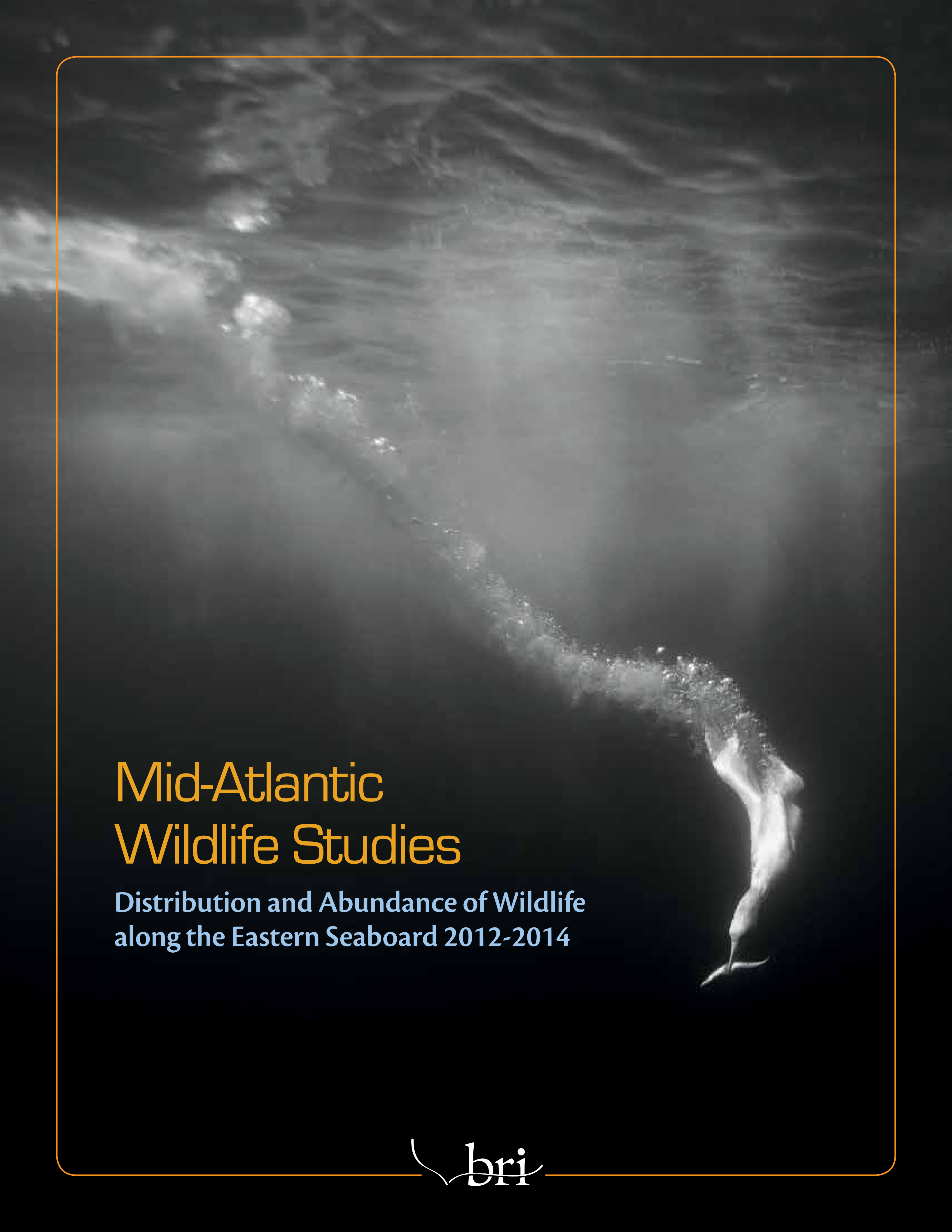

Mid-Atlantic Wildlife Studies

Distribution and Abundance of Wildlife along the Eastern Seaboard 2012-2014

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Project investigators included scientists from Biodiversity Research Institute, North Carolina State University, City University of New York, Duke University, Oregon State University, and the University of Oklahoma.

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ACCESS TO DATA

All survey data from this study (including both the Mid-Atlantic Baseline Studies and Maryland projects) are available for download on the project website: **www.briloon.org/mabs**.

Data are also included in the Northwest Atlantic Seabird Catalog, a federal database managed by the USFWS that is used by BOEM and other agencies as a key repository for wildlife distribution data on the Atlantic Outer Continental Shelf.

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Executive Summary

The Mid-Atlantic Baseline Studies Project was funded by the Department of Energy's (DOE) Wind and Water Power Technologies Office in 2011, with additional support from a wide range of partners. The study goal was to provide comprehensive baseline ecological data and associated predictive models and maps to regulators, developers, and other stakeholders for offshore wind energy. This knowledge will help inform the siting and permitting of offshore wind facilities on the mid-Atlantic Outer Continental Shelf.

Research collaborators studied wildlife distributions, abundance, and movements between 2012 and 2014. The specific study area was chosen because it is a likely location for future wind energy development offshore of Delaware, Maryland, and Virginia, including three federally designated Wind Energy Areas (WEAs). Project objectives were to:

- Conduct standardized surveys to quantify wildlife abundance seasonally and annually throughout the study region, and identify important habitat use or aggregation areas. Boat-based surveys and high resolution digital video aerial surveys were conducted to reach this objective.
- Develop statistical models to help understand the drivers of wildlife distribution patterns and to predict the environmental conditions likely to support large densities of wildlife.
- Use individual tracking methods for several focal bird species to provide information on population connectivity, individual movements, and seasonal site fidelity that is complementary to survey data.
- Identify species that are likely to be exposed to offshore wind energy development activities in the mid-Atlantic study area.
- Explore technological advancements and assessment methods aimed at simplifying and minimizing the cost of environmental risk assessments.
- Help meet regulatory data needs by contributing several years of data and analysis towards future Environmental Impact Statements.

This report is a synthesis of many aspects of the Mid-Atlantic Baseline Studies project. A more detailed examination may be found in the full project report (Williams et al. 2015) and related publications (e.g., Hatch et al. 2013 and others).

In this publication, we explore aspects of the mid-Atlantic ecosystem; describe our survey and analytical approaches; and present a range of results, featuring several case studies on specific species or phenomena. Each case study includes the integration of data from multiple study components, presenting a comprehensive view of wildlife distribution and movement patterns. Key findings include:

- Boat-based and digital video aerial surveys each had specific advantages and disadvantages, but were 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.
- Habitat gradients in nearshore waters were important influences on productivity and patterns of species distributions and abundance. Areas offshore of the mouths of Chesapeake and Delaware Bays, as well as to the south of Delaware Bay along the coast, were consistent hotspots of abundance and species diversity, regardless of survey methodology or analytical approach.
- The study area was important for wintering and breeding taxa, and its location also made it a key migratory corridor. There was considerable variation in species composition and spatial patterns by season, largely driven by dynamic environmental conditions.

The results of this study offer insight to help address environmental permitting requirements for current and future projects. These data serve as a starting point for more site-specific studies, risk analyses, and evaluation of potential measures to avoid and minimize risks to wildlife from human activity in the offshore environment.

