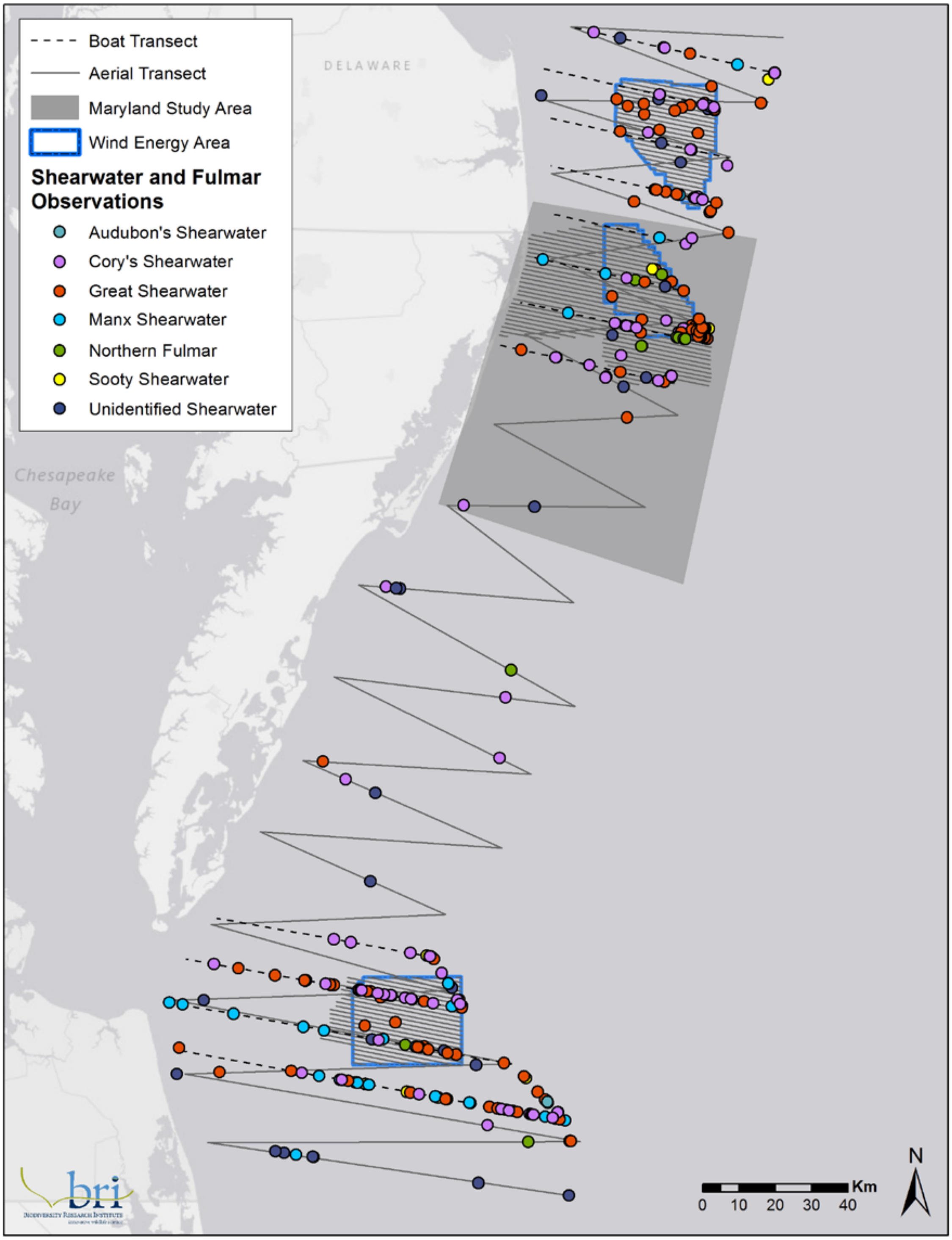


Figure 11-28. Shearwaters and fulmars (Procellariidae) observed on boat and video aerial surveys (March 2012-May 2014).

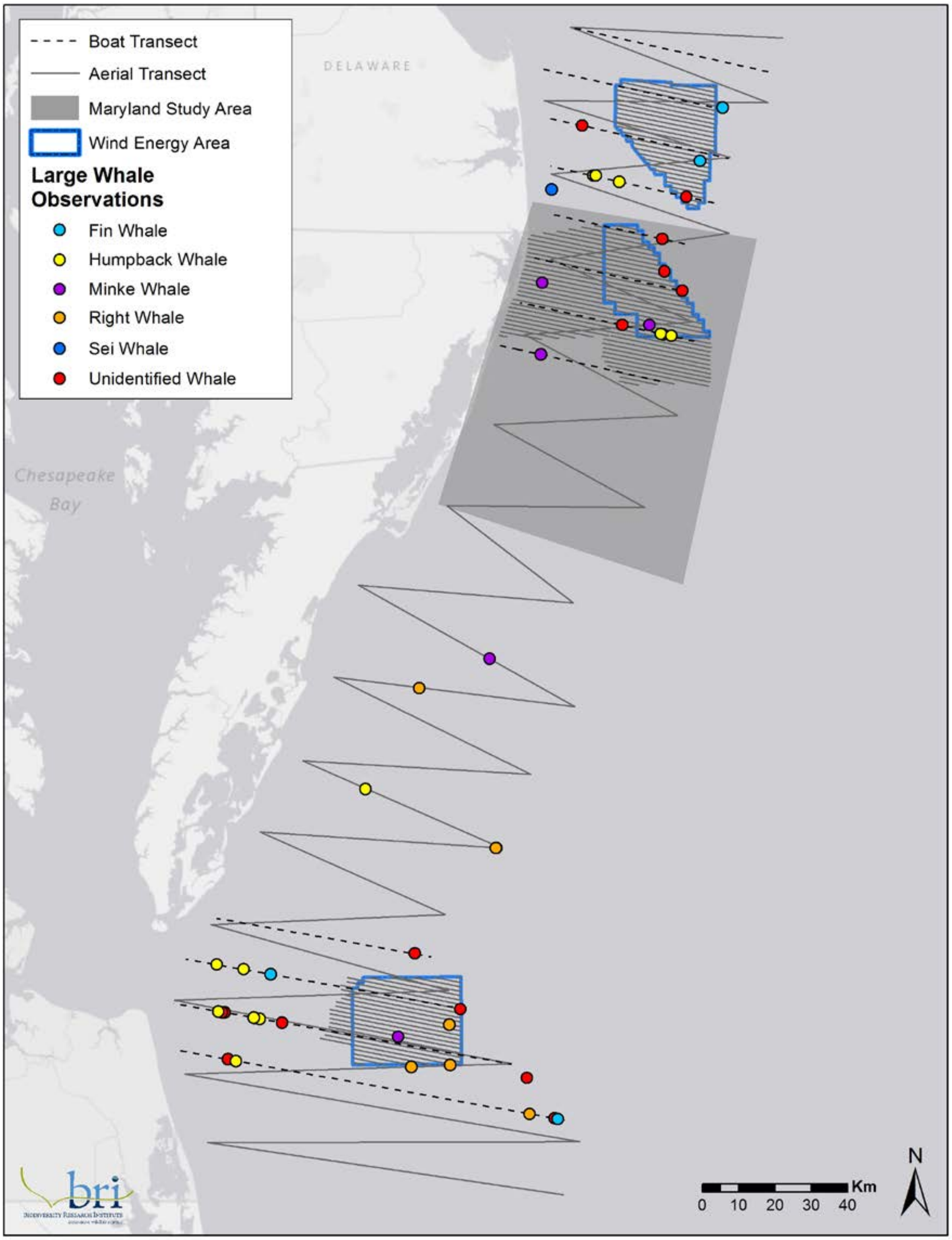


Figure 11-29. Large whale observations (Mysticeti) from boat and video aerial surveys (March 2012-May 2014).

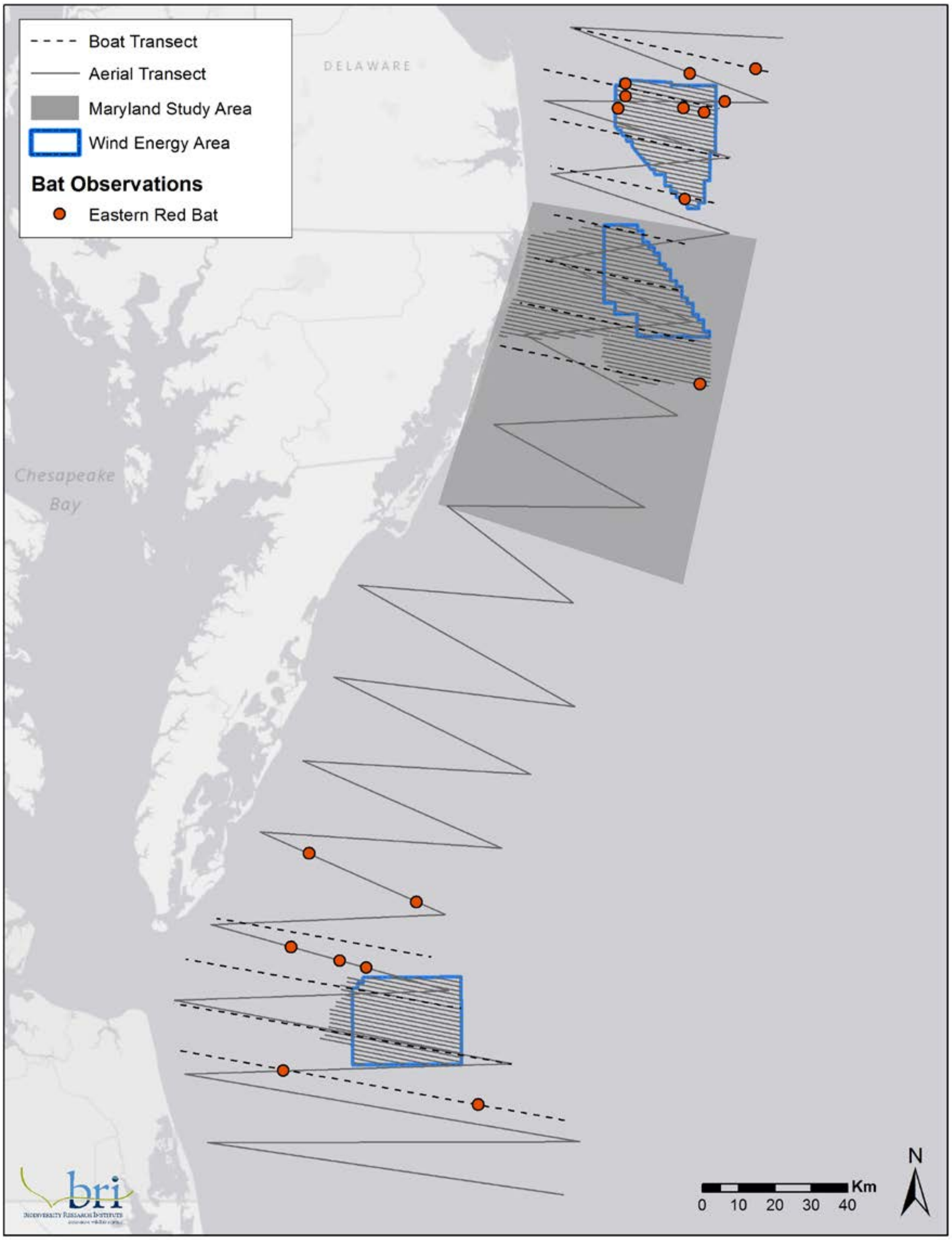
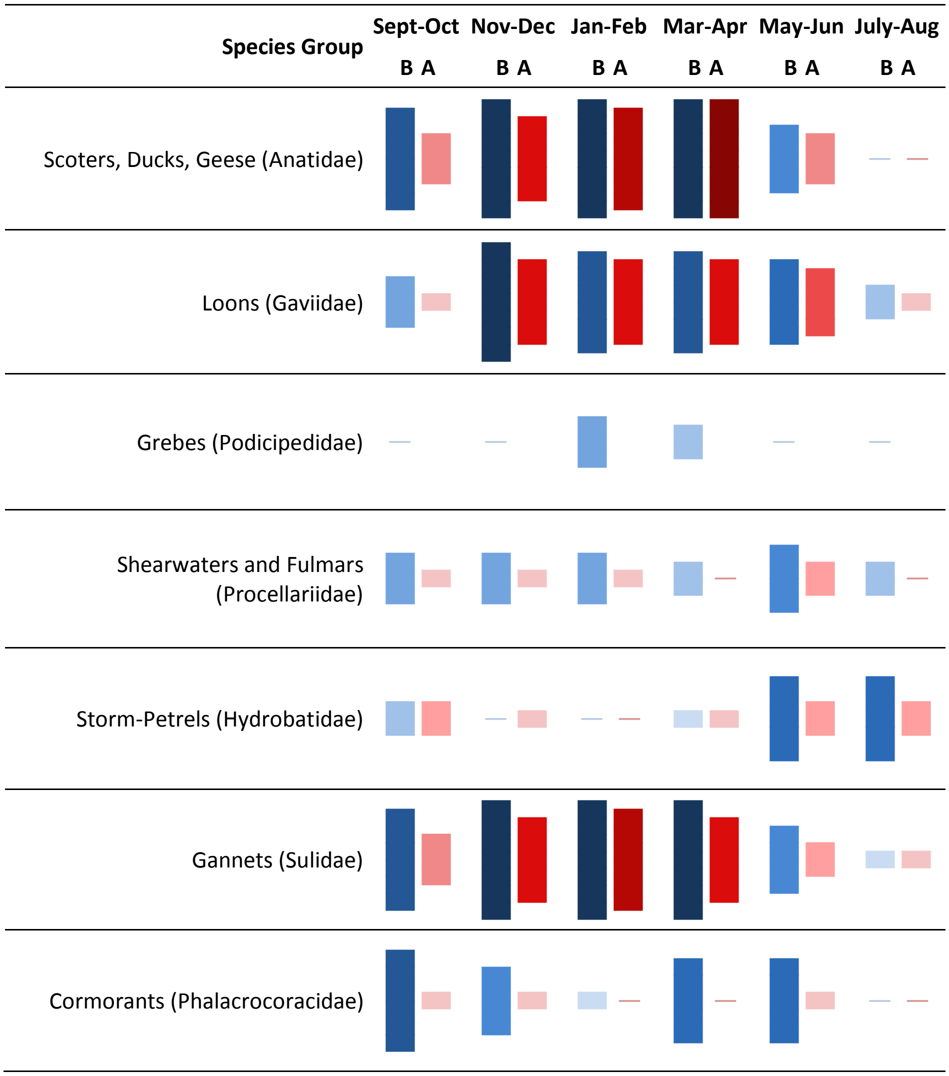


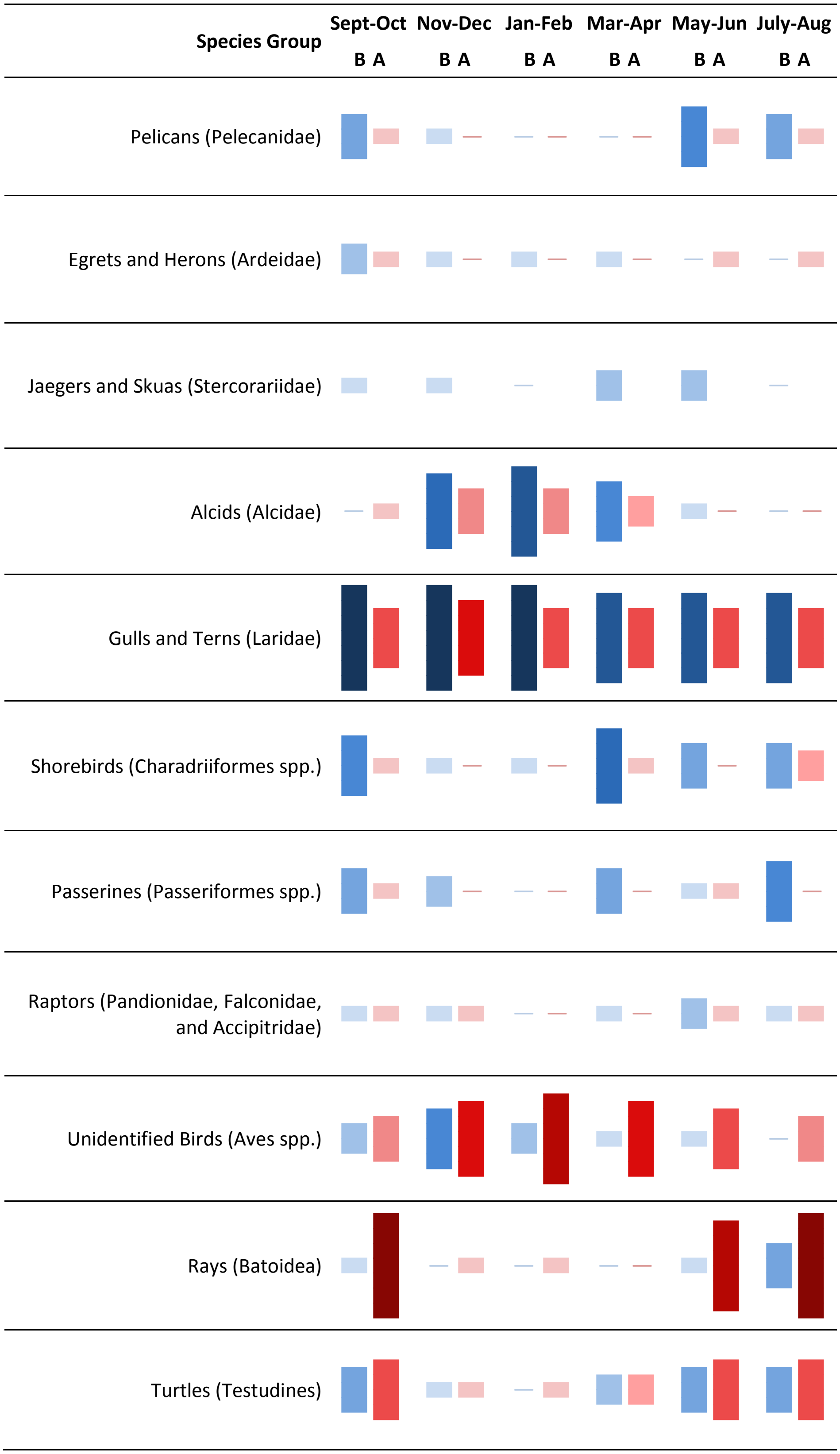
Figure 11-30. Red bat observations from boat and video aerial surveys (September 2012 and September 2013).

Table 17-1. Figure legend for grouped species temporal charts. Darker and larger bars show time periods when a species or group was more commonly observed in surveys. Effort-corrected counts that correspond with percentile values are shown in kilometers.

Percentile:	0	≤50%	50-60%	60-70%	70-80%	80-90%	90-95%	95-100%
Effort-corrected count:	0	0.00319	0.0101	0.0354	0.0997	0.371	0.892	6.661
Method:	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial

Table 17-2. Temporal bar charts for all taxonomic groups with more than 10 observations in the boat (B) and video aerial (A) surveys. When fewer than ten animals were observed in one survey type they were left blank for that survey type (e.g. bats in the boat survey). Avian and non-avian animals are presented in taxonomic order.




Species Group
Sept-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
July-Aug
B A
B A
B A
B A
B A
B A
Pelicans (Pelecanidae)
Egrets and Herons (Ardeidae)
Jaegers and Skuas (Stercorariidae)
Alcids (Alcidae)
Gulls and Terns (Laridae)
Shorebirds (Charadriiformes spp.)
Passerines (Passeriformes spp.)
Raptors (Pandionidae, Falconidae, and Accipitridae)
Unidentified Birds (Aves spp.)
Rays (Batoidea)
Turtles (Testudines)

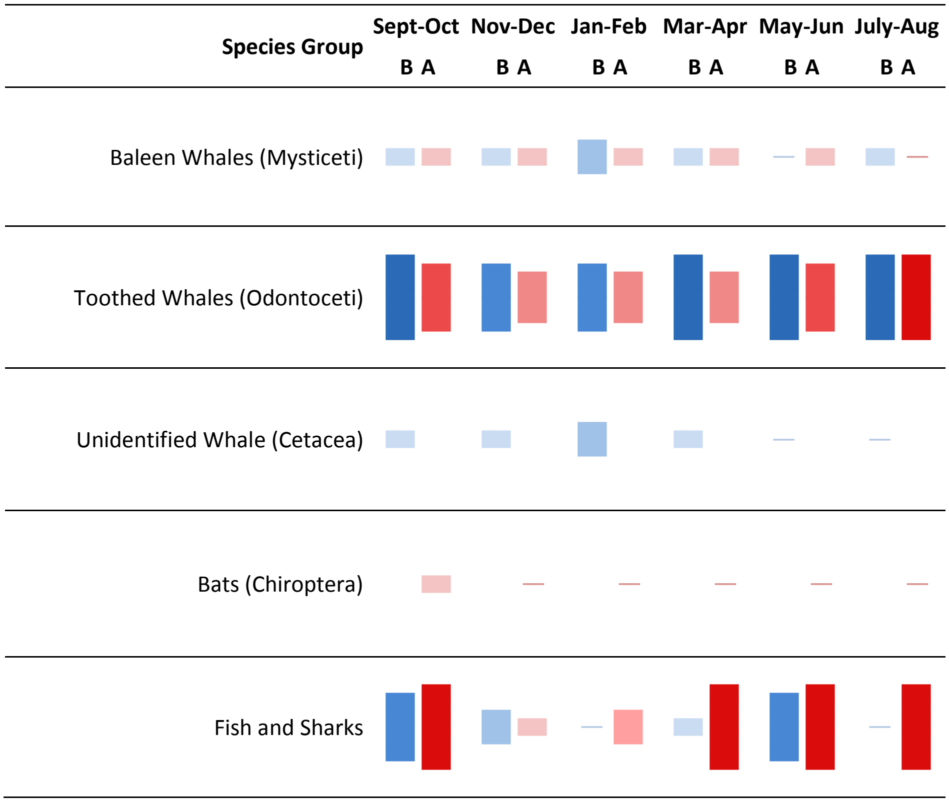
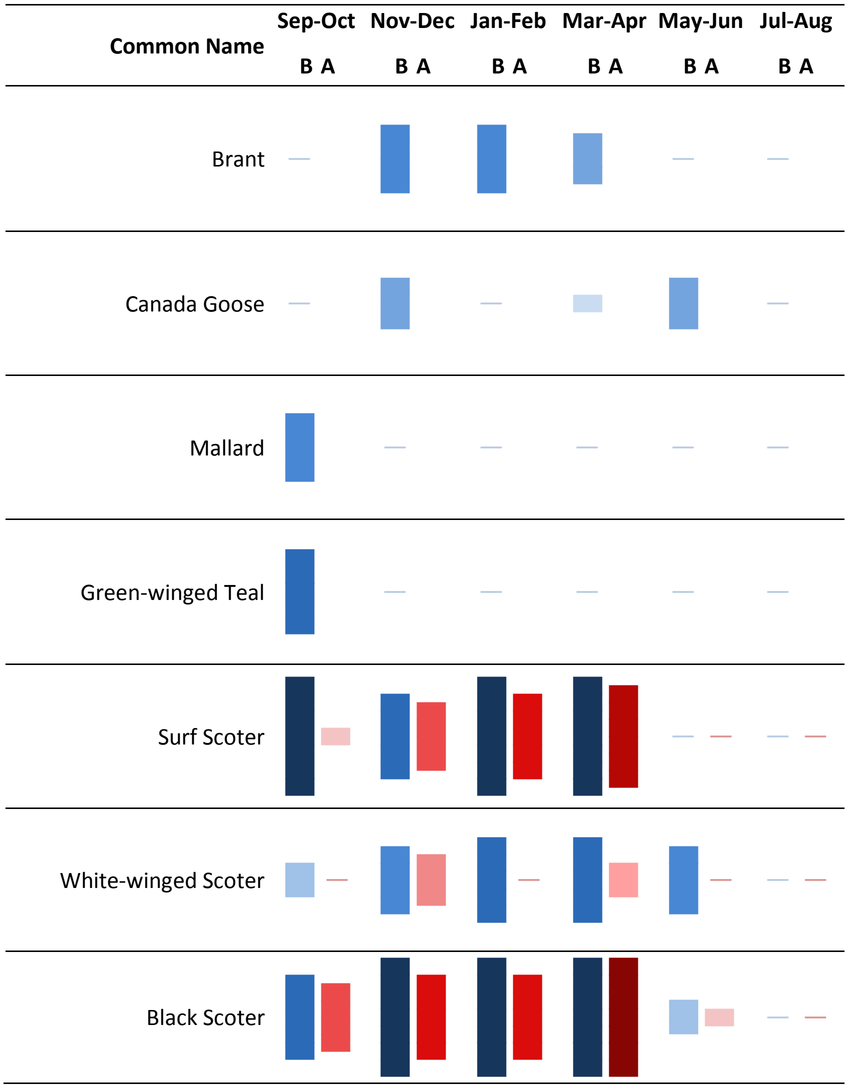
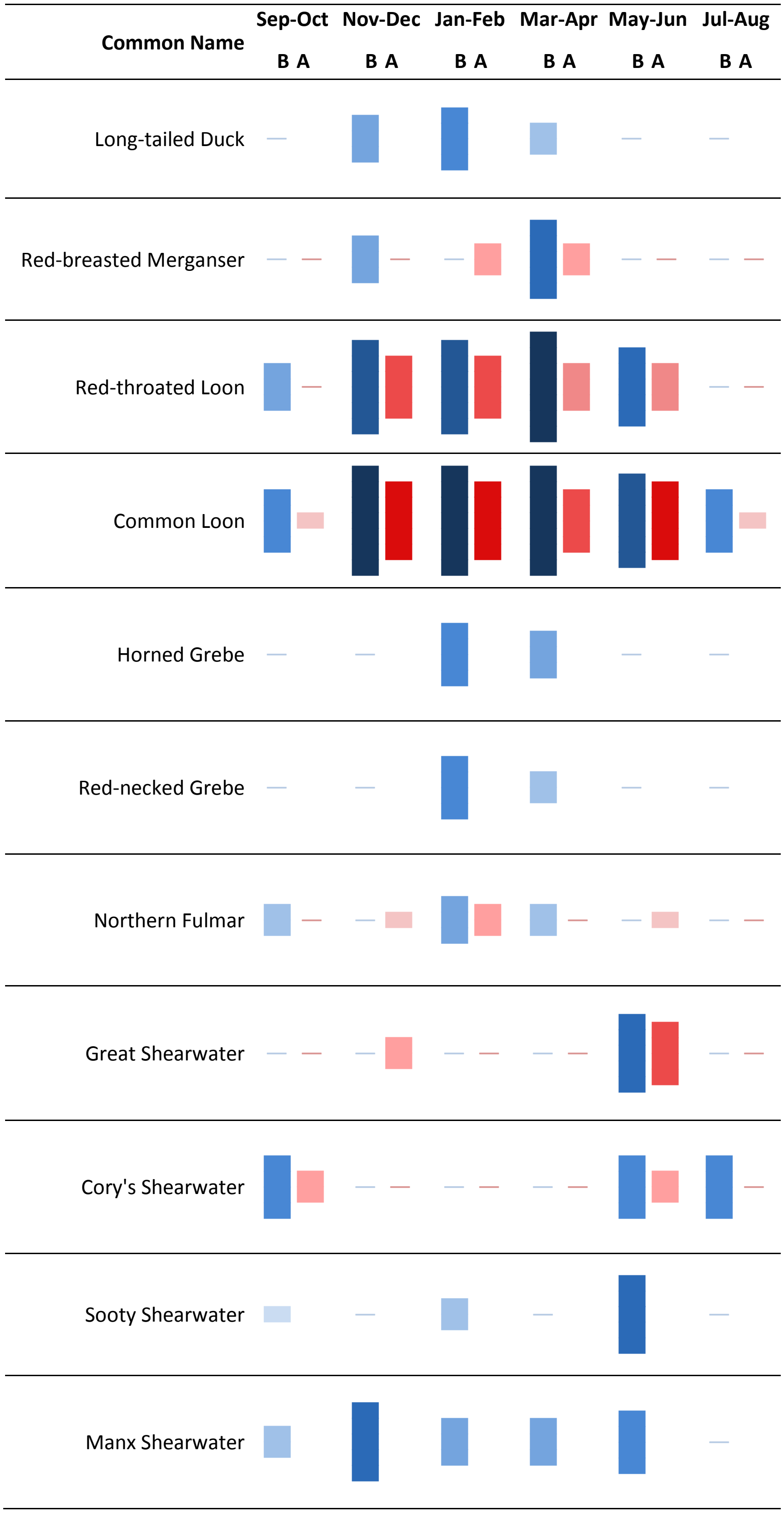

Species Group
Sept-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
July-Aug
B A
B A
B A
B A
B A
B A
Baleen Whales (Mysticeti)
Toothed Whales (Odontoceti)
Unidentified Whale (Cetacea)
Bats (Chiroptera)
Fish and Sharks

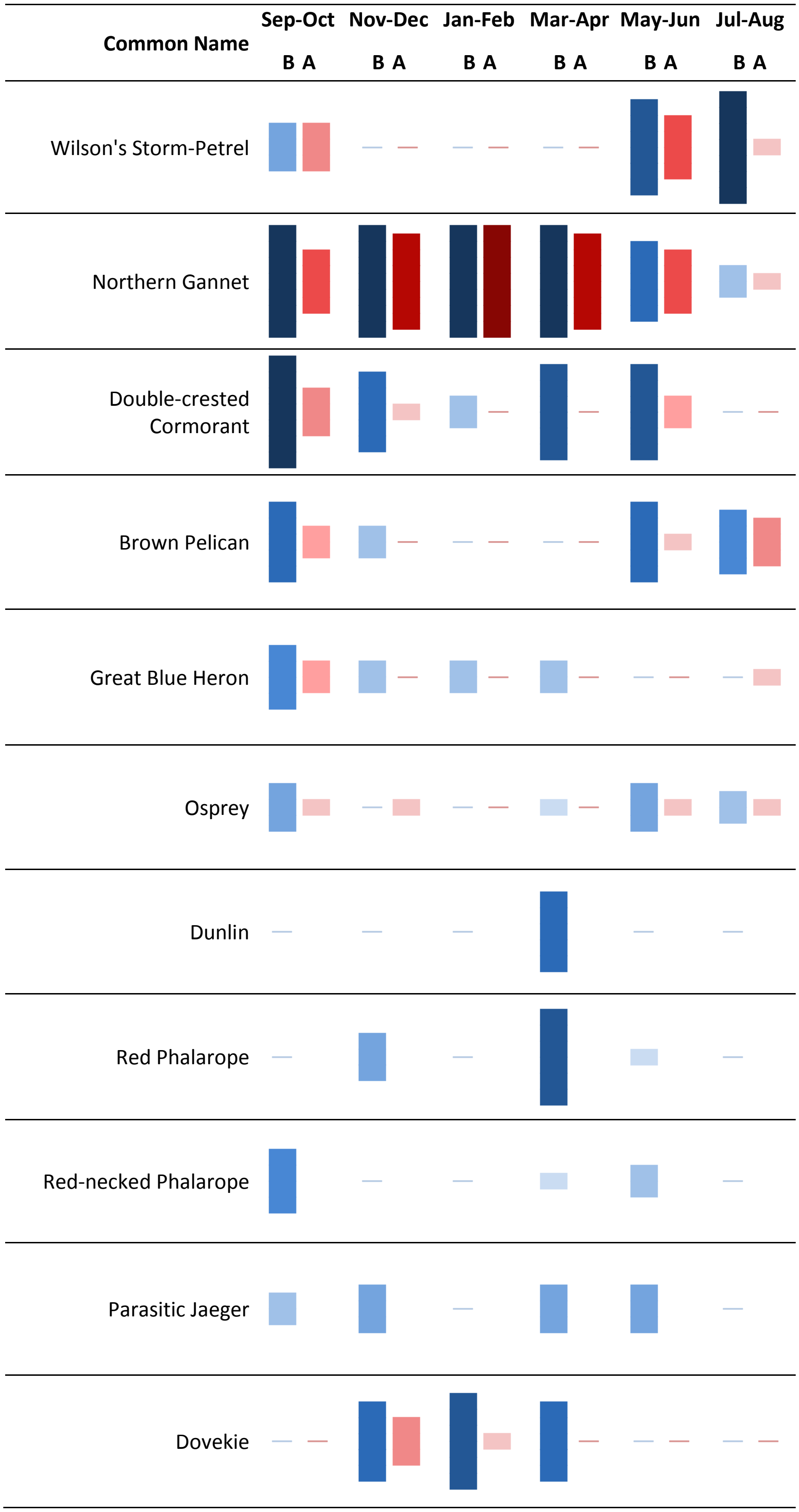
Table 17-3. Figure legend for individual species temporal charts. Darker and larger bars show time periods when a species or group was more commonly observed in surveys. Effort-corrected counts that correspond with percentile values are shown in kilometers.

