Chapter 1: Ecosystem background and project activities

Final Report to the Department of Energy Wind and Water Power Technologies Office, 2015

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Abstract

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. The Mid-Atlantic Baseline Studies 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 areas include waters on the Outer Continental Shelf off the coasts of Delaware, Maryland, and Virginia, and extend from the state-federal boundary (5.6 km from shore) east to the 30 m isobath (with the exception of some waters offshore of Maryland, where the study area extends westward to the shoreline). Methods employed in this study included boat surveys, high resolution digital video aerial surveys, satellite telemetry for focal species, and several approaches for examining nocturnal avian migration patterns. 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. We discuss the relative strengths of digital video aerial surveys and other methods employed in this study, with a particular focus on comparing boat-based surveys and digital video aerial surveys. We also briefly discuss the various approaches used to present results in this report; understanding each analytical method and its limitations is essential to appropriately interpret maps, figures, and other analyses.

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.

This study also provides the first comprehensive assessment of taxa that are likely to become exposed to future offshore wind energy development in the mid-Atlantic region. This information may be used during permitting processes for future development, as well as for siting projects and designing development plans that minimize wildlife impacts.

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, to identify 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 effects and climatic change (Griffies, 2004; Tallis et al., 2010).

Marine ecosystems are particularly complex and dynamic assemblages that involve multitudes 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 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.

Importance of the mid-Atlantic study area to wildlife

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, 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. Beyond the shelf edge, the continental slope descends rapidly to around 3,000 m. Much of this mid-Atlantic 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 Gulf Stream current (Townsend et al., 2006). The region also exhibits a strong seasonal cycle in sea surface temperatures (spanning approximately 5-

30 °C), and in 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 drives overall annual primary productivity across the broader study area, with the largest and most persistent phytoplankton blooms in the late fall and winter (Schofield et al., 2008; Yoder et al., 2001). However, areas near the mouths of the Delaware Bay and Chesapeake Bay typically have the highest levels of chlorophyll *a* in the study area, due to their proximity to highly productive estuarine ecosystems. The influxes of fresh water from the bays deliver nutrients such as nitrogen and phosphorous and year-round mixing of saline and fresh waters through estuarine circulation, in combination with strong tidal currents, boost primary productivity in these areas. As water flows from the bays into the study 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.

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 Mid-Atlantic Bight (Dawe et al., 2007; Hendrickson, 2004). In this study, we observed numerous shoals of small fish across the study area, most commonly from May to October (Chapter 17). The presence of these forage fish populations indicate the exceptional productivity of the area, and are likely responsible, in part, for the relatively high density of predators that use the area (Chapter 10).

Thus, 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). This results in a complex ecosystem where the community composition is constantly shifting, 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 visit 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 to warmer climes, 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.

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. Additionally, this region has great economic importance, including commercial fisheries, shipping, and the potential for offshore renewable energy development. Areas with an annual average wind speed of 7 m/s (15.7 mph) or greater at 90 m in height are considered suitable for offshore wind energy generation (Schwartz et al., 2010). 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 Wind Energy Areas (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 diurnal and nocturnal distributions, abundance, habitat use, and movements 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 and Maryland Projects

The Mid-Atlantic Baseline Studies project area extends from three nautical miles off the coastline (the interface of state and federal waters) east to the 30 m isobath (roughly 40-90 km from shore), and includes waters on the Outer Continental Shelf off the coasts of Delaware, Maryland, and Virginia (Figure 1-1). The Maryland Project, added to the scope of the Baseline Studies Project during the second year of surveys, includes more intensive coverage of waters offshore of Maryland, including state waters (within 5.6 km of shore). Study methods included boat surveys, high resolution digital video aerial surveys, satellite telemetry for focal species, and several approaches for examining nocturnal avian migration patterns. This study includes the first use of digital aerial surveys on a large scale in North America, and the combination of different survey approaches allowed for a comparison of digital aerial vs. boat survey results.

Each of the methods that we used to examine marine wildlife distributions and movements in the mid-Atlantic had inherent strengths and weaknesses. By using a complimentary suite of methods, we aimed to minimize knowledge gaps and develop a comprehensive understanding of the mid-Atlantic marine ecosystem.