The Mid-Atlantic Marine Ecosystem

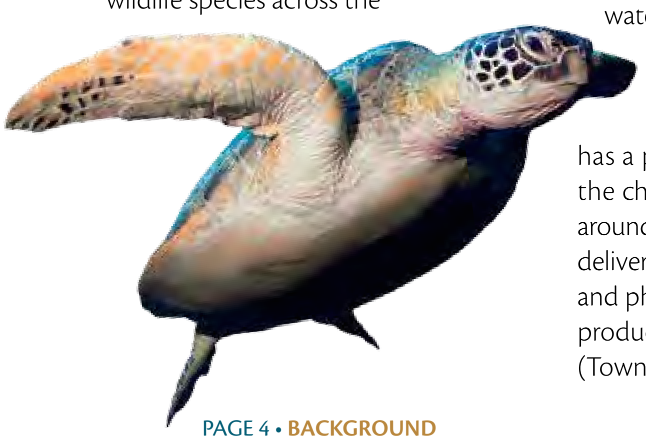
The study of ecology attempts to identify the connections between organisms and the world around them, and explain how those relationships affect, or are impacted by, the physical attributes of their habitats. Marine ecosystems are particularly complex and dynamic assemblages that involve multitudes of co-evolved species. Thus, research studies integrated across taxonomic groups and among trophic levels are critical to understanding marine ecosystem processes and mechanisms.

In this study, we analyzed the distributions and movements of prominent marine wildlife species across a large swath of the mid-Atlantic coastal region, and also examined the influence of environmental factors, such as productivity, water depth, and salinity, on these distributions.

This ecosystem-based approach establishes a broad baseline from which to understand the impacts of future development or management decisions on the offshore environment.

THE MID-ATLANTIC BIGHT

Significant both ecologically and economically, the mid-Atlantic region is used by a broad range of marine wildlife species across the entire annual cycle, including several dozen species listed as threatened or endangered at the federal level or state level. The importance of the region for these wildlife species is due, in part, to the region's central location in a major migratory flyway and a relatively high level of primary productivity (growth of phytoplankton).



The Mid-Atlantic Bight is an oceanic region that spans an area from Cape Cod to Cape Hatteras and is characterized by a broad expanse of gently sloping, sandy-bottomed continental shelf. This shelf extends up to 150 km offshore, where the waters reach about 200 m deep. Beyond the shelf edge, the continental slope descends rapidly to around 3,000 m.

Most of this mid-Atlantic coastal region is bathed in cool Arctic waters introduced by the Labrador Current. At the southern end of this region, around Cape Hatteras, North Carolina, these cool waters collide with the warmer waters of the Gulf Stream.

The mid-Atlantic region exhibits a strong seasonal cycle in temperature, with sea surface temperatures spanning 3-30 °C. There is also a wide range in salinity, with large volumes of fresh water emptying onto the shelf from the Hudson Estuary, Delaware Bay, and Chesapeake Bay. This influx of fresh water has a particularly strong effect on the characteristics of this ecosystem around the mouths of the bays, delivering nutrients such as nitrogen and phosphorous that boost primary productivity in coastal waters (Townsend et al. 2006). In these areas, year-round mixing of saline and fresh waters through estuarine circulation, in combination with strong tidal currents, leads to increased primary productivity. Nutrient- and phytoplankton-rich waters flow from these bays and are swept southwards by the Labrador Current.

Seasonal stratification on the shelf drives annual primary productivity across the region, with the largest and most persistent phytoplankton blooms in the late fall and winter. In shallow coastal waters, sunlight is able to penetrate a relatively high proportion of the water column, fueling photosynthetic activity and growth of phytoplankton where nutrients are available. Phytoplankton blooms are followed by a pulse in secondary productivity—zooplankton species that forage on the phytoplankton—which in turn become food for larger predators, such as small fishes.

The Mid-Atlantic Bight is generally rich with small, schooling 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). The presence of these forage fish populations indicates the high levels of productivity in the mid-Atlantic region, and is likely responsible, in part, for the large numbers of predators that use the area.

WILDLIFE POPULATIONS

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.

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. 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 summer, some of which breed in the area, such as coastal birds and some sea turtles. Other summer residents, such as shearwaters and storm-petrels, visit from the Southern Hemisphere (where they breed during the austral summer). In the fall, many of the summer residents leave the area and migrate south to warmer climes, and are replaced by species that breed further north and winter in the mid-Atlantic.

FILLING THE MID-ATLANTIC DATA GAP

Despite recent and ongoing data compilation and survey efforts for marine wildlife in the western North Atlantic (e.g., extensive survey efforts in New Jersey and Rhode Island; Geo-Marine, Inc. 2010, Paton et al. 2010), several geographic holes still remain. The Mid-Atlantic Baseline Studies and Maryland projects, described here, fill a significant information gap for a large swath of the mid-Atlantic region.

Given the high levels of productivity in the region, and its year-round importance to a broad suite of species, it is essential to understand this ecosystem in order to manage it effectively, particularly with regard to anthropogenic stressors such as offshore development.

This study provides the first comprehensive view of taxa that are likely to be exposed to offshore wind energy development in the mid-Atlantic region.

These seasonal baseline data on wildlife species composition, distributions, and relative abundance are essential for:

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.

OFFSHORE WIND AND WILDLIFE

Offshore wind energy development has progressed rapidly in Europe since the first facility became operational in 1991, 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.

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 (Langston 2013). Some species are negatively affected, while others show no net effect, or may even be affected positively.

Possible effects to fish, marine mammals, sea turtles, birds, and bats include: mortality or injury from collisions with turbines or vessels; displacement from, or attraction to, habitat use areas; avoidance of facilities during migration or daily movements, which may necessitate increased energetic expenditures; and changes to habitat or prey populations (Fox et al. 2006).

The scale of development is likely to be important in determining the significance of these effects. Exposure alone does not necessarily indicate the severity of these effects, however. The vulnerability of different species to development activities will also play a role in determining impacts.

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, behaviors, and other oceanographic and biological factors.

Effects from offshore wind may also be combined with other natural and anthropogenic stressors. As a result, physical and ecological context is essential for understanding and minimizing effects of offshore development on wildlife.

Study Area and Methods

The Mid-Atlantic Baseline Studies project focused on a 13,245 km^2 area on the Outer Continental Shelf off the coasts of Delaware, Maryland, and Virginia. This study area extended from 5.6 km (3 nautical miles) off the coast to the 30 m isobath (Figure 1). Beginning in March 2013, surveys were extended offshore of Maryland (funded by the Maryland Department of Natural Resources and the Maryland Energy Administration).

We used several study methods to document animal movements, distributions, abundance, and habitat use; each method had strengths and weaknesses (Table 1). The combination of these methods resulted in a more comprehensive understanding of wildlife patterns in the region.

BOAT SURVEYS

Boat-based surveys are widely used to monitor marine wildlife. Due to relatively slow survey speeds (19 km/hr), observers can record detailed data on species identities, relative abundance, and behaviors, including contextual data, such as "feeding frenzies" of dolphins and seabirds preying on forage fish.

In collaboration with the City University of New York, we conducted 16 surveys over two years (April 2012–April 2014) along 559 km of transects (572 km including the Maryland project in 2013-14; Figure 1).

Our surveys were conducted by teams of two observers on a 55-foot charter vessel. In addition to recording the location, relative abundance, and behaviors of animals such as marine birds, mammals, and turtles, observers recorded sea state, visibility, ocean temperature, and salinity. Distance and angle to each animal were also recorded for use in modeling.

HIGH RESOLUTION DIGITAL VIDEO AERIAL SURVEYS

High resolution digital video aerial surveys are a relatively new method for collecting distribution and relative abundance data on animals (Thaxter and Burton 2009). Our study was the first to use these methods on a broad scale in the U.S. HiDef Aerial Surveying, Ltd. developed this approach in the United Kingdom and conducted the surveys for this study. Surveys were flown in small twin-engine airplanes at 250 km/hr and an altitude of 610 m, which is much higher and faster than traditional visual aerial surveys (flown at 60-180 m). Flying at this altitude is safer for the flight crew and less disruptive to the animals being counted.

We conducted 15 surveys over two years (March 2012–May 2014) along 2,857 km of transects (3,601 km including the Maryland project; Figure 1). Four belly-mounted cameras recorded video data, resulting in a 200 m wide transect.