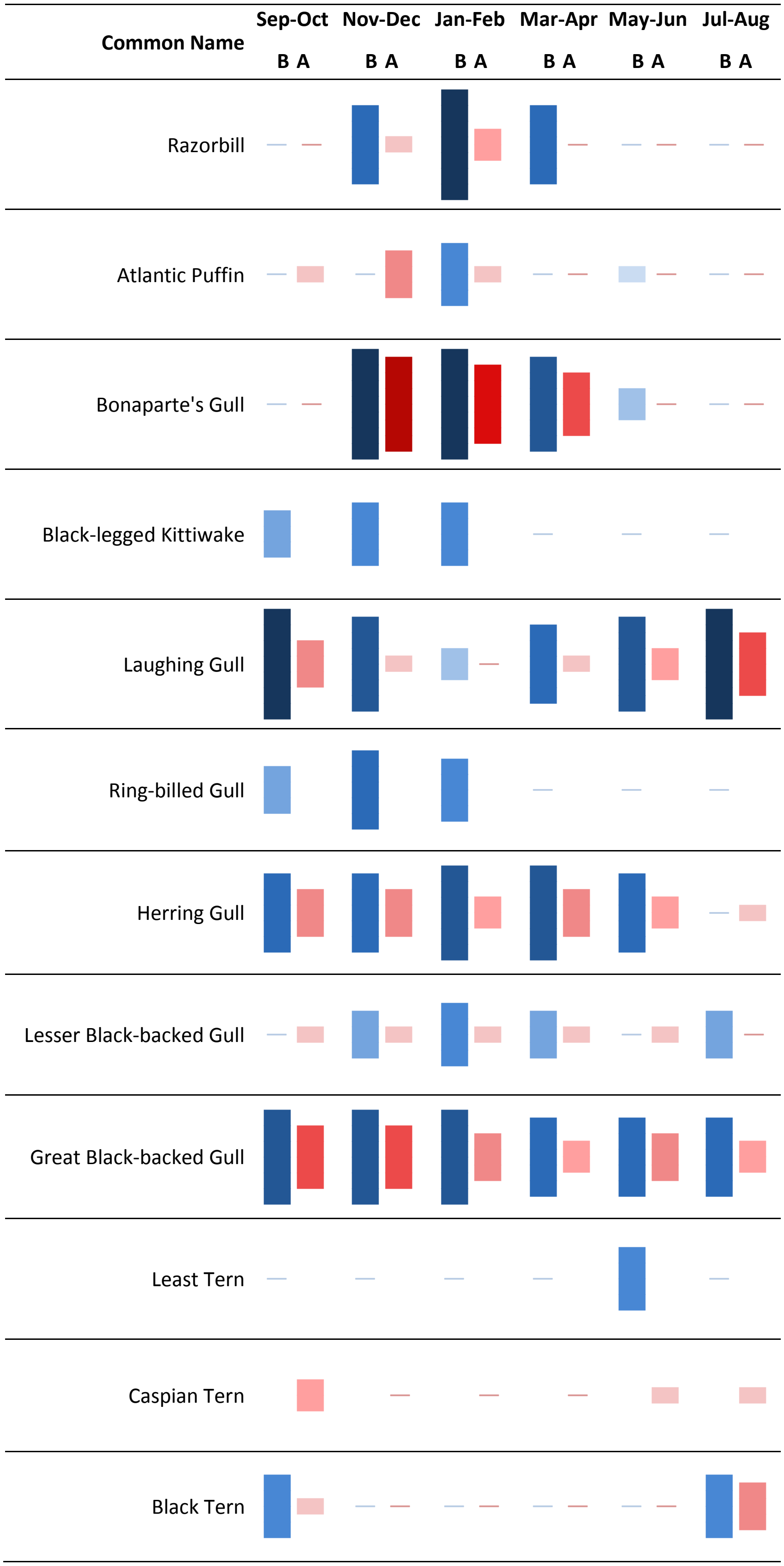
Percentile:	0	≤50%	50-60%	60-70%	70-80%	80-90%	90-95%	95-100%
Effort-corrected count:	0	0.000543	0.00153	0.00490	0.0178	0.118	0.309	3.902
Method:	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial	Boat Aerial

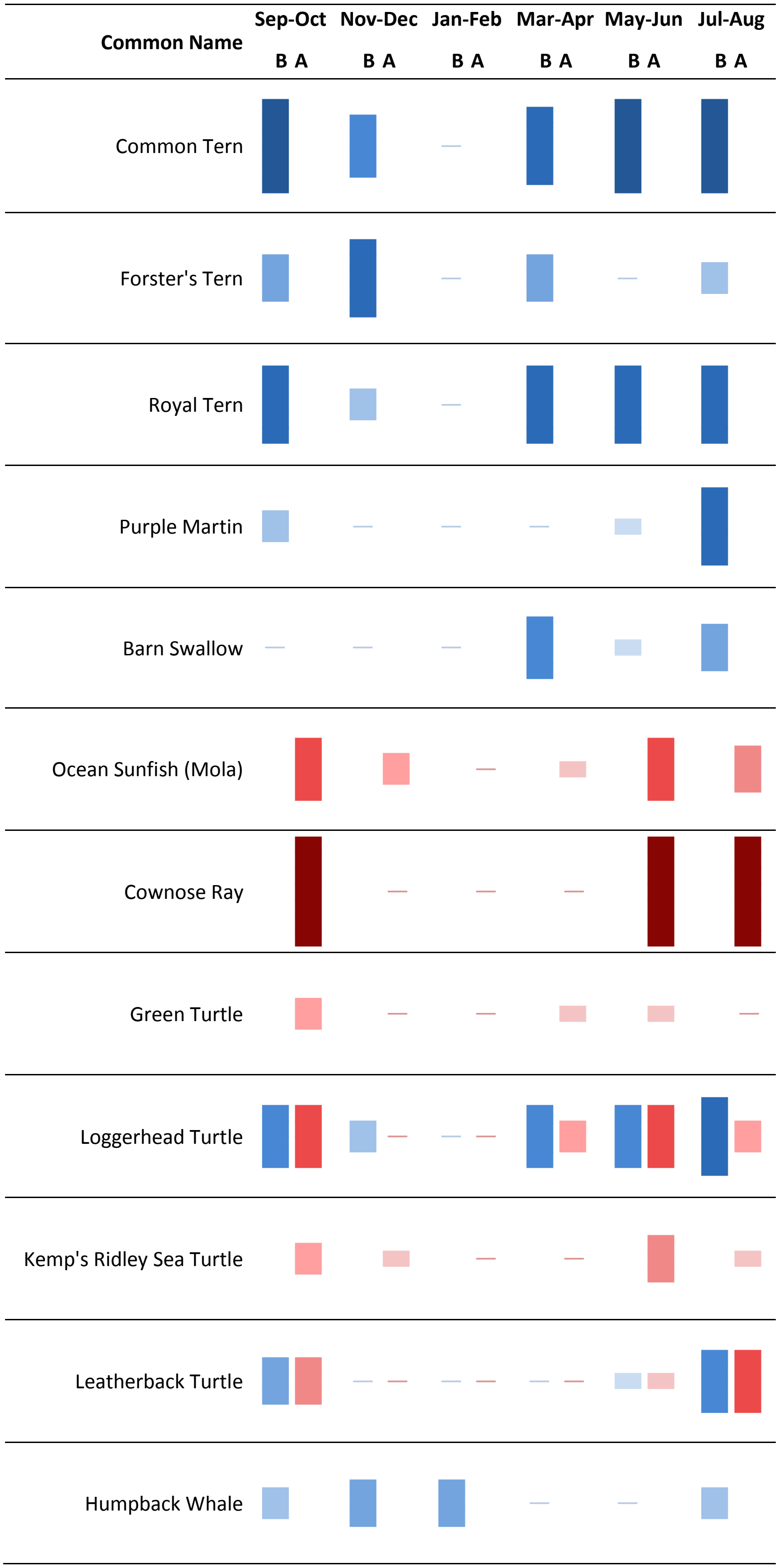
Table 17-4. Temporal bar charts for all individual species with more than 10 observations in the boat (B) and video aerial (A) surveys. When fewer than ten animals were observed in one survey type they were not calculated for that survey type (e.g. Brants in the video aerial survey). Avian and non-avian animals are presented in taxonomic order.

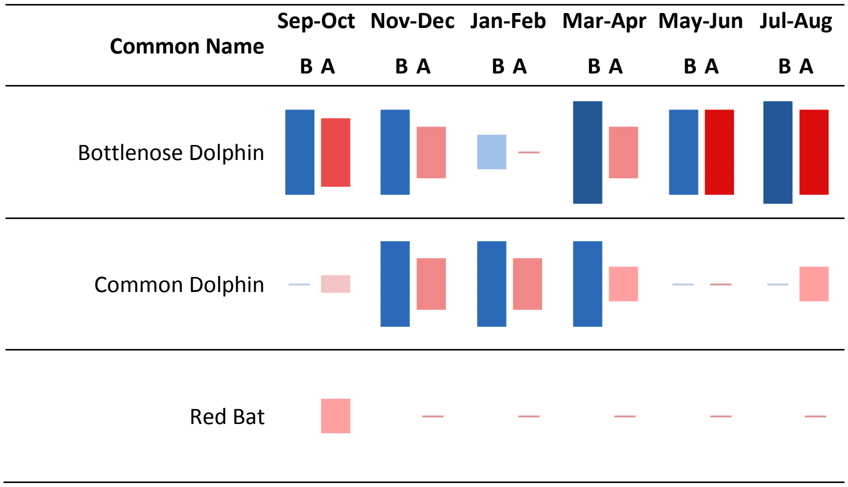



Common Name
Sep-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
B A
B A
B A
B A
B A
B A
Long-tailed Duck
Red-breasted Merganser
Red-throated Loon
Common Loon
Horned Grebe
Red-necked Grebe
Northern Fulmar
Great Shearwater
Cory's Shearwater
Sooty Shearwater
Manx Shearwater


Common Name
Sep-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
B A
B A
B A
B A
B A
B A
Wilson's Storm-Petrel
Northern Gannet
Double-crested Cormorant
Brown Pelican
Great Blue Heron
Osprey
Dunlin
Red Phalarope
Red-necked Phalarope
Parasitic Jaeger
Dovekie


Common Name
Sep-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
B A
B A
B A
B A
B A
B A
Razorbill
Atlantic Puffin
Bonaparte's Gull
Black-legged Kittiwake
Laughing Gull
Ring-billed Gull
Herring Gull
Lesser Black-backed Gull
Great Black-backed Gull
Least Tern
Caspian Tern
Black Tern


Common Name
Sep-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
B A
B A
B A
B A
B A
B A
Common Tern
Forster's Tern
Royal Tern
Purple Martin
Barn Swallow
Ocean Sunfish (Mola)
Cownose Ray
Green Turtle
Loggerhead Turtle
Kemp's Ridley Sea Turtle
Leatherback Turtle
Humpback Whale


Common Name
Sep-Oct
Nov-Dec
Jan-Feb
Mar-Apr
May-Jun
Jul-Aug
B A
B A
B A
B A
B A
B A
Bottlenose Dolphin
Common Dolphin
Red Bat

Chapter 12: Density modeling for marine mammals and sea turtles with environmental covariates

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

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Chapter 12 Highlights

Density modeling for marine mammals and sea turtles

Context[1]

Part IV of this report contains several instances in which boat survey and digital video aerial survey datasets were modeled with environmental covariates to describe populations of interest (Chapters 12-14). Cetaceans and sea turtles are taxa of regulatory and conservation concern in the Mid-Atlantic region. By combining boat and aerial survey data for these taxa with remotely sensed environmental data, we can use spatial-temporal modeling methods to estimate habitat influences on distributions and relative abundance, and explore potential overlap with offshore human interests, including Wind Energy Areas (WEAs). In some cases, one survey method was significantly better than the other for surveying a particular taxon, as with digital video aerial surveys for sea turtles. Both boat and aerial surveys were suspected to inaccurately estimate group size for cetaceans, so models were developed to identify patterns of occurrence of delphinid pods, rather than abundance of individual animals.

Study goal/objectives addressed in this chapter

Describe the distributions of cetaceans and sea turtles across the Mid-Atlantic Outer Continental Shelf using boat and aerial survey data.

Highlights

- At least five different species of dolphins and porpoises were observed in surveys, four of which occurred within the Maryland study area. Five species of baleen whales were also observed, two of which occurred within the Maryland study area.
- Bottlenose dolphins were observed primarily closer to shore in spring through fall. Primary productivity and sea surface temperature were also important predictors; models suggest minimal presence of the species in Mid-Atlantic WEAs during cooler months.
- Common dolphins were most frequently observed in offshore areas in winter and early spring.
- Five species of sea turtles were observed in boat and aerial surveys, all of which occurred within the Maryland study area.
- Turtles were much more frequently observed in digital aerial surveys than in boat surveys.
- Sea turtles were most abundant from May to October. In addition to water temperature, primary productivity and distance from shore were important influences, and sea turtles were primarily distributed offshore. There was substantial overlap of predicted habitat use with WEAs, particularly in the southern part of the Mid-Atlantic Baseline Studies (MABS) study area.

Implications

Small sample sizes made modeling difficult for some taxa, but results suggest that there may be overlap between cetacean and sea turtle distributions and areas of potential offshore wind development in the Mid-Atlantic. Given the protected status of these species, additional research may be indicated on their distributions, as well as potential approaches for mitigating the effects of wind power development.

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[1] For more detailed context for this chapter, please see the introduction to Part IV of this report.

Abstract

Marine mammals and sea turtles are often of management and conservation concern, and effective management of these large marine vertebrates requires reliable information on distribution, abundance, and trends in habitat use. This chapter utilizes observation data of cetaceans and sea turtles from boat and digital video aerial surveys to describe the distributions of these taxa across the Mid-Atlantic Outer Continental Shelf, determine the habitat or environmental drivers of these distributions, and identify the locations and timing of potential overlap with areas of potential offshore wind energy development. Dolphin, porpoise, whale, and sea turtle observations from boat and aerial surveys were assessed for species composition, relative numbers, and geographic and temporal distributions. Relative density estimates were produced for sea turtles (using digital video aerial survey data) and bottlenose dolphins (using boat survey data) using both general linear and general additive models (GLMs and GAMs, respectively). For both bottlenose dolphins and sea turtles, GAMs proved more effective at modeling the density of these animals with relation to spatial covariates then their counterpart GLMs. Bottlenose dolphins were observed primarily in more near shore areas in spring, summer, and fall, in areas with high levels of primary productivity and higher sea surface temperatures. There were few observations of the species during cooler months. Sea turtles were also most abundant from May to October, and their densities were correlated with warmer water temperatures and farther distances from shore. There was substantial overlap between sea turtle distributions and WEAs, particularly in the southern part of the Mid-Atlantic Baseline Studies (MABS) study area. There was also overlap between WEAs and predicted habitat usage of bottlenose dolphins and other delphinids, although the degree of this overlap was difficult to discern with the datasets used in this analysis.

Introduction

Marine mammals and sea turtles are often of management and conservation concern, as their large home ranges and habitat requirements may overlap and conflict with human activities such as offshore development and commercial fishing (Trites et al. 1997). As the United States pursues the development of offshore wind energy it will be important to consider interactions with other offshore uses including commercial fisheries, shipping lanes, recreational areas, and military areas, as well as areas of ecological importance.

Cetaceans (whales, dolphins, and porpoises) and sea turtles represent a particular challenge for population monitoring, due to their vast ranges and cryptic behaviors, resulting in only small portions of the animals' bodies being visible (Hammond et al. 2002). However, the conservation and management of these large marine vertebrates requires reliable information on distribution, abundance, and trends in habitat use, and quantitative research is essential for overcoming these challenges. Acoustic disturbance has been recently identified as a primary concern for marine mammals and sea turtles within the marine environment (Dow Piniak et al. 2012; Bergström et al. 2014). This includes such noises as shipping, seismic surveys, blasting, pile driving, and operational wind turbines. The severity of avoidance and displacement effects appear to vary with a variety of factors, including the species being exposed as well as the frequency, intensity, and duration of noise (Goold 1996; McCauley et al. 2000; Madsen et al. 2002). These disturbances may not only deter marine species from development areas, but have the potential to be detrimental to the animals in other ways as well, including a variety of behavioral, acoustical, and physiological effects (Nowacek et al. 2007; Southall et al. 2007; Tyack et al. 2011).

The Mid-Atlantic Outer Continental Shelf (OCS) is of key importance to many large marine species during both breeding and nonbreeding periods. This region also acts as a key migration route for one of the most sensitive and protected marine mammals, the North Atlantic Right whale (Kenney et al. 2001). The most recent marine mammal stock assessment reports (SARs) for the North Atlantic place 13 cetacean and three pinniped species within the MABS study area, all of which are protected under the Marine Mammal Protection Act (Waring et al. 2011; Waring et al. 2013). It is also important to note that sound travels long distances underwater, and just to the east of the MABS study area (over the shelf break), a whole new group of deep diving cetacean species that are highly sensitive to marine noise, such as sperm and beaked whales, may also be exposed to development noise from the MABS study area (Mate et al. 1994; Cox et al. 2006). Furthermore, five of the seven extant species of sea turtle occur in the Mid-Atlantic OCS, and all five are protected under the Endangered Species Act. The abundance of large marine megafauna within the Mid-Atlantic OCS makes it a potentially sensitive and challenging location for offshore development.

Given the difficulties associated with estimating animal abundance (or occurrence) based on count data from large-scale surveys (Royle et al. 2007), modeling spatial and temporal distributions of animals can help to determine areas of high and low use and inform decisions for development (Garthe and Hüppop 2004; Kinlan et al. 2012). However, distributions of animals in the offshore environment can be highly variable, and are driven by environmental and biophysical factors working at a variety of temporal and spatial scales (O'Connell et al. 2009; Zipkin et al. 2010). By combining boat and aerial survey data with oceanographic habitat and climatological data, we can use spatial-temporal modeling methods to estimate these habitat influences on the distributions and relative abundances of a species of interest, and explore potential overlap with offshore human interests. Accurately assessing such relationships is essential for predicting spatial distributions and the potential shifts that could occur in these geographic distributions. In this study, we quantify sea turtle and marine mammal densities seasonally throughout the MABS study area; develop models to examine spatial patterns and trends based on interactions with environmental conditions; and help identify species at potential risk from turbine construction and operation due to their movements, behavior, or migration strategies.

Methods

Survey methods

Standardized boat-based surveys are a widely used method of obtaining density estimates for birds, sea turtles, and marine mammals (Thompson and Harwood 1990). In our boat-based surveys, transects extended perpendicularly to the coastline, from three nautical miles offshore to the 30 m isobath or the eastern extent of the Mid-Atlantic Wind Energy Areas (WEAs), whichever was furthest. Boat transects were spaced 10 km apart and extended at least one transect north and south of each WEA (Figure 12-1 to Figure 12-3). We conducted eight surveys per year on a scheduled basis as the weather allowed, between April 2012 and April 2014, as part of the Mid-Atlantic Baseline Studies (MABS) project. Eight of the 16 surveys (from March 2013 to February 2014) also included extensions of three transects farther west into Maryland state waters. Two pairs of observers alternated 2-hour shifts collecting standard line-transect data using distance sampling (Buckland et al. 1993). While the recorder entered data into the program dLOG (R.G. Ford Consulting, Inc.), and regularly updated changes in environmental conditions (sea state, etc.), the observer scanned the horizon, focusing on one forward quadrant on either side of the vessel. We continuously recorded the species, count, distance, and angle to the observation (see Chapter 6 for more details on data collection methods). Cetaceans were photographed when possible. Photos were submitted for individual identification using the established North Atlantic fin whale, humpback whale, and North Atlantic right whale catalogues. Surveys were conducted in "passing mode", meaning that the boat stayed on transect and at constant survey speed (10 knots) except when complying with National Marine Fisheries Service (NMFS) rules about approaching marine mammals, including rules regarding vessel speed and encounters with endangered North Atlantic Right Whales (*Eubalaena glacialis*). More detailed methods for boat surveys may be found in Chapter 6.

Fifteen high resolution digital video aerial surveys were conducted by HiDef Aerial Surveying, Ltd. (hereafter, HiDef), across the MABS study area between March 2012 and May 2014 (Chapter 3). Each survey was completed using two small commercial aircraft, allowing complete coverage of the MABS study area in two to three days (weather permitting). Aerial transects were flown at high densities within the Delaware, Maryland, and Virginia WEAs to obtain accurate abundance estimates within these specific footprints; the remainder of the study area was surveyed on an efficient sawtooth transect path to provide broad-scale context for the intensive WEA surveys (Figure 12-4 to Figure 12-6). Beginning in March 2013, surveys included the addition of high-density video aerial survey transects in a large area south and west of the Maryland WEA (adding about 21% of additional transect length to the existing study design; Chapter 3). A fifteenth survey was conducted in August 2013, and covered only the Maryland WEA and the high-density Maryland Project area (Chapter 3). Recorded images were stored on heavy duty disk drives or solid state recording devices for subsequent review and analysis. Wildlife locations, taxonomic identities, and behaviors were determined from the video footage (Hatch et al. 2013).

Data preparation

Boat-based and aerial survey observations of marine mammals and sea turtles seen within the MABS dataset are summarized in Table 12-1 and Table 12-2, with effort data summarized in Table 12-3. Observations specific to the Maryland study area (shown in all map figures) are summarized in Table 12-4 and Table 12-5, with effort information in Table 12-6. All animals not identified to the species level were combined into an "unidentified" category. Due to the lack of data at the species level for the aerial surveys, sea turtle observations were grouped as a single taxon for all further analyses by season (Spring: Mar-May, Summer: June-Aug., Fall: Sept-Nov., Winter: Dec-Feb). The number of whale sightings from both surveys (n = 51) was not sufficient to produce descriptive models, and thus this taxon was excluded from further analysis.

Effort and species observation data were modeled using the "count" method (Hedley et al. 1999). Boat and aerial survey track lines were divided into segments approximately 5 km in length. Start and end locations of these segments were calculated using the COGO proportions function in ArcMap 10.2 (ESRI

2011). The location of the midpoint of each segment (latitude and longitude) was calculated using the feature to point command in ArcMap 10.2.

Oceanographic processes were evaluated as spatial covariates to predict marine mammal and sea turtle location and density. Sea surface temperature (SST) and chlorophyll *a* (Chl *a*), were extracted using the Marine Geospatial Ecology Toolbox (MGET) data products function in order to provide spatial coverage across the MABS study area (Roberts et al. 2010). SST and Chl *a* data were extracted as a monthly average, for all twelve months, at a 4 km spatial resolution. The monthly averages were then averaged by season. Additionally, the distance from shore (DFS) from each transect segment's midpoint to the nearest coastline was calculated (ESRI 2011).

Modeling detection probability

A conventional stratified analysis was conducted on the boat-based survey data in program DISTANCE to estimate the probability of detecting delphinids within a 5% truncation of the trackline (Laake 1994). In standard distance sampling a truncation limit of the largest distances, generally 5%, is set to avoid a size bias and increase the estimation of the detection function. Detection probability of bottlenose dolphin encounters across seasons was modeled at the species level as a smooth function of perpendicular distance. Common dolphin, unidentified dolphin, and sea turtle sightings were not included in this distance analysis due to the lack of total individuals. The sightings included in the line transect distance analysis only included those within the front 180 degree observation window from the boat, and thus effective strip width was used to calculate relative density of bottlenose dolphin encounters. Encounters of bottlenose dolphin groups (rather than individuals) were modelled due to uncertainty in group size estimates arising from "passing mode" surveys. Relative density modelling was stratified by season for spring, summer and fall (Figure 12-7 to Figure 12-9), as there were not enough sightings of bottlenose dolphins in winter. Candidate forms for the detection function were the half-normal model and hazard rate function with a cosine smoothing term (Buckland et al. 2001). Sea state, as recorded by observers on the Beaufort scale, was not included as a candidate covariate as no plausible detection functions were produced. Models were selected using Akaike's Information Criterion (AIC; Akaike 1973).

Aerial transects were treated as strip transects, whereby density was determined as the number of sightings per transect length of 5 km and strip width of 200 m, and detection was assumed to be perfect (Buckland et al. 2005). Relative density estimates from the aerial transects were only produced for sea turtles by season for spring, summer and fall, as there were not enough sea turtle sightings during the winter aerial surveys. Species specific aerial density estimates for marine mammals were not modelled due to the small sample size of individuals identified at the species level. Furthermore, a general "all delphinids" model was not run due to the challenges that arise by lumping multiple species that have distinct behaviors.

Building descriptive models

The covariates for each 5 km transect segment midpoint were joined with their corresponding density and input into R for model fitting. For the purposes of this study, both general additive models, or GAMs (using R package mgcv), and general linear models, or GLMs (using the built-in glm R function), were used in model development following a negative binomial family fitting response (Wood 2006; Dobson and Barnett 2011; R Core Team 2014). Both model outputs were a result of different combinations of covariates. Seven different models were used for each model type (Table 12-7 to Table 12-12). The selection of the best model was based according to the AIC score and the percent of deviance from the null model that the model explained (Table 12-7 to Table 12-12). The higher the percent of deviance explained from the null model, the better that particular model fits the input data. In cases where the AIC values of two models were very similar, the percent deviance was solely used as the deciding criterion for model selection.

Once a model had been chosen according the selection criterion above, a 4 km square gridded data set was created for each season to act as the predicting platform for the model results. This platform extended 25-30 km east of the WEAs, 30 km south of the VA WEA and 75 km north of the DE WEA. Every grid cell centroid was assigned a distance to shore value, as well as SST and Chl *a* values extracted from seasonal climatologies using the MGETs data products toolbox in ArcGIS (Roberts et al. 2010). The seasonal prediction grids were then passed to the chosen descriptive model for bottlenose dolphins and sea turtles using the predict.gam command in R. The estimated encounter rates from the bottlenose dolphin detection functions and the calculated relative density of sea turtles per strip segment were used as the model response variables. The output of the model was an estimate of the predicted relative density at 1 km^2 at the center of each grid cell according to the variables used in the chosen model. These predicted densities were scaled according to the 16 km^2 prediction grid, imported in ArcMap 10.2 as a raster data set, and smoothed using the point to raster conversion function (ESRI 2011). Missing (white) cells in the interpolated relative density maps indicate areas where no covariate data were available or the prediction grid limits ended.

Results

A total of 374 marine mammal and sea turtle sightings were reported in the MABS boat-based surveys, representing 1,349 individuals. Of these, 1,211 individuals were identified to the species level (Table 12-1). Of all observed marine mammal and sea turtle individuals, 1,200 were dolphins, 35 were whales, and 114 were sea turtles (Table 12-1). A total of 3,808 individual marine mammals and sea turtles were observed during the MABS aerial surveys (Table 12-2). Of these, 2,036 were dolphins, 3 were porpoises, 16 were whales, 5 were unidentified cetaceans, and 1,748 were sea turtles (Table 12-2). A total of 278 individual marine mammal and sea turtles were observed within the Maryland study area from boat based surveys (Table 12-4). Of these individuals, 259 were dolphins, 7 were whales, and 120 were sea turtles (Table 12-4).

A total of 1,489 individual marine mammal and sea turtles were observed within the Maryland study area from aerial surveys (Table 12-5). Of these individuals, 1,119 were dolphins, 3 were whales, 1 was a porpoise, and 366 were sea turtles (Table 12-5). Locations of whales, dolphins, and sea turtles observed on the boat surveys are presented in Figure 12-1 to Figure 12-3. Locations of whales, dolphins, and sea turtles observed on the aerial surveys are presented in Figure 12-4 to Figure 12-6. MABS aerial survey observations were highest in May and July (late spring, mid-summer) and aerial observations within the Maryland study area were highest in the summer and fall (Table 12-3, Table 12-6). Humpback whales (*Megaptera novaeangliae*) were the most common large whales observed in the MABS study, although minke whales (*Balaenoptera acutorostrata*) were the most common whale observed within the Maryland study area. Five species of whales were observed in the MABS study, with two species observed within the Maryland study area (Table 12-1, Table 12-2, Table 12-4, Table 12-5). Bottlenose dolphins (*Tursiops truncatus*) were the most common of the four delphinid species observed in the MABS study and within the Maryland study area, and were observed mainly inshore (Table 12-1, Table 12-2, Table 12-4, Table 12-5, Figure 12-2, Figure 12-5). Common dolphins (*Delphinus delphis*) were the next most abundant species, and were more commonly observed offshore (Figure 12-2, Figure 12-5). Sea turtle distributions were primarily offshore (Figure 12-3, Figure 12-6), and loggerhead sea turtles (*Caretta caretta*) were the most abundant of the five species observed within both the MABS and the Maryland study areas (Table 12-1, Table 12-2, Table 12-4, Table 12-5).

In all cases, GAMs outperformed GLMs (Table 12-7 to Table 12-12). The encounter rate (number of sightings per km^2) model for bottlenose dolphins in the spring predicted a strong nearshore-oriented density gradient within the prediction area, and the corresponding density map correlated well with the bottlenose dolphin sighting data spatially. The highest predicted encounter rates were at the mouth of the Delaware Bay (Figure 12-10), as well as near the western edges of the Delaware and Maryland WEAs. Like the spring model, the encounter rate model for bottlenose dolphins in the summer predicted very strong nearshore-oriented, northerly concentrated density gradient in and around the mouth of the Delaware Bay (Figure 12-11), including a density of encounters near the western edges of the Delaware and Maryland WEAs. Like the spring model, the encounter rate model for bottlenose dolphins in the fall predicted a strong nearshore-oriented density gradient along the prediction area, with the highest densities seen farther south at the mouth of the Chesapeake Bay (Figure 12-12). The fall model predicted no substantial encounter overlap with any of the WEAs.

The relative density model for sea turtles in the spring predicted a very strong off shore-oriented, southern density gradient (Figure 12-13), including high densities within the Virginia WEA. The density model for sea turtles in the summer predicted a less dense gradient across the southeastern portions of the MABS study area, including areas near and within the Virginia WEA (Figure 12-14). In the summer density map, the relative density of sea turtles also begins to migrate north. The predicted density model for sea turtles in the fall predicted a less dense, latitudinally uniform density gradient (Figure 12-15). The corresponding fall density map predicted high densities within all three WEAs.

Discussion

Effective conservation plans require precise assessments of the spatial distributions and densities of the species they are trying to protect. With such information, policy makers, regulators, and managers can predict how a species' distribution may respond to changes within their environment, including naturally occurring fluctuations and human activities. Species distribution modeling can provide a measure of a species' spatial density over a desired region. Our primary goal was to quantify sea turtle and marine mammal densities seasonally throughout the MABS study area by developing models to examine spatial patterns and trends based on interactions with environmental conditions, in hopes of identifying species that could be exposed to future turbine construction and operation. By applying spatial modelling techniques to line transect boat-based survey data and high resolution digital video aerial survey footage, we produced relative density estimates of sea turtles and relative encounter rate estimates for Bottlenose Dolphins (as dolphin sightings may represent either an individual or a pod) across the MABS study area by correlating species abundance to spatial and environmental covariates. One of the possible advantages gained by utilizing a spatial model to estimate density is an enhancement in the estimated precision, as deviation in density can be explained by relatively few spatial covariates (Hedley et al. 1999).

The combined effort of both surveys did not yield enough whale sightings to investigate potential density relationships with environmental covariates. An examination of publicly available whale data outside the MABS study area was conducted, but there were still insufficient sightings within the last ten years to allow for parameterization of a model (the 10-year temporal limit was set to avoid any variation in sighting patterns that could be caused by climate change). It is still important to note, however, that large whales were observed across the survey area during both surveys, including within each of the WEAs. Of particular importance, nine North Atlantic right whales were observed during the surveys of the MABS study area, of which none occurred within the Maryland study area. Currently, North Atlantic Right Whales are among the most endangered whales in world, with an estimated 455 individuals left in the western North Atlantic (Fisheries 2015). They are protected under the United States Endangered Species Act (ESA) as well as the Marine Mammal Protection Act (MMPA). Vessel strikes and entanglement in fishing gear account for nearly half of all North Atlantic right whale mortality since 1970 (Knowlton and Kraus 2001). Considering hearing is a sensory modality for these animals, as well as most other marine mammals, it is important to understand the potential increase in underwater noise posed by construction of offshore wind energy facilities. A study published in 2012 discovered that a decrease in underwater noise was associated with a decrease in baseline levels of stress-related hormones, such as glucocorticoids and cortisol, which are associated with chronic stress, and if not produced at proper levels can hinder the processes of a successful birth and even lead to adult mortality (Rolland et al. 2012). A recent passive acoustic study showed that North Atlantic right whales were present off the coasts of North Carolina and Georgia in all seasons, with peaks in abundance in autumn and winter, when they were not expected to be present (Hodge et al. 2015). We encourage further data collection in the region to better understand the distribution of large whales, in particular the North Atlantic right whale, in relation to environmental covariates and the position of the WEAs.

For both bottlenose dolphins and sea turtles, GAMs proved more effective at modelling the density of these animals with relation to spatial covariates than their counterpart GLMs. This is due to GAMs' capacity to model the non-linear nature of ecological data and produce complex response curves (Guisan et al. 2002; Venables and Dichmont 2004). It is also important to look at the effectiveness of each models capacity to model temporal trends. GLMs are generally used in modelling long-term trends, such as annual outcomes, while GAMs are better at modelling short term responses, such as across seasons (Cheng and Gallinat 2004). It is also important to note, however, that if not used carefully, GAMs can seriously over-fit data, and, thus, have low predictive power. GAMs also do not allow for the depiction of the interaction of two or more spatial covariates.

The relative density of bottlenose dolphin encounters within the MABS study area during the spring was explained by Chl *a* and DFS, the summer model was best explained by only SST and Chl *a*, and the fall model was best explained by SST and DFS. The relationship with SST may be attributed to the bottlenose dolphins' migratory behavior, as the species generally moves south as temperatures decline (Barco et al. 1999; Natoli et al. 2005). It is also probable that there are permanent residents, transients, and seasonal migrants of this species that occupy estuarine, coastal, and offshore waters from Florida to New Jersey (Urian et al. 2009). North of Cape Hatteras, North Carolina, bottlenose dolphins display a bimodal distribution with coastal and offshore components (Kenney 1990), and the Mid-Atlantic study area likely contains several different coastal morphotypes at different times of year, including both Northern Migratory and Southern Migratory stocks (Waring et al. 2013).The relationship between bottlenose dolphin encounter rates and DFS in this study is likely due to the inshore distribution of the coastal ecotype of bottlenose dolphins during the spring, summer, and fall seasons (Kenney 1990; Gannon and Waples 2004). It is possible that during the spring and fall months, resident coastal ecotype dolphins were surveyed more often, thus, producing the very nearshore density gradient observed in this study. In summer, however, the influx of transient populations may have produced a more robust density gradient from west to east. The association with high areas of Chl *a* may be attributed to delphinids' capacity to utilize areas of high primary productivity for feeding, particularly in and around the mouths of the Chesapeake Bay and Delaware Bay (Young and Phillips 2002). It is important to note that the development of the bottlenose dolphin models excluded dolphins lumped into the "unidentified" category, of which some proportion were likely bottlenose dolphins.