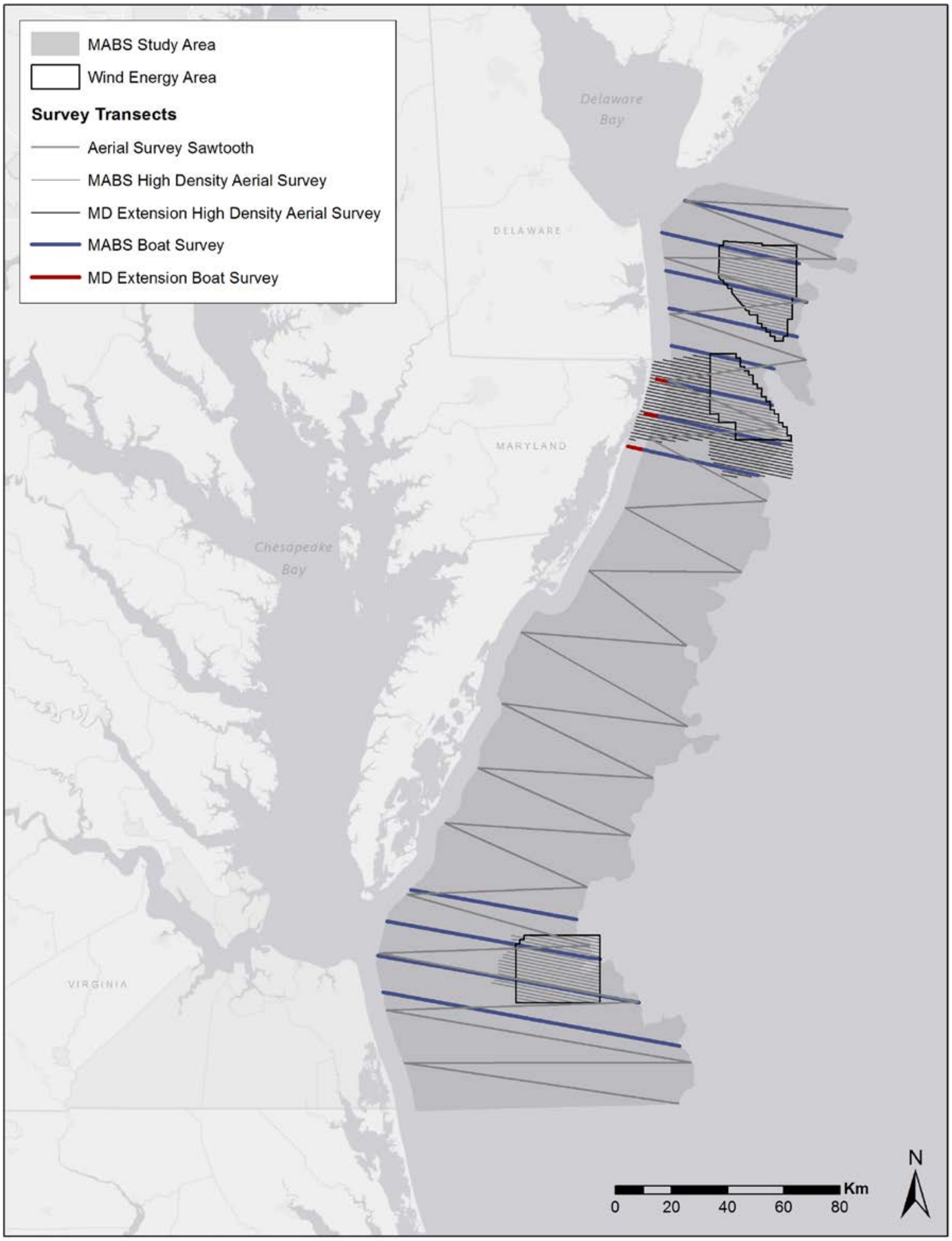

Figure 1-1. Map of aerial and boat survey transects for the Mid-Atlantic Baseline Studies and Maryland Projects (2012-2014). High resolution digital video aerial survey transects are shown in light and dark gray; boat-based survey transects are shown in blue and red. Maryland extension transects (initiated in 2013) are shown in red (boat) and dark gray (aerial).

Boat surveys

Boat-based surveys are a widely-used method to monitor offshore wildlife. They provide a great deal of information about marine ecosystems, and are a key element in this study of the mid-Atlantic. Due to the relatively slow speed of survey vessels, observers have considerable time to collect data on species presence and abundance, and 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 7, 10, 18A). Observers also collect *in-situ* environmental and biological data, such as wind speed, wave height, sea surface temperature, salinity, and biomass densities (Chapters 7 and 9). Relating these directly to sightings can help explain animals' distributions and the drivers of those distributions, as well as variations in detection rates for different species (Ainley et al., 2005).