Video data were analyzed by two teams of observers who located and identified objects in the footage. These processes included multiple quality control procedures. Flight heights were estimated for flying animals (Hatch et al. 2013).

SATELLITE TELEMETRY

Tracking techniques, such as attaching satellite transmitters to individual animals, allow us to obtain detailed

North Atlantic Right Whales in high resolution digital video recorded during aerial surveys.

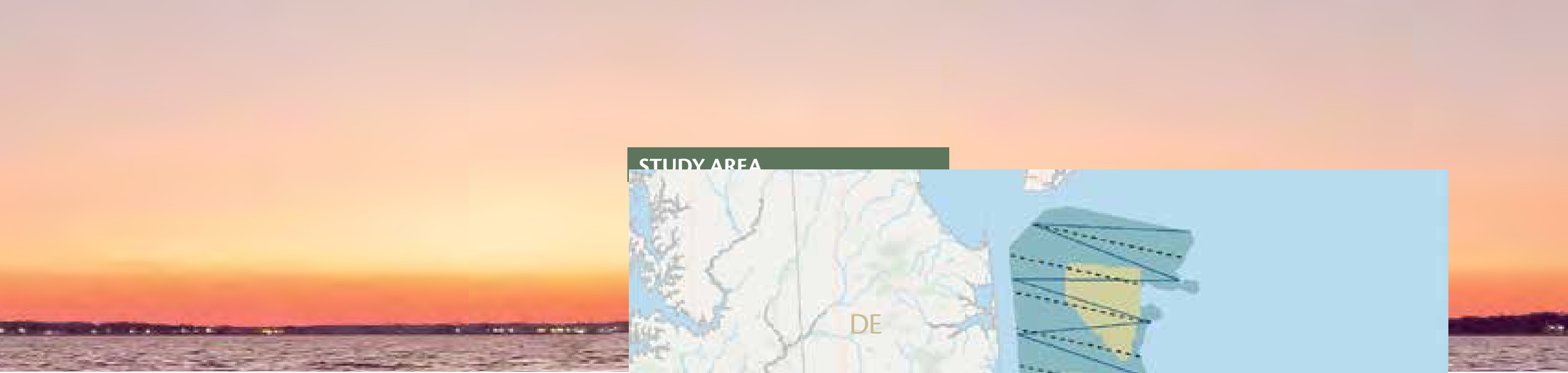
information on the movements of individuals and potentially identify ecologically important areas (Montevecchi et al. 2012). Satellite transmitters send data on locations of individuals to orbiting satellites during predetermined periods of the day.

We deployed satellite transmitters on Surf Scoters, Northern Gannets, Red-throated Loons, and Peregrine Falcons, four species that make use of the study area during wintering or migration periods. Birds were captured at several locations along the east coast of North America. Satellite transmitters were attached to birds externally or were surgically implanted.

Telemetry data presented in this report were gathered as part of several longer-term studies funded by multiple agencies and organizations. These preliminary results will be updated as research continues.

NOCTURNAL MIGRATION MONITORING

Oceans can act as barriers to migrating landbirds, including songbirds and raptors, but many species also make long transoceanic flights, especially at night (Delingat et al. 2008). We used two methods to document nocturnal avian migration. During nights spent on the



water, a passive acoustic monitoring device was deployed on the survey vessel to detect flight calls of landbirds migrating through the study area. We also analyzed weather surveillance radar (NEXRAD) to detect offshore migratory activity in the atmosphere on a broad scale.

Neither method allowed for estimation of actual animal abundance, and NEXRAD data were not species specific, but together these approaches provided information on offshore migration during a time of day when visual surveys were impossible.

INTEGRATING METHODOLOGIES

By using the above research methods, we developed a more complete picture of wildlife populations in the mid-Atlantic study region (Table 1). For example, satellite tracking provided data on broad-scale movements of individual birds, including nocturnal locations that were missing from survey data. Survey data allowed for population-level analyses of abundance and distributions that were not possible with tracking alone.

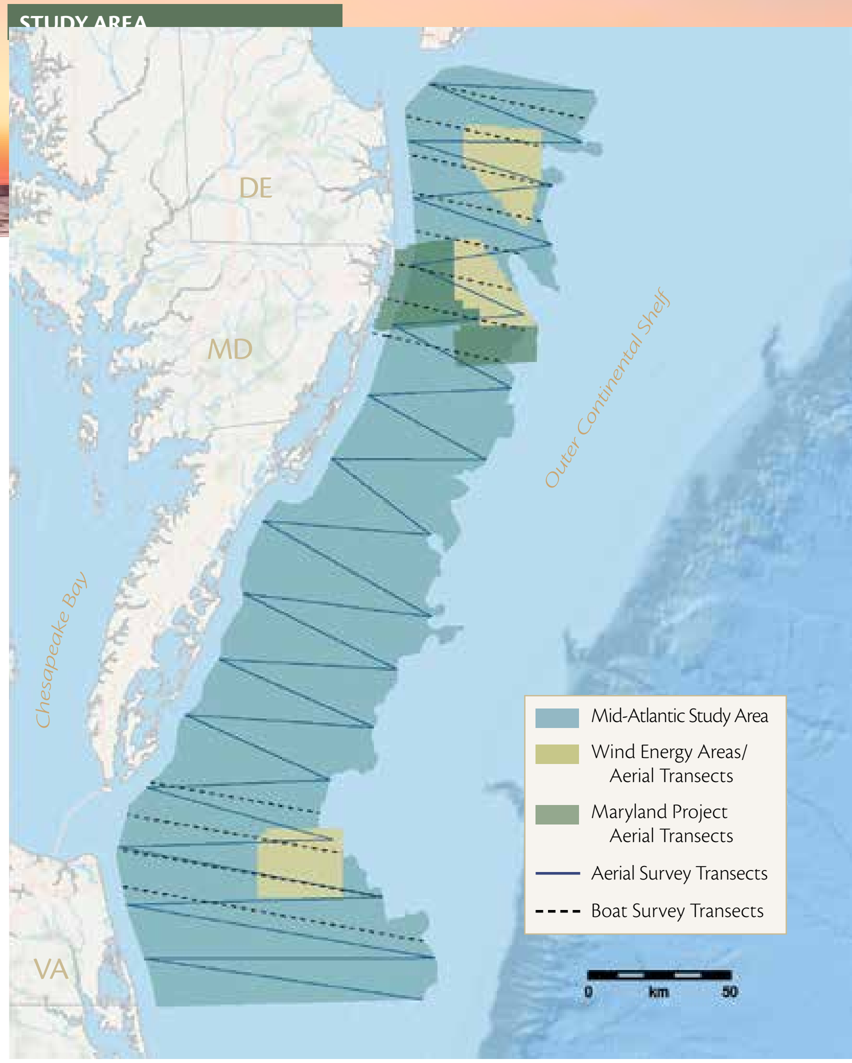


Figure 1: The study areas for the Mid-Atlantic Baseline Studies and Maryland projects, with WEAs and boat and aerial survey transects. Fine scale aerial transects (20% coverage) were carried out within the WEAs and the Maryland project area.

	Video Aerial Survey	Boat Survey	Satellite Telemetry	Avian 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*	■ 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

Table 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 (■ = good, ■ = fair, ■ = poor). A dash indicates that data were 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."

**Either absolute or relative abundance.*

Analytical Methods

We use several different approaches for presenting results in this report. Understanding each analytical method and its limitations is essential to appropriately interpret maps, figures, and other analyses.

RAW OBSERVATION DATA

In rare instances, we simply map the locations where wildlife were observed during surveys, without any additional analysis (Figure 2A). This approach is straightforward, but has severe limitations.