The relative density of sea turtles during the spring was best explained by SST and DFS. The relative density of sea turtles during the summer was best explained by SST and Chl *a*, while the fall model was best explained by only DFS. Past aerial surveys have shown that Loggerhead sea turtles, in particular, migrate into Mid-Atlantic coastal waters at depths of 60 m or less as the water warms during the spring (Shoop 1980). This would explain the higher density of sea turtles predicted in the spring, as roughly 60% of the identified sea turtles from both surveys were loggerheads. In general, there was a decreasing trend in density from spring to fall. The most common sea turtles observed in the aerial survey were loggerhead and leatherback sea turtles. Prime nesting for these two species occurs from March to September along the east coast of the United States (Miller et al. 2003; Rabon Jr et al. 2003). As nesting of female sea turtles occurs on sandy beaches, we would expect the sexually mature females to be closer to shore during the nesting season. It is possible that the aerial survey did not efficiently survey the nesting population during the summer, as surveys did not extend within 5.5 km of shore in most locations; this could explain the lower predicted densities than in spring. Furthermore, the northern migration of predicted densities during the summer and fall could be a result of the mixing of the northern Labrador and Gulf Stream currents. The complete mixing of the these currents around the survey region occurs in late summer and early fall (Talley and McCartney 1982; Rossby and Benway 2000). The delayed uniform mixing of these currents has the potential to hinder the northern migration of these turtles. This is also likely why so few turtles were observed in the winter, as bottom temperatures in the Mid-Atlantic drop to 10°C or less by mid-December, a known lethal thermal limit for some species of sea turtles (Schwartz 1978; Lutcavage and Musick 1985; Hawkes et al. 2007). It is also possible that this delayed mixing accounts for the greater number of turtles observed in the summer as it is estimated that turtles within the MABS study area spend about 25% of the time at the surface basking during the spring (cooler water temps), as opposed to about 5% of the time during the summer and fall when current mixing has occurred (Barco et al. 1999).

Sea turtles and offshore wind energy development in the Mid-Atlantic

Five of the seven extant species of sea turtle occur in the Mid-Atlantic study area, and all five are protected under the Endangered Species Act. As such, they are likely to be priority species for regulators during the offshore wind environmental permitting process. Sea turtles are uncommon in European waters, so no information is available about their interactions with offshore wind facilities. Sea turtles could potentially be affected by offshore wind energy development in several ways, however, including noise from seismic surveys, construction, and operations; electromagnetic fields; vessel collisions; and changes to habitat caused by artificial reef effects (Read 2013).

Construction of offshore wind facilities has been identified as the development period with the most potential risks for sea turtles, due to noise from pile driving and other activities, though the potential for injury remains largely unknown (Michel 2013). Sea turtles can detect low-frequency sounds (Lenhardt et al. 1983; Dow Piniak et al. 2012), and the frequencies emitted by seismic airguns, offshore drilling, low-frequency and mid-frequency sonar, pile driving, cargo vessels, and operational wind turbines are all within the underwater hearing range of Leatherback sea turtles (Dow Piniak et al. 2012). Sea turtles have exhibited startle responses when exposed to low frequency sounds and vibrations in a laboratory setting (Lenhardt et al. 1983), and laboratory and *in situ* studies on seismic airguns for offshore oil and gas exploration have showed changes in sea turtle swimming pattern and orientation (O'Hara and Wilcox 1990) and a range of avoidance behaviors up to at least one kilometer away from the source (O'Hara and Wilcox 1990; McCauley et al. 2000). Sea turtles are known to collide with vessels, and are also displaced from areas with vessel traffic, though observed responses to boat noise have varied with species (Samuel et al. 2005; Lester et al. 2013).

During operations of offshore wind facilities, sea turtles may be displaced due to turbine or vessel noise, or may aggregate around turbine foundations due to artificial reef effects, which change local habitats (Read 2013). Similar aggregation patterns have been observed around oil rigs in the Gulf of Mexico (Continental Shelf Associates 2004). The degree to which turbines may aggregate sea turtles will likely vary by location and other factors, and the effects on individuals or populations are unclear. Likewise, past studies have shown that electromagnetic fields (EMF) and heat signatures associated with offshore turbines have the potential to affect species such as sea turtles that use geomagnetic cues during migration (Lohmann et al. 2008). Data on the effects of EMF on sea turtles are generally lacking, however (Read 2013), and we know of no studies to date that have assessed whether EMF emissions from subsurface cables at operational facilities influence navigational decisions of turtles.

Overall, our results indicate that there is overlap between predicted habitat usage of sea turtles and the placement of WEAs in the Mid-Atlantic. Chesapeake Bay and the coastal waters of Virginia are known to serve as a key summer developmental habitat for juvenile sea turtles, particularly loggerheads and Kemp’s ridley sea turtles, thus placing the Virginia WEA in a potentially sensitive location (Lutcavage and Musick 1985). During spring, summer, and fall, the relative density of sea turtles did not change drastically, though the distribution of turtles across the MABS study area varied substantially; of note, the Maryland study area had lowest densities of turtles in the spring, and highest densities in the fall (Figure 12-13 to Figure 12-15). Winter is the time period where the likelihood of interactions between offshore construction and sea turtles is lowest, but winter is a difficult time for offshore construction, and most development activities are likely to occur in the other three seasons. As such, and given the group's conservation status, the development of techniques to avoid or reduce interactions between sea turtles and construction activities, vessel traffic, and other development activities should be considered a priority. The development of taxon-specific effects data is also a key area for additional research.

Bottlenose dolphins and offshore wind energy development in the Mid-Atlantic

All cetaceans that occur in the U.S. are protected under the Marine Mammal Protection Act. Cetaceans use sound for communication, and some, like dolphins, also use echolocation to navigate through their environment and hunt for prey. Acoustic disturbance has been recently identified as the primary concern for marine mammals with regards to offshore wind development in Europe (Bergström et al. 2014). This may include noise from seismic surveys, blasting, pile driving, and operational turbines. The severity of avoidance and displacement effects appear to vary with a variety of factors, including the frequency, intensity, and duration of noise, as well as species and time of year (Goold 1996; McCauley et al. 2000; Madsen et al. 2002). European studies have indicated that Harbor Porpoises could hear pile driving noise over 80 km from the source, and 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, even nine years after construction had been completed, porpoise acoustic activity levels were at only 29% of pre-construction levels (Teilmann and Carstensen 2012). Prey availability may be an important factor affecting porpoise behavior around operational wind facilities (Teilmann and Carstensen 2012).

Overall, our results indicate that there is overlap between predicted habitat usages of bottlenose dolphins and the placement of WEAs in the Mid-Atlantic, although the relationship between dolphin distributions and potential offshore wind energy development may be somewhat difficult to interpret from this particular data set. During spring, summer, and fall, bottlenose dolphin encounters within the Maryland study area were highest near shore (Figure 12-10 to Figure 12-12). During the summer, higher densities of bottlenose dolphins encounters were predicted within the western portion of the Maryland WEA (Figure 12-13). Our models suggest minimal presence of bottlenose dolphins within all WEAs during cooler months. However, it is important to note that other species of delphinids, such as common dolphins, are more cold-tolerant than bottlenose dolphins. Common dolphin observations increased in both the boat-based and aerial surveys during winter and early spring. Thus, it is possible that delphinids will be present in some numbers in WEAs during all seasons. Efforts to mitigate the effects of construction activities, in particular, will be important as offshore wind energy development proceeds in the Mid-Atlantic.

Caveats, considerations, and next steps

Conservationists and policy-makers must remember that models are simply an approximation of a species' potential distribution and density. Modeling the density and distributions of marine mammals and sea turtles in the present study was challenging due to the methods employed during surveys, the limited number of sightings generated during surveys, and the difficulties of merging aerial and boat-based survey data. "Passing mode" surveys, where the research vessel does not deviate from the transect line, present significant challenges in determining species identifications and group size. Many marine mammals will form multi-species groups that often become apparent only after close approach, and the movements and dive behavior of these animals make judging group size from a distance difficult. As a result, we chose to model encounter rates (with one or more delphinid) rather than predict numbers of individual animals. Clearly, in applying any analytical technique to ecological data, tradeoffs are often involved to meet certain assumptions. Traditional distance sampling, in particular, assumes all objects on or near the transect line are detected with 100% certainty, that the animals are detected at their initial location, and that recorded distances and angles made by the observer are exact, and without measurement error or bias (Thomas et al. 2002). The marine environment and the general physiology (diving behavior) of these animals make it very difficult to meet these assumptions. As previously mentioned, marine mammals were not modelled using any of the aerial data due to the small sample size of individuals identified at the species level. Furthermore, a general "all delphinids" model would not have been useful as lumping multiple species that have distinct behaviors would have likely been problematic and uninformative. Many species of marine mammals can be highly clustered in space and time, leading to difficulties in merging datasets collected under disparate methods, both of which contained methodological and technological shortcomings.

Future boat survey assessments of marine mammals in this region should be designed to best address issues associated with species identification and group size estimation, ideally using a "closing mode" approach, whereby the research vessel would deviate from the transect line to more accurately describe a sighting by allowing more time for each encounter. A dedicated dual observer approach would also be warranted, as observers searching for both birds and marine mammals must maintain an extremely high level of vigilance to achieve appropriate survey effort. Clearly, aerial surveys pose a challenge to marine mammal surveys due to behaviors such as fast surface intervals as well as species identification success. However, the aerial survey did prove useful in sea turtle relative density estimates, where, unlike marine mammals, the number of species present in our study area was limited, as is the diversity in species-specific behaviors.

Finally, small sample sizes pose challenges to any statistical analyses, and result in diminished analytical potential as compared to models developed with more data (McPherson et al. 2004). As sample size increases, accuracy and predictive power also increase, at least until reaching a maximum accuracy potential (Hernandez et al. 2006). Future surveys designed specifically for marine mammals will help address this issue and improve our understanding of marine mammal distributions and habitat use in the Mid-Atlantic region.

Literature cited

Akaike H (1973) Maximum likelihood identification of Gaussian autoregressive moving average models. Biometrika 60: 255-265

Barco SG, Swingle WM, Mlellan WA, Harris RN, Pabst D (1999) Local abundance and distribution of bottlenose dolphins (Tursiops truncatus) in the nearshore waters of Virginia Beach, Virginia. Marine Mammal Science 15: 394-408

Bergström L, Kautsky L, Malm T, Rosenberg R, Wahlberg M, Capetillo NÅ, Wilhelmsson D (2014) Effects of offshore wind farms on marine wildlife—a generalized impact assessment. Environmental Research Letters 9: 034012

Boesch DF, Rabalais NN (1987) Long-term environmental effects of offshore oil and gas development. CRC Press

Buckland S, Anderson D, BurnhamLaake P (2001) DL Borchers &L. T. Tomas. 2001. Introduction to distance sampling: Estimating abundance of biological populations. Oxford University Press. Oxford. UK.

Buckland ST, Anderson DR, Burnham KP, Laake JL (1993) Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London

Buckland ST, Anderson DR, Burnham KP, Laake JL (2005) Distance sampling. Wiley Online Library

Cheng YW, Gallinat MP (2004) Statistical analysis of the relationship among environmental variables, inter-annual variability and smolt trap efficiency of salmonids in the Tucannon River. Fisheries Research 70: 229-238

Continental Shelf Associates (2004) Explosive removal of offshore structures information synthesis report. U.S. Department of the Interior

Cox TM, Ragen T, Read A, Vos E, Baird R, Balcomb K, Barlow J, Caldwell J, Cranford T, Crum L (2006) Understanding the impacts of anthropogenic sound on beaked whales. DTIC Document

Dobson AJ, Barnett A (2011) An introduction to generalized linear models. CRC press

Dow Piniak W, Eckert S, Harms C, Stringer E (2012) Underwater hearing sensitivity of the leatherback sea turtle (Dermochelys coriacea): Assessing the potential effect of anthropogenic noise. US Dept of the Interior, Bureau of Ocean Energy Management, Headquarters, Herndon, VA OCS Study BOEM 1156

ESRI R (2011) ArcGIS desktop: release 10. Environmental Systems Research Institute, CA

Fisheries (2015) North Atlantic Right Whales (Eubalaena glacialis): NOAA Fisheries

Gannon DP, Waples DM (2004) Diets of coastal bottlenose dolphins from the US Mid-Atlantic coast differ by habitat. Marine Mammal Science 20: 527-545

Garthe S, Hüppop O (2004) Scaling possible adverse effects of marine wind farms on seabirds: developing and applying a vulnerability index. Journal of Applied Ecology 41: 724-734

Goold JC (1996) Acoustic assessment of populations of common dolphin Delphinus delphis in conjunction with seismic surveying. Journal of the Marine Biological Association of the United Kingdom 76: 811-820

Guisan A, Edwards TC, Hastie T (2002) Generalized linear and generalized additive models in studies of species distributions: setting the scene. Ecological modelling 157: 89-100

Hammond P, Berggren P, Benke H, Borchers D, Collet A, Heide-Jørgensen M, Heimlich S, Hiby A, Leopold MF, Øien N (2002) Abundance of harbour porpoise and other cetaceans in the North Sea and adjacent waters. Journal of Applied Ecology 39: 361-376

Hatch SK, Connelly EE, Divoll TJ, Stenhouse IJ, Williams KA (2013) Offshore observations of eastern red bats (Lasiurus borealis) in the Mid-Atlantic United States using multiple survey methods. PloS one 8: e83803

Hawkes LA, Broderick AC, Coyne MS, Godfrey MH, Godley BJ (2007) Only some like it hot—quantifying the environmental niche of the loggerhead sea turtle. Diversity and distributions 13: 447-457

Hedley SL, Buckland ST, Borchers DL (1999) Spatial modelling from line transect data. Journal of Cetacean Research and Management 1: 255-264

Hernandez PA, Graham CH, Master LL, Albert DL (2006) The effect of sample size and species characteristics on performance of different species distribution modeling methods. Ecography 29: 773-785

Hodge KB, Muirhead CA, Morano JL, Clark CW, Rice AN (2015) North Atlantic right whale occurrence near wind energy areas along the mid-Atlantic US coast: implications for management. Endanger Species Res 28:225–234. doi: 10.3354/esr00683

Kenney RD (1990) Bottlenose dolphins off the northeastern United States. The bottlenose dolphin, Academic Press, San Diego: 369-386

Kenney RD, Mayo CA, Winn HE (2001) Migration and foraging strategies at varying spatial scales in western North Atlantic right whales: a review of hypotheses. Journal of Cetacean Research and Management 2: 251-260

Kinlan B, Menza C, Huettmann F (2012) Predictive modeling of seabird distribution patterns in the New York Bight. 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

Knowlton AR, Kraus SD (2001) Mortality and serious injury of northern right whales (Eubalaena glacialis) in the western North Atlantic Ocean. Journal of Cetacean Research and Management (Special Issue) 2: 193-208

Laake JL (1994) Distance User's Guide: Version 2.1. Chapman & Hall

Lenhardt ML, Bellmund S, Byles R, Harkins S, Musick J (1983) Marine turtle reception of bone-conducted sound. The Journal of auditory research 23: 119-125

Lester LA, Avery HW, Harrison AS, Standora EA (2013) Recreational boats and turtles: behavioral mismatches result in high rates of injury. PLoS One 8:e82370.

Lohmann KJ, Lohmann CMF, Endres CS (2008) The sensory ecology of ocean navigation. Journal of Experimental Biology 211: 1719-1728 doi Doi 10.1242/Jeb.015792

Lutcavage M, Musick JA (1985) Aspects of the biology of sea turtles in Virginia. Copeia: 449-456

Madsen P, Møhl B, Nielsen B, Wahlberg M (2002) Male sperm whale behaviour during exposures to distant seismic survey pulses. Aquatic Mammals 28: 231-240

Mate BR, Stafford KM, Ljungblad DK (1994) A change in sperm whale (Physeter macroephalus) distribution correlated to seismic surveys in the Gulf of Mexico. The Journal of the Acoustical Society of America 96: 3268-3269

McCauley RD, Production AP, Association E (2000) Marine seismic surveys: a study of environmental implications. Australian Petroleum Production and Exploration Association

McPherson J, Jetz W, Rogers DJ (2004) The effects of species' range sizes on the accuracy of distribution models: ecological phenomenon or statistical artefact? Journal of applied ecology 41: 811-823

Michel J (2013) South Atlantic Information Resources: Data Search and Literature Synthesis. US Department of the Interior, Bureau of Ocean Energy Management, Gulf of Mexico OCS Region, New Orleans, LA OCS Study BOEM 1157

Miller JD, Limpus CJ, Godfrey MH (2003) Nest site selection, oviposition, eggs, development, hatching, and emergence of loggerhead turtles. Loggerhead sea turtles: 125-143

Natoli A, Birkun A, Aguilar A, Lopez A, Hoelzel AR (2005) Habitat structure and the dispersal of male and female bottlenose dolphins (Tursiops truncatus). Proceedings of the Royal Society B: Biological Sciences 272: 1217-1226

Nowacek DP, Thorne LH, Johnston DW, Tyack PL (2007) Responses of cetaceans to anthropogenic noise. Mamm Rev 37:81–115. doi: 10.1111/j.1365-2907.2007.00104.x

O'Hara J, Wilcox JR (1990) Avoidance responses of loggerhead turtles, Caretta caretta, to low frequency sound. Copeia: 564-567

O'Connell A, Gardner B, Gilbert A, Laurent K (2009) Compendium of Avian Occurrence Information for the Continental Shelf Waters along the Atlantic Coast of the United States, Final Report (Database Section-Seabirds). Prepared by the USGS Patuxent Wildlife Research Center, Beltsville, MD. US

Department of the Interior, Geological Survey, and Bureau of Ocean Energy Management Headquarters, OCS Study BOEM 2012-076.

R Core Team (2014) R: A language and environment for statistical computing. . R Foundation for Statistical Computing, Vienna, Austria

Rabon Jr DR, Johnson SA, Boettcher R, Dodd M, Lyons M, Murphy S, Ramsey S, Roff S, Stewart K (2003) Confirmed leatherback turtle (Dermochelys coriacea) nests from North Carolina, with a summary of leatherback nesting activities north of Florida. Marine Turtle Newsletter 101: 4-8

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

Roberts JJ, Best BD, Dunn DC, Treml EA, Halpin PN (2010) Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modelling & Software 25: 1197-1207

Rolland RM, Parks SE, Hunt KE, Castellote M, Corkeron PJ, Nowacek DP, Wasser SK, Kraus SD (2012) Evidence that ship noise increases stress in right whales. Proceedings of the Royal Society B: Biological Sciences 279: 2363-2368

Rossby T, Benway R (2000) Slow variations in mean path of the Gulf Stream east of Cape Hatteras. Geophysical Research Letters 27: 117-120

Royle JA, Kéry M, Gautier R, Schmid H (2007) Hierarchical spatial models of abundance and occurrence from imperfect survey data. Ecological Monographs 77: 465-481

Scheidat M, Tougaard J, Brasseur S, Carstensen J, van Polanen Petel T, Teilmann J, Reijnders P (2011) Harbour porpoises (Phocoena phocoena) and wind farms: a case study in the Dutch North Sea. Environmental Research Letters 6: 025102

Schwartz FJ (1978) Behavioral and tolerance responses to cold water temperatures by three species of sea turtles (Reptilia, Cheloniidae) in North Carolina. Florida Marine Research Publications 33: 16-18

Shoop C (1980) Sea turtles in the Northeast. Maritimes 24: 9-11

Southall BL, Bowles AE, Ellison WT, et al (2007) Marine Mammal Noise Exposure Criteria: Initial Scientific Recommendations. Aquatic Mammals 33:411–521. doi: 10.1578/AM.33.4.2007.411

Talley L, McCartney M (1982) Distribution and circulation of Labrador Sea water. Journal of Physical Oceanography 12: 1189-1205

Teilmann J, Carstensen J (2012) Negative long term effects on harbour porpoises from a large scale offshore wind farm in the Baltic—evidence of slow recovery. Environmental Research Letters 7: 045101

Thomas L, Buckland ST, Burnham KP, Anderson DR, Laake JL, Borchers DL, Strindberg S (2002) Distance sampling. Encyclopedia of environmetrics

Thompson PM, Harwood J (1990) Methods for estimating the population size of common seals, Phoca vitulina. Journal of Applied Ecology: 924-938

Thomsen F, Lüdemann K, Kafemann R, Piper W (2006) Effects of offshore wind farm noise on marine mammals and fish. Biola, Hamburg, Germany on behalf of COWRIE Ltd: 62

Trites AW, Christensen V, Pauly D (1997) Competition between fisheries and marine mammals for prey and primary production in the Pacific Ocean. Journal of Northwest Atlantic Fishery Science 22: 173-187

Tyack PL, Zimmer WMX, Moretti D, et al (2011) Beaked whales respond to simulated and actual navy sonar. PLoS One 6:e17009. doi: 10.1371/journal.pone.0017009

Urian KW, Hofmann S, Wells RS, Read AJ (2009) Fine-scale population structure of bottlenose dolphins (Tursiops truncatus) in Tampa Bay, Florida. Marine Mammal Science 25: 619-638

Venables WN, Dichmont CM (2004) GLMs, GAMs and GLMMs: an overview of theory for applications in fisheries research. Fisheries research 70: 319-337

Waring G, Josephson E, Maze-Foley K, Rosel P (2011) US Atlantic and Gulf of Mexico marine mammal stock assessments--2010. NOAA Tech Memo NMFS NE 219: 02543-01026

Waring GT, Josephson E, Maze-Foley K, Rosel PE (2013) US Atlantic and Gulf of Mexico Marine Mammal Stock Assessments--2012. NOAA Tech Memo NMFS NE 223: 02543-01026

Wood S (2006) Generalized additive models: an introduction with R. CRC press

Young RF, Phillips HD (2002) Primary production required to support bottlenose dolphins in a salt marsh estuarine creek system. Marine Mammal Science 18: 358-373

Zipkin EF, Royle JA, Dawson DK, Bates S (2010) Multi-species occurrence models to evaluate the effects of conservation and management actions. Biological Conservation 143: 479-484

Figures and tables

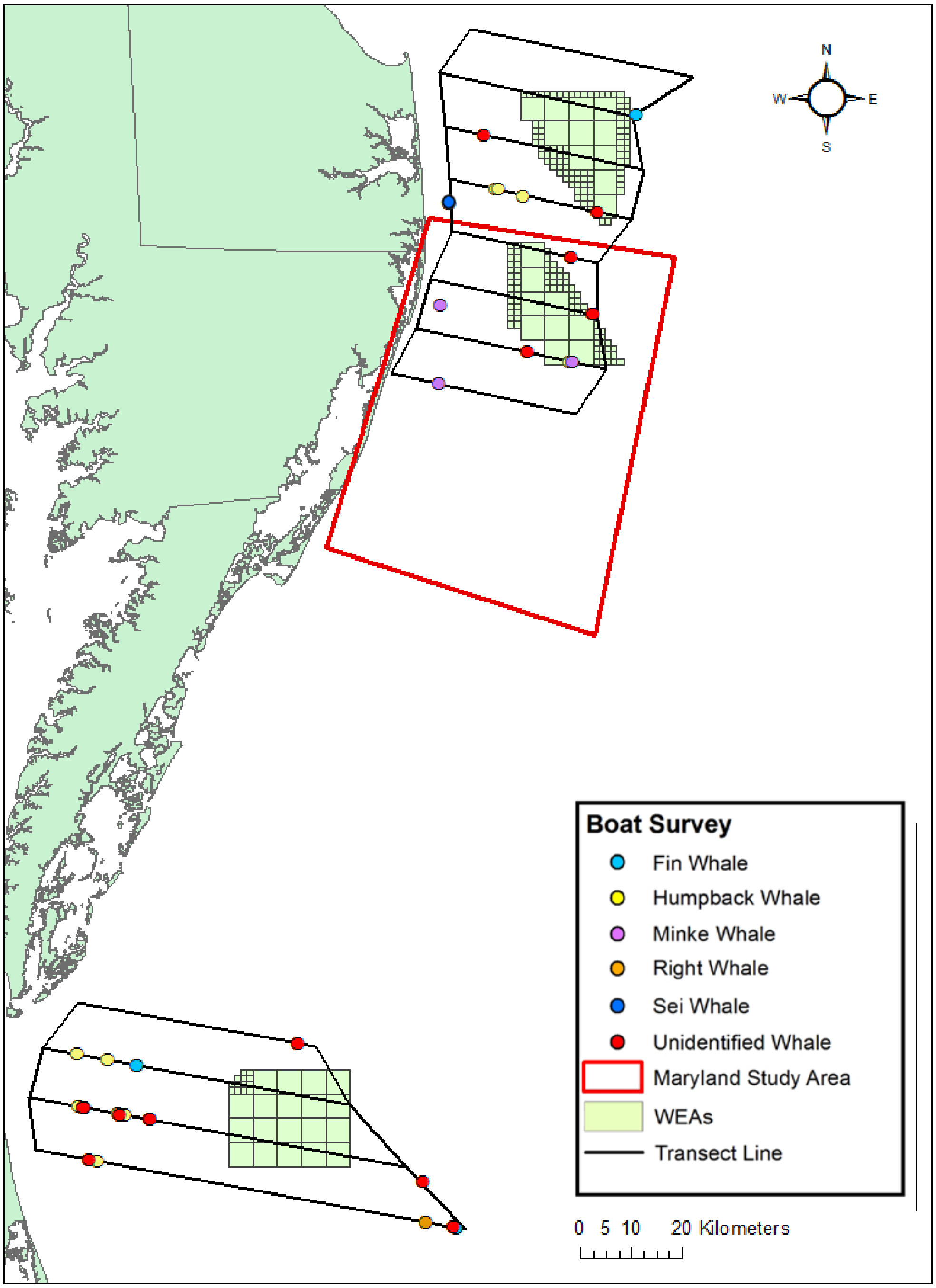

Figure 12-1. Whale sightings from boat survey transects (all surveys, 2012-2014).

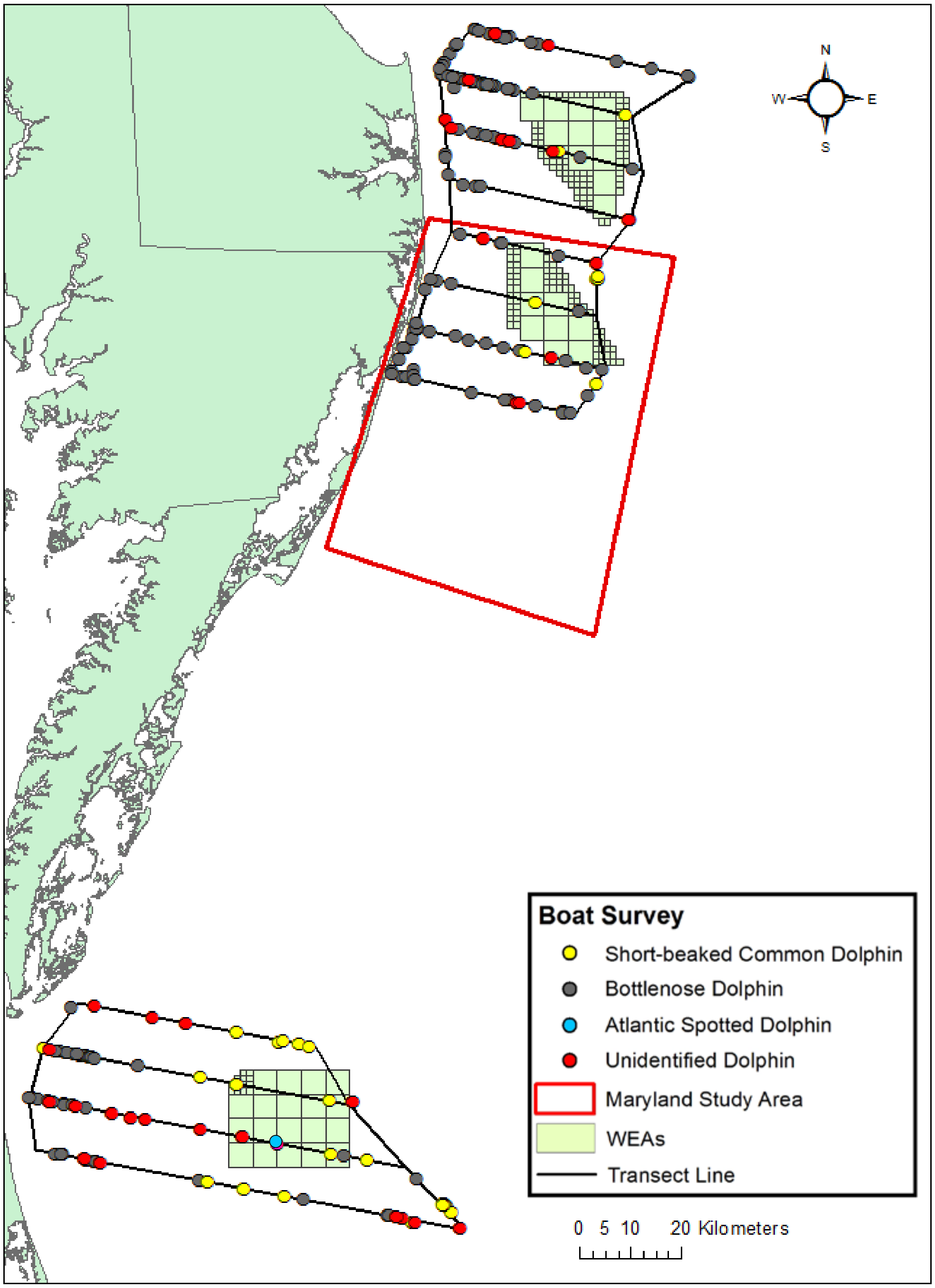

Figure 12-2. Delphinid sightings from boat survey transects (all surveys, 2012-2014).

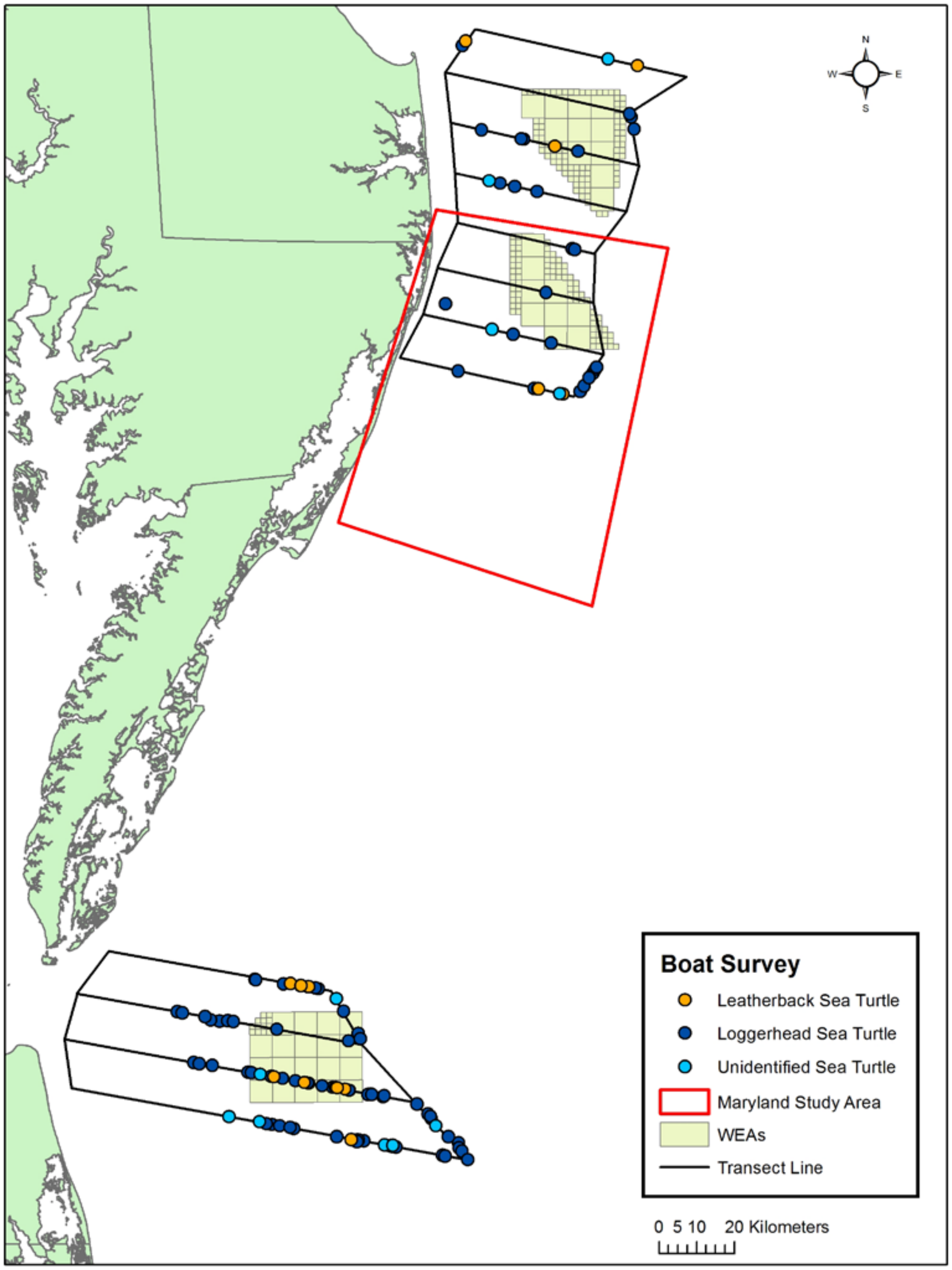

Figure 12-3. Sea turtle sightings from boat survey transects (all surveys, 2012-2014). Unidentified sea turtles are non-Leatherback Sea Turtles that were not definitively identified to species.