Detection of animals 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 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). Depending on the size of the survey vessel and target taxon, boat-based surveys are limited in their ability to collect data under certain weather conditions; 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). Employing two independent observers can be used to assess 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 alter animal behaviors as well, whether through disturbance or attraction (Chapter 13; Bodey et al., 2014; Schwemmer et al., 2014; Spear et al., 2004). 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 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 (Hazel et al., 2007; Mattson et al., 2005; Normandeau Associates Inc., 2013; Richardson et al., 1995).

There is a tradeoff between maximizing survey coverage and minimizing sampling time. 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; however, increased time to cover the study area risks greater turnover of animals in the study region, resulting 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 limit our understanding of nocturnal behaviors and animal behaviors in harsher weather conditions.

Lastly, 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 individual movements and use of the study area. We were able to compensate for some of these limitations in this study through the use of weather radar and satellite telemetry.

High resolution video aerial surveys

High resolution 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 is the first to use 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 survey vessels (Chapter 13; Buckland et al., 2012). This high altitude is considerably safer than low-level visual surveys, which are flown at 60-180 m, and also 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 to try to understand potential collision risk for animals flying through a project site. Digital aerial surveys are also excellent for collecting data on aquatic animals such as marine mammals and sea turtles (Chapters 14-15; Normandeau Associates Inc., 2013). As with boat surveys, digital aerial surveys are only flown in daylight hours under fair weather, which limits our understanding of animal behaviors at night and in harsh weather conditions. As with boat surveys, digital aerial surveys provide a "snapshot" of animal distributions at a given point in time, rather than data on movements or behaviors within the ecosystem.

Importantly, the data collected using digital surveys are recorded, allowing for species identification verifications, the application of rigorous audit protocols, and archived footage for later review (Chapters 3-4). This is a distinct advantage over visual survey approaches. The survey transects are relatively narrow, however, which in our study may have led to problems of availability for highly mobile animals (Chapter 13). Researchers continue to develop solutions to correct for many of the detection biases described above for boat-based surveys (Chapter 11). 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 (Chapter 13).

In this study, identification to species of most taxa in digital video aerial surveys was lower than identification rates for boat surveys (Chapters 13 and 14). Recent technological advancements in camera designs and image quality have improved identification rates beyond what occurred 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 14). The high speed of 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”, “sitting”, and “moving”, because the footage recorded of a specific target animal is brief (<1 second), and more complex behaviors can rarely be discerned.

Satellite telemetry

Satellite telemetry allows us to track the movements of individual animals within their environment, and potentially identify marine biodiversity hotspots and ecologically important areas (Montevecchi et al., 2012). In this study, we deployed satellite transmitters on four different avian taxa (Chapters 20-25). With this method temporal coverage is limited only by battery power and tag longevity, making it possible to track movements of individual birds at a seasonal or annual temporal scale and to collect data regardless of weather or time of day (though such tracking is seldom continuous, due to power limitations). There is a distinct tradeoff between this level of individual temporal and spatial coverage and sample size, however, and it can be difficult to extrapolate population-wide distributions and behaviors from a few individuals (Lindberg and Walker, 2014). Moreover, tracking does not allow for development of relative abundance estimates. Instead, kernel density estimates are often used to characterize and visualize home ranges, and utilization distributions can be extended to quantify the relative frequency distribution of an animal’s occurrence in space and time (Keating and Cherry, 2009; Loring et al., 2014; Worton, 1989).

The mid-winter deployment of satellite tags in the study area, dictated by the study design, proved to be problematic for studying detailed winter movements of individuals because it split the winter season over two years. Tag longevity for implants was also disappointing in some cases, also limiting our ability to track individuals through an entire second winter season.

By definition, telemetry studies are species-specific—they do not provide data on the broader marine community (at least not directly). Remote tracking by satellite remains the best approach available for studying animal movements, however, including both diurnal and nocturnal movements. Although transmitters were only deployed on birds in this study, there is analogous technology available for turtles and mammals (which is being deployed on turtles and pinnipeds in other studies, including the ongoing Atlantic Marine Assessment Program for Protected Species [AMAPPS[1]] study). Devices can only be deployed on species and individuals robust enough to carry them, but increasingly smaller and lighter units are in development (Guilford et al., 2011).