There are known sources of bias in raw survey data that make it difficult to compare values across space, time, and species without first controlling for those biases (Burnham and Anderson, 1984, Spear et al. 2004, Wintle et al. 2004).

Because of these limitations, we only present raw survey data when there were insufficient observations to support alternative approaches that address these sources of error (e.g., observations of baleen whales; Figure 18).

PERSISTENT HOTSPOTS OF ABUNDANCE

Persistent hotspots are locations where animals were most often found in large aggregations relative to their typical distribution patterns. These areas likely provide important habitat for foraging, roosting, or other activities (Santora and Veit 2013).

Before identifying hotspots, we grouped survey observations into grid cells. These cells, or lease blocks, are defined by the Bureau of Ocean Energy Management for offshore development activities. Counts were standardized by the amount of survey effort in each lease block. The lease blocks with the largest effort-corrected relative abundance values within each survey were labeled as survey-specific hotspots.

Blocks that were repeatedly identified as hotspots during the two years of boat and aerial surveys were categorized as "persistent" hotspots. To combine data from boat and aerial surveys for lease blocks that were surveyed by both methods, we weighted each dataset to address differences in detection and/or identification rates between survey methods. The survey method that detected or identified the taxon at the highest rate was given greater importance (i.e., weight).

Hotspot maps use a gradation of colors to indicate increasing hotspot persistence (Figure 2B). In addition to showing persistent patterns for various taxonomic groups (e.g., for sea turtles; Figure 21), we also use this analytical approach to illustrate persistent patterns of species richness across all taxa (Figure 7).

Continued on page 10

Figure 2: Types of Maps Used in this Document*

Example A: Raw Survey Data
Maps of observation points show where individual animals were recorded during boat and aerial surveys. They do not correct for known sources of bias in observations.

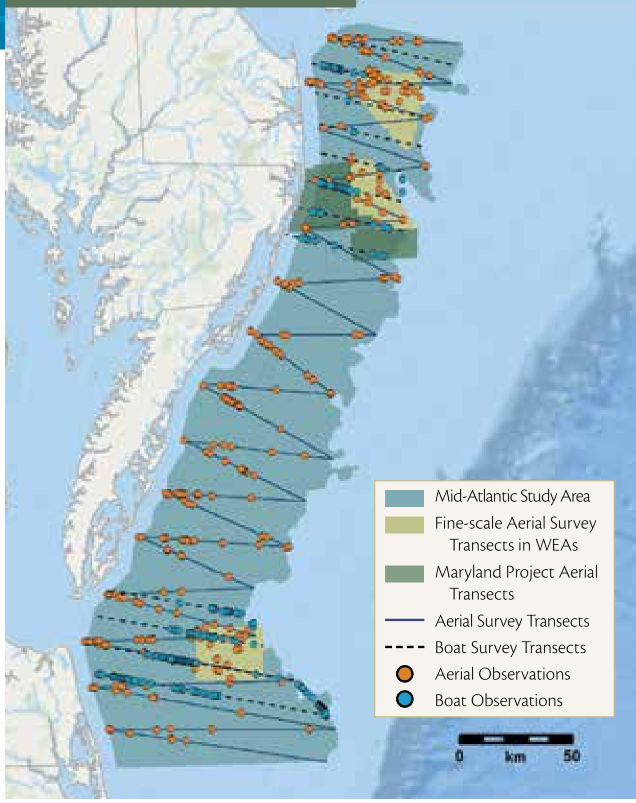
Example B: Persistent Hotspots
Persistent hotspot maps use effort-corrected boat and digital video aerial survey data, aggregated across all surveys, to illustrate where the highest numbers of animals were most consistently observed. This presentation corrects for variation in effort, but does not address detection bias. Colors range from no color (never a hotspot) to red (in the 95th percentile for persistence of hotspots across all cells and surveys in which the taxon was present).

Example C: Predicted Abundance
Seasonal predicted abundance maps display outputs from generalized linear models (GLMs) or generalized additive models (GAMs). These models use effort- and bias-corrected survey data from either boat surveys or digital video aerial surveys, in combination with environmental covariate data, to predict seasonal animal distribution and abundance across the study area. Values represent estimated numbers of individuals or groups of individuals per grid cell.

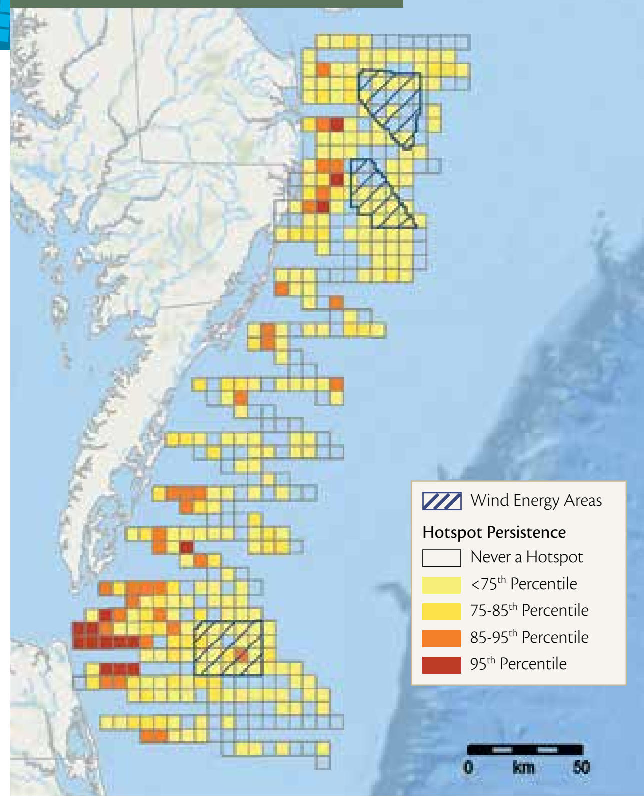
Example D: Utilization Distribution
Utilization distribution (UD) maps are derived from satellite telemetry data. They display the estimated core use areas, where tagged individuals spent the majority (>50%) of their time, and broader utilization distributions, in which individuals spent >95% of their time. While survey data provide "snapshot" information on population distributions, UD maps characterize the movements and habitat use of a group of individual animals over time.