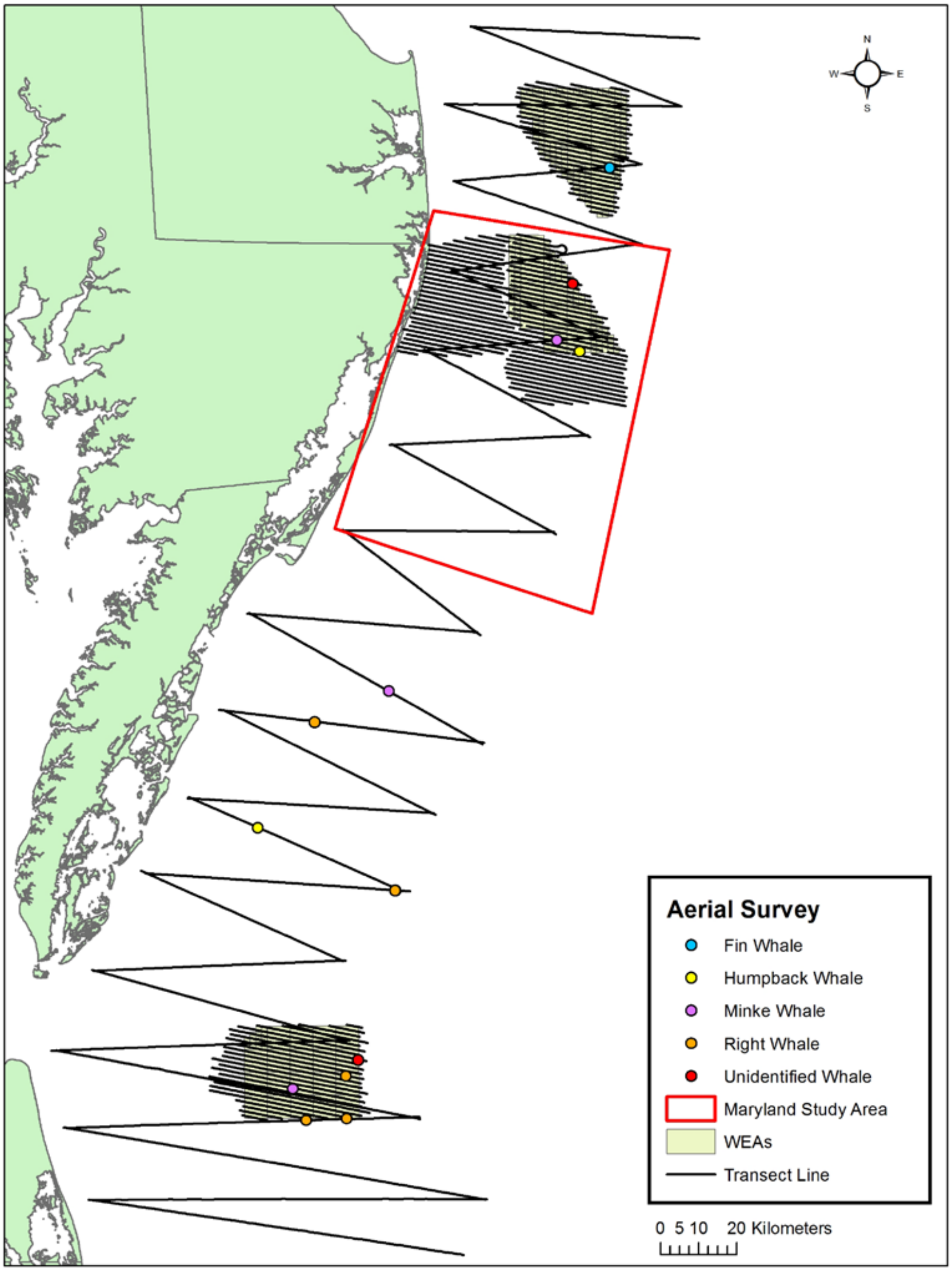

Figure 12-4. Whale sightings from aerial survey transects (all surveys, 2012-2014).

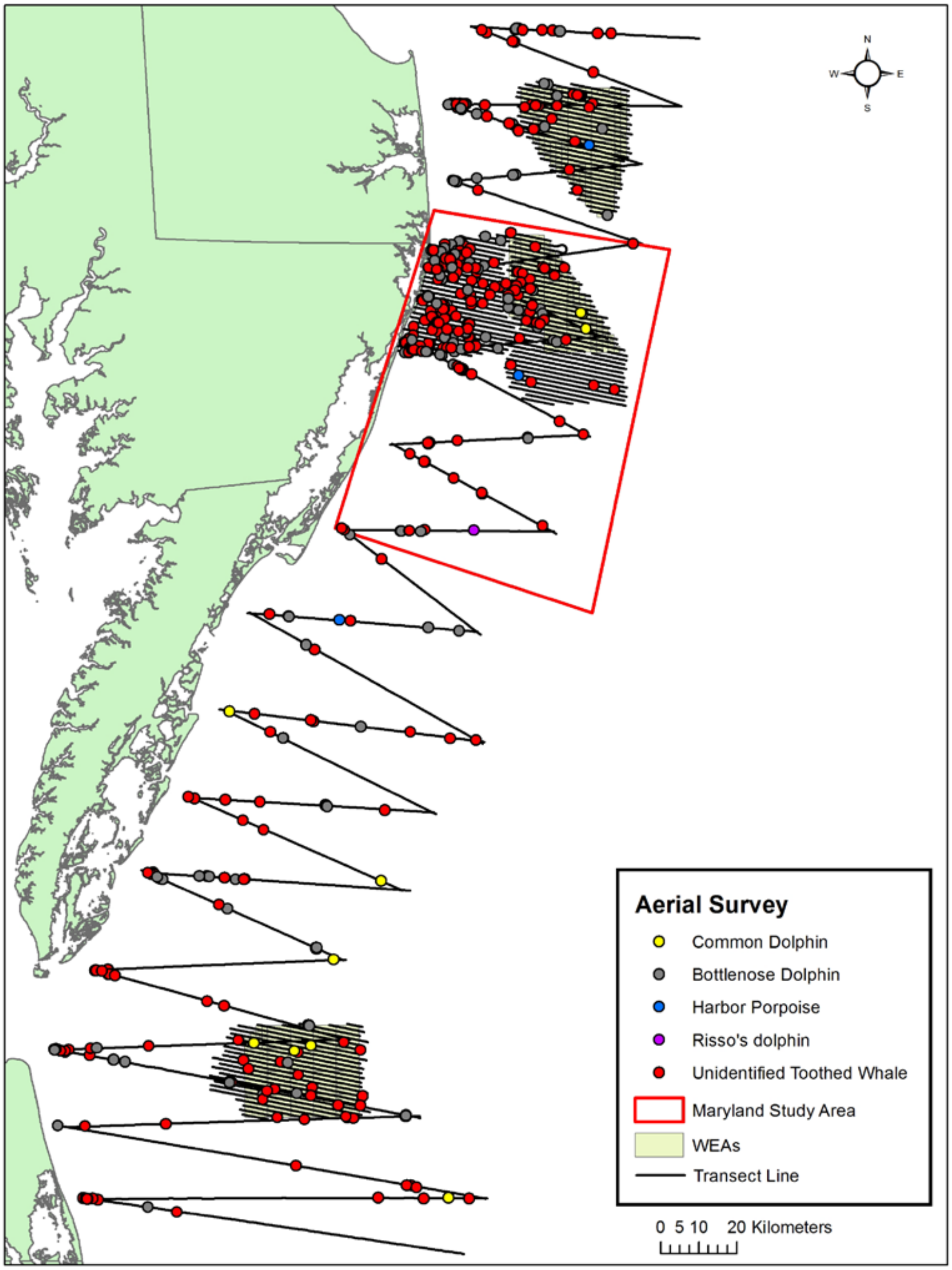

Figure 12-5. Delphinid and porpoise sightings from aerial survey transects (all surveys, 2012-2014).

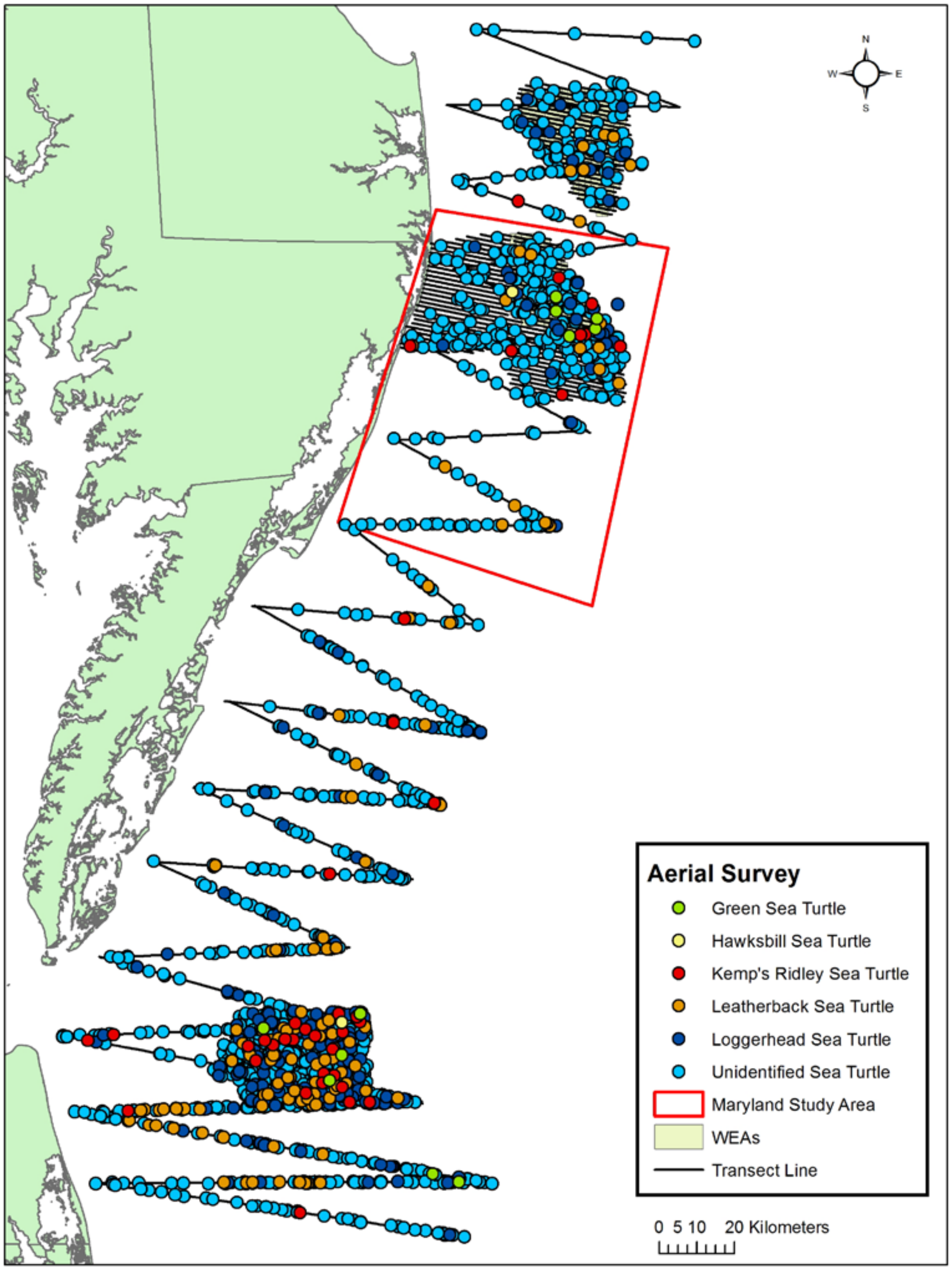

Figure 12-6. Sea turtle sightings from aerial survey transects (all surveys, 2012-2014). Unidentified sea turtles are non-Leatherback Sea Turtles that were not definitively identified to species.

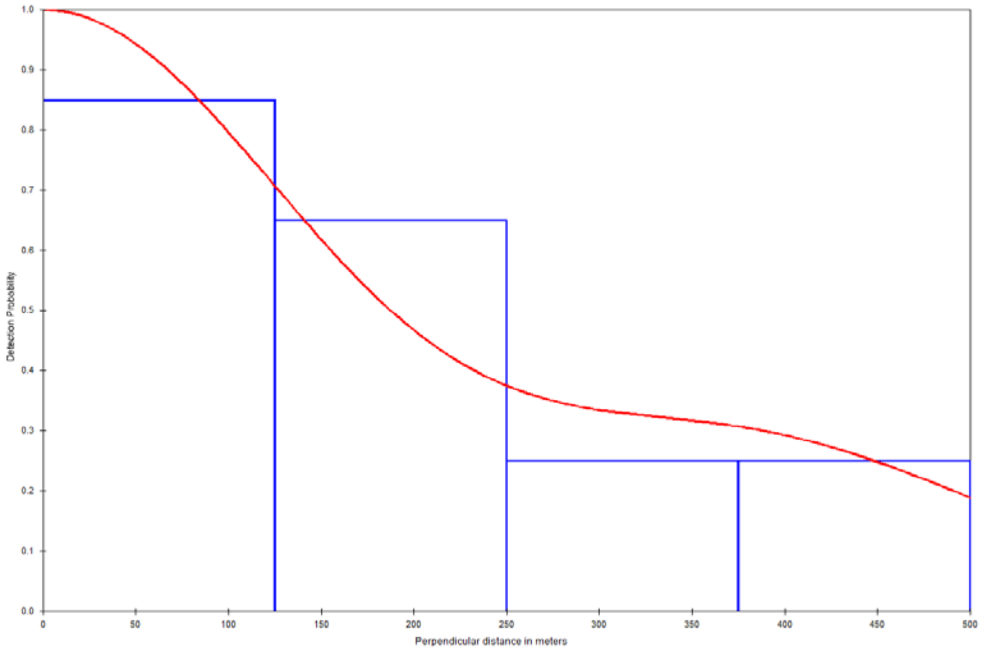

Figure 12-7. Spring global detection function used in boat survey bottlenose dolphin line transect distance density analysis.

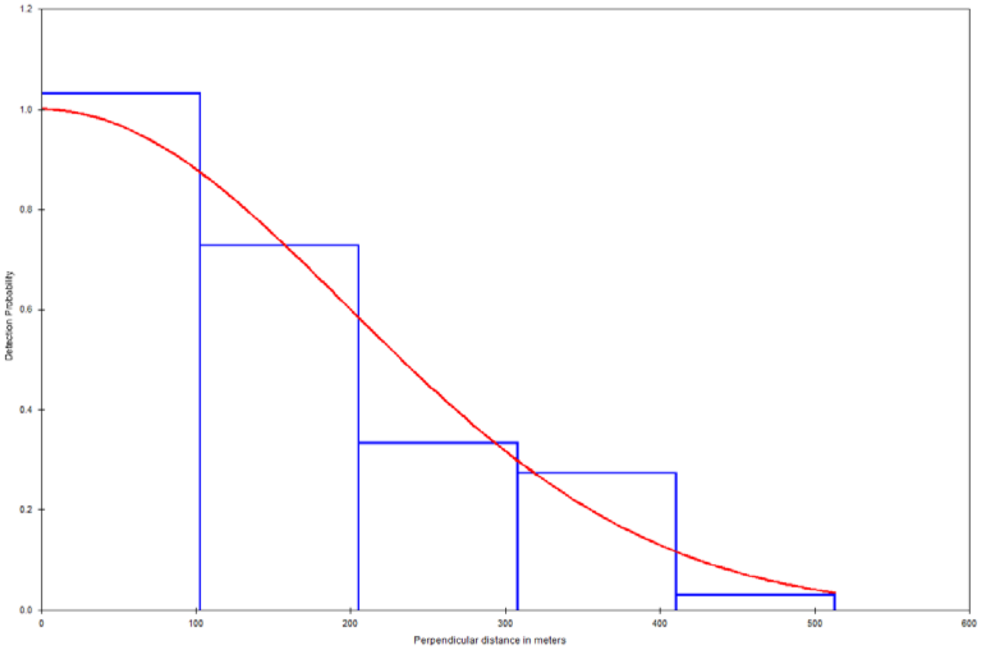

Figure 12-8. Summer global detection function used in boat survey bottlenose dolphin line transect distance density analysis.

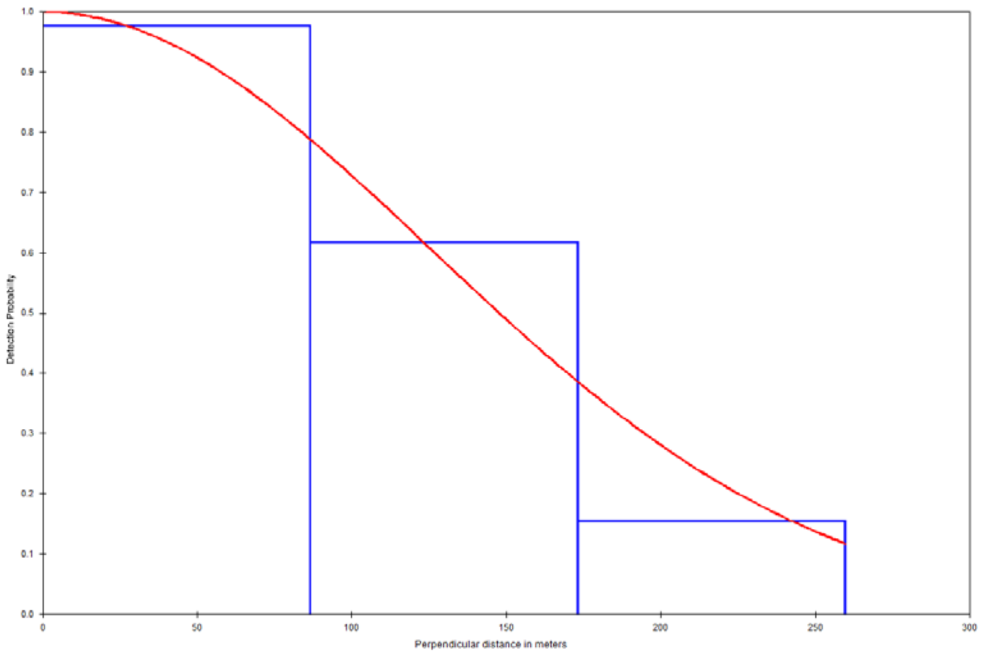

Figure 12-9. Fall global detection function used in boat survey bottlenose dolphin line transect distance density analysis.

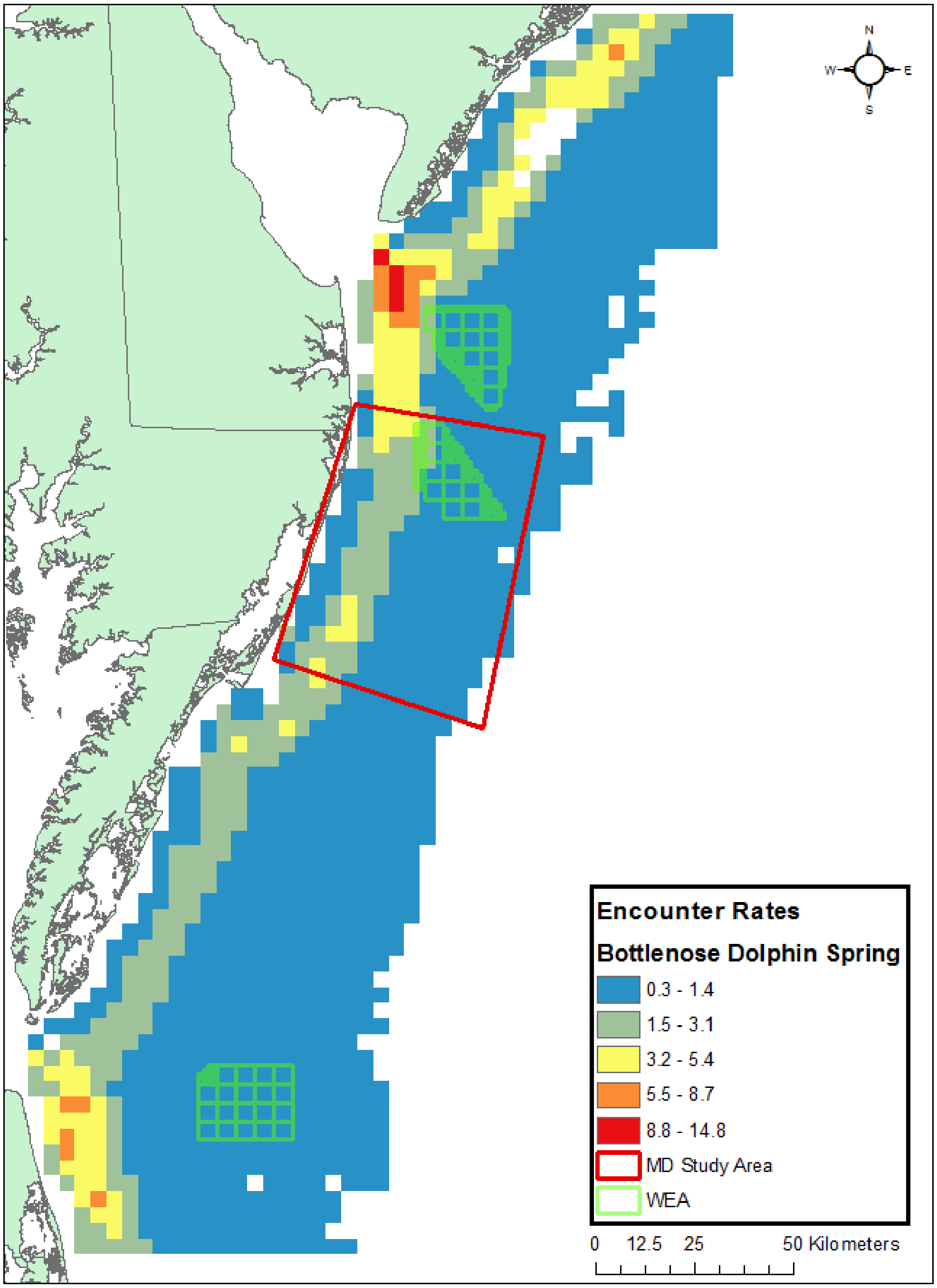

Figure 12-10. Interpolation of encounter rates of bottlenose dolphins in the study area during the spring (Mar.-May), based on two years of boat survey data (2012-2014).

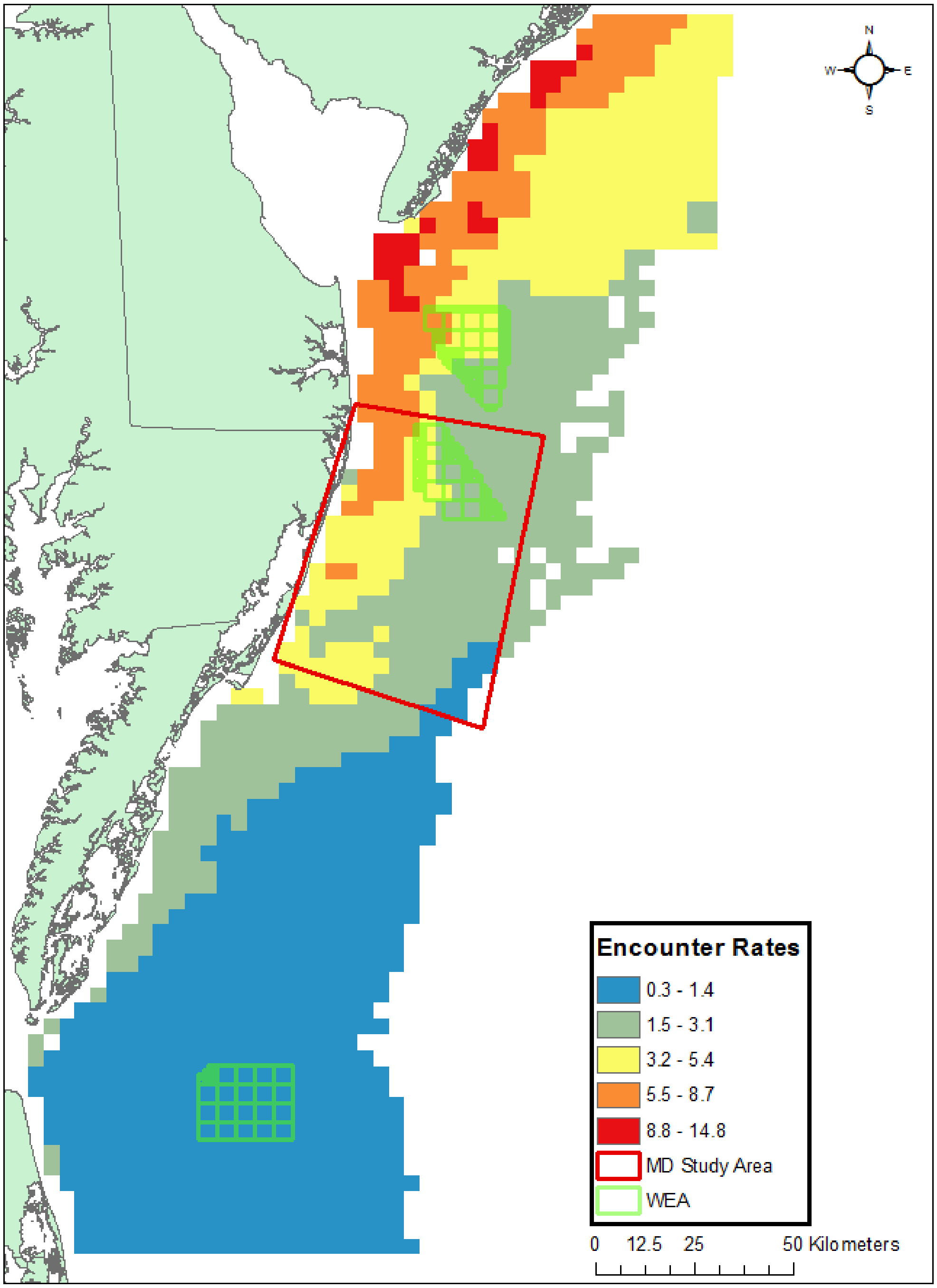

Figure 12-11. Interpolation of encounter rates of bottlenose dolphins in the study area during the summer (Jun. –Aug.), based on two years of boat survey data (2012-2014).

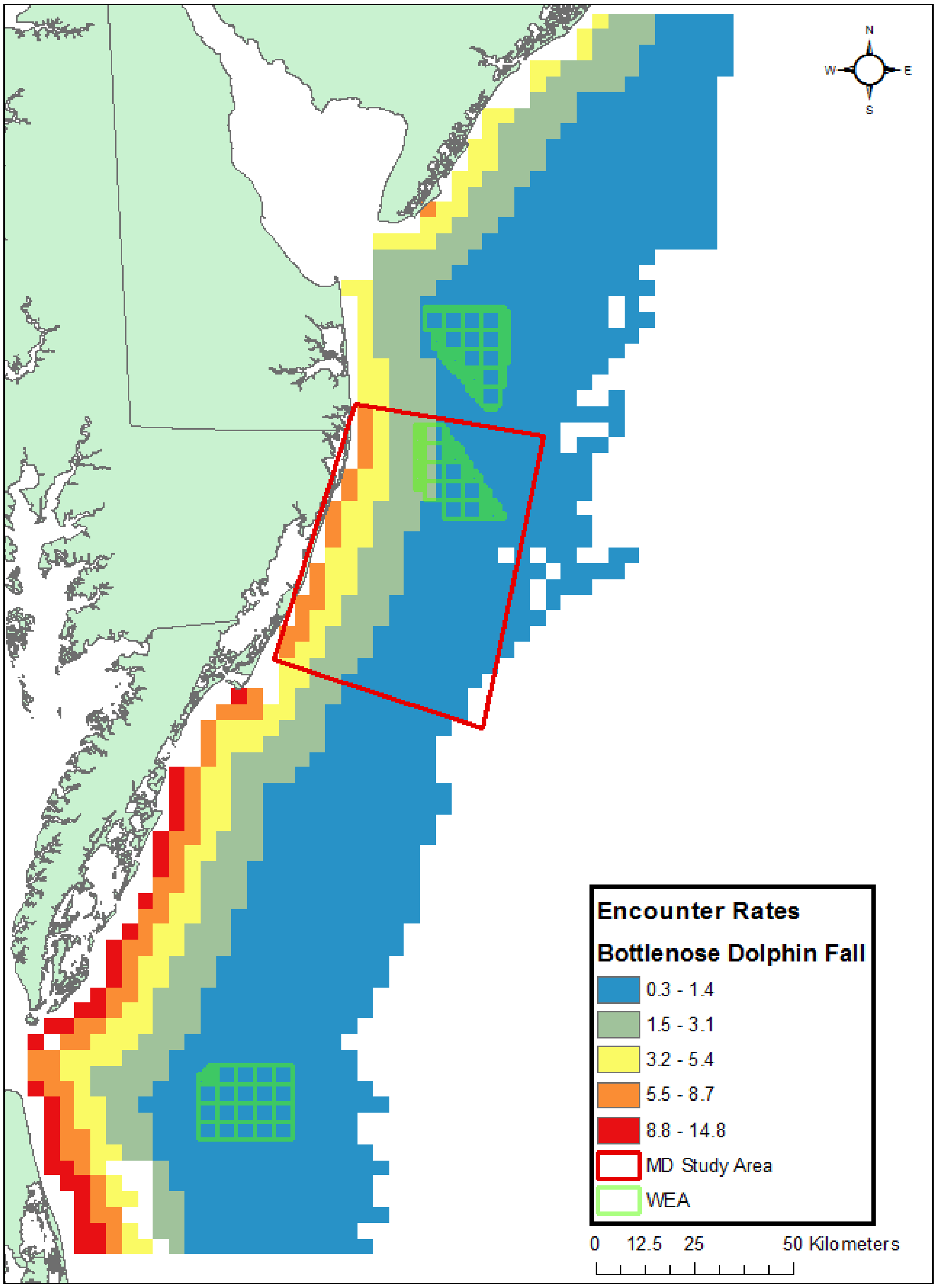

Figure 12-12. Interpolation of encounter rates of bottlenose dolphins in the study area during the fall (Sep.-Nov.), based on two years of boat survey data (2012-2014).

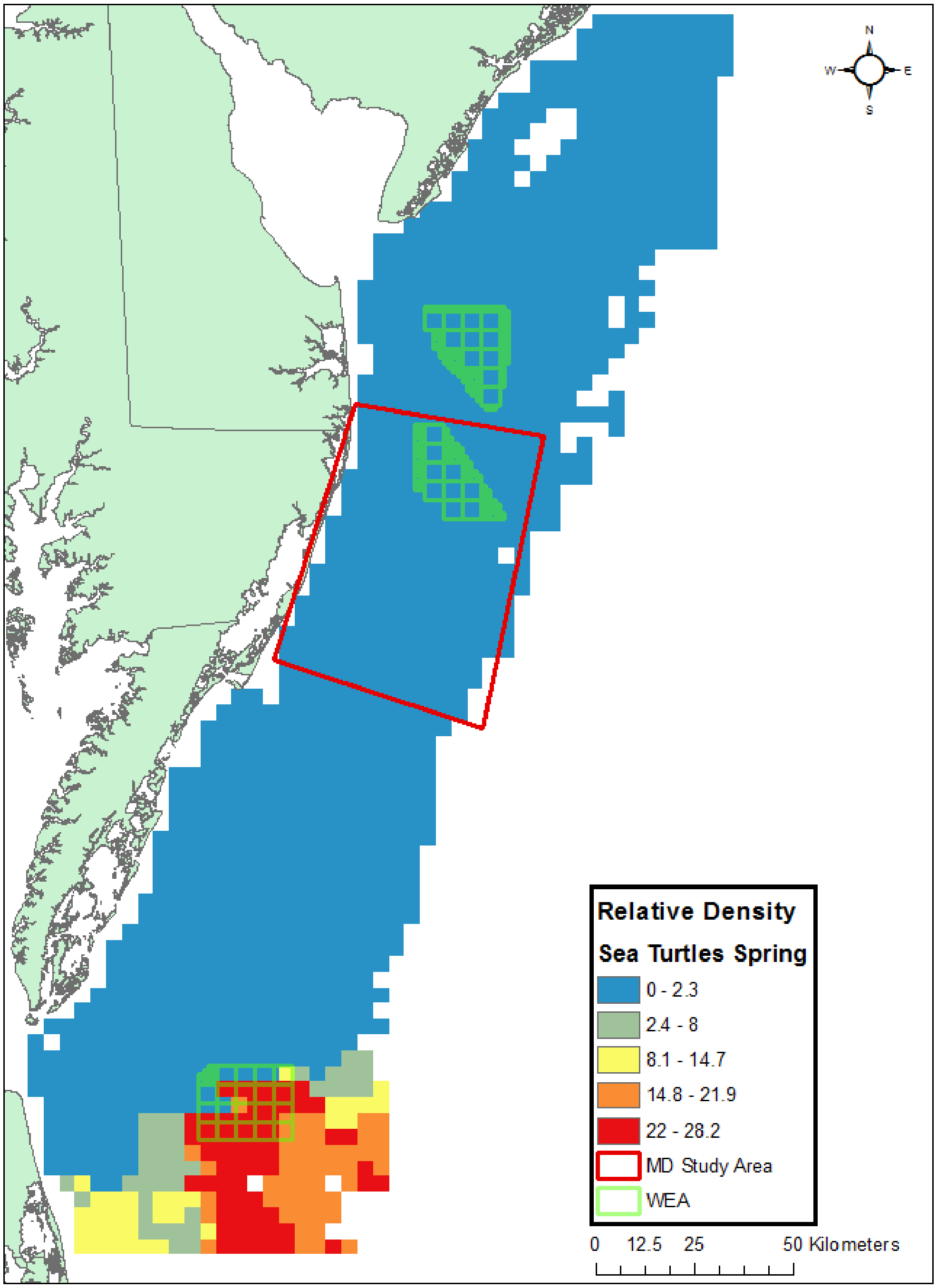

Figure 12-13. Interpolation of predicted relative density of sea turtles in the study area during the spring (Mar.-May), based on two years of aerial survey data (2012-2014).