Nocturnal avian passive acoustics

Oceans and other large bodies of water can act as barriers to migrating landbirds, including passerines and raptors, but many species make long transoceanic flights (Delingat et al., 2008). Cape May and Delaware Bay are both known as areas where large numbers of migrants stop over during migration (Clark et al., 1993; Moore et al., 1995), but there is less known about migrant use of offshore regions of

[1] www.nefsc.noaa.gov/psb/AMAPPS/

the mid-Atlantic. Many landbird species migrate at night and emit short species-specific vocalizations during flight (Evans 2012). Nocturnal passive acoustic monitoring stations can record these flight calls and provide data on species presence, as well as an index of migratory activity. In this study, we deployed an avian passive acoustic monitoring system on the survey vessel to test the effectiveness of this method from such a platform, and to obtain preliminary data about the species composition of nocturnal migrants in the offshore environment of the mid-Atlantic (Chapter 26).

Passive acoustic monitoring is useful for obtaining information on the species composition of nocturnal migrant populations offshore, which is not currently possible via other methods explored in our study. It also provides extensive temporal coverage, as recorders run continuously. There are limitations to this method, however, including poor geographic coverage, intensive analytical requirements, difficulties with differentiating some species acoustically, variation in acoustic activity among target species, and issues associated with attempting to use call frequency as an index of abundance. But our options for studying nocturnal migration over water are currently limited, and even presence information (unaccompanied by information on behavior or abundance) can be useful data. Our study was focused on avian migration, but equivalent studies exist for other acoustically active taxa, including marine mammals, bats, and some fishes. The Bureau of Ocean Energy Management (BOEM), the Maryland Department of Natural Resources[2], and other agencies are currently funding mammal acoustic studies in the study area (e.g., Bailey and Rice, 2015; Muirhead et al., 2014).

WSR-88 weather radar

Weather surveillance radars regularly detect "bioscatter", reflectivity caused by biological entities in the atmosphere, and are increasingly being incorporated into studies of avian and bat nocturnal migratory activity (Chilson et al., 2012). Our study incorporated WSR-88 (NEXRAD) weather radar to identify potential offshore migration pathways and timing, as well as environmental and temporal variables correlated with these patterns (Chapter 27). Though they lack the fine scale resolution of traditional marine radar, NEXRAD data allow for efficient monitoring of geographical and temporal patterns in migration on a broad scale (Gauthreaux and Belser, 2003), at any time of day or night, and have proved useful for developing a better understanding of patterns of offshore migratory activity.

Geographic coverage is poor in offshore areas along the eastern seaboard, compared with terrestrial locations, and characteristics of the radar beam make it increasingly difficult to detect low altitude and low density bioscatter with increasing range from the radar, though we present an analytical approach for addressing this issue (Chapter 27). NEXRAD data also does not allow for identification to species, nor direct translation of migratory activity (measured as radar reflectivity) to actual abundance of animals using the radar technology in this study, since the sizes of individuals being detected are unknown. However, weather radars provide information on the nocturnal distributions and migratory patterns of animals at a scale which is impossible to achieve via other methods. Innovations developed during this study allowed for targeted exclusion of meteorological phenomena, greatly improving the sample size of available data and allowing for examination of migratory activity even during nights with precipitation, which had previously been impossible.

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[2] www.boem.gov/Determining-Offshore-Use-by-Marine-Mammals-Maryland-PAM/

Comparing and integrating methods

By using the five research methods outlined above to collect a broad range of data, we aimed to develop a more complete picture of the mid-Atlantic study region. For example, the inclusion of satellite telemetry provided information on broad-scale movements of specific species in the environment, including nocturnal movements and habitat use, which was missing from our survey data; but the survey data allowed for population-level analyses of abundance and distributions that were not possible with tracking data alone.

Each of the methods that we used to examine marine wildlife distributions and movements in the mid-Atlantic had inherent strengths and weaknesses (Table 1-1). 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). Seabird telemetry efforts in this study, for example, provided useful information on population distributions in the mid-Atlantic, due to the large sample sizes made possible via collaborations among multiple organizations and funding agencies (Chapters 20-24), but many telemetry studies are limited by sample size, and are constrained in their population inference as a result.