**These example maps show a subset of data for the Northern Gannet.*

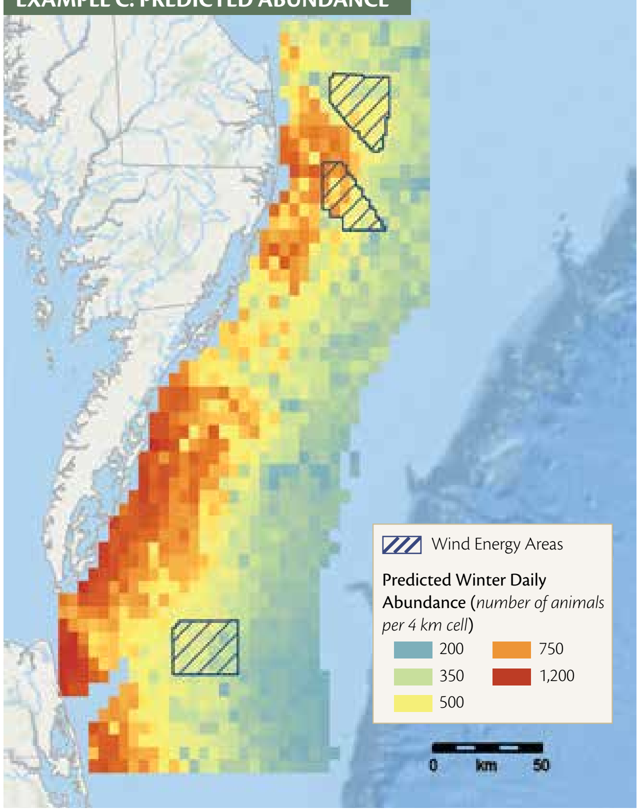
EXAMPLE A: RAW SURVEY DATA



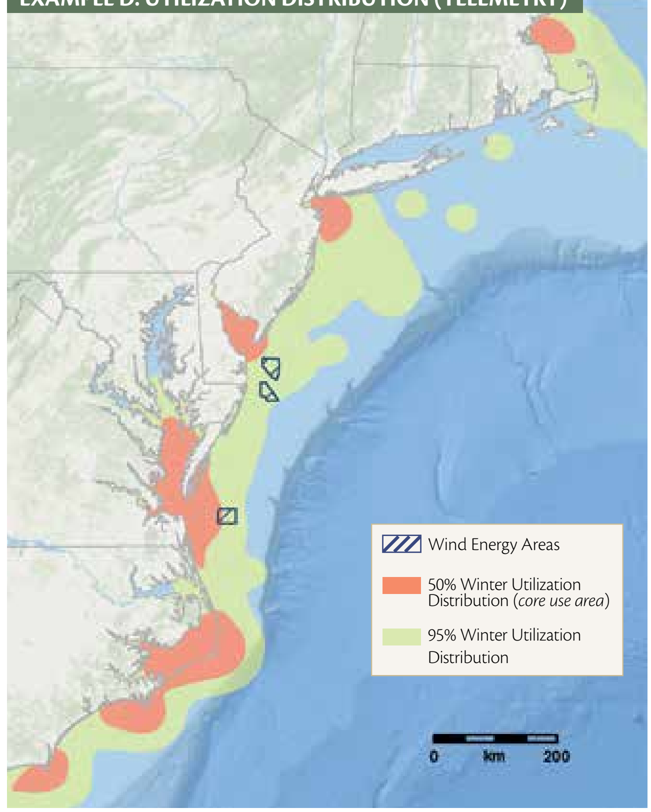
EXAMPLE B: PERSISTENT HOTSPOTS



EXAMPLE C: PREDICTED ABUNDANCE



EXAMPLE D: UTILIZATION DISTRIBUTION (TELEMETRY)



Analytical Methods, Continued

Continued from page 8

Several limitations of persistent hotspot maps should be noted. First, they do not indicate the full range of species' habitat use within the study area. Hotspots may occur in areas that were not surveyed (and are thus not represented in these maps). Second, individual grid cell "persistence" values should be interpreted with caution, as this analysis was intended to identify patterns at a regional scale.

PREDICTIVE MODELS

Several statistical modeling approaches are used in this study, including generalized linear models (GLMs) and generalized additive models (GAMs). These modeling frameworks are frequently used in ecological research (Guisan et al. 2002), and can incorporate environmental data (covariates), effort corrections, and observation biases into their structure. These approaches are used to make predictions about where animals occur and what environmental factors influence their distribution or abundance (Mordecai et al. 2011).

"Detection probability" in modeling is the probability of observing an animal given that it is present. There are several detection biases implicit in survey methods. For example, in boat-based surveys, the probability of detecting an animal decreases with its distance from the observer (Figure 3).

Because we recorded the distance and angle at which each animal was seen from the boat, modelers were able to fit a detection curve to survey data, indicating the estimated detection probability for an animal at a specified distance. This curve can be used to "correct" for undercounting of animals farther from the transect line.

The modeling approaches in this study also use environmental covariates to predict abundance or relative abundance. Correlating survey data with remotely sensed environmental data from satellites allows us to make predictions in areas or during time periods that were not directly surveyed. Distribution models are chosen to fit the observed abundance data (Gardner et al. 2008, Zipkin et al. 2010), similarly to fitting a distance curve (Figure 3).

The use of models to make predictions requires the assumption that correlations have consistent causal mechanisms, so that relationships between wildlife distributions and covariates will remain consistent even in locations or time periods where surveys did not actually occur. It should also be noted that a causal relationship is not explicitly assumed in the model, and that correlations between wildlife distributions and covariate data may not be direct or causal in nature. Initial models for this study incorporated either boat or aerial survey data, but researchers at North Carolina State University are developing predictive models that integrate both survey data sets to provide a more comprehensive view of wildlife distributions.

Generalized Linear Models: Seabirds

Project collaborators at North Carolina State University first focused on the development of a community distance sampling (CDS) GLM for seabirds from the boat survey data. This is a novel multi-species approach for estimating seabird abundance and distributions. Like similar models, it explicitly estimates detection as well as

EXAMPLE DETECTION FUNCTION

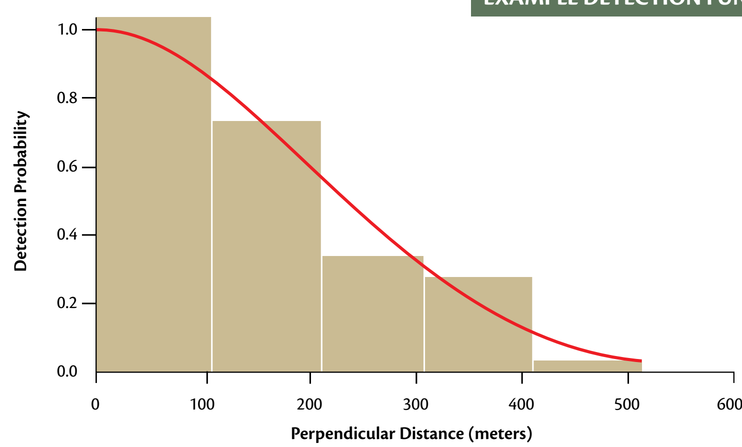


Figure 3: Detection function for Bottlenose Dolphins from boat surveys (in summer). A detection probability of 1.0 (y-axis) indicates the 100% probability of an observer spotting an animal that is present in the transect strip. The probability of detection decreases with distance of the animal from the observer (x-axis), with <10% probability of spotting a dolphin at 500 m. Actual survey data are summarized by tan bars; the distance curve, fitted to these data, indicates the estimated detection probability for an animal at a specified strip width.

abundance parameters for each species. However, sharing information across species allows us to make inferences about rare species that often have too few observations to be analyzed separately.

Building on the CDS model, we incorporated remotely collected environmental covariate data into the hierarchical modeling structure to develop geospatial models that predict seabird abundance throughout the study area by season (Figure 2C).

Generalized Additive Models: Cetaceans and Sea Turtles

GAMs are extensions of GLMs that use smoothing functions to improve model fit. These models can be particularly useful for situations with complex, nonlinear relationships between predictor and response variables (Guisan et al. 2002, Hastie and Tibshirani 1990). Collaborators at Duke University developed GAMs with remotely collected environmental covariate data to predict sea turtle densities and Bottlenose Dolphin pod densities throughout the study area by season.

TELEMETRY DATA ANALYSES

Satellite telemetry provides data on the individual locations (and, by inference, movements) of animals. These temporally explicit movement data are not feasible via surveys, and can be aggregated to identify species-specific patterns in habitat use and movement behaviors in relation to changing environmental conditions.

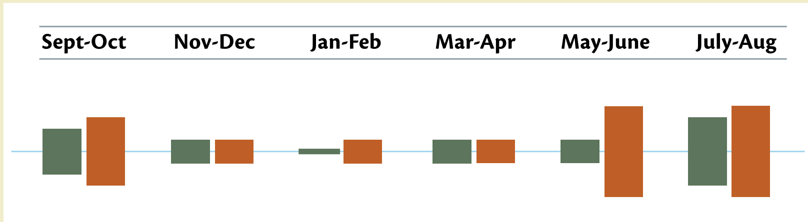
Kernel density estimation involves the use of point data from telemetry to estimate relative spatial use during specified time intervals. Random samples of point locations from tagged birds were pooled to create a composite utilization distribution map for all wintering individuals. Utilization distributions illustrate the estimated core use areas, where tagged individuals spent the majority (>50%) of their time, and broader utilization distributions, in which individuals spent most (>95%) of their time (Figure 2D).