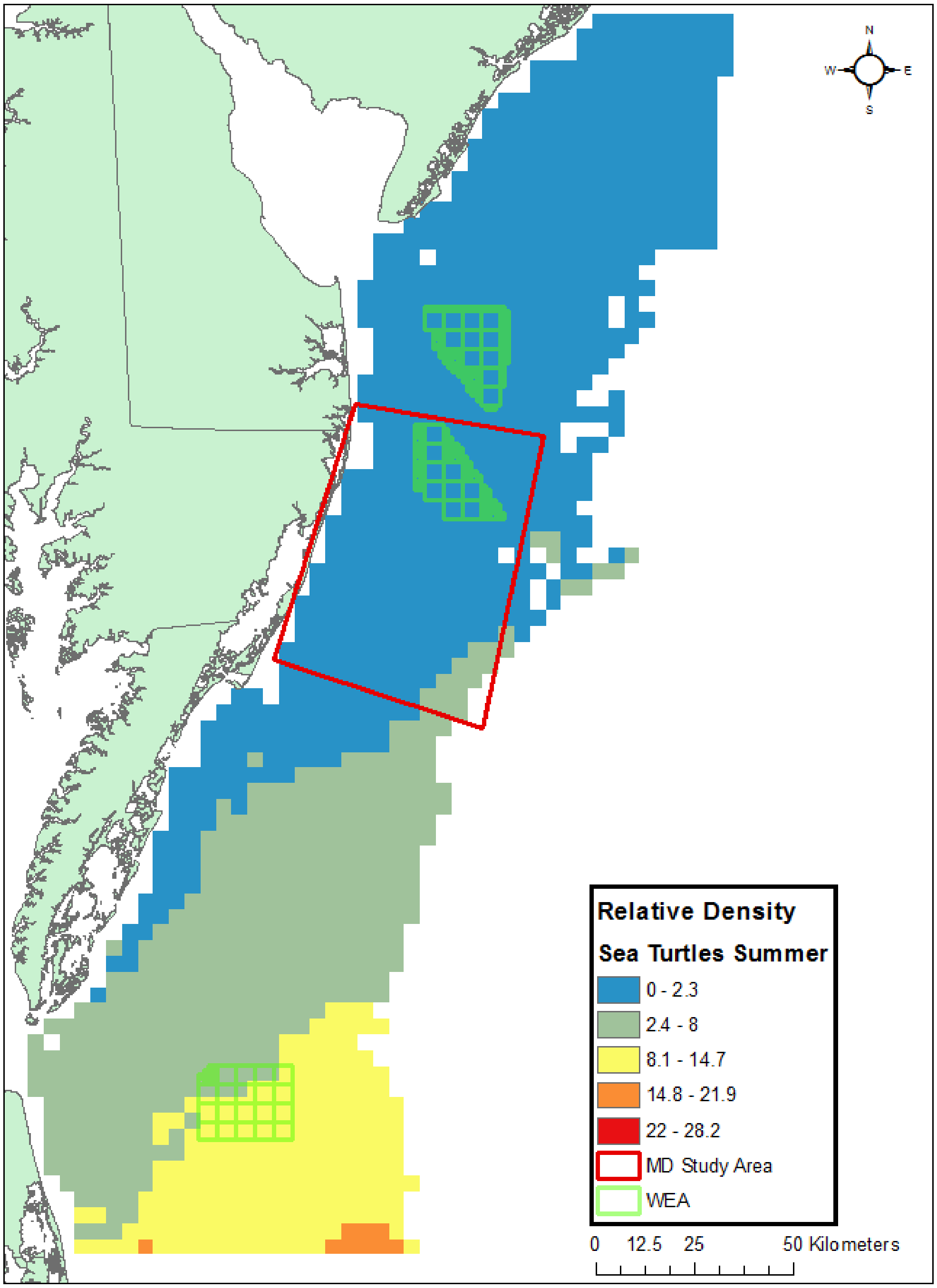

Figure 12-14. Interpolation of predicted relative density of sea turtles in the study area during the summer (Jun.-Aug.), based on two years of aerial survey data (2012-2014).

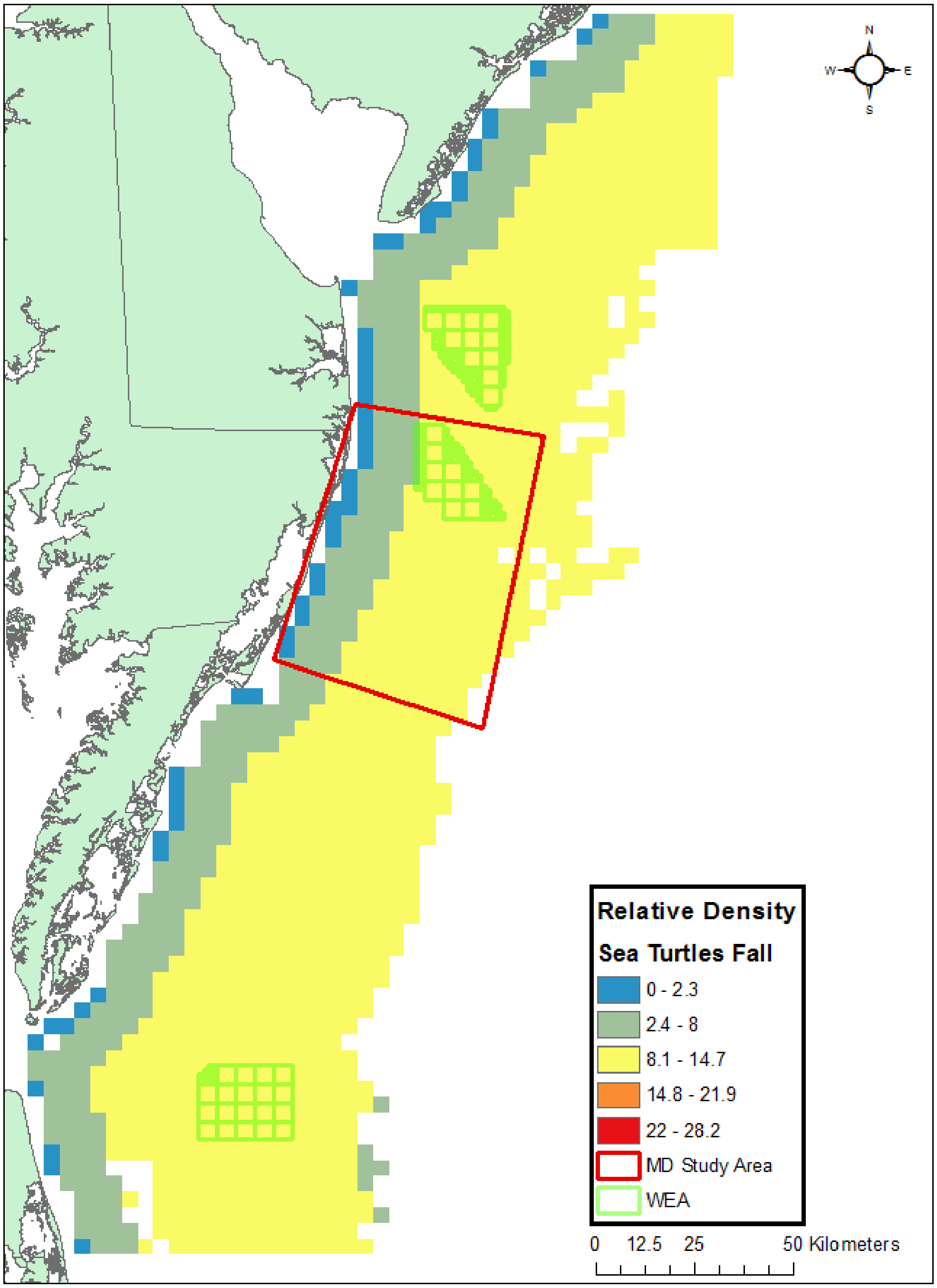

Figure 12-15. Interpolation of predicted relative density of sea turtles in the study area during the fall (Sep.-Nov.), based on two years of aerial survey data (2012-2014).

Table 12-1. Summary data for the MABS boat surveys by season. (Spring: March - May; Summer: June - August; Fall: September - November; Winter: December – February). Counts include all observed individuals seen on survey transects.

Species Group	**Spring**	**Summer**	**Fall**	**Winter**	**Total Count (Ind.)**
Tursiops truncatus (Bottlenose)	239	400	227	8	874
Delphinus delphis (Common)	65	0	0	144	209
Stenella frontalis (Spotted)	0	4	0	0	4
Unidentified Delphinid	11	35	54	13	113
Dolphins Total	**315**	**439**	**281**	**165**	**1200**
Balaenoptera physalus (Fin)	2	0	0	1	3
Balaenoptera borealis (Sei)	0	0	0	1	1
Balaenoptera acutorostrata (Minke)	0	0	1	2	3
Eubalaena glacialis (Right)	1	0	0	0	1
Megaptera novaeangliae (Humpback)	0	1	4	7	12
Unidentified Whale	2	0	3	10	15
Whales Total	**5**	**1**	**8**	**21**	**35**
Caretta caretta (Loggerhead)	11	52	26	0	89
Dermochelys coriacea (Leatherback)	0	9	6	0	15
Unidentified Sea Turtle	2	4	4	0	11
Sea Turtles Total	**13**	**65**	**36**	**0**	**114**
Percent of Total by Season:	24.68	37.43	24.09	13.78	100
Grand Total	***333***	***505***	***325***	***186***	***1,349***

Table 12-2. Summary data for the MABS aerial surveys by season. (Spring: March - May; Summer: June - August; Fall: September - November; Winter: December - February). Counts include all observed individuals seen on survey transects.

Species Group	**Spring**	**Summer**	**Fall**	**Winter**	**Total Count (Ind.)**
Tursiops truncatus (Bottlenose)	226	265	176	10	677
Delphinus delphis (Common)	11	7	4	39	61
Grampus griseus (Risso's)	0	0	1	0	1
Unidentified Delphinid	282	420	454	141	1297
Dolphins Total	**519**	**692**	**635**	**190**	**2036**
Phocoena phocoena (Harbor Porpoise)	2	0	0	1	3
Porpoises Total	**2**	**0**	**0**	**1**	**3**
Balaenoptera physalus (Fin)	0	0	0	1	1
Balaenoptera acutorostrata (Minke)	1	0	1	1	3
Eubalaena glacialis (Right)	3	0	0	5	8
Megaptera novaeangliae (Humpback)	0	0	0	2	2
Unidentified Whale	1	0	0	1	2
Whales Total	**5**	**0**	**1**	**10**	**16**
Unidentified Cetacean (Whale or Dolphin)	2	1	2	0	5
Unidentified Cetaceans Total	**2**	**1**	**2**	**0**	**5**
Caretta caretta (Loggerhead)	60	50	78	0	188
Dermochelys coriacea (Leatherback)	2	78	42	0	122
Chelonia mydas (Green)	3	1	7	0	11
Eretmochelys imbricate (Hawksbill)	0	0	2	0	2
Lepidochelys kempii (Kemp's)	13	10	14	1	38
Unidentified Sea Turtle	523	438	425	1	1387
Sea Turtles Total	**601**	**577**	**568**	**2**	**1748**
Percent of Overall Total by Season:	29.65	33.35	31.67	5.33	100
Grand Total	***1129***	***1270***	***1206***	***203***	***3808***

Table 12-3. Individual marine mammal and sea turtle aerial survey sightings by month in relation to survey effort. Sightings are summarized by linear transect km, as well as per hour of survey time based on a constant flight speed of 250km/hr.

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Avg**
Number of Sightings/km	0.00	0.06	0.07	0.00	0.61	0.25	0.77	0.31	0.38	0.18	0.00	0.10	0.23
Number of Sightings/hr	0.00	15.00	17.50	0.00	152.50	62.50	192.50	77.50	95.00	45.00	0.00	25.00	56.88

Table 12-4. Summary data for boat surveys by season within the Maryland survey area. (Spring: March - May; Summer: June - August; Fall: September - November; Winter: December – February). Counts include all observed individuals seen on survey transects.

Species Group	**Spring**	**Summer**	**Fall**	**Winter**	**Total Count (Ind.)**
Tursiops truncatus (Bottlenose)	20	156	67	0	243
Delphinus delphis (Common)	2	0	0	24	6
Stenella frontalis (Spotted)	0	0	0	0	0
Unidentified Delphinid	0	26	1	2	29
Dolphins Total	**22**	**182**	**68**	**26**	**298**
Balaenoptera physalus (Fin)	0	0	0	0	0
Balaenoptera borealis (Sei)	0	0	0	0	0
Balaenoptera acutorostrata (Minke)	0	0	1	2	3
Eubalaena glacialis (Right)	0	0	0	0	0
Megaptera novaeangliae (Humpback)	0	0	0	1	1
Unidentified Whale	0	0	2	2	4
Whales Total	**0**	**0**	**3**	**5**	**8**
Caretta caretta (Loggerhead)	0	8	7	0	15
Dermochelys coriacea (Leatherback)	0	0	3	0	3
Unidentified Sea Turtle	0	1	1	0	2
Sea Turtles Total	**0**	**9**	**11**	**0**	**20**
Percent of Total by Season:	7.2	60.8	27.3	4.7	100
Grand Total	***22***	***191***	***82***	***31***	***326***

Table 12-5. Summary data for aerial surveys by season conducted within the Maryland survey area. (Spring: March - May; Summer: June - August; Fall: September - November; Winter: December - February). Counts include all observed individuals seen on survey transects.

Species Group	Spring	Summer	Fall	Winter	Total Count (Ind.)
Tursiops truncatus (Bottlenose)	59	165	116	0	340
Delphinus delphis (Common)	0	7	1	19	27
Grampus griseus (Risso's)	0	0	1	0	1
Unidentified Toothed Whale	84	356	293	18	751
Dolphins Total	**143**	**528**	**411**	**37**	**1119**
Phocoena phocoena (Harbor Porpoise)	1	0	0	0	1
Porpoises Total	**1**	**0**	**0**	**0**	**1**
Balaenoptera physalus (Fin)	0	0	0	0	0
Balaenoptera acutorostrata (Minke)	1	0	0	0	1
Eubalaena glacialis (Right)	0	0	0	0	0
Megaptera novaeangliae (Humpback)	0	0	0	1	1
Unidentified Whale	0	0	0	1	1
Whales Total	**1**	**0**	**0**	**2**	**3**
Caretta caretta (Loggerhead)	2	4	16	0	22
Dermochelys coriacea (Leatherback)	0	3	13	0	16
Chelonia mydas (Green)	1	0	4	0	5
Eretmochelys imbricate (Hawksbill)	0	0	1	0	2
Lepidochelys kempii (Kemp's)	2	0	6	0	8
Unidentified Sea Turtle	123	84	107	0	314
Sea Turtles Total	**129**	**91**	**146**	**0**	**366**
Percent of Total by Season:	18.4	41.6	37.4	2.6	
Grand Total	***274***	***619***	***557***	***39***	***1489***

Table 12-6. Individual marine mammal and sea turtle aerial survey sightings by season in relation to survey effort within the Maryland survey area. Sightings are summarized by linear transect km, as well as per hour of survey time based on a constant flight speed of 250 km/hr.

Season	Spring	Summer	Fall	Winter	Avg
Number of Sightings/km	0.24	0.55	0.50	0.03	0.33
Number of Sightings/hr	60	137.5	125	7.5	52.5

Table 12-7. Model selection criterion for bottlenose dolphins in the spring. The chosen model is highlighted in green. (AIC-Akaike's Information Criterion, % Dev-Percent of deviance explained from the null model, Mean-average predicted density, SE-Standard error, SST-Sea Surface Temperature, Chl a-Chlorophyll a, DFS- Distance from shore)

#	GAM Model Covariates	AIC	% Dev	Mean	SE
1	s(SST) + s(Chl a) + s(DFS)	92.43	43.00	0.09	0.67
2	s(SST) + s(Chl a)	92.45	42.10	0.10	0.56
3	s(SST) + s(DFS)	92.89	37.90	0.10	0.65
4	s(Chl a) + s(DFS)	90.49	42.70	0.10	0.67
5	s(SST)	103.40	16.90	0.10	0.33
6	s(Chl a)	93.24	31.90	0.10	0.51
7	s(DFS)	92.72	33.70	0.10	0.66
#	**GLM Model Covariates**	**AIC**	**% Dev**	**Mean**	**SE**
8	s(SST) + s(Chl a) + s(DFS)	100.60	20.52	0.10	2.29
9	s(SST) + s(Chl a)	100.73	17.57	0.11	2.26
10	s(SST) + s(DFS)	99.74	18.95	0.10	2.15
11	s(Chl a) + s(DFS)	98.90	20.12	0.10	0.94
12	s(SST)	107.91	4.81	0.10	2.23
13	s(Chl a)	99.59	16.38	0.11	0.50
14	s(DFS)	98.12	18.42	0.10	0.37

Table 12-8. Model selection criterion for bottlenose dolphins in the summer. The chosen model is highlighted in green. (AIC-Akaike's Information Criterion, % Dev-Percent of deviance explained from the null model, Mean-average predicted density, SE-Standard error, SST-Sea Surface Temperature, Chl a-Chlorophyll a, DFS- Distance from shore)

#	GAM Model Covariates	AIC	% Dev	Mean	SE
1	s(SST) + s(Chl a) + s(DFS)	153.67	23.90	0.20	0.32
2	s(SST) + s(Chl a)	152.63	24.10	0.20	0.30
3	s(SST) + s(DFS)	159.96	17.20	0.20	0.25
4	s(Chl a) + s(DFS)	155.81	23.20	0.20	0.31
5	s(SST)	157.24	19.70	0.20	0.29
6	s(Chl a)	158.36	17.30	0.20	0.24
7	s(DFS)	164.66	12.50	0.20	0.25
#	**GLM Model Covariates**	**AIC**	**% Dev**	**Mean**	**SE**
8	s(SST) + s(Chl a) + s(DFS)	157.75	23.16	0.20	5.75
9	s(SST) + s(Chl a)	156.63	22.29	0.20	0.59
10	s(SST) + s(DFS)	165.98	13.18	0.20	0.60
11	s(Chl a) + s(DFS)	155.82	23.09	0.20	5.62
12	s(SST)	171.80	5.56	0.20	0.52
13	s(Chl a)	157.24	19.75	0.20	5.30
14	s(DFS)	164.66	12.52	0.20	0.29

Table 12-9. Model selection criterion for bottlenose dolphins in the fall. The chosen model is highlighted in green. (AIC-Akaike's Information Criterion, % Dev-Percent of deviance explained from the null model, Mean-average predicted density, SE-Standard error, SST-Sea Surface Temperature, Chl a-Chlorophyll a, DFS- Distance from shore)

#	GAM Model Covariates:	AIC	% Dev	Mean	SE
1	s(SST) + s(Chl a) + s(DFS)	126.54	23.50	0.14	0.31
2	s(SST) + s(Chl a)	125.45	22.10	0.14	0.31
3	s(SST) + s(DFS)	125.09	22.30	0.14	0.31
4	s(Chl a) + s(DFS)	127.43	19.9	0.14	0.3
5	s(SST)	138.00	10.10	0.14	0.25
6	s(Chl a)	126.35	18.20	0.14	0.30
7	s(DFS)	125.71	19.10	0.14	0.30
#	**GLM Model Covariates**	**AIC**	**% Dev**	**Mean**	**SE**
8	s(SST) + s(Chl a) + s(DFS)	128.57	18.31	0.15	4.04
9	s(SST) + s(Chl a)	127.67	17.02	0.16	3.63
10	s(SST) + s(DFS)	127.99	16.65	0.14	5.07
11	s(Chl a) + s(DFS)	128.69	15.82	0.14	1.27
12	s(SST)	139.48	0.88	0.14	4.17
13	s(Chl a)	127.22	15.20	0.15	0.46
14	s(DFS)	127.89	14.42	0.14	0.41

Table 12-10. Model selection criterion for sea turtles in the spring. The chosen model is highlighted in green. (AIC- Akaike's Information Criterion, % Dev-Percent of deviance explained from the null model, Mean-average predicted density, SE-Standard error, SST-Sea Surface Temperature, Chl a-Chlorophyll a, DFS- Distance from shore)

#	GAM Model Covariates	AIC	% Dev	Mean	SE
1	s(SST) + s(Chl a) + s(DFS)	1572.07	31.40	0.72	0.08
2	s(SST) + s(Chl a)	1572.56	30.90	0.73	0.08
3	s(SST) + s(DFS)	1570.71	31.00	0.72	0.08
4	s(Chl a) + s(DFS)	1625.67	24.30	0.72	0.07
5	s(SST)	1589.60	27.40	0.73	0.07
6	s(Chl a)	1633.23	21.30	0.73	0.06
7	s(DFS)	1649.61	18.40	0.72	0.06
#	**GLM Model Covariates**	**AIC**	**% Dev**	**Mean**	**SE**
8	s(SST) + s(Chl a) + s(DFS)	1604.50	24.47	0.73	0.80
9	s(SST) + s(Chl a)	1602.80	24.43	0.73	0.70
10	s(SST) + s(DFS)	1609.10	23.50	0.74	0.70
11	s(Chl a) + s(DFS)	1663.00	15.52	0.72	0.40
12	s(SST)	1627.60	20.47	0.74	0.65
13	s(Chl a)	1667.60	14.54	0.72	0.12
14	s(DFS)	1669.20	14.31	0.74	0.10

Table 12-11. Model selection criterion for sea turtles in the summer. The chosen model is highlighted in green. (AIC- Akaike's Information Criterion, % Dev-Percent of deviance explained from the null model, Mean-average predicted density, SE-Standard error, SST-Sea Surface Temperature, Chl a-Chlorophyll a, DFS- Distance from shore)

#	GAM Model Covariates	AIC	% Dev	Mean	SE
1	s(SST) + s(Chl a) + s(DFS)	1725.07	34.60	0.89	0.07
2	s(SST) + s(Chl a)	1723.65	34.20	0.89	0.07
3	s(SST) + s(DFS)	1724.79	34.70	0.89	0.07
4	s(Chl a) + s(DFS)	1780.89	27.80	0.89	0.06
5	s(SST)	1744.02	30.90	0.89	0.06
6	s(Chl a)	1781.20	26.80	0.89	0.07
7	s(DFS)	1813.78	21.90	0.09	0.06
#	**GLM Model Covariates**	**AIC**	**% Dev**	**Mean**	**SE**
8	s(SST) + s(Chl a) + s(DFS)	1725.80	33.49	0.90	2.20
9	s(SST) + s(Chl a)	1729.30	32.72	0.89	2.19
10	s(SST) + s(DFS)	1725.90	33.21	0.90	2.14
11	s(Chl a) + s(DFS)	1821.50	19.88	0.89	0.31
12	s(SST)	1749.90	25.59	0.90	1.95
13	s(Chl a)	1840.20	17.00	0.87	0.11
14	s(DFS)	1827.00	18.84	0.91	0.13

Table 12-12. Model selection criterion for sea turtles in the fall. The chosen model is highlighted in green. (AIC- Akaike's Information Criterion, % Dev-Percent of deviance explained from the null model, Mean-average predicted density, SE-Standard error, SST-Sea Surface Temperature, Chl a-Chlorophyll a, DFS- Distance from shore)

#	GAM Model Covariates	AIC	% Dev	Mean	SE
1	s(SST) + s(Chl a) + s(DFS)	1494.74	8.31	0.56	0.07
2	s(SST) + s(Chl a)	1501.47	5.42	0.56	0.06
3	s(SST) + s(DFS)	1492.79	8.40	0.56	0.07
4	s(Chl a) + s(DFS)	1493.04	8.02	0.56	0.07
5	s(SST)	1512.83	4.74	0.56	0.06
6	s(Chl a)	1500.29	5.29	0.56	0.06
7	s(DFS)	1491.42	7.98	0.56	0.07
#	**GLM Model Covariates**	**AIC**	**% Dev**	**Mean**	**SE**
8	s(SST) + s(Chl a) + s(DFS)	1501.20	5.80	0.56	3.11
9	s(SST) + s(Chl a)	1501.50	5.42	0.56	2.67
10	s(SST) + s(DFS)	1509.50	4.11	0.56	2.90
11	s(Chl a) + s(DFS)	1501.80	5.36	0.56	0.34
12	s(SST)	1517.10	2.52	0.56	1.57
13	s(Chl a)	1500.30	5.29	0.56	0.11
14	s(DFS)	1507.90	4.04	0.56	0.13

Chapter 13: Comparison of boat and aerial models of seabird abundance with environmental covariates

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

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Chapter 13 Highlights

Comparison of habitat relationships and abundance estimates from boat and digital aerial surveys across the Mid-Atlantic study area

Context[1]

Identifying the exposure of seabird species to proposed development projects often requires an understanding of how their abundance relates to environmental covariates. When multiple survey approaches are used, we must additionally determine how such sampling methods differ in estimating species' abundance in relation to these covariates. In this chapter, we focus on comparing data between survey methods for the purpose of determining how best to combine boat and digital aerial survey data for analysis. We tried to make the models as similar between survey types and species as possible, to facilitate comparison, which meant sometimes using slightly different formulations of models from other chapters. We analyzed the boat data similarly to Chapter 9, but with single species instead of a community. The digital aerial data are modeled similarly to Chapter 12, but using generalized linear models rather than generalized additive models.

This chapter presents a preliminary analysis of data from four seabird groups (terns, gannets, loons, and alcids) across the seasons when they were present in the study region. Remotely-collected environmental data were incorporated into separate boat and digital aerial models, to compare and contrast the estimated effects of habitat on seabird abundance using data from each sampling method. Chapter 14 builds upon these results and examines an integrated modeling approach for these taxa.

Study goal/objectives addressed in this chapter

Compare the estimated effect of habitat on the predicted abundance of marine bird species by season for models based on boat and aerial digital videography data.

Highlights

- Distance to shore was generally the most common predictor of abundance across species and surveys.
- Similar habitat relationships were estimated between the two survey types for Northern Gannets, terns, and loons; alcids were less consistent between the survey types and years.
- Accounting for imperfect detection in the boat data resulted in higher abundance for the boat-based than the aerial models.

Implications

Boat-based and digital aerial survey data provide comparable estimates of habitat relationships. This suggests that a model that can combine both data types may be the most powerful for understanding seabird distributions, although there are many ways to jointly model the data. Based on these results, caution should be taken for species like alcids, where different patterns were observed between survey types. Such differences may be due to differences in the sampling domain, detectability, or temporal variation.

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[1] For more detailed context for this chapter, please see the introduction to Part IV of this report.

Abstract

This chapter is a preliminary analysis that explores the patterns of seabird abundances observed in the shipboard and digital aerial surveys. Other chapters in this report (e.g., Chapter 9) focus on analysis of only the boat survey data, but the goal in this chapter is to compare the boat data with the aerial data to determine how best to combine the data types into one joint analysis. These results are not meant to be compared with other chapters that focused on abundance estimates, but instead just to evaluate the patterns and differences between the survey types. As such, this chapter uses slightly different approaches than other chapters, in order make the models as similar between survey types and species as possible and facilitate direct comparisons. The surveys have some spatial and temporal mis-match, which may cause variation in the observations. Additionally, there has been little previous work that jointly models boat surveys with distance-sampling and aerial digital videography surveys, thus demonstrating the need to conduct a preliminary exploration of the two datasets.

Our results indicate that for the species and groups included in this analysis (terns, alcids, loons, and Northern Gannets), we generally find that the habitat relationships are consistent between survey types, with distance to shore being the most common significant predictor of abundance. For alcids, we saw a lack of consistency in the patterns, both between years and survey types. We also found that the estimated abundance was generally higher for the boat surveys, likely due to the ability of our models to address imperfect detection in the boat sampling. The findings in this chapter were used to inform the development of an integrated model, presented in Chapter 14.

Introduction

Shipboard and traditional aerial survey methodologies have been compared extensively in their performance at estimating species richness and abundance (for overview, see Camphuysen et al. 2004). Comparisons between shipboard and high resolution digital video aerial surveys, however, remain sparse given the novelty of high resolution digital videography (Buckland et al. 2012). Digital videography covers a larger geographic area in a faster time frame, but the technology used in this study was limited by a few components: 1) only 200 meters of width was sampled, which is a small snapshot of the marine realm, 2) the angle and resolution of the video restricted most objects to being identified to family or group, as opposed to individual or species, and 3) there is no method to address issues of detection and availability, which likely vary by species, season, weather, or other factors. We evaluate the variation that may arise in digital videography data and identify issues related to inherent detection and identification constraints. We postulate that, were the digital aerial and boat surveys to provide similar parameter and abundance estimates, then both surveys would not need to be conducted simultaneously; however, if there are differences in the datasets, then finding ways that make use of the information in both datasets (a 'joint model') will be very informative. Before taking the next step in creating a joint model, we first aim to compare the two methods of sampling by using a suite of species (terns, alcids, loons, and Northern Gannets) and examining their habitat relationships across different seasons.

Our objectives include:

1. Compare the habitat parameter estimates from boat and aerial habitat models for various species across different seasons.
2. Based on the results of the habitat modeling, compare the predicted abundance from boat-based and digital videography estimates.
3. Evaluate the high intensity surveys over Maryland waters as compared to the Mid-Atlantic Baseline Studies project area to see if there are regional differences in habitat responses (not complete; see Future Work section for preliminary analyses).

It is important to note that there are methodological differences in sampling from the boat versus digital videography. Some differences are inherent to the two survey methods, such as transect width; the boat surveys sample wider transect widths for most species, and use distance sampling to account for variation in detection. Other differences are specific to the survey design utilized in this study (e.g., boat and aerial transects were located in slightly different geographic areas and occurred at different days and times). To minimize the study-specific sources of variation, we used an offset for area sampled, and compiled data from multiple surveys within each survey year. We expected that boat-based models would estimate higher abundance as a result of accounting for imperfect detection in the sampling.

Methods

One wind energy area (WEA) is designated within the Maryland study area (MD), with two additional WEAs in the broader Mid-Atlantic Baseline Studies (MABS) project area, located off the coasts of Delaware (DE) and Virginia (VA; Figure 13-1). Field methods for the video aerial and boat surveys are explained elsewhere in this report (Chapters 3 and 6, respectively). Aerial identification protocols for video analysis are discussed in Chapter 4. For this comparison, we used boat and video aerial survey data collected over the entire MABS study area (including the Maryland Project surveys), and did not separately examine data collected within the Maryland study area. We used boat survey observations that were sampled from the forward quadrant on one side of the vessel, extending up to 1 km from the trackline, and digital aerial observations that were collected from 4 cameras, which each recorded a 50 m band (totaling 0.2 km strip width). For both the boat and video aerial surveys, we divided survey transects into 4 km segments ('sites'); this resulted in some shorter segments at the transect ends, so site area was included as an offset in our analysis. The number of individuals for each species was summed by 4 km segment per survey (defined as the time period over which the entire MABS study area was sampled). Many species, including terns, Northern Gannets, and loons, are seasonally present in the region or observed in low numbers, so specific surveys were combined within each year for analysis but varied depending on the species. We compared Northern Gannets, terns, loons, and alcids between the two survey methods; due to slight differences between each taxonomic group, we created group-specific models, described below.

Covariates

We used five covariates in our analyses: three static (distance to shore, slope, and grain size), and two dynamic (sea surface temperature and salinity). We excluded chlorophyll-*a* in these analyses because it was collinear with distance to shore in some of the surveys and we wanted to keep the covariates consistent across surveys for the purpose of comparison within each species; due to missing data at higher resolutions it also varied monthly, which is a lower temporal resolution than the other dynamic covariates. Remotely sensed covariate data corresponded to the values located at the midpoint of each transect segment. For the static covariates, we calculated distance to shore (m) within ArcGIS 10.2 (ESRI, Redlands, CA) and extracted slope (% rise, 370-m resolution) and grain size ($\phi = -\log2$[mean grain diameter in mm], 370-m resolution) from the data layer derived by NOAA/NOS National Centers for Coastal Ocean Science (Kinlan et al. 2013). For the dynamic covariates, we used Marine Geospatial Ecology Tools in ArcGIS (Roberts et al. 2010) to download remotely-sensed data at the highest resolution available for all segments. We compiled daily values for sea surface temperature (SST, °C, 1-km GHRSST L4) and salinity (Practical Salinity Units, 9-km HYCOM GLBa0.08 Equatorial 4D). In the boat survey analysis, we additionally included one covariate on detection: Beaufort sea state on the binary scale, which varied by segment (0 = calm seas, Beaufort state 0-2; 1 = rough seas, Beaufort state 3-6).

Models

To facilitate comparisons, we ran the same model across both the boat and aerial data for each species, except that the boat-based model included an additional component for estimating detection using distance sampling (Buckland et al. 1993). For each species or group, we conducted preliminary diagnostics to evaluate the data and select the best model for abundance, considering the Poisson, Negative Binomial, and zero-inflated versions of both distributions. For the boat-based models, we considered a detection as a single individual, thus breaking down each flock into separate detections of individuals (as opposed to modeling the flock, as in Sollmann et al. (2015) and Chapter 9, so that we could compare parameters directly with the video aerial surveys.

Terns

Terns included Least Terns (*Sternula antillarum*), Caspian Terns (*Hydroprogne caspia*), Black Terns (*Chlidonias niger*), Common Terns (*Sterna hirundo*), Roseate Terns (*Sterna dougallii*), Royal Terns (*Thalasseus maximus*), and Sandwich Terns (*Thalasseus sandvicensis*), as well as those individuals classified as "unidentified terns." Vague identifications that could have included other species such as gulls (e.g., "large tern or small gull,") were excluded. Terns were primarily present in the MABS study area during spring, summer and fall (Chapters 5, 7, and 9), so we compared three boat and two video aerial surveys from June 2012 – September 2012 (first year), and June 2013 – September 2013 (second year, excluding the August 2013 aerial survey, which covered only the MD WEA and surrounding areas). For the tern models we used a Negative Binomial distribution on abundance and a negative exponential distribution on detection (only in the boat survey models). The abundance component of the model for both boat and video aerial surveys was constructed such that each count of terns at segment i, $\mathrm{y_i}$, was modeled as:

$$\mathrm{y_i} \sim \mathrm{NegBin}(\lambda_i,\ r)$$

$$\log(\lambda_i) = \beta_0 + offset\ (site\ area_i) + \beta_1 \mathrm{Dst_i} + \beta_2 \mathrm{Slp_i} + \beta_3 \mathrm{Grn_i} + \beta_4 \mathrm{Sst_i} + \beta_5 \mathrm{Sal_i}$$

where Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and r is the overdispersion parameter.

Northern Gannets

The only gannets in the area are Northern Gannet (*Morus bassanus*), thus we only included one species in this model. Northern Gannets were primarily present in the MABS study area in late fall to early spring (Chapters 5, 7, and 9), so we compared three boat and three video aerial surveys from October 2012 – February 2013 (first year), and October 2013 – February 2014 (second year). For the Northern Gannetmodels we used a Negative Binomial distribution for abundance, and a half-Normal distribution for detection (only in the boat survey models). The abundance component of the model for both boat and video aerial surveys was constructed such that each count of Northern Gannets at segment i, $\mathrm{y_i}$, was defined:

$$\mathrm{y_i} \sim \mathrm{NegBin}(\lambda_i,\ r)$$

$$\log(\lambda_i) = \beta_0\ + offset\ (site\ area_i) + \beta_1 \mathrm{Dst_i} + \beta_2 \mathrm{Slp_i} + \beta_3 \mathrm{Grn_i} + \beta_4 \mathrm{Sst_i}$$

where Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, and Sst = sea surface temperature. We removed salinity in these models because it was highly collinear with SST and distance to shore.