Compared to the other study methods used in this project, boat and aerial surveys provided relatively comprehensive information on wildlife populations in the offshore environment (Table 1-1). 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 14; 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 13-14). 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 likely 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 were a main focus for determining distributions and relative abundance of taxa of interest throughout the study area, and for developing analytical products that are useful for marine spatial planning and decision making regarding offshore development activities. By using a complementary suite of methods, we aimed to minimize knowledge gaps and develop a more comprehensive understanding of the mid-Atlantic marine ecosystem.

Table 1-1. Methods for studying offshore wildlife that were incorporated into this study. Relative strengths and weaknesses of each approach are indicated by depth of color (dark blue = good; medium blue = fair; pale blue = poor). A dash indicates that data were not available from this survey method. Values are subjective; for example, detection of avian species in our boat surveys was probably better than detection in our digital video aerial surveys in many cases, at least after correction for distance bias in aerial data (Chapters 13-14 and 18), so boat surveys were categorized as "good" for this type of data, while digital video aerial surveys were "fair." Avian passive acoustics were also rated "fair" for this data category, as some species and individuals emit flight calls infrequently, or at different time periods throughout the night, limiting species-specific detections.

	Video Aerial Survey	Boat Survey	Satellite Telemetry	Avain Passive Acoustics	WSR-88 Weather Radar
Geographic Coverage	good	good	good	poor	fair
Temporal Coverage	poor	poor	good	good	good
Population Distributions	good	good	fair	—	good
Abundance or Relative Abundance	good	good	—	poor	poor
Detection (marine mammals)	good	good	—	—	—
Detection (sea turtles)	good	poor	—	—	—
Detection (birds)	fair	good	—	fair	fair
Species Identification	fair	good	—	good	—
Behaviors	fair	good	fair	—	—
Movements	poor	poor	good	—	good
Diurnal Activities	good	good	good	—	—
Nocturnal Activities	—	—	good	good	good