In addition to utilization distributions, we used state-space models to identify more detailed behavioral patterns in Northern Gannets. Fast, straight movements are generally thought to indicate transient behavior, while slower, circular movements indicate that the animal is using resources on or under the water (perhaps foraging or resting; Jonsen et al. 2007). We used these movement patterns to identify the environmental conditions correlated with more intensive resource use.

It is important to keep in mind that these distributions represent a small subset of individuals from the broader population, and could potentially be affected by animals' capture location or other factors. However, telemetry data can provide useful information on the habitat use and likely movements of animals in relation to environmental conditions.

As mentioned previously, telemetry data presented in this report are preliminary (drawn from the first two years of a four-year study) and results will be updated as research continues.

HOW TO INTERPRET CHARTS ILLUSTRATING TEMPORAL CHANGES



Bar charts, as in the example above, were developed to summarize temporal patterns of relative abundance for species or taxonomic groups in the study area. For each survey method, we summed effort-corrected total counts of individuals by two-month time period, so each period included data from two to four surveys. Boat (■, *left*) and aerial (■, *right*) bars are placed side by side to illustrate differences in detection and/or identification between the two survey methods.

Larger bars represent higher effort-corrected counts of a species or group. Relative bar sizes are comparable among individual species, but not between species and broader taxonomic groups, as species and group percentiles were calculated separately. The light blue horizontal center line provides a reference point for comparison.

Comparing Boat and Aerial Surveys

Together, boat-based surveys and high resolution digital video aerial surveys provided a more complete understanding of the ecology of the mid-Atlantic than either method achieved alone.

The ideal survey approach will depend on project goals and the particular characteristics of a given study area, but may involve a combination of these complementary survey methods.

BOAT-BASED SURVEYS

A total of 64,462 animals were observed in 16 boat surveys, including more than 62,000 birds and 1,500 aquatic animals (marine mammals, sea turtles, sharks, and fishes). At least 97 bird species and 12 species of aquatic animals were represented. The greatest numbers of animals were observed in December and January, when large flocks of birds wintered in the study area.

Wintering scoters, including Black Scoter, White-winged Scoter, and Surf Scoter, were the most abundant avian group observed in boat surveys (34% of all observations). Various species of gulls and terns were observed throughout the year, and collectively were the next most abundant group (23%), followed by wintering and migrating Northern Gannets (22%). The boat survey dataset also included observations of almost 600 shorebirds and 200 landbirds.

Bottlenose Dolphins were the most common aquatic taxon observed (1.4% of the dataset), along with sea turtles (0.18%, or 114 individuals), predominantly in warmer months.

DIGITAL VIDEO AERIAL SURVEYS

A total of 107,003 animals were observed in 15 aerial surveys, including more than 46,000 birds and 60,000 aquatic animals. At least 48 species of birds and 19 species of aquatic animals were represented. The greatest numbers of animals were observed in March, July, and September, due to peaks in seabird and ray observations.

Scoters were the most abundant birds observed (20% of all observations), followed by Northern Gannets (7% of the dataset) and loons (5%), all predominantly observed in winter and spring. A variety of gull and tern species were observed throughout the year (4%).

Large numbers of animals were observed below the water's surface during digital video aerial surveys. Rays were the most common taxon, constituting 45% of all observations (excluding some schools where animals could not be individually counted). Fish were the next most commonly observed aquatic animals, including large groups of forage fishes.

Dolphins represented 2% of the dataset, with Bottlenose Dolphins most commonly identified to species. A notable number of sea turtles were observed (1.63%, or 1,748 individuals) in warmer months.

COMPARING SURVEY METHODS

The two survey methods generally showed similar species-habitat relationships, though there were clear differences in detectability between the two survey types (Figure 4).

Boat survey observers recorded larger numbers of birds per unit area, likely

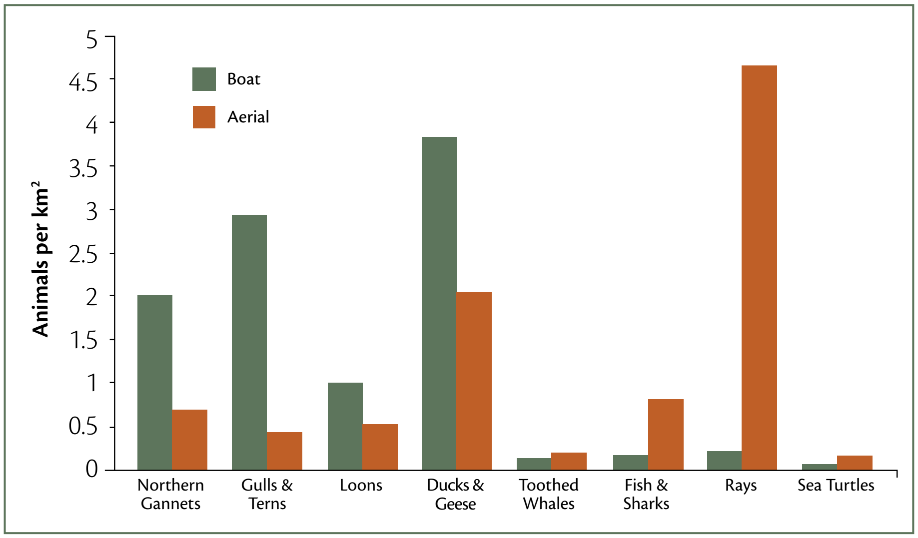


Figure 4: Comparison of total effort-corrected boat and aerial survey counts across all surveys for selected taxa. Aerial densities were calculated using actual transect strip widths, and boat densities were calculated using estimated strip widths for each taxon. Effective boat transect strip widths were calculated for avian taxa based on their effective half strip widths, and for aquatic taxa based on their median distance of observations from the boat. Observations of groups that were not individually counted or identified (e.g., some fish and ray schools) are excluded from this figure.