Loons

We considered loons by species (Common Loons, *Gavia immer*, and Red-throated Loons, *G. stellata*) and as a group (all loons, which included both species and all unidentified loon observations), to examine whether habitat relationships varied by species. Loons were primarily present in the MABS study area from late fall to early spring (Chapters 5, 7, and 9), so we included three boat and three video aerial surveys from December 2012 – March 2013 (first year), and December 2013 – May 2014 (second year).

For all of the loon models, we used a Negative Binomial distribution on abundance, and a half-Normal distribution on detection (only in the boat survey models). The abundance component of the model for both boat and video aerial surveys was constructed such that each count of loons at segment i, $\mathrm{y_i}$, was defined:

$$\mathrm{y_i} \sim \mathrm{NegBin}(\lambda_i,\ r)$$

$$\log(\lambda_i) = \beta_{0,survey} + offset\ (site\ area_i) + \beta_1 \mathrm{Dst_i} + \beta_2 \mathrm{Slp_i} + \beta_3 \mathrm{Grn_i} + \beta_4 \mathrm{Sst_i} + \beta_5 \mathrm{Sal_i}$$

where Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and a survey specific intercept to address interannual variation in the survey counts.

Alcids

The alcid group included Razorbills (*Alca torda*), Dovekies (*Alle alle*), Atlantic Puffins (*Fratercula arctica*), Common Murres (*Uria aalge*), Thick-billed Murres (*U. lomvia*), and Black Guillemots (*Cepphus grille*), as well as those individuals classified as "unidentified alcids." Alcids were primarily present in the MABS study area during winter (Chapters 5, 7, and 9), therefore we compared two boat and two video aerial surveys from December 2012 – February 2013 (first year), and December 2013 – February 2014 (second year). For all alcid models we used a Negative Binomial distribution on abundance, and a half-Normal distribution on detection (only in the boat survey models). To model abundance for both boat and video aerial surveys we defined the counts of alcids at segment i, $\mathrm{y_i}$, such that:

$$\mathrm{y_i} \sim \mathrm{NegBin}(\lambda_i,\ r)$$

$$\log(\lambda_i) = \beta_0 + offset\ (site\ area_i) + \beta_1 \mathrm{Dst_i} + \beta_2 \mathrm{Slp_i} + \beta_3 \mathrm{Grn_i} + \beta_4 \mathrm{Sst_i} + \beta_5 \mathrm{Sal_i}$$

where Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, and Sal = salinity. In the second year of the video aerial surveys, we had to set the overdispersion parameter $r = 0.02$ in order to achieve convergence in the model. There were only 45 transects with observed alcids during this year, which is a relatively small sample size for the number of parameters we are interested in; this particular model requires further exploration.

Implementation

We implemented all models in a Bayesian framework using the package "rjags" to run the software JAGS (Plummer 2003) in program R version 2.15.3 (R Core Team 2014). We standardized the covariates for analysis to center them on a mean = 0, with a variance close to 1. We initialized three parallel Markov chains at different values and ran them for 30,000 iterations (boat models) or 10,000 (aerial models) following a burn-in of 1,000 iterations. We checked for chain convergence visually (posterior density and trace plots), and quantitatively using the Gelman-Rubin statistic (Gelman et al. 2014). This statistic (termed R-hat) is a measure of among-chain versus between-chain variance and values < 1.1 indicate convergence (Gelman et al. 2014). We also assessed goodness of fit by computing Bayesian p-values. We used Freeman-Tukey fit statistics to evaluate the model for abundance, and to select the negative exponential or half-Normal detection function (Gelman et al. 2014). Fitting the models resulted in estimated abundance to the sampled transects, summed across segments and surveys. Using the posterior means of each model parameter, we additionally predicted the abundance of each wintering species to habitat covariates from a representative day (25 Dec 2012), which covered unsampled locations in the three WEAs within the MABS study area.

Results

Overall, we found that fewer individuals were observed on the video aerial surveys than the boat surveys for smaller species (e.g., terns, alcids), and the observations varied by survey date, year, and species (Table 13-1). Accounting for detection resulted in higher abundance in the boat than the video aerial surveys, which carried through to the predicted number of birds in each of the WEAs. In Year 1, the estimated number of Northern Gannets was very similar for the boat and video aerial surveys, with the Virginia WEA having a lower predicted number of birds from the boat survey than the aerial (Table 13-1). Similarly, in Year 2, the number of predicted alcids in all the WEAs from the aerial survey was near 40 birds, while it was near 0 birds from the boat survey, though 127 alcids were predicted to the entire MABS study region (Table 13-1). These two cases are the only situations where the boat surveys did not predict higher abundance of birds than the aerial survey, and are likely due to the strong effect of proximity to shore reducing the numbers predicted to the VA WEA (see below for more details on parameter effects). Predicted abundance within the Maryland WEA for both boat and video aerial surveys were generally similar to predicted counts within the Virginia and Delaware WEAs (Table 13-1). Boat and aerial counts for the MD WEA showed similar patterns by year and species group, though aerial predictions for the MD WEA were consistently lower than boat predictions for the same years and species.

Across both the boat and video aerial surveys, proximity to shore was the most important predictor of abundance. The abundance of terns, Northern Gannets, and loons increased with proximity to shore (Table 13-2 through Table 13-6). Alcids associated more closely with the shoreline in Year 2, but they were farther from shore in Year 1 boat surveys (Table 13-7). The detectability of terns, loons, and alcids decreased as seas became rougher, whereas Northern Gannets showed no change in detectability in Year 1, and an opposite effect in Year 2 (Table 13-2 through Table 13-7).

The general patterns in habitat relationships between the aerial and boat surveys were consistent. Terns showed similar parameter estimates for the habitat covariates between survey methods, though this was not true for all parameters (Table 13-2); terns were associated with warm water in the first year aerial surveys and with fine sand in the second year aerial surveys. We found that Northern Gannets had a positive relationship with cold water in all surveys except the first year of the boat surveys, when we found no significant relationship (Table 13-3). Northern Gannets were significantly related to all four habitat covariates in the second year of surveys, with similar parameter estimates between all models except that they associated with coarse sand in the aerial surveys and fine sand in the second year boat surveys.

For loons, we found similar patterns as with Northern Gannets and terns; however, it is useful to note that there were some differences when using species-level data (Table 13-4 to Table 13-6). For example, in Year 2 of the aerial survey, only one Red-throated Loon was identified, while there were 2062 total loon observations (Table 13-1). This meant that we were unable to model the distribution of Red-throated Loons that year for the aerial data; the boat data that same year had 754 observed Red-throated loons. In comparison, the Year 2 aerial survey for Common Loons had the most number of significant covariates of any of the loon analyses (Table 13-5). Looking at the boat survey results for year 1, Red-throated Loons had significant negative effects of distance to shore, slope, and salinity (Table 13-6); Common Loons also had a significant negative effect of salinity, but additionally a positive effect of sea surface temperature (Table 13-5). The model for all loons had a significant negative effect of salinity and distance to shore and a significant positive effect of sea surface temperature (Table 13-4). Thus the combined model smoothes out the individual species effects, losing the importance of slope on Red-throated Loons and suggesting a relationship with distance to shore that was not detected in Common Loons. Similar results were observed in the first year aerial survey: Common Loons had no significant effects (Table 13-5), Red-throated Loons had a significant negative effect of distance to shore (Table 13-6), and all loons had a significant negative effect of distance to shore and a positive effect of sea surface temperature (Table 13-4). Here, we may be seeing some differences due to increases in sample size; as we add observations from unidentified loons, more patterns can be detected.

Bayesian p-values suggest that model fit was generally adequate for all of the abundance model components (Table 13-8); the aerial data for the Northern Gannets and the combined loons did not fit very well, and thus other distributions may be explored in these cases. Futher investigation into the detection component may be necessary, but in general the estimates of abundance have been rather insensitive to the detection model (half-Normal vs. negative exponential; unpublished results), so the results are not likely to change significantly even under a different detection model in these cases.

Discussion

As expected, proximity to shore was the primary driver of abundance in this study. Chlorophyll concentration also increased with proximity to shore and was not included due to this collinearity, which suggests that distance to shore may be a proxy for primary productivity in this region. A large effect of primary productivity on predator distributions may indicate strong bottom-up forcing in this region. This is consistent with studies suggesting that, in waters off the east coast of the US where productivity and species richness are relatively high, bottom-up control dominates and resource limitation induces positive predator-prey relationships (Ainley and Hyrenbach 2010; Frank et al. 2007; Hunt and McKinnell 2006).

The boat surveys generally resulted in higher estimates of abundance compared to the video aerial surveys, taking effort into account. The total length of an aerial survey’s transects (3,613 km including the Maryland extensions, Chapter 3) is much greater than in a boat survey (571 km including the Maryland extensions, Chapter 6). The strip width is 1/5 of the 1 km truncation distance we used for the detection function in the boat survey models. Therefore, the aerial survey effort (total area sampled) is 1.3 fold greater, so we would expect to estimate more individuals in the video aerial surveys. However, our results show the opposite: that the boat survey models consistently estimated and predicted higher abundance, which is primarily due to accounting for imperfect detection. The differences are particularly noticeable with the smaller species (e.g., terns and alcids), indicating estimating detection bias is important for smaller species.

Detection decreased with increased sea state for all species except Northern Gannets in the Year 2 boat surveys. The observer team moved into the pilot house during rough seas, following safety protocol, which likely contributed to reduced visibility. We suspect that the increased detection of Northern Gannets in rough seas was a result of differences in behavior, as Northern Gannets are less likely to sit on the water during rough seas, and flying Northern Gannets are generally considered to be more visible.

In general, habitat relationships were similar within a season and between survey types (boat and aerial), with a few exceptions. These exceptions could be due to (1) more habitat sampled between the MD and VA WEAs in the aerial surveys, or to (2) the extreme habitat values that occurred in the shipping channel to Delaware Bay, which were sampled on Transect 2 of the boat surveys (e.g., steep slopes and a strong salinity front). Gulf Stream waters on the outer edge of the continental shelf tend to be warmer than coastal waters, and salinity also tends to decrease with distance from the freshwater outlets inshore of the Delaware and Chesapeake Bays. Thus, the significant influence of warm water and fine sand on abundance of terns in the aerial surveys (unlike the boat surveys) may be due to aerial observations of them close to shore between the MD and VA WEAs. Opposite effects of sediment grain size on Northern Gannets occurred in the Year 2 boat surveys and aerial surveys, which may have been due to differences in sampling effort by survey type, where aerial surveys covered more area between the MD and VA WEA footprints. In Year 2, the boat surveys also showed that Common Loons associated with steep slope, and with more gradual slope in the aerial surveys, which again could be due to areas between the MD and VA WEAs, where the bottom is relatively flat. Low salinity had a strong effect on Red-throated Loons in the boat surveys, but not in the first year video aerial survey. However, Red-throated Loon data from the video aerial surveys should be interpreted with caution, since many Red-throated Loons were not identified to species (Hostetter et al., 2015), which may cause biased results. Alcids were likely to be far from shore, associating with cold water in the first year boat surveys (similarly to Chapter 9), but the first year video aerial surveys showed an association only with warmer water, which may be a result of collinearity between SST and distance to shore in gulf stream waters on the outer edge of the continental shelf.

Similarities between survey types were most pronounced with proximity to shore, which had consistently significant effects on (1) terns and loons across both seasons and survey types (Chapter 9), (2) Northern Gannets across three of the four models (Chapter 9), and (3) alcids in the second year across both survey types. Significant effects were consistent across both survey types in year 2, with respect to cold water and Northern Gannets, as well as grain size and Common Loons. Significant effects of warm water on loons occurred across both seasons and survey types. Common and Red-throated Loons also associated with low salinity in different survey types and seasons. Our results suggest that using both boat and video aerial surveys can provide more complete ecological context compared to either survey type alone.

Future work

The results of this chapter suggest that combining the two survey types into one comprehensive model would be fruitful. The results between the boat and video aerial surveys were generally consistent for the species we examined, and variations between the methods may be due to differences in the sampled area (larger coverage with video aerial) and in detection (accounted for by distance sampling in boats). Further data exploration of yearly differences (as opposed to survey-specific) in covariate values and patterns would be useful (e.g., to address issues of collinearity). Additionally, testing the impacts of localized habitat on the results for the entire MABS study area would be informative, and could be achieved by removing parts of the dataset to evaluate changes in the results (for example transect 2 of the boat survey, which sampled some extreme covariate values). Teasing apart differences due to variation in survey type, inter-annual differences, and sampling space will help to better understand the differences observed in the relationships between seabird abundance and habitat covariates.

Combining the data into a single model would likely play to the strengths of both survey methodologies and provide more reliable inferences about the underlying ecological drivers of seabird distributions and abundance. In a first attempt at this, we have implemented an integrated model, described in Chapter 14. There are a number of approaches that can be taken when developing a joint model, and we will continue to pursue these options in future work. One issue to be addressed is how to deal with availability in the digital aerial surveys (see Winiarski et al. 2014); we currently have no measure of availability, and this would be difficult to acquire for all species. Thus, in addition to a joint modeling approach to combine the survey types, we suggest also conducting an analysis of model sensitivity to availability and detection, to better understand the impact of these processes on abundance estimates for the digital aerial surveys.

Recent studies have shown that species in disparate locations can respond very differently to habitat covariates, even in study areas that are in close proximity (Flanders et al. 2015). When enough observations are recorded for a species, a reduced area or ‘regional’ model can be fit, though this is not common, as marine birds tend to be sparsely distributed over large regions of the ocean. This ‘regional’ type model is likely possible for a few select species groups in the Maryland study area, because of the high intensity of aerial surveys in the MD WEA and surrounding waters. Using the same model described above, we conducted a simple preliminary analysis of the high density aerial surveys in the Maryland study area for terns, Northern Gannets, and loons observed in year 2 (when the high-density coverage was expanded in Maryland; only data from the MD WEA and MD extension transects were included). Alcids were not included in this because only 7 observations were made in Maryland waters in year 2 (Table 13-9). For the tern analysis, we included the August 2013 survey, which covered exclusively Maryland waters; we also added this survey to the MABS analysis, so that the two were more directly comparable. Terns had a similar number of observations between the MABS and MD study areas (Table 13-9), suggesting that most terns were observed in MD waters; this likely resulted in the two models (MABS and MD only) having similar parameter estimates (Table 13-10). Northern Gannets and loons had a reduced number of observations in MD waters, which is expected given that this was a subset of the full data (Table 13-9). The reduction in data, i.e., number of observed birds, along with what are likely regional effects due to different sampled areas, resulted in differences for the two species between the two models (Table 13-10). For example, in MD waters, loons did not show a significant response to distance to shore, and showed an opposite response to grain size (Table 13-10). These results suggest that while there are some main consistencies between the larger MABS study area and MD waters, there may be some fine scale variation that is important for making localized decisions. In this latter case, and when the data are sufficient, further exploration of regional or local models may prove useful in determining the sources of fine scale variation in seabird abundances.

Literature cited

Ainley, D.G., Hyrenbach, D., K., 2010. Top-down and bottom-up factors affecting seabird population trends in the California current system (1985–2006). Progress in Oceanography 84, 242-254.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 1993. Distance Sampling: Estimating Abundance of Biological Populations. Chapman and Hall, London.

Buckland, S.T., Burt, M.L., Rexstad, E.A., Mellor, M., Williams, A.E., Woodward, R., 2012. Aerial surveys of seabirds: the advent of digital methods. Journal of Applied Ecology 49, 960-967.

Camphuysen, C.J., Fox, A.D., Leopold, M.F., Petersen, I.K., 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. Royal Netherlands Institute for Sea Research, Texel.

Flanders, N.P., Gardner, B., Winiarski, K.J., Paton, P.W.C., Allison, T., and O'Connell, A.F. 2015. Key seabird areas in southern New England identified using a community occupancy model. Marine Ecology Progress Series. 533:277-290.

Frank, K.T., Petrie, B., Shackell, N.L., 2007. The ups and downs of trophic control in continental shelf ecosystems. Trends in Ecology & Evolution 22, 236-242.

Gelman, A., Carlin, J.B., Stern, H.S., Dunson, D.B., Vehtari, A., Rubin, D.B., 2014. Bayesian Data Analysis, Third Edition. Taylor & Francis, New York, NY, USA.

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 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.

Hunt, J.G.L., McKinnell, S., 2006. Interplay between top-down, bottom-up, and wasp-waist control in marine ecosystems. Progress in Oceanography 68, 115-124.

Kinlan, B.P., Poti, M., Drohan, A., Packer, D.B., Nizinski, M., Dorfman, D., Caldow, C., 2013. Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch. Released August 2013. Available at: http://coastalscience.noaa.gov/projects/detail?key=35.

Plummer, M., 2003. JAGS: A program for analysis of Bayesian graphical models using Gibbs sampling, In Proceedings of the 3rd International Workshop on Distributed Statistical Computing (DSC 2003). March, pp. 20-22.

R Core Team, 2014. R: A language and environment for statistical computing, Version 3.0.3. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org

Roberts, J., Best, B., Dunn, D., Treml, E., Halpin, P., 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. http://mgel.env.duke.edu/mget

Sollmann, R., Gardner, B., Gilbert, A., Williams, K., Veit, R., 2015. A community distance sampling model to investigate the abundance and distribution of seabirds, 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.

Winiarski, K.J., Burt, M.L., Rexstad, E., Miller, D.L., Trocki, C.L., Paton, P.W.C., McWilliams, S.R., 2014. Integrating aerial and ship surveys of marine birds into a combined density surface model: A case study of wintering Common Loons. The Condor, 149-161.

Figures and tables

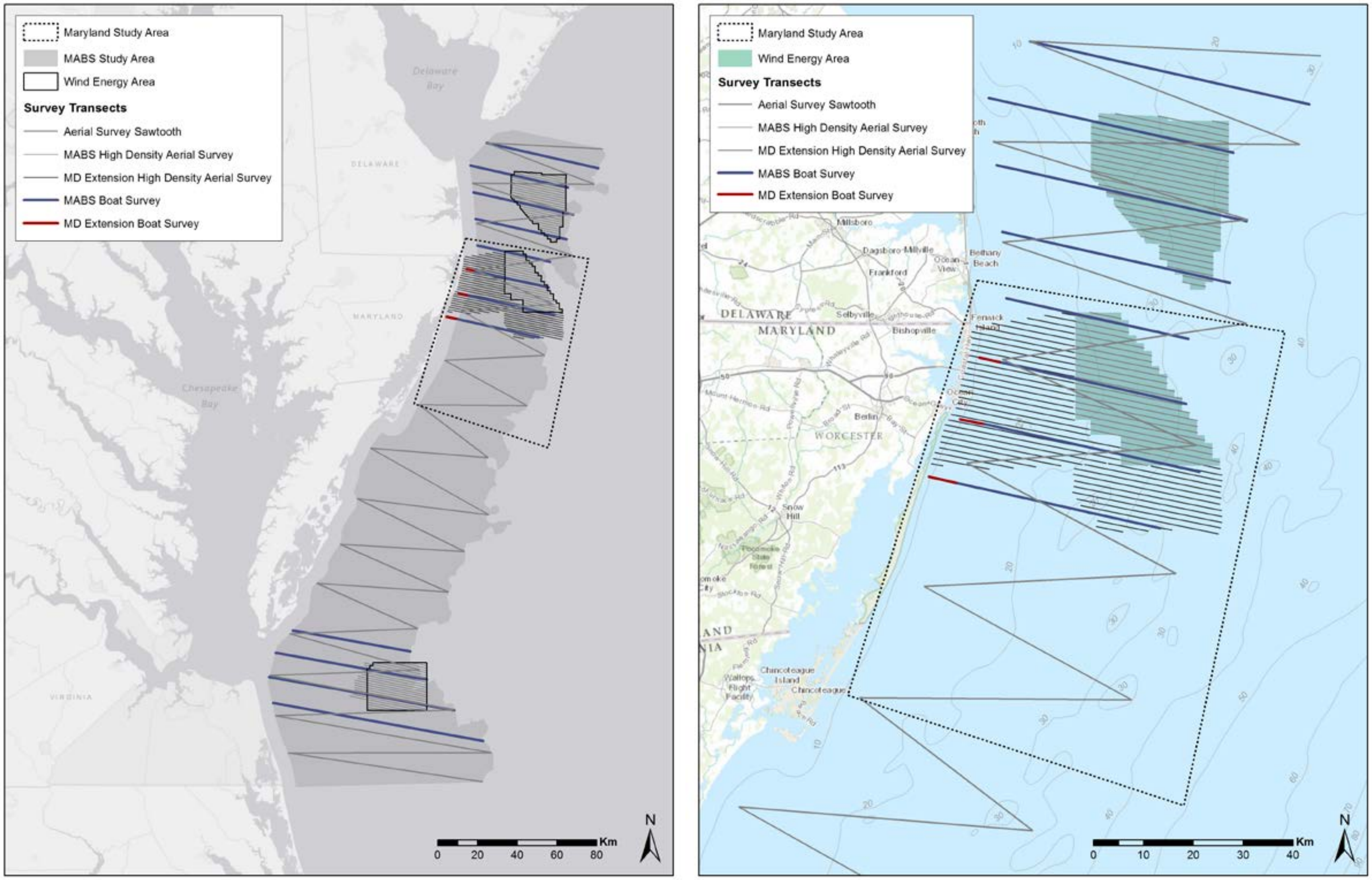

Figure 13-1. **Boat and aerial survey transects for the Mid-Atlantic Baseline Studies (MABS) and Maryland Projects.** The broader Mid-Atlantic study area, or MABS study area (left), includes surveys funded by both DOE and Maryland (2012-2014). The "Maryland study area" (right, black dashed line) includes all boat and aerial survey transects in waters offshore of Maryland (both DOE and Maryland-funded surveys, 2012-2014). The Maryland Project surveys are a subset of the surveys within the Maryland study area that were specifically funded by the state of Maryland in 2013-2014. These surveys included boat survey extensions into state waters (red bars), aerial survey high-density transect extensions west and south of the Maryland WEA (charcoal lines), and a 15th aerial survey of the Maryland WEA and Maryland extension high-density transects in 2013.

Table 13-1. Surveys used in the analysis for each species/group and the abundance of each species/group. Observed (Obs.) refers to raw counts and estimated abundance (Estim.) is fit to the sampled transects (summed across the listed surveys). We predicted (Predicted) the abundance of each species to a representative summer or winter day (25 Jul 2012 for terns; 25 Dec 2012 for **Northern Gannets**, loons, alcids) in each wind energy area (WEA) by state: Delaware (DE), Maryland (MD), and Virginia (VA). [a]Predictions used first survey intercept.

Year	Boat Surveys			Aerial Surveys			Group	Boat abundance					Aerial abundance			
								Obs.	Estim.	Predicted			Obs.	Predicted		
								trans.	trans.	DE WEA	MD WEA	VA WEA	trans.	DE WEA	MD WEA	VA WEA
First	**Jun-12**	**Aug-12**	**Sep-12**	**Jun-12**	**Sep-12**		Terns	534	3,378.4	1,151.5	1,382.4	152.4	108	93.4	109.6	11.2
	Nov-12	**Dec-12**	**Jan-13**	**Oct-12**	**Dec-12**	**Feb-13**	Gannets	3,998	8,960.5	1,215.5	1,313.6	408.0	4,190	1,158.3	932.6	1,022.6
	Dec-12	**Jan-13**	**Mar-13**	**Dec-12**	**Feb-13**	**Mar-13**	Loons[a]	996	3,811.2	1,139.6	804.8	1,356.0	1,661	368.7	329.8	307.5
							Common L.[a]	517	2,094.7	647.3	462.5	1,140.0	173	74.9	59.7	67.5
							Red-thr. L.[a]	441	1,805.9	360.7	260.3	185.4	117	64.2	62.1	30.7
		Dec-12	**Jan-13**		**Dec-12**	**Feb-13**	Alcids	598	3,495.1	1,409.3	889.5	2839.9	339	122.9	191.9	201.8
Second	**Jun-13**	**Aug-13**	**Sep-13**	**Jul-13**	**Sep-13**		Terns	243	1,877.9	269.4	309.0	74.4	154	19.8	29.0	1.5
	Oct-13	**Dec-13**	**Jan-14**	**Oct-13**	**Dec-13**	**Feb-14**	Gannets	4,723	5,693.9	5,340.3	1,578.3	2,272.4	1,612	419.3	412.8	152.2
	Dec-13	**Jan-14**	**Apr-14**	**Dec-13**	**Feb-14**	**May-14**	Loons[a]	2,626	10,884.9	1,476.7	1,512.9	941.5	2,062	666.7	521.9	697.6
							Common L.[a]	1,851	8,453.8	407.2	510.5	250.6	122	55.8	42.1	105.5
							Red-thr. L.[a]	754	2,586.0	216.0	187.1	97.9	1	NA	NA	NA
		Dec-13	**Jan-14**		**Dec-13**	**Feb-14**	Alcids	578	1,769.4	0.3	0.9	0.1	102	10.8	12.6	19.6

Table 13-2. Parameter estimates by year from the boat and high resolution digital video aerial surveys, using a Negative Binomial distribution to model counts of terns. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, r is the overdispersion parameter, and all abundance parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% Bayesian credible interval (BCI) does not overlap zero are in bold italics.

Terns		**Boat**								**Aerial**							
		First year				**Second year**				**First year**				**Second year**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**	-0.33	0.21	-0.74	0.08	***-0.94***	0.21	-1.33	-0.53	***-3.81***	0.24	-4.31	-3.36	***-4.18***	0.26	-4.70	-3.70
	Dst	***-1.96***	0.33	-2.64	-1.35	***-1.42***	0.20	-1.83	-1.05	***-1.61***	0.22	-2.05	-1.19	***-2.14***	0.20	-2.55	-1.77
	Slp	-0.32	0.19	-0.71	0.07	-0.02	0.17	-0.36	0.32	0.01	0.13	-0.24	0.26	0.08	0.10	-0.12	0.28
	Grn	-0.12	0.19	-0.48	0.25	0.24	0.19	-0.13	0.62	0.18	0.14	-0.11	0.45	***0.37***	0.13	0.13	0.63
	Sst	0.62	0.37	-0.10	1.33	0.17	0.16	-0.15	0.49	***0.64***	0.22	0.20	1.07	0.02	0.12	-0.21	0.25
	Sal	-0.31	0.32	-0.90	0.32	-0.08	0.18	-0.44	0.26	-0.39	0.25	-0.87	0.09	-0.30	0.16	-0.63	0.02
	Overdisp; r	0.12	0.02	0.09	0.15	0.21	0.04	0.14	0.31	0.22	0.07	0.12	0.38	0.31	0.08	0.18	0.49
Detection	**Beaufort 0-2**	***5.25***	0.07	5.12	5.38	***5.16***	0.09	5.00	5.33								
	Beaufort 3-6	***4.84***	0.07	4.70	4.98	***4.46***	0.11	4.24	4.68								

Table 13-3. Parameter estimates by year from the boat and high resolution digital video aerial surveys, using a Negative Binomial distribution to model counts of Northern Gannets. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, r is the overdispersion parameter, and all abundance parameters are on the log scale . Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% Bayesian credible interval (BCI) does not overlap zero are in bold italics.

Gannets		**Boat**								**Aerial**							
		First year				**Second year**				**First year**				**Second year**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**	***0.92***	0.10	0.72	1.13	***1.07***	0.09	0.89	1.26	***-0.14***	0.07	-0.28	0.01	***-0.80***	0.06	-0.93	-0.68
	Dst	***-1.21***	0.12	-1.43	-0.97	***-1.08***	0.13	-1.34	-0.83	0.11	0.08	-0.05	0.27	***-0.79***	0.07	-0.92	-0.65
	Slp	-0.11	0.11	-0.30	0.11	***0.30***	0.09	0.12	0.48	-0.09	0.07	-0.23	0.05	***0.26***	0.06	0.15	0.37
	Grn	0.13	0.10	-0.07	0.31	***-0.29***	0.12	-0.54	-0.07	***0.20***	0.07	0.05	0.34	***0.15***	0.06	0.03	0.26
	Sst	-0.02	0.12	-0.25	0.21	***-0.76***	0.10	-0.96	-0.56	***-1.87***	0.10	-2.06	-1.68	***-0.65***	0.08	-0.80	-0.50
	Overdisp; r	0.28	0.02	0.23	0.32	0.25	0.02	0.22	0.30	0.14	0.01	0.13	0.16	0.14	0.01	0.12	0.16
Detection	**Beaufort 0-2**	***5.86***	0.02	5.82	5.89	***5.67***	0.02	5.63	5.72								
	Beaufort 3-6	***5.91***	0.02	5.87	5.95	***5.82***	0.01	5.80	5.85								

Table 13-4. Parameter estimates by year from the boat and high resolution digital video aerial surveys, using a Negative Binomial distribution to model counts of all loons (Common, Red-throated, and unknowns combined). SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, r is the overdispersion parameter, and all abundance parameters are on the log scale (from the count process). Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% Bayesian credible interval (BCI) does not overlap zero are in bold italics.

Loons		Boat								Aerial							
		First year				Second year				First year				Second year			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept (survey 1)**	0.04	0.23	-0.40	0.50	***1.20***	0.24	0.72	1.70	**-0.95**	0.21	-1.36	-0.54	**0.13**	0.06	0.01	0.25
	Intercept (survey 2)	***0.56***	0.15	0.28	0.85	***1.32***	0.21	0.92	1.74	**0.67**	0.10	0.48	0.87	**0.72**	0.08	0.55	0.88
	Intercept (survey 3)	***1.37***	0.19	1.01	1.74	***1.31***	0.15	1.01	1.61	0.01	0.18	-0.35	0.35	**-2.06**	0.13	-2.31	-1.82
	Dst	***-0.25***	0.10	-0.45	-0.05	***-0.76***	0.17	-1.10	-0.43	**-0.65**	0.06	-0.76	-0.54	**-0.28**	0.04	-0.35	-0.20
	Slp	-0.11	0.08	-0.26	0.04	***0.21***	0.08	0.06	0.37	-0.02	0.04	-0.09	0.05	-0.07	0.04	-0.14	0.00
	Grn	-0.08	0.08	-0.23	0.07	***0.37***	0.09	0.20	0.57	-0.06	0.04	-0.13	0.02	0.00	0.03	-0.06	0.07
	Sst	***0.35***	0.12	0.12	0.57	***0.53***	0.12	0.30	0.76	**0.75**	0.11	0.53	0.96	**0.45**	0.07	0.32	0.58
	Sal	***-0.50***	0.12	-0.74	-0.26	-0.12	0.21	-0.53	0.30	-0.09	0.12	-0.33	0.14	**-0.23**	0.05	-0.32	-0.13
	Overdisp; r	0.67	0.07	0.54	0.82	0.44	0.04	0.37	0.52	0.51	0.03	0.46	0.58	0.66	0.04	0.58	0.75
Detection	**Beaufort 0-2**	***5.38***	0.03	5.32	5.43	***5.61***	0.03	5.56	5.66								
	Beaufort 3-6	***5.28***	0.04	5.21	5.36	***5.14***	0.02	5.10	5.17								

Table 13-5. Parameter estimates by year from the boat and high resolution digital video aerial surveys, using a Negative Binomial distribution to model counts of Common Loons. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, ***r*** is the overdispersion parameter, and all abundance parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% Bayesian credible interval (BCI) does not overlap zero are in bold italics.

Common Loons		**Boat**								**Aerial**							
		First year				**Second year**				**First year**				**Second year**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept (survey 1)**	***-0.94***	0.31	-1.54	-0.35	***1.23***	0.29	0.66	1.80	**-1.98**	0.48	-2.93	-1.03	**-2.37**	0.16	-2.70	-2.06
	Intercept (survey 2)	0.26	0.17	-0.06	0.60	***0.78***	0.26	0.27	1.28	**-2.00**	0.24	-2.47	-1.54	**-2.24**	0.25	-2.74	-1.76
	Intercept (survey 3)	***0.54***	0.24	0.08	1.02	***0.52***	0.19	0.15	0.90	**-4.37**	0.51	-5.41	-3.40	**-5.73**	0.46	-6.67	-4.86
	Dst	-0.15	0.13	-0.41	0.11	***-0.79***	0.22	-1.22	-0.34	-0.21	0.15	-0.52	0.08	0.07	0.11	-0.14	0.29
	Slp	-0.04	0.09	-0.21	0.14	***0.28***	0.10	0.09	0.48	0.05	0.10	-0.14	0.24	**-0.30**	0.14	-0.57	-0.04
	Grn	-0.07	0.09	-0.25	0.11	***0.42***	0.12	0.18	0.67	-0.06	0.10	-0.26	0.13	**0.22**	0.11	0.01	0.46
	Sst	***0.88***	0.16	0.57	1.21	***0.71***	0.15	0.41	1.00	-0.04	0.26	-0.55	0.46	**0.81**	0.20	0.41	1.21
	Sal	***-0.45***	0.15	-0.76	-0.15	0.23	0.26	-0.28	0.71	-0.07	0.28	-0.62	0.49	**-0.39**	0.13	-0.65	-0.14
	Overdisp; r	0.51	0.07	0.39	0.66	0.29	0.03	0.24	0.35	0.26	0.07	0.17	0.42	0.40	0.21	0.17	0.97
Detection	**Beaufort 0-2**	***5.32***	0.04	5.25	5.40	***5.47***	0.04	5.41	5.54								
	Beaufort 3-6	***5.20***	0.06	5.09	5.31	***5.09***	0.02	5.05	5.13								

Table 13-6. Parameter estimates by year from the boat and high resolution digital video aerial surveys, using a Negative Binomial distribution to model counts of Red-throated Loons. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, r is the overdispersion parameter, and all abundance parameters are on the log. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% Bayesian credible interval (BCI) does not overlap zero are in bold italics. There was only 1 observed Red-throated Loon in the second year aerial surveys, so no model was fit to these data.