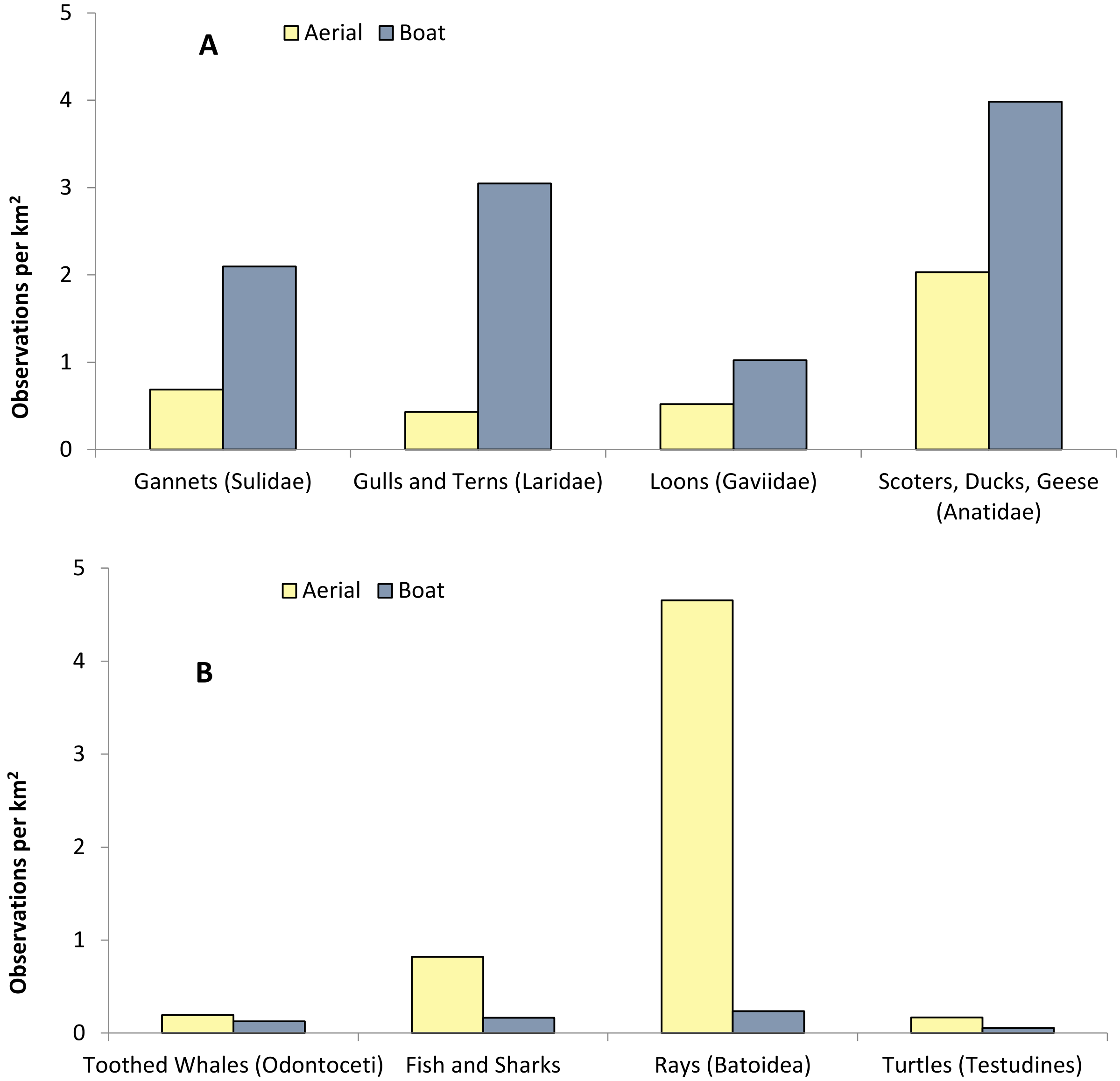

Figure 1-2. Comparison of total effort-corrected boat and aerial survey counts by taxon for all surveys. Aerial densities were calculated using transect strip widths (either 200 or 300 m). A) Effective boat transect strip widths were estimated using distance data for each avian family (Chapter 14). B) 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 = 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).

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 or tracking 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 1-2). In addition, there are several known sources of bias associated with survey data that prevent consistency across a spatial extent, 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 (Chapters 11-12; Spear et al. 2004; Royle, Dawson, and Bates 2004; Hedley and Buckland 2004; Evans and Hammond 2004). We would expect lower detectability of animals that are far 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 12). Survey effort is another factor that greatly influences observations made in a given location. If survey effort varies across a region (as in our boat and aerial surveys across the mid-Atlantic study area), 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 essential 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 (Table 1-2).

Biotic and abiotic factors, including weather, habitat characteristics, prey distributions, and hydrography, drive the distribution and abundance of marine wildlife (Ainley et al., 2005). Environmental factors, or covariates, that we believe could be important for predicting animal distributions or abundance can be incorporated into a single modeling framework with effort and bias corrections (Chapters 12, 15, and 18). This allows us to identify correlations between these covariates and to understand the factors influencing animal distribution. These relationships can also be used to predict animal distributions to locations or time periods where/when surveys were not conducted, given available environmental covariate data. 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 1-2. General approaches for presenting spatial data from offshore surveys. The distance between animals and the transect line, observer abilities, and environmental conditions 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 17-28 (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 that were not surveyed, or to predict future distributions in surveyed areas.	Figure 5-12 (maps of relative ray densities, corrected for effort, across areas surveyed by plane)
Predictive model	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 that were not surveyed, or to predict future distributions in surveyed areas.	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 12-3 (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 specifically on generalized additive models (GAMs) and on 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 11-12, 16, and 18) 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 15) 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 biases 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; Chapter 15). The ray distribution maps presented in Chapter 5 (Figure 5-12) 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 are presented as relative estimates of 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, are presented in several other chapters in this report (Chapters 11-12, 16, and 18).

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 any analytical approach so that results can be correctly interpreted.

Combining data from different sources: survey data

Regulators and resource managers are often required to make decisions using imperfect information on wildlife resources. Wildlife data are collected in a variety of approaches and circumstances, which makes 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 joint products that can 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 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 14). We also identified several different species-habitat relationships from boat survey data than from digital aerial data (Chapter 18). As a result of this variability, our approaches for combining datasets to develop the best possible distribution and abundance data varied by taxon and analytical goal. In some cases (sea turtles in Chapter 15, for example), one survey dataset alone provided the best available picture of animal distributions, and combining 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 and distribution to identify ecological drivers of distribution, abundance, and local hotspots (Chapter 19). Joint modeling approaches that more formally integrate the two datasets will be published in an addendum to this final report.

Initial efforts at integrating data included the following approaches:

- Using species identifications from the boat survey to inform species proportions in the video aerial dataset (Chapter 16).
- 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 17).
- Comparing datasets, particularly in relation to environmental covariates, to understand when and how integration is warranted (Chapter 18).
- 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 19).

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

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