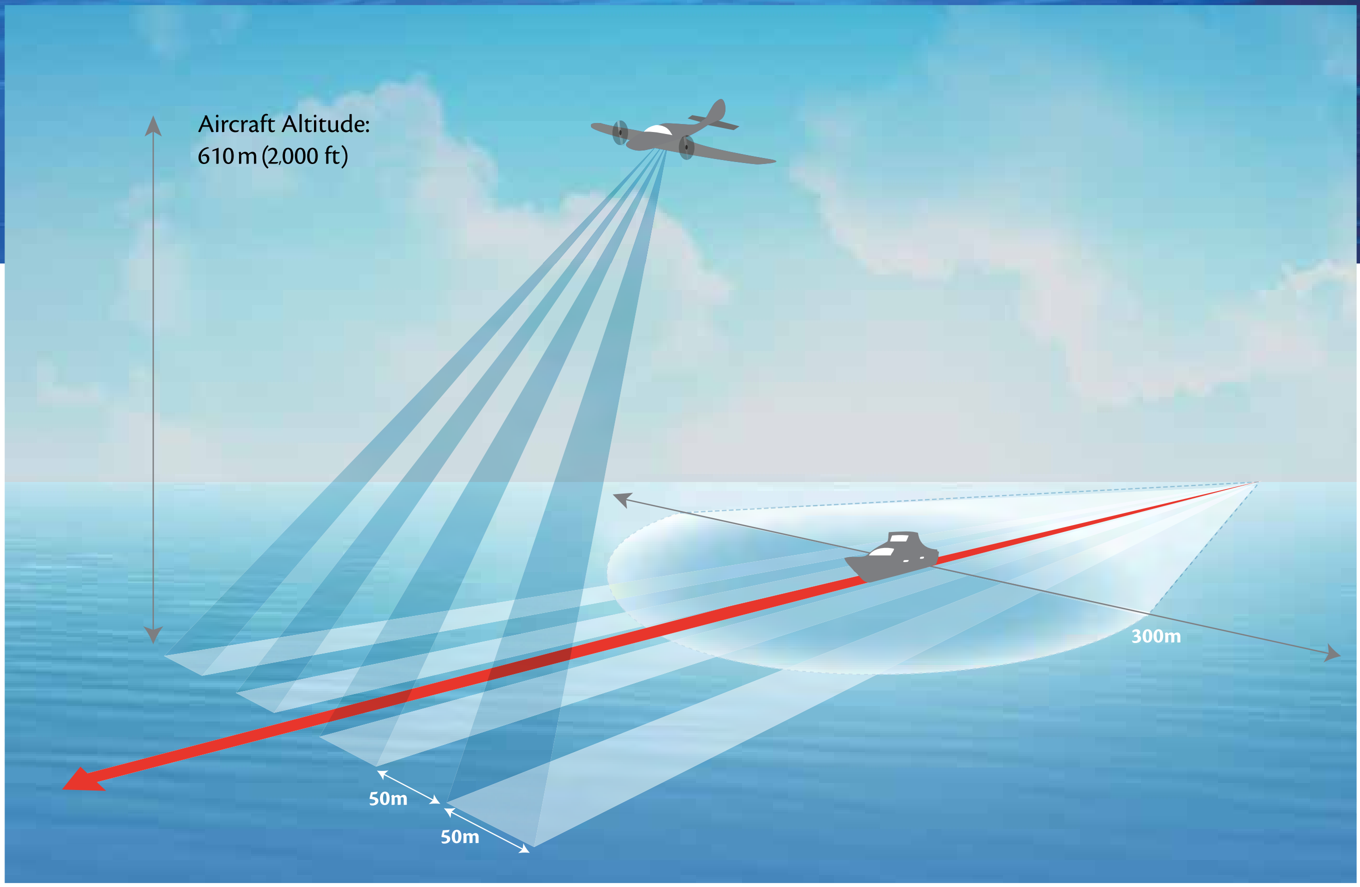


Figure 5: Boat–aerial survey comparison. The diagram shows the fields of view available during boat surveys and digital video aerial surveys. The combined strip width for all four video cameras was 200 m; the boat transect had an intended minimum strip width of 300 m, although observations of animals were made up to 1,000 m from the vessel. Apart from the experimental comparison (see below), boat and plane followed different transect lines (Figure 1).

because some species were more reliably detected and identified from the boat.

HiDef Aerial Surveying's digital aerial surveys proved to be highly effective at detecting many aquatic taxa, including sharks, fish, and rays (Figure 4). While some of these animals were also observed in the boat surveys, the aerial surveys provided an excellent platform for detecting and identifying animals within the upper reaches of the water column that were not easily observed from the boat.

In addition to detection of animals, there were differences between survey types in observers' ability to identify animals. Only 45% of aerial observations were identified to species, as compared to 72% of boat observations. Scoters, the most common avian group in surveys, were more often identified to species from the air, however (27% boat, 52% aerial). Scoters are known to be disturbed by boats, which may have pushed them out of range for definitive identification by boat-based observers in many cases. Excluding scoters, the rate of definitive identifications during boat surveys was 97%.

The relatively low rate of species identifications in aerial video was likely due in part to variation in image quality, as well as difficulties differentiating small species with subtle distinguishing features. Video reviewers also had difficulty differentiating Common Loons and Red-throated Loons due to the overlapping body sizes of birds wintering in the region (Gray et al. 2014). Identification rates were lower for sea turtles from the air than from the boat (21% aerial, 91% boat), but more species were observed in aerial data, and many more individuals were detected from the air.

COMPARISON STUDY

To understand the effectiveness of digital video aerial surveys and the specific challenges faced in employing the technique in North America, we experimentally compared results from simultaneous boat and digital video aerial surveys off of Virginia in 2013 (Figure 5).

The two methods each had clear strengths and weaknesses. Overall, the boat-based survey provided better species identification for many species groups than the digital aerial survey, but the boat also caused substantial disturbance for some taxa, potentially complicating identification efforts and abundance estimation.

Geographic and Temporal Patterns

The mid-Atlantic region provides important habitat for marine wildlife throughout the year. Each season in our study brought a unique shift in habitat characteristics, and with it a new array of species reliant on the specific resources available (Figure 6).

SEASONAL PATTERNS

Fall: Seabird species composition shifted as summer residents, such as terns, shearwaters, and storm-petrels, migrated south to more productive waters and milder climes. Winter residents, such as scoters, Northern Gannets, and Red-throated Loons, migrated into the study area from breeding grounds farther north or inland. In general, seabirds tended to be more associated with nearshore habitats in the fall as compared to winter and spring.

Songbirds, shorebirds, Eastern Red Bats, and Peregrine Falcons, among other species, migrated over open waters across the Outer Continental Shelf. Cownose Rays were observed in dense migratory aggregations in early fall. Large schools of forage fish were also observed along the coast. Sea turtles and Bottlenose Dolphins remained in the region through late fall, while Common Dolphins largely arrived in the area in November.

Winter: Wintering seabirds generally occupied habitat throughout the study area, although distribution patterns varied among species. Northern Gannets tended to be broadly distributed across the study area, for example, while scoters were most concentrated in nearshore regions adjacent to the bays.

Alcids (Atlantic Puffins, Razorbills, Dovekies, and murres) were observed in small numbers throughout the study area. Baleen whales were most commonly observed during this season. Dolphin species composition shifted from Bottlenose Dolphins, which were commonly observed in the spring, summer, and fall, to Common Dolphins, which were most abundant in the winter.

Spring: Wintering seabirds departed the study area in spring, while summer resident seabirds arrived. Bottlenose Dolphins and a variety of sea turtle species also began using the study area. We observed songbirds, shorebirds, and raptors migrating over open waters across the region.

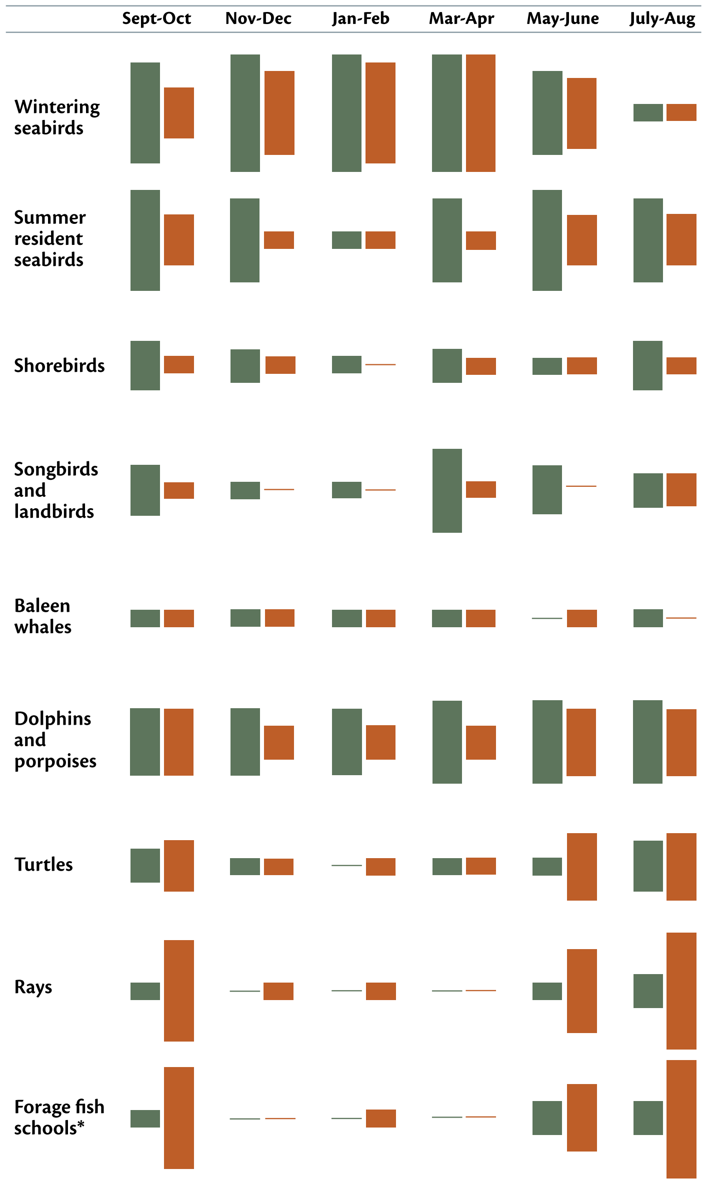


Figure 6: Temporal changes in relative abundance for major taxonomic groups. Data are from the boat-based surveys (■, *left*) and high resolution digital video aerial surveys (■, *right*) conducted in 2012-2014. Species included in each category are listed in Williams et al. (2015). Labels refer to seasons in the Northern Hemisphere.

**Forage fish were counted as schools, not as individuals, unlike the other animal groups.*

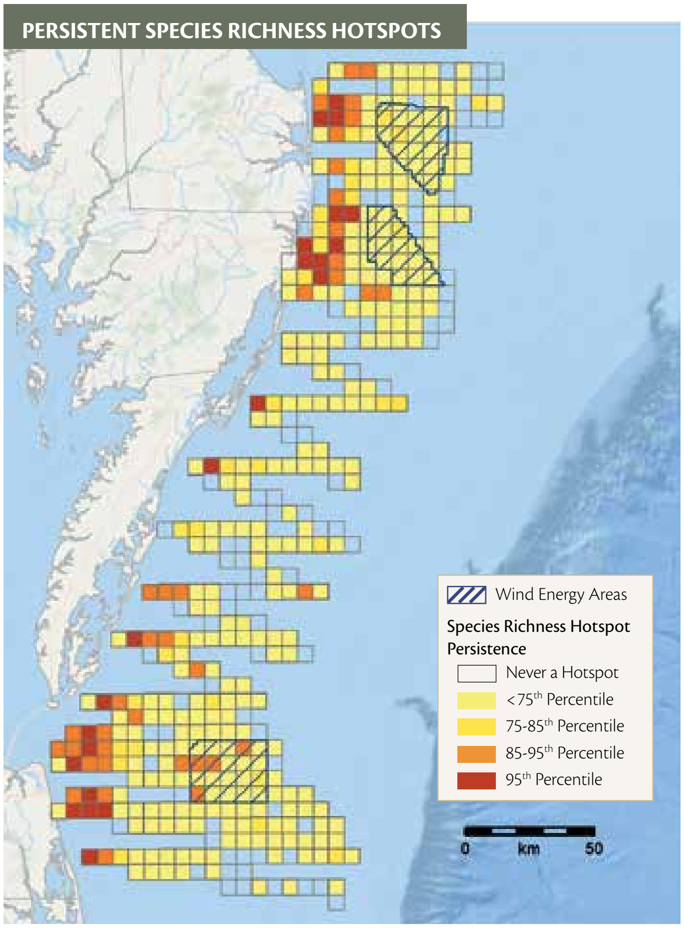


Figure 7: Persistent species richness hotspots—areas with consistently greater numbers of species across all surveys.

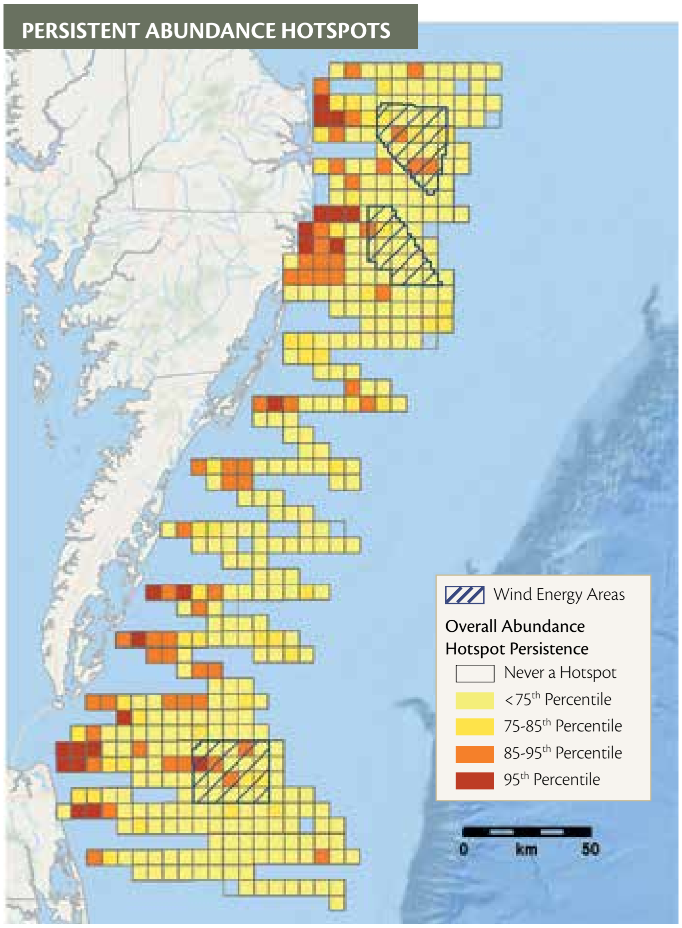


Figure 8: Persistent abundance hotspots—areas with consistently greater numbers of individuals across all taxa and surveys.

Summer: Breeding seabirds, such as Common Terns, were observed foraging near shore and near the mouths of the bays, while nonbreeding species, such as Wilson's Storm-Petrels, tended to be more broadly distributed across the study area. Across all species, seabirds were generally more associated with nearshore areas during summer months. Large numbers of Cownose Rays migrated through the study area, and sea turtles and Bottlenose Dolphins were most abundant during the summer.

PERSISTENT PATTERNS

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 30 km of shore) consistently showed high species diversity and relative abundance of animals across all taxa observed in this study (Figures 7 and 8). Areas offshore of Maryland, where high-density surveys were conducted in nearshore areas, also showed high diversity and relative abundance.

These areas were likely attractive to a wide variety of animals due to consistently high primary productivity relative to the broader study area. 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 likely provided important and reliable foraging habitat for a multitude of species year-round.

[CASE STUDY]

Scoters

Scoters are medium-sized sea ducks that breed near lakes or slow-moving rivers in the boreal forest and taiga from Labrador to Alaska. Breeding pairs are formed in the wintering areas, which are located mostly in shallow bays and estuaries in temperate regions along the east and west coasts of North America. They are known to migrate in flocks, flying high over land between breeding and wintering sites, and stopping on inland lakes to rest and molt (Kaufman 1996, Anderson et al. 2015).

Scoters forage exclusively by diving and swimming underwater. While on the breeding grounds, they primarily consume aquatic invertebrates as well as some plant material (Kaufman 1996, Anderson et al. 2015). During the winter, scoters predominately forage on mollusks in shallow nearshore waters with sandy substrates (Stott and Olson 1973, Anderson et al. 2015).

The Surf Scoter and