Red-throated Loons		**Boat**								**Aerial**							
		First year				**Second year**				**First year**				**Second year**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept (survey 1)**	***-0.99***	0.37	-1.72	-0.30	***-2.29***	0.33	-2.94	-1.66	**-1.88**	0.90	-3.66	-0.15	NA	NA	NA	NA
	Intercept (survey 2)	***-1.43***	0.27	-1.98	-0.91	0.01	0.22	-0.42	0.44	**-2.60**	0.45	-3.48	-1.72	NA	NA	NA	NA
	Intercept (survey 3)	***0.85***	0.32	0.24	1.50	0.33	0.16	0.03	0.64	**-6.12**	0.87	-7.88	-4.48	NA	NA	NA	NA
	Dst	***-0.78***	0.17	-1.12	-0.46	***-1.13***	0.18	-1.50	-0.80	**-0.62**	0.31	-1.25	-0.03	NA	NA	NA	NA
	Slp	***-0.30***	0.12	-0.53	-0.07	-0.12	0.09	-0.30	0.06	-0.26	0.17	-0.59	0.06	NA	NA	NA	NA
	Grn	-0.08	0.13	-0.33	0.17	***0.23***	0.09	0.05	0.41	-0.05	0.17	-0.38	0.26	NA	NA	NA	NA
	Sst	-0.22	0.17	-0.56	0.11	***0.33***	0.12	0.09	0.58	-0.34	0.46	-1.22	0.58	NA	NA	NA	NA
	Sal	***-0.92***	0.25	-1.43	-0.45	***-0.54***	0.22	-0.98	-0.08	0.21	0.54	-0.85	1.28	NA	NA	NA	NA
	Overdisp; r	0.35	0.05	0.26	0.46	0.65	0.09	0.50	0.84	0.06	0.01	0.04	0.08	NA	NA	NA	NA
Detection	**Beaufort 0-2**	***5.34***	0.05	5.25	5.44	***5.70***	0.04	5.63	5.77								
	Beaufort 3-6	***5.20***	0.05	5.10	5.30	***5.26***	0.04	5.19	5.33								

Table 13-7. Parameter estimates by year from the boat and high resolution digital video aerial surveys, using a Negative Binomial distribution to model counts of alcids. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, ***r*** is the overdispersion parameter, and all abundance parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% Bayesian credible interval (BCI) does not overlap zero are in bold italics. There was only 1 observed Red-throated Loon in the second year aerial surveys, so no model was fit to these data.

Alcids		**Boat**								**Aerial**							
		First year				**Second year**				**First year**				**Second year**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**	***1.00***	0.12	0.78	1.24	***-0.51***	0.16	-0.83	-0.19	***-1.71***	0.12	-1.95	-1.47	***-2.95***	0.21	-3.35	-2.52
	Dst	***0.54***	0.15	0.24	0.84	***-1.45***	0.24	-1.93	-0.94	0.04	0.13	-0.20	0.29	**-0.61**	0.28	-1.18	-0.07
	Slp	0.13	0.10	-0.06	0.34	-0.03	0.14	-0.30	0.27	-0.19	0.12	-0.43	0.05	-0.43	0.23	-0.88	0.02
	Grn	-0.20	0.12	-0.44	0.04	0.13	0.19	-0.23	0.50	0.26	0.14	-0.02	0.53	0.02	0.25	-0.47	0.50
	Sst	***-0.28***	0.13	-0.54	-0.02	0.00	0.18	-0.37	0.34	***0.65***	0.15	0.36	0.95	***-0.58***	0.23	-1.03	-0.13
	Sal	-0.09	0.11	-0.30	0.13	***2.06***	0.26	1.53	2.54	***0.79***	0.12	0.55	1.03	0.38	0.29	-0.18	0.95
	Overdisp; r	0.38	0.05	0.29	0.49	0.25	0.04	0.18	0.33	0.08	0.01	0.06	0.10	0.02	fixed		
Detection	**Beaufort 0-2**	***5.19***	0.04	5.12	5.27	***5.61***	0.05	5.52	5.72								
	Beaufort 3-6	***4.56***	0.06	4.45	4.67	***5.54***	0.04	5.46	5.61								

Table 13-8. Bayesian p-values for the abundance and detection components of the models. Values close to 0.5 indicate good model fit.

Group	Sub-group	Boat				Aerial	
		First year		Second year		First year	Second year
		Abundance	Detection	Abundance	Detection	Abundance	Abundance
Terns		0.58	0.50	0.51	0.39	0.39	0.58
Gannets		0.66	0.45	0.71	0.75	0.99	0.72
Loons	All	0.5	0.81	0.6	0.99	0.85	0.65
	COLO	0.53	0.55	0.63	0.88	0.42	0.42
	RTLO	0.55	0.62	0.55	0.97	0.51	NA
Alcids		0.52	0.54	0.51	0.58	0.48	0.49

Table 13-9. Observed values in the digital aerial surveys for year 2, comparing the larger study area (MABS) to surveys of Maryland (MD WEA and MD extension transects). Note the tern analysis here includes the August 2013 surveys.

Group	MABS	MD
Terns	223	155
Gannets	1612	506
Loons	2062	423
Alcids	102	7

Table 13-10. Parameter estimates for terns, gannets, and loons for the larger study area (MABS) and surveys including only Maryland (MD WEA and MD extension transects). Estimates considered significantly different from 0 are in bold. All results are for the same seasons as Table 13-1, but only the aerial data for the second year results are shown here. For this analysis of terns, we included the August 2013 survey because it included all of the Maryland waters (the survey is also included in the MABS study area analysis, which changed the parameter estimate slightly from those presented in Table 13-1). Salinity was not included in the Northern Gannet model.

Term	**Terns**				**Gannets**				**Loons**			
	MABS		**MD**		**MABS**		**MD**		**MABS**		**MD**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Intercept; α_0	**-3.88**	0.21	**-2.86**	0.22	**-0.80**	0.06	**-0.62**	0.10	**-0.21**	0.04	**-0.54**	0.07
Dst; α_1	**-2.17**	0.17	**-1.77**	0.17	**-0.79**	0.07	**-0.74**	0.11	**-0.23**	0.04	0.00	0.08
Slp; α_2	0.16	0.08	**0.27**	0.10	**0.26**	0.06	0.13	0.09	**-0.15**	0.04	-0.11	0.07
Grn; α_3	0.13	0.09	0.07	0.09	**0.15**	0.06	0.03	0.09	**0.11**	0.04	**-0.21**	0.07
Sst; α_4	0.03	0.1	-0.19	0.14	**-0.65**	0.08	**-0.62**	0.12	**-0.41**	0.04	**-0.42**	0.07
Sal; α_5	**-0.42**	0.14	**-0.43**	0.14	-	-	-	-	**0.16**	0.04	-0.05	0.06
Overdisp.	0.43	0.09	1.02	0.46	0.14	0.01	0.19	0.02	0.49	0.03	0.83	0.15

Chapter 14: Developing an integrated model of marine bird distributions with environmental covariates using boat and digital video aerial survey data *This chapter is in draft form

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

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Chapter 14 Highlights

Developing an integrated model of marine bird distributions with environmental covariates using boat and digital video aerial survey data

Context[1]

A broad geographic and temporal scale of analysis is required to assess exposure to wildlife from proposed development projects. In this study, data were collected via traditional methods (boat-based distance sampling) and with newer technologies (high definition videography) with the intention of addressing similar questions related to marine wildlife abundance and distribution. Chapter 13 explored the two datasets to determine if similar patterns were detected by each sampling method. Based on those results, Chapter 14 aims to develop a method of integrating these two datasets into a combined approach that makes use of the strengths of each survey type, to produce a single prediction of marine bird abundance and distribution.

In this approach, predictions of marine bird abundance and distribution are jointly informed by aerial surveys, which encompassed a large geographic area, and boat surveys, which allowed for estimation of detection probability. We analyze data from the same four species groups as Chapter 13 (terns, alcids, loons, and Northern Gannets), and incorporate remotely collected environmental covariate data into the hierarchical modeling structure. This approach accounts for imperfect detection to estimate “true” abundance, and predicts marine bird distributions to help identify important habitat use areas and patterns.

Study goal/objectives addressed in this chapter

Evaluate potential exposure of the marine bird community to offshore development by: (1) developing a model to integrate data from the two survey platforms; and (2) producing a single prediction of abundance and distribution to identify ecological drivers of distribution, abundance, and local hotspots.

Highlights

- Distance to shore was generally the most common predictor of abundance, as was found in Chapters 9 and 13.
- Integrated models predicted species-specific hotspots that generally concurred with Chapters 9 and 11, with terns largely distributed along near shore habitats, alcids distributed across large areas of the regional study area, loon hotspots near the mouth of the Chesapeake Bay, and Northern Gannet aggregations that were generally outside of the Maryland study area.
- Integrated models outperformed models based only on the boat data when predicting back to the original datasets, but boat-only models were better at predicting to independent datasets (i.e., separate boat and aerial surveys conducted in the same season)

Implications

Developing new approaches to jointly model disparate datasets can improve identification of important habitat use areas, while also providing a framework to combine historical and new sources of data.

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[1] For more detailed context for this chapter, please see the introduction to Part IV of this report.

Abstract

We investigated an approach to combine shipboard and digital video aerial survey data for marine birds to produce a single prediction of marine bird abundance and distribution. Modeling frameworks were similar to those in other chapters (for example, the boat survey data are modeled similarly to Chapter 9, Chapter 13, and Sollmann et al. [2015], but with single species instead of a community), but we aimed to create a method for integrating the boat and aerial datasets. Our approach in this chapter creates a covariate based on the data from the digital video aerial surveys to be included as a predictor variable in the boat surveys. We compare models with and without the aerial covariate and evaluate the model performance. As in Chapter 13, we focused on terns (summer 2013), Northern Gannets (winter 2012), loons (winter 2012), and alcids (winter 2012). The preliminary results showed that integrated and boat-only models predicted similar total abundance across the Mid-Atlantic regional study area, but distributions and hotspot locations often varied between approaches. Northern Gannets and loons showed strong associations between aerial and boat data, which led to concentrated hotspots for both species. The influence of integrated models were less evident for terns and alcids, but differences in predicted spatial patterns of abundance were still evident. Model evaluation indicated that integrated models outperformed models that only used boat data when predicting back to the same boat and aerial data used for the analysis, but boat-only models were better at predicting distributions from separate surveys (i.e., boat and aerial surveys conducted in the same season but during a different month than the data used in the analysis). The results of this chapter generally support conclusions of Chapters 9, 11, and 13, which found that the distribution of marine birds was often patchy, species- and survey-specific, and correlated with habitat covariates. Developing new joint modeling approaches can improve identification of important habitat use areas (particularly local dynamic hotspots) and provides a framework to compare historical and new sources of data. Further exploration of seasonal, annual, and species-specific results will be useful to evaluate the performance of integrated models to predict important habitat use areas.

Introduction

Shipboard and traditional aerial survey methodologies have been compared extensively in their performance at estimating marine bird species richness and abundance (see Camphuysen et al. 2004 for an overview). Advantages of shipboard and aerial survey methods vary by species of interest, logistical constraints, size of area surveyed, and specific research questions (Camphuysen et al. 2004). High resolution digital video aerial surveys (hereafter “digital video aerial surveys”) have become common practice for monitoring of marine wildlife in Europe in relation to offshore wind energy development, but the technology is still relatively new, and thus has seldom been compared to more traditional survey approaches. Digital video aerial surveys provide several benefits, including coverage of a larger geographic area in a faster timeframe than is possible with boat surveys (Buckland et al. 2012). Likewise, boat-based surveys provide advantages such as the ability to estimate detection probability based on distance sampling, and thereby adjust raw counts to develop estimates of abundance (Buckland et al. 1993, see Chapter 9 for details). Application of concurrent shipboard and digital video aerial surveys in this study provided a unique opportunity to integrate data collected from both these survey types, thus utilizing the strengths of each survey platform.

Herein, we investigate an approach to combine shipboard and digital aerial surveys for marine birds into a single model that uses information from both datasets (hereafter "integrated model"). We aim to compare integrated models and models that use strictly boat data (here after "boat-based"). This chapter includes the same suite of species as Chapter 13 (terns, Sternidae; alcids, Alcidae; loons, *Gavia* spp.; and Northern Gannets, *Morus bassanus*) to allow for improved comparisons and insights across multiple species groups.

Our objectives include:

1. Develop an integrated modeling approach that combines digital video aerial and boat-based data to produce a single prediction of marine bird abundance and distribution.
2. Compare the performance of integrated and boat-based models by evaluating their predictive ability to (1) the original boat and aerial datasets (Fitted surveys) and (2) independent boat and aerial surveys (i.e., independent surveys conducted in the same season but during a different month).

It is important to note that there are methodological differences in sampling from the boat versus digital videography. Some differences are inherent to the two survey methods, such as transect width; the boat surveys sample wider transect widths for most species, and use distance sampling to account for variation in detection, while aerial surveys sample a defined strip width for all species. Other differences are specific to the survey design utilized in this study (e.g., boat and aerial transects were located in slightly different geographic areas and occurred at different dates and times). To minimize the study-specific sources of variation, we accounted for the differences in area sampled, and only used data from boat and aerial surveys that occurred within a similar temporal period (i.e., within the same or consecutive months of each other).

In general, our approach first utilized the large geographic coverage of digital video aerial surveys to predict areas of higher or lower than average expected marine bird abundance across the Mid-Atlantic Baseline Studies survey area (hereafter "regional study area"), essentially mapping raw hot and cold spots for each species. Smoothed counts from the digital video aerial surveys (i.e., the degree to which grid cells were above or below expected values) were then integrated as a covariate in analysis of boat surveys. As in Chapters 9, 12, and 13, habitat covariates were also included in the analysis. This approach allowed predicted marine bird abundance from boat data to not only vary by habitat covariates (similar to Chapters 9 and 13), but also by information on expected abundance derived from digital video aerial surveys. This additional covariate should inform model predictions if similar trends in distribution and abundance were observed in both boat and digital video aerial surveys (Chapter 13). Specific details on our modeling approach are provided in the Methods section.

We caution the reader that the approach we use in this chapter is not a fully integrated model, as we use the aerial survey data as a covariate for analyzing the boat survey data. However, we implemented this approach to see if the aerial data would provide useful information for estimating abundance and local hotspots of abundance. After building the models, we compare and contrast those with and without the aerial data covariate to see how well the models do at (1) estimating overall abundance and local hotspots and (2) predicting future seabird patterns. This chapter is an important step towards simultaneously modeling the two data types, which is the ultimate goal and will continue to be pursued in an addendum to the final report, to be completed in 2016.

Methods

Field methods for the aerial and boat surveys were explained elsewhere in this report (Chapters 3 and 6, respectively). Aerial identification protocols for video analysis were discussed in Chapter 4. For this comparison, we used boat survey observations that were sampled from the forward quadrant on one side of the vessel, extending up to 1 km from the trackline, and digital aerial observations that were collected from four cameras, which each recorded a 50 m band (totaling 0.2 km strip width). For both the boat and aerial surveys, we divided survey transects into 4 km segments; this resulted in some shorter segments at the transect ends, and segment area (the segment length by the abovementioned strip widths for each survey method) was included in our analysis as an offset. The number of individuals for each species was summed by segment and survey. We compared two modeling methods to estimate abundance and covariate relationships for the same species groups examined in Chapter 13, using data from boat and aerial surveys that were closely coincident in time.

Species

We investigated the same suite of species as Chapter 13 (terns, alcids, loons, and Northern Gannets).

Terns

Terns included Least Terns (*Sternula antillarum*), Caspian Terns (*Hydroprogne caspia*), Black Terns (*Chlidonias niger*), Common Terns (*Sterna hirundo*), Roseate Terns (*Sterna dougallii*), Royal Terns (*Thalasseus maximus*), and Sandwich Terns (*Thalasseus sandvicensis*), as well as those individuals classified as “unidentified terns.” Vague identifications that could have included other species such as gulls (e.g., “large tern or small gull,”) were excluded. Terns were primarily present in the regional study area during spring, summer and fall (Chapters 5, 7, and 9), so we focused on boat and aerial surveys during the summer (Chapter 13), specifically August (boat) and September (aerial) 2013, both of which included Maryland Project surveys (Table 14-1, Figure 14-2).

Northern Gannets

Northern Gannets are the only gannet species found in the regional study area. Because Northern Gannets were primarily present in the regional study area in late fall to early spring (Chapters 5, 7, and 9), it made sense to focus on boat and aerial surveys during the winter season (Chapter 13), and for this analysis, we selected the survey from December 2012.

Loons

We considered loons as a group (all loons, which included Common Loons, *Gavia immer*, Red-throated Loons, *G. stellata,* and all unidentified loon observations). Similar to Northern Gannets, loons were primarily present in the regional study area from late fall to early spring (Chapters 5, 7, and 9). We used the same survey, December 2012, for the analysis of loons.

Alcids

The alcid group included Razorbills (*Alca torda*), Dovekies (*Alle alle*), Atlantic Puffins (*Fratercula arctica*), Common Murres (*Uria aalge*), Thick-billed Murres (*U. lomvia*), and Black Guillemots (*Cepphus grille*), as well as those individuals classified as "unidentified alcids". Alcids were primarily present in the regional study area during winter (Chapters 5, 7, and 9), so again we focused on boat and aerial surveys during the winter season (Chapter 13), specifically December 2012.

Covariates

As in Chapter 13, we used five covariates in our analyses: three static (distance to shore, slope, and grain size), and two dynamic (sea surface temperature and salinity). We excluded chlorophyll-*a* in these analyses because it was co-linear with distance to shore in some of the surveys and we wanted to keep the covariates consistent across species. As in Chapter 13, remotely sensed covariate data corresponded to the values located at the midpoint of each transect segment. For the static covariates, we calculated distance to shore (m) within ArcGIS 10.2 (ESRI, Redlands, CA) and extracted slope (% rise, 370-m resolution) and grain size (ϕ = -log2[mean grain diameter in mm], 370-m resolution) from the data layer derived by NOAA/NOS National Centers for Coastal Ocean Science (Kinlan et al. 2013). For the dynamic covariates, we used Marine Geospatial Ecology Tools in ArcGIS (Roberts et al. 2010) to download remotely-sensed data at the highest resolution available for all segments. We compiled daily values for sea surface temperature (SST, °C, 1-km GHRSST L4) and salinity (Practical Salinity Units, 9-km HYCOM GLBa0.08 Equatorial 4D). In the boat survey analysis, we additionally included Beaufort sea state on the binary scale as a covariate to detection, which varied by segment (0 = calm seas, Beaufort state 0-2; 1 = rough seas, Beaufort state 3-6; see Chapters 9 and 13).

We overlaid a predictive grid (approximately 4x4 km grid cells) that encompassed the regional sampled area, including the Maryland study area (Figure 14-1, Figure 14-2, and Figure 14-3; note that this predictive grid is a restricted version of the one used in Chapter 9, to represent the area covered by digital aerial surveys). As in Chapter 9, we used data from the midpoint of each cell and the central date for each season to predict overall flock abundance to a representative day (summer [terns]: 25 July 2013, winter [Northern Gannets, loons, and alcids]: 25 December 2012).

Models

To facilitate comparisons, we used the same modeling approach across all species. We summarized the aerial data such that y_i is the count at segment i. For each species or group, we then modeled the aerial data using an overdispersed Poisson conditional autoregressive (CAR) model. This approach allowed us to capture excess heterogeneity in counts at the segment level (overdispersion), while also allowing spatial clustering of counts at a broader level with the CAR portion. To implement the model, we assigned each segment to the predictive grid cell that it fell within, thus the notation $i[j]$ indicates that segment i is within grid cell j.

The model for aerial surveys was:

$$y_i \sim \text{Poisson}(\lambda_i)$$

$$\log(\lambda_i) = \alpha_0 + offset\ (segment\ area_i) + \varepsilon_i + \theta_{i[j]}$$

where α_0 is the intercept, ε_i is a random effect at the segment level (i), and $\theta_{i[j]}$ is the spatially correlated random effect at the predictive grid cell level (j). Random segment effects (ε_i) were distributed $\mathrm{Normal}(0, \tau^2)$. Spatial autocorrelation was evaluated at the grid cell level, thus repeated segments (i) within grid cell j were assigned the same $\theta_{i[j]}$. Specifically,

$$\theta_j | \theta_k \neq \theta_j \sim \mathrm{Normal}\left(\frac{1}{m_j} \sum_{k \in c_j} \theta_k, \frac{\sigma^2}{m_j}\right)$$

where $m_j$is the number of neighbors for predictive grid cell j and c_j is the specific set of neighbors for predictive grid cell j. The set of neighbors for each predictive grid cell (c_j) was all adjacent grid cells (i.e., Queen's neighborhood). The CAR model also allows inference to unsampled grid cells by utilizing the spatial correlation observed in counts across the sampled area. Grid cell specific random effects (θ_j) had a sum to 0 constraint. The θ_j valuesindicate higher or lower expected grid cell abundance and were then used to inform abundance estimates from the boat data.

Next, for each species or group, we conducted preliminary diagnostics to evaluate boat-based data and select the best model for flock abundance, considering the Poisson and Negative Binomial distributions (see Chapters 9 and 13 for details). It should be noted that in this chapter, as well as Chapter 9, abundance of flocks was the sampling unit of analysis; however, Chapter 13 used individuals instead of flocks to make direct comparisons between boat and aerial surveys. Boat-based models for Northern Gannets, loons, and terns used a Negative Binomial distribution on abundance. The abundance component of the boat-based model was constructed such that the flock abundance at segment i, N_i, was modeled as:

$$N_\mathrm{i} \sim \mathrm{NegBin}(\lambda_i,\ r)$$

$$\log(\lambda_i) = \beta_0 + offset\ (segment\ area_i) + \beta_1 \mathrm{Dst_i} + \beta_2 \mathrm{Slp_i} + \beta_3 \mathrm{Grn_i} + \beta_4 \mathrm{Sst_i} + \beta_5 \mathrm{Sal_i} + \ \beta_5 \theta_{i[j]}$$

where Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, $\theta_{i[j]}$ = the estimated spatially correlated random effect defined above from the aerial data, and r is the overdispersion parameter. In this approach, a positive parameter estimate for the aerial covariate (β_5) indicates that aerial and boat surveys were observing similar trends, and data integration is informative for understanding the abundance patterns between the two surveys. Alcid boat-based data were adequately fit with a Poisson distribution, which was identical to the above model except that $N_\mathrm{i} \sim \mathrm{Pois}(\lambda_\mathrm{i})$.

Raw count of flocks at segment i, n_i were linked to true abundance (N_i) through estimation of detection probability using a half-normal distribution (i.e., distance sampling, see Chapters 9 and 13, Buckland et al. 1993). As in Chapters 9 and 13, we allowed the detection function to vary by a binary indicator of sea state.

Model evaluation

We evaluated integrated and boat-based models by predicting abundance to the original boat and aerial survey data (i.e., fitted surveys) and independent boat and aerial data (i.e., independent surveys in the same season). Specifically, we compared tern predictions to the original survey data, August 2013 (boat) and September 2013 (aerial), as well as to independent surveys conducted during September 2013 (boat) and July 2013 (aerial). For Northern Gannets, loons, and alcids we compared predictions to the original survey data in December 2012 (boat and aerial) and independent surveys conducted during January 2013 (boat and aerial). Using the posterior means of each model parameter, we predicted the abundance of each species using survey-specific habitat covariates. Predictive ability was evaluated using root mean squared error (smaller indicates better model fit) with each segment considered as a replicate.

Implementation

We implemented all models in a Bayesian framework using the package “R2OpenBUGS” (Sturtz et al. 2010) to run the software OpenBUGS (Thomas et al. 2006) in program R version 3.2.0 (R Core Team 2014). We standardized the covariates for analysis to center them on a mean = 0, with a variance close to 1. We ran three parallel Markov chains for 40,000 iterations following a burn-in of 20,000 iterations, thinning by 5. We checked for chain convergence visually (posterior density and trace plots), and quantitatively using the Gelman-Rubin statistic (Gelman et al. 2014). This statistic (termed R-hat) is a measure of among-chain versus between-chain variance and values < 1.1 indicate convergence (Gelman et al. 2014). We also assessed goodness of fit by computing Bayesian p-values. We used Freeman-Tukey fit statistics to evaluate the model for abundance, and the Half Normal detection function (Gelman et al. 2014).

Results

The number of species/group-specific observations were > 100 for loons, Northern Gannets, and alcids in both boat (flocks) and digital aerial surveys (individuals), and > 60 for terns (Table 14-1). Mean flock size varied by species, but most observed flocks were $\leq$ 2 individuals (Table 14-1). Distributions of flock size were right-skewed for all species, with larger flocks ($\geq$ 18) only observed on rare occasions (Table 14-1). Bayesian p-values suggested that model fit was adequate for all of the abundance and detection model components (Table 14-2).

Integrated and boat-based models often resulted in similar abundance estimates for the regional study area (Table 14-3). For example, predicted tern abundance from the integrated and boat-based models was 3,367 and 3,727, respectively. Covariate relationships were also similar between integrated and boat-based models (Table 14-4 to Table 14-7). The noticeable exception to this trend was parameter estimates for distance to shore, especially for Northern Gannets. Integrated models for Northern Gannets predicted a significant positive relationship, while boat-based models predicted a negative relationship (Table 14-6). A reversal of the distance to shore parameter estimate was also observed for loons and alcids, but differences were generally smaller or non-significant (Table 14-6, Table 14-7, see next paragraph and Discussion for detailed explanations). Parameter estimates for the aerial covariate were positive and significant for both Northern Gannets and loons (Table 14-5, Table 14-6). Positive parameter estimates indicated that variation in expected grid cell abundance in the aerial-based models were positively correlated with variation in expected grid cell abundance estimated from the boat data. Mean parameter estimates for terns and alcids were negative, but not significant (Table 14-4, Table 14-7).

Predicted regional distribution and abundance from both integrated and boat-based models showed similar relationships, with terns, loons, and Northern Gannets predicted to be closer to shore (Figure 14-3 to Figure 14-5). Integrated models, however, often identified regional hotspots that were not predicted in boat-based models (Figure 14-3 to Figure 14-6). Hotspots were particularly evident for Northern Gannets (Figure 14-4) and loons (Figure 14-5). Predicted regional distributions for terns and alicds were often more similar across models, but areas of higher and lower abundances were still noticeable (Figure 14-3, Figure 14-6). For instance, boat-based models for Northern Gannets predicted a rather uniform trend in abundance that decreased with distance to shore. Integrating information from aerial surveys, however, predicted a much more clustered distribution, even though total abundance was similar between the models (Figure 14-4, Table 14-1). Predicted clustering of loons and Northern Gannets across the regional study area reduced the predicted abundance of these species in the Maryland study area (Figure 14-4 and Figure 14-5). For instance, the integrated model predicted increased loon clustering near the mouth of the Chesapeake Bay, and lower abundance in the Maryland study area relative to boat-based model predictions (Figure 14-5). Similarly, though predicted distribution and abundance of terns and alcids in the Maryland study area were generally similar between the two models (Figure 14-3 and Figure 14-6), boat-based models for terns predicted a relatively ubiquitous near-shore abundance that quickly decreased with distance to shore (Figure 14-3), while integrated models also indicated several areas of higher and lower abundances in the nearshore environment (Figure 14-3). Over the regional study area, the range of predicted grid cell-specific flock abundances was much smaller for alcids (range = 0 - 40 flocks per grid cell) and terns (0 - 60 flocks per grid cell) relative to Northern Gannets (0 - 400 flocks per grid cell) and loons (0 - 200 flocks per grid cell; note species-specific scales for Figure 14-3 to Figure 14-6).

Root mean squared error for integrated models was generally lower, or at least equal to boat-based models when predicting back to the original boat and aerial survey data (Table 14-8). Boat-based predictions, however, often outperformed integrated models when predicting to independent boat and aerial survey data (i.e., predicting to a different survey in the same season, Table 14-8).

Discussion

Jointly modeling aerial and boat survey data can improve our understanding of several important ecological phenomena important to proposed wind energy development, especially (1) clustering of marine wildlife within the regional study area and (2) relationships between marine wildlife abundance and spatially varying habitat covariates. An integrated approach utilizes beneficial aspects of both survey methods, with study area predictions informed by both aerial surveys, which encompassed a large geographic area, and boat surveys that allowed for estimation of detection probability (see Chapters 9 and 13, Winiarski et al. 2014). The integrated model presented herein had noticeable improvements in predicting local hotspots and marine bird distribution relative to models that only included boat-based data. The integrated model, however, had relatively low predictive power to independent surveys (data collected from a survey different than the one used to fit the models), which was likely a consequence of interseasonal variation in local hotspots, changes in habitat covariates, and possibly changes in the relationships with those covariates (Winiarski et al. 2013, Winiarski et al. 2014, Chapter 13).

In general, habitat relationships were similar to those presented in Chapter 13. For instance, relationships with distance to shore were consistently negative for terns, loons, and Northern Gannets in boat-based models herein and in Chapter 13. Conversely, parameter estimates for distance to shore were sometimes reversed (positive) in the integrated model. Both boat-based and integrated models, however, still predicted increased nearshore distribution patterns (e.g., areas of higher predicted abundance for Northern Gannet were generally closer to shore). Distance to shore and the aerial covariate used in the integrated model were collinear for all species (≤ 0.60), but likely not strong enough to completely explain the differences in the distance to shore parameter estimate. Instead, integrating aerial data likely provided more information on areas of particularly high or low abundances, and was a more informative covariate than the less variable distance to shore covariate. These examples demonstrate the necessity of investigating both parameter estimates and predicted abundance maps to determine proper interpretations from boat-based and integrated models.

In line with our hypotheses, integrated models improved the identification of species-specific hotspots and areas of lower than expected abundances. The greater spatial coverage of aerial surveys improved the detection of latitudinal gradients and hotspots, especially those occurring outside of areas surveyed by the boat. Covariate relationships identified during boat surveys, however, remained important predictors of marine bird abundance and distribution. Differences between modeling approaches were most evident for Northern Gannets and loons, where integrated models predicted increased clustering relative to boat-based model predictions. For loons, integrated models predicted both a distance to shore effect and latitudinal gradient, with abundances highest near the mouth of the Chesapeake Bay (southwest section of the regional study area). Similarly, integrated model predictions for Northern Gannets were clustered near the mouth of the Chesapeake Bay and a few nearshore areas off the coast of Virginia. Predicted clustering of loons and Northern Gannets in the integrated model resulted in lower predicted flock abundances in the Maryland study. Predictions for terns and alcids in the Maryland study area, however, were generally similar across modeling approaches.

Integrated models were an improvement over boat-only models at identifying hotspots and predicting to the original surveys. Boat-only models, however, were better at predicting patterns observed in independent surveys conducted in the same season, which are likely longer-term patterns of abundance. Short-term changes in local hotspot locations, possibly due to shifting prey distributions, affect the predictive ability of both modeling approaches. Predictions from integrated models may be particularly affected by shifting hotspot locations, as aerial data from one sampling period will not necessarily improve predictions for a different sampling period. Further exploration of seasonal, annual, and species-specific differences beyond those explored here will help evaluate the performance of integrated models. Overall, integrated models improved identification of important habitat use areas, but further work is required to explore their predictive ability across surveys.

Developing new approaches to jointly model disparate datasets can improve identification of important habitat use areas, while also providing a framework to compare and possibly combine historical (i.e., boat-based) and new sources of data (i.e., boat-based and high definition videography). Here, we have used the aerial data as a covariate for estimating abundance from the boat data, but have not formally integrated the two data types. Identification of positive relationships between boat and aerial surveys suggests that these survey types often identify similar trends in abundance and distribution across the regional study area. Verifying the consistency of these results across multiple surveys, species, and geographic areas will be vital to developing fully integrated modeling approaches.

Literature cited

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., 1993. Distance sampling: Estimating abundance of biological populations. Chapman and Hall, London.

Buckland, S.T., Burt, M.L., Rexstad, E.A., Mellor, M., Williams, A.E., Woodward, R., 2012. Aerial surveys of seabirds: the advent of digital methods. Journal of Applied Ecology 49, 960-967.

Camphuysen, C.J., Fox, A.D., Leopold, M.F., Petersen, I.K., 2004. Towards standardised seabirds at sea census techniques in connection with environmental impact assessments for offshore wind farms in the U.K. Royal Netherlands Institute for Sea Research, Texel.

Gelman, A., Carlin, J.B., Stern, H.S., Dunson, D.B., Vehtari, A., Rubin, D.B., 2014. Bayesian Data Analysis, Third Edition. Taylor & Francis, New York, NY, USA.

Kinlan, B.P., Poti, M., Drohan, A., Packer, D.B., Nizinski, M., Dorfman, D., Caldow, C., 2013. Digital data: Predictive models of deep-sea coral habitat suitability in the U.S. Northeast Atlantic and Mid-Atlantic regions. Downloadable digital data package. Department of Commerce (DOC), National Oceanic and Atmospheric Administration (NOAA), National Ocean Service (NOS), National Centers for Coastal Ocean Science (NCCOS), Center for Coastal Monitoring and Assessment (CCMA), Biogeography Branch. Released August 2013. Available at: http://coastalscience.noaa.gov/projects/detail?key=35.

R Core Team. 2014. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Roberts, J., Best, B., Dunn, D., Treml, E., Halpin, P., 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. http://mgel.env.duke.edu/mget.

Sollmann, R., Gardner, B., Gilbert, A., Williams, K., Veit, R., 2015. A community distance sampling model to investigate the abundance and distribution of seabirds, 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.

Sturtz S., Ligges U., Gelman A., 2010. R2OpenBUGS: a package for running OpenBUGS from R. http://openbugs.info/w/UserContributedCode

Thomas, A., O'Hara, B., Ligges, U., and Sturtz, S., 2006. Making BUGS Open. R News 6, 12-17.

Winiarski, K.J., Miller D.L., Paton P. W.C., and McWilliams S.R., 2013. A spatially explicit model of wintering common loons: Conservation implications. Marine Ecology Progress Series 492:273–278.

Winiarski, K.J., Burt, M.L., Rexstad, E., Miller, D.L., Trocki, C.L., Paton, P.W.C., McWilliams, S.R., 2014. Integrating aerial and ship surveys of marine birds into a combined density surface model: A case study of wintering Common Loons. The Condor, 149-161.

Figures and tables

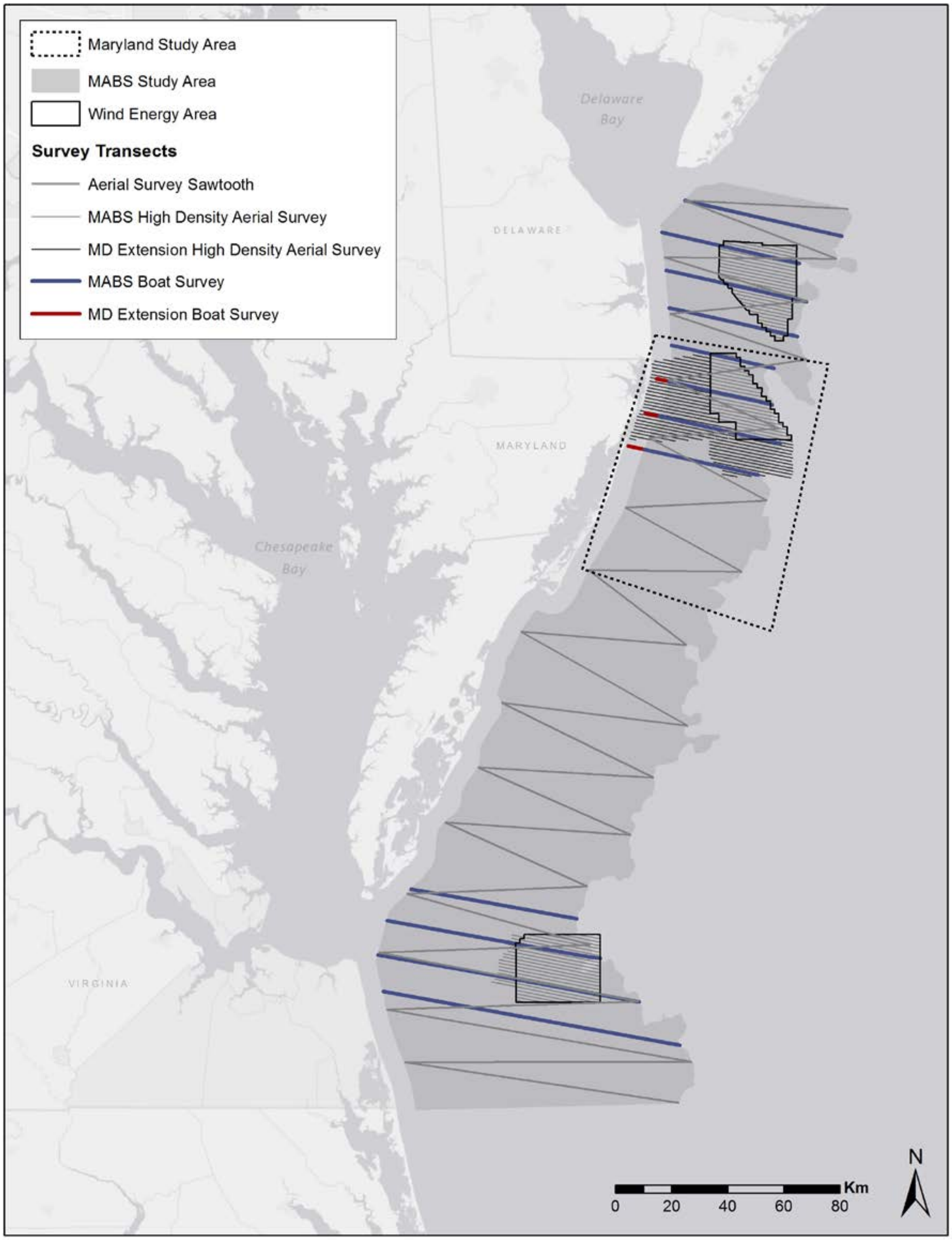

Figure 14-1. Regional study area. Boat transects are shown in blue and red; aerial transects are shown in gray; Maryland extension transects (funded by the state of Maryland and conducted only in the second year of surveys) are shown red (boat) and dark gray (aerial). Department of Energy (DOE)-funded high density aerial surveys were located within federally designated wind energy areas (WEAs).

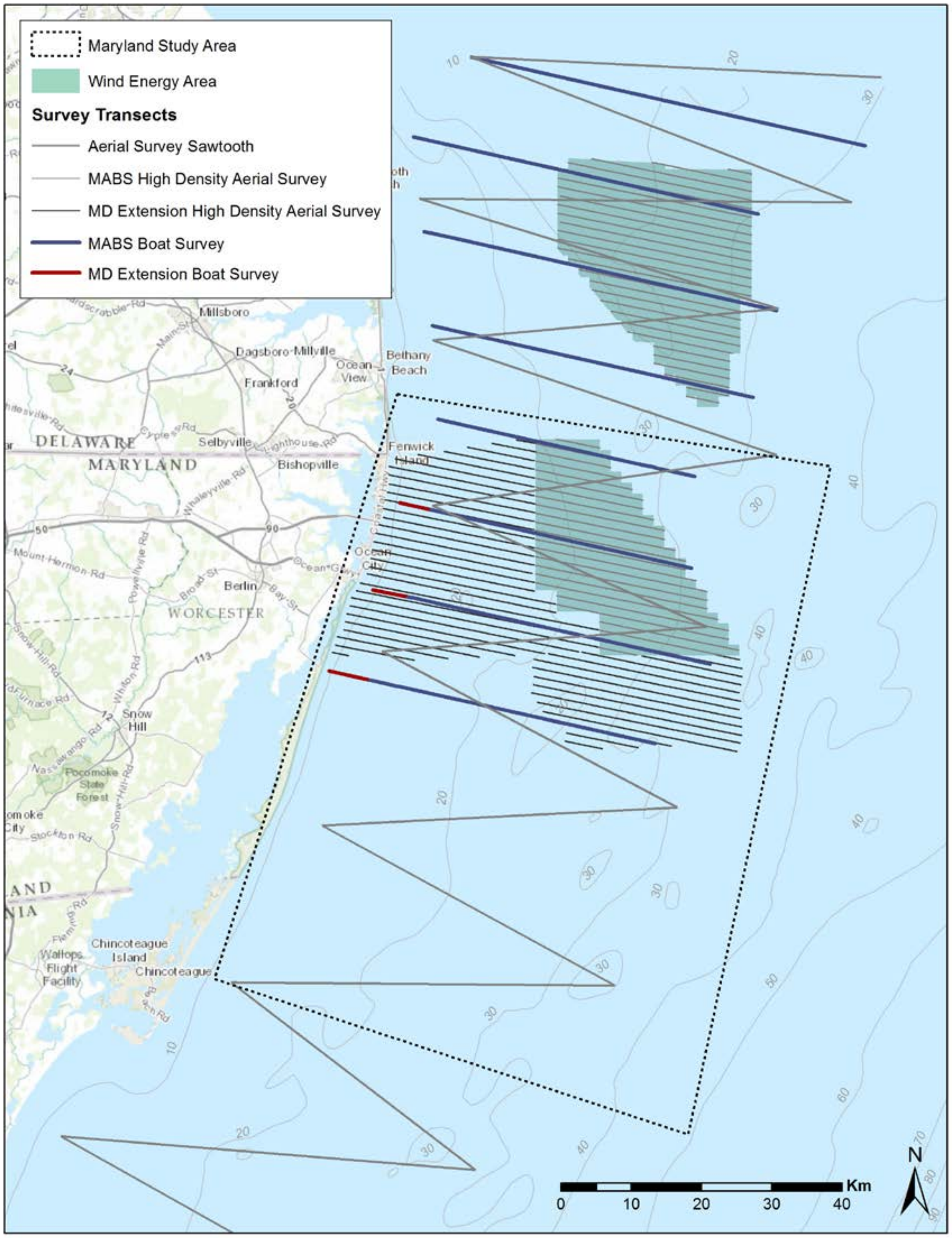

Figure 14-2. Detailed map of aerial survey transects focused on the digital video aerial surveys and boat surveys for the Maryland-funded Maryland Project (2013-2014) along with the adjacent DOE-funded Mid-Atlantic Baseline Studies project (2012-2014). The "Maryland Study Area" includes all boat and aerial survey transects in waters offshore of Maryland (both DOE and Maryland-funded surveys). The Maryland extension surveys are a subset of the surveys within the Maryland study area that were specifically funded by the state of Maryland in 2013-2014. These surveys included boat survey extensions into state waters (red bars), aerial survey high-density transect extensions west and south of MD WEA (dark gray lines), and a 15th aerial survey of the Maryland WEA and Maryland extension high-density transects in 2013. Surrounding transect lines for the MABS study are also shown.

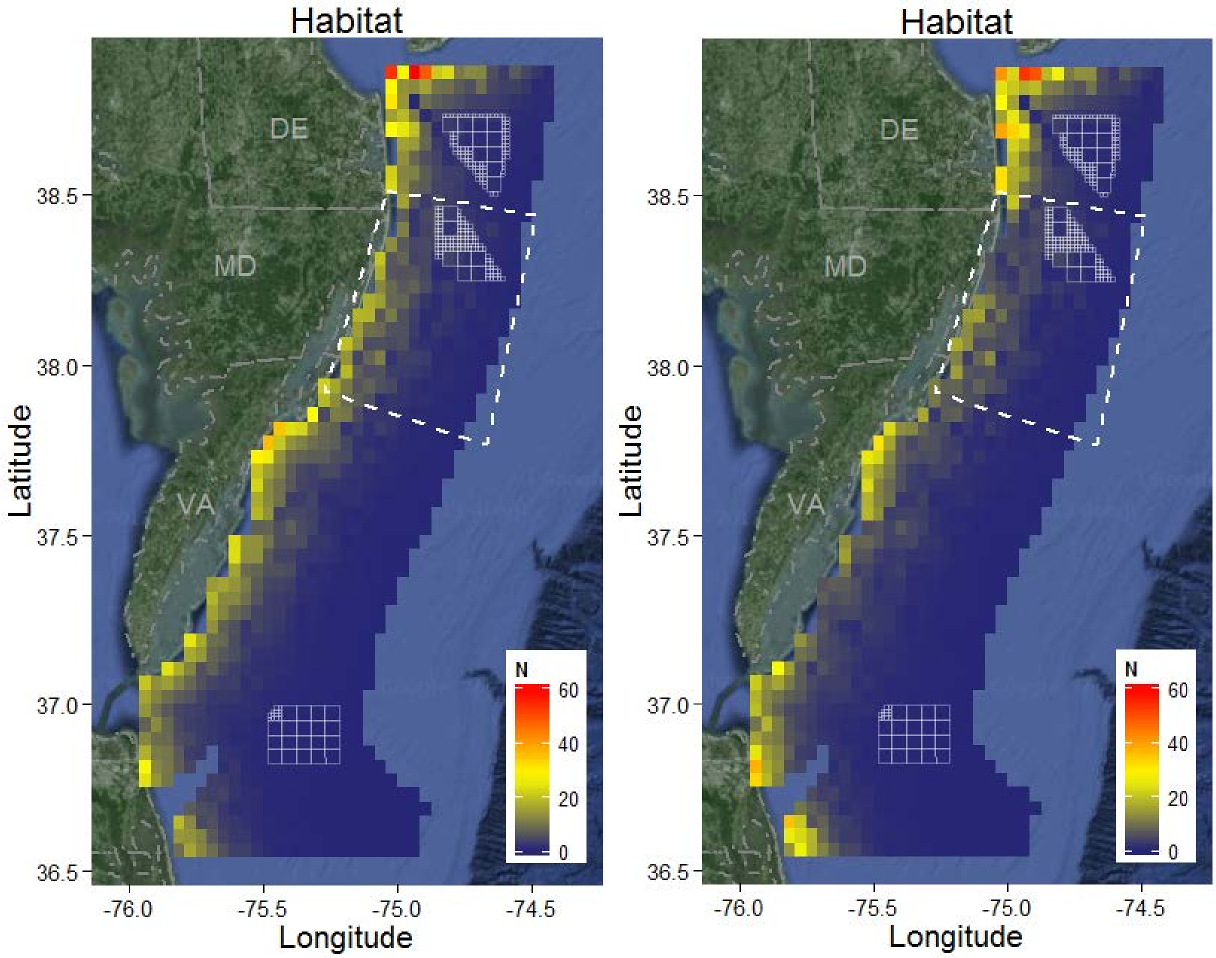

Figure 14-3. Predicted tern flock abundance using the boat-based model (Habitat, left) or integrated model (Habitat + Aerial, right). Note species-specific flock abundance scale. Covariate values were from the midpoint date for the summer season (25 July 2013). White grids represent WEAs and dashed polygon denotes Maryland study area.

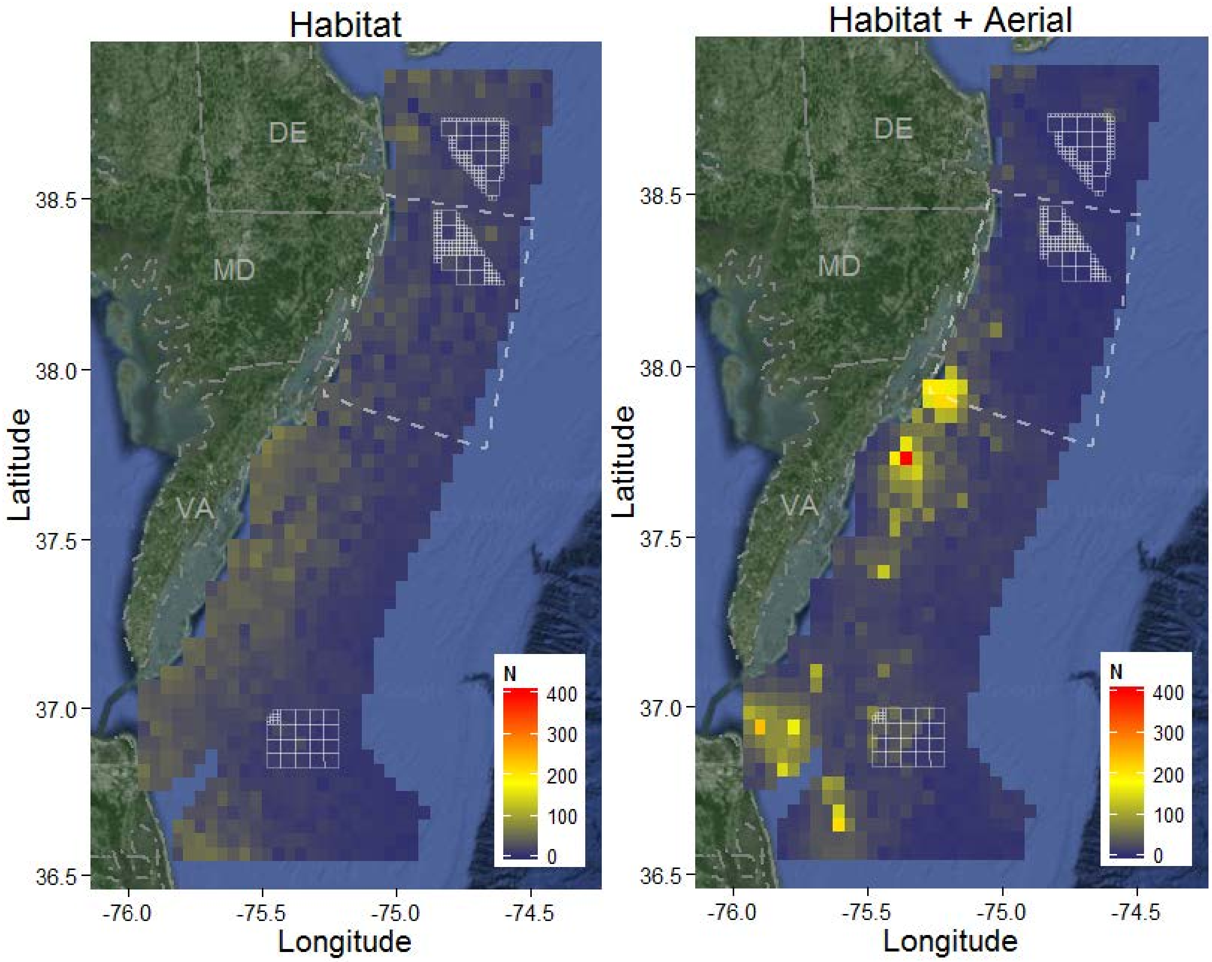

Figure 14-4. Predicted Northern Gannet flock abundance using the boat-based model (Habitat, left) or integrated model (Habitat + Aerial, right). Note species-specific flock abundance scale. Covariate values were from the midpoint date for the winter season (25 December 2012). White grids represent WEAs and dashed polygon denotes Maryland study area.

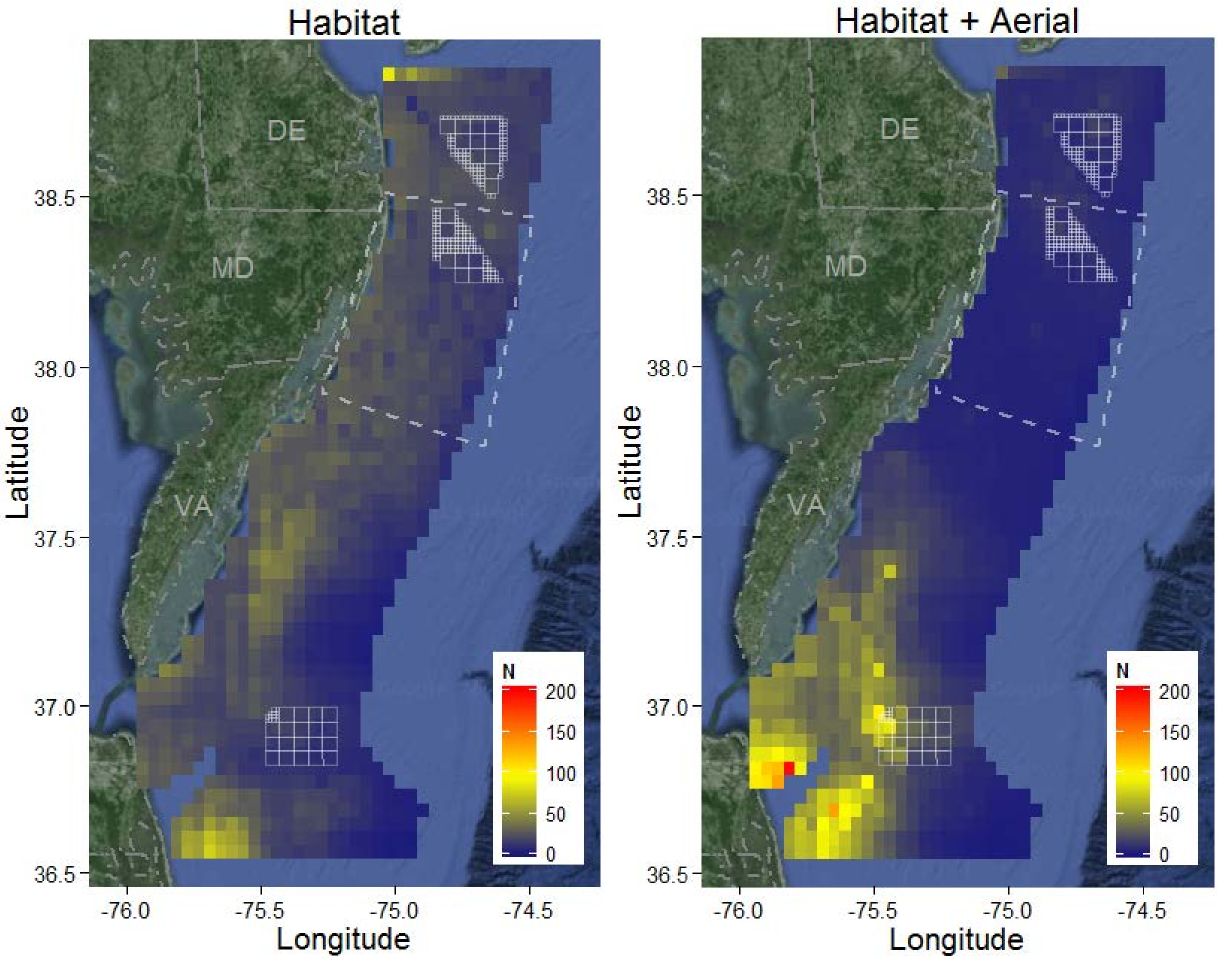

Figure 14-5. Predicted loon flock abundance using the boat-based model (Habitat, left) or integrated model (Habitat + Aerial, right). Note species-specific flock abundance scale. Covariate values were from the midpoint date for the winter season (25 December 2012). White grids represent WEAs and dashed polygon denotes Maryland study area.

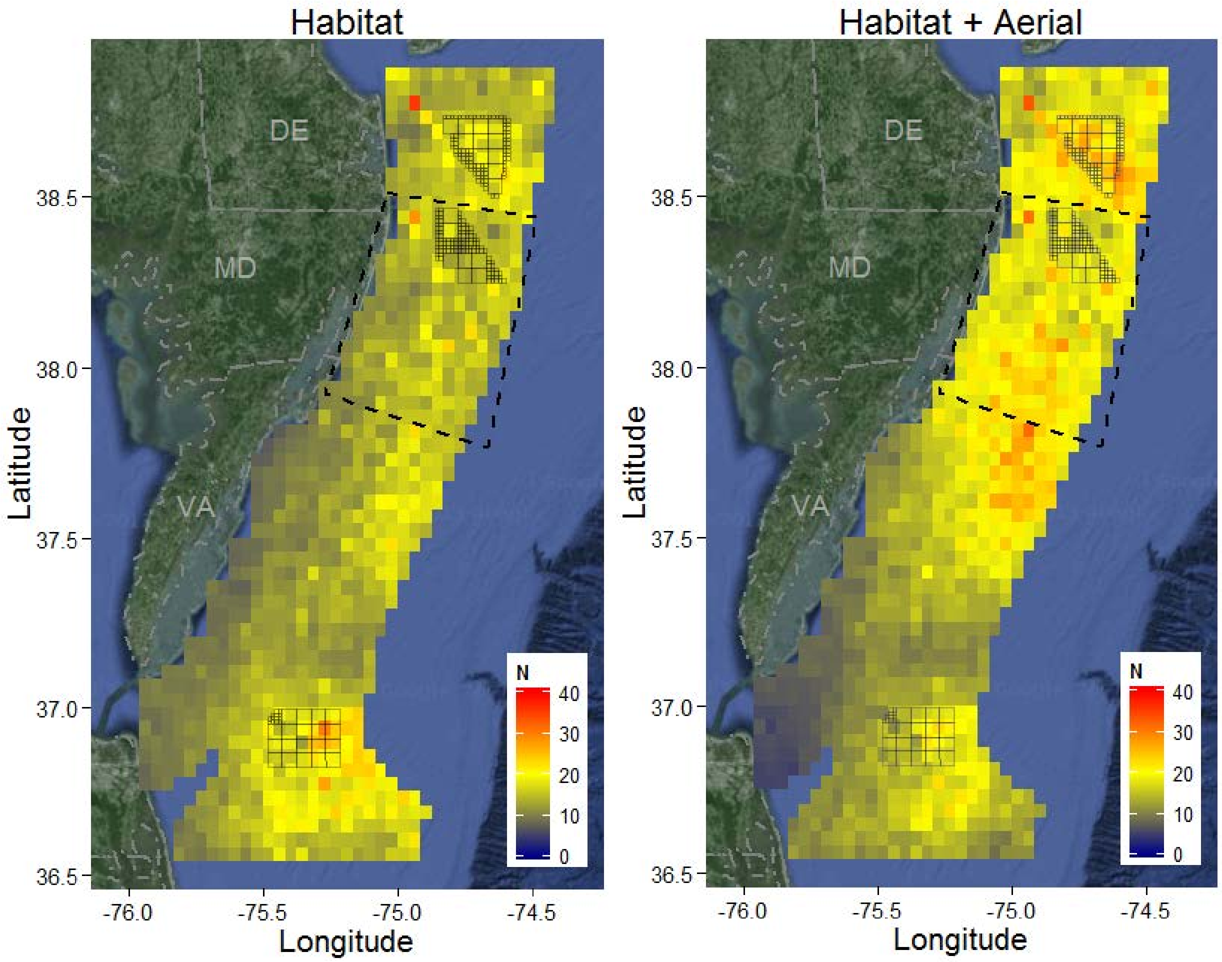

Figure 14-6. Predicted alcid flock abundance using the boat-based model (Habitat, left) or integrated model (Habitat + Aerial, right). Note species-specific flock abundance scale. Covariate values were from the midpoint date for the winter season (25 December 2012). Black grids represent WEAs and dashed polygon denotes Maryland study area.

Table 14-1. Surveys used in the analysis for each species/group, and the raw counts (observations) for each species/group.

Boat Survey	Aerial survey	Group	Boat observations					Aerial observations
			Flocks	Flock size				Individuals
				Mean	Median	Min	Max	
Aug 2013	Sep 2013	Terns	67	1.7	1.0	1	30	69
Dec 2012	Dec 2012	Northern Gannets	306	3.4	1.0	1	350	407
Dec 2012	Dec 2012	Loons	299	1.4	1.0	1	25	703
Dec 2012	Dec 2012	Alcids	122	2.3	2.0	1	18	148

Table 14-2. Bayesian p-values for the abundance and detection components of the models, using either the boat-based model (Habitat) or integrated model (Habitat +Aerial). Values close to 0.5 indicate good model fit.

Group	Model	Boat		Aerial
		Abundance	Detection	Abundance
Terns	Habitat	0.51	0.48	NA
	Habitat + Aerial	0.51	0.48	0.44
Northern Gannets	Habitat	0.44	0.23	NA
	Habitat + Aerial	0.48	0.23	0.57
Loons	Habitat	0.57	0.32	NA
	Habitat + Aerial	0.58	0.31	0.26
Alcids	Habitat	0.58	0.31	NA
	Habitat + Aerial	0.58	0.31	0.44

Table 14-3. Predicted flock abundance of each species/group across the regional study area. Predictions were to a representative summer day (25 Jul. 2013; terns) or winter day (25 Dec. 2012; Northern Gannets, loons, and alcids) using either the boat-based model (Habitat) or integrated model (Habitat +Aerial). Prediction area was constant across species and designed to represent the regional study area (see Figure 18-1).

Boat survey	Species/Group	Predicted abundance	
		Habitat	Habitat + Aerial
Aug 2013	Terns	3,726.8	3,366.6
Dec 2012	Northern Gannets	19,576.9	20,275.4
Dec 2012	Loons	18,503.6	17,371.6
Dec 2012	Alcids	12,969.0	14,653.6

Table 14-4. Parameter estimates for terns from the boat based-model (Habitat) or integrated model (Habitat + Aerial). Abundance was modeled using a Negative Binomial distribution. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, $\boldsymbol{r}$ is the overdispersion parameter, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Aerial = aerial covariate (i.e., smoothed aerial counts), and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% credible interval does not overlap zero are in bold italics.

Terns									
Negative Binomial		**Habitat**				**Habitat + Aerial**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**; α_0	***-2.12***	0.35	-2.85	-1.48	***-2.29***	0.39	-3.10	-1.58
	Dst; α_1	***-1.91***	0.37	-2.67	-1.23	***-2.12***	0.42	-2.99	-1.35
	Slp; α_2	-0.33	0.25	-0.86	0.15	-0.39	0.26	-0.94	0.10
	Grn; α_3	0.22	0.23	-0.22	0.68	0.18	0.23	-0.27	0.64
	Sst; α_4	-0.20	0.30	-0.79	0.41	-0.29	0.33	-0.96	0.33
	Sal; α_5	-0.31	0.23	-0.77	0.14	-0.07	0.29	-0.62	0.52
	Aerial; α_6	-	-	-	-	-0.26	0.18	-0.63	0.08
	Overdisp.; r	1.10	0.74	0.38	2.89	1.17	0.93	0.39	3.17
Detection	**Beaufort 0-2**;β_0	***5.28***	0.11	5.08	5.50	***5.28***	0.11	5.08	5.50
	Beaufort 3-6; β_1	***5.02***	0.14	4.76	5.32	***5.03***	0.14	4.77	5.32

Table 14-5. Parameter estimates for Northern Gannets from the boat based-model (Habitat) or integrated model (Habitat + Aerial). Abundance was modeled using a Negative Binomial distribution. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, $\boldsymbol{r}$ is the overdispersion parameter, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Aerial = aerial covariate (i.e., smoothed aerial counts), and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% credible interval does not overlap zero are in bold italics.

Northern Gannets									
Negative Binomial		**Habitat**				**Habitat + Aerial**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**; α_0	0.11	0.14	-0.17	0.41	0.11	0.13	-0.15	0.37
	Dst; α_1	***-0.48***	0.21	-0.88	-0.07	***0.80***	0.32	0.21	1.46
	Slp; α_2	-0.33	0.18	-0.68	0.02	-0.31	0.16	-0.64	0.00
	Grn; α_3	0.20	0.16	-0.13	0.52	0.00	0.15	-0.31	0.29
	Sst; α_4	0.06	0.18	-0.30	0.40	***-0.86***	0.24	-1.33	-0.39
	Sal; α_5	-0.14	0.19	-0.54	0.21	-0.24	0.19	-0.64	0.12
	Aerial; α_6	-	-	-	-	***0.86***	0.17	0.54	1.24
	Overdisp.; r	0.54	0.10	0.37	0.76	0.77	0.17	0.50	1.14
Detection	**Beaufort 0-2**;β_0	***5.67***	0.05	5.58	5.77	***5.66***	0.05	5.57	5.76
	Beaufort 3-6; β_1	***5.80***	0.08	5.65	5.97	***5.83***	0.08	5.68	6.01

Table 14-6. Parameter estimates for loons from the boat based-model (Habitat) or integrated model (Habitat + Aerial). Abundance was modeled using a Negative Binomial distribution. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, $\boldsymbol{r}$ is the overdispersion parameter, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Aerial = aerial covariate (i.e., smoothed aerial counts), and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% credible interval does not overlap zero are in bold italics.

Loons									
Negative Binomial		**Habitat**				**Habitat + Aerial**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**; α_0	***0.26***	0.12	0.03	0.49	0.02	0.12	-0.22	0.25
	Dst; α_1	***-0.86***	0.20	-1.25	-0.48	0.09	0.26	-0.45	0.60
	Slp; α_2	-0.08	0.11	-0.30	0.15	0.02	0.11	-0.20	0.24
	Grn; α_3	0.06	0.12	-0.17	0.30	0.00	0.11	-0.21	0.22
	Sst; α_4	***0.69***	0.15	0.40	0.98	-0.39	0.26	-0.89	0.15
	Sal; α_5	***-0.51***	0.14	-0.79	-0.25	***-0.44***	0.12	-0.68	-0.22
	Aerial; α_6	-	-	-	-	***1.26***	0.26	0.75	1.77
	Overdisp.; r	1.42	0.42	0.81	2.42	1.94	0.65	1.04	3.55
Detection	**Beaufort 0-2**; β_0	***5.42***	0.05	5.33	5.52	***5.41***	0.05	5.33	***5.50***
	Beaufort 3-6; β_1	***5.48***	0.09	5.33	5.66	***5.53***	0.09	5.36	***5.71***

Table 14-7. Parameter estimates for alcids from the boat based-model (Habitat) or integrated model (Habitat + Aerial). Abundance was modeled using a Poisson distribution. SD is the standard deviation, 2.5% and 97.5% are the respective quantiles, $\boldsymbol{r}$ is the overdispersion parameter, $\boldsymbol{\alpha}$ and $\boldsymbol{\beta}$ parameters are on the log scale. Dst = distance to shore, Slp = slope of the seafloor, Grn = sediment grain size, Sst = sea surface temperature, Sal = salinity, Aerial = aerial covariate (i.e., smoothed aerial counts), and Beaufort sea state 3-6 are rough seas (as opposed to calm, 0-2). The posterior mean for covariates where the 95% credible interval does not overlap zero are in bold italics.

Alcids									
Poisson		**Habitat**				**Habitat + Aerial**			
Component	**Term**	**Mean**	**SD**	**2.5%**	**97.5%**	**Mean**	**SD**	**2.5%**	**97.5%**
Abundance	**Intercept**; α_0	-0.02	0.12	-0.26	0.21	0.03	0.12	-0.21	0.27
	Dst; α_1	0.09	0.15	-0.20	0.37	-0.20	0.25	-0.70	0.30
	Slp; α_2	0.08	0.09	-0.10	0.25	0.07	0.09	-0.12	0.23
	Grn; α_3	-0.12	0.10	-0.33	0.08	-0.10	0.10	-0.31	0.10
	Sst; α_4	-0.02	0.14	-0.28	0.25	0.30	0.26	-0.21	0.82
	Sal; α_5	-0.15	0.10	-0.33	0.06	-0.17	0.10	-0.36	0.04
	Aerial; α_6	-	-	-	-	-0.27	0.19	-0.65	0.11
Detection	**Beaufort 0-2**; β_0	***5.07***	0.07	4.93	5.22	***5.07***	0.07	4.94	5.22
	Beaufort 3-6; β_1	***4.79***	0.13	4.54	5.05	***4.77***	0.13	4.53	5.03

Table 14-8. Root mean squared error (RMSE) evaluating the ability of each model to predict abundance in (a) the original boat and aerial datasets (Original surveys) and (b) independent boat and aerial datasets (Independent surveys). Predictions were from the boat-based (Habitat) or integrated model (Habitat + Aerial). Dates for the original surveys and independent surveys are provided. Root mean squared error values closer to zero indicate better model fit (lower value for each comparison is in bold italics).

(a) Original surveys		Original survey date	RMSE	
Group	Dataset		Habitat	Habitat + Aerial
Terns	Boat	Aug-13	0.9	0.9
	Aerial	Sep-13	0.7	***0.6***
Northern Gannets	Boat	Dec-12	3.6	***3.1***
	Aerial	Dec-12	1.8	***1.0***
Loons	Boat	Dec-12	2.2	***2.0***
	Aerial	Dec-12	3.2	***2.7***
Alcids	Boat	Dec-12	1.0	1.0
	Aerial	Dec-12	***1.1***	1.4

(b) Independent surveys		Independent survey date	RMSE	
Group	Dataset		Habitat	Habitat + Aerial
Terns	Boat	Sep-13	1.0	1.0
	Aerial	Jul-13	***0.5***	0.6
Northern Gannets	Boat	Jan-13	***4.5***	14.4
	Aerial	Feb-13	***21.5***	22.1
Loons	Boat	Jan-13	***2.1***	3.9
	Aerial	Feb-13	***3.2***	3.4
Alcids	Boat	Jan-13	1.6	1.6
	Aerial	Feb-13	1.7	***1.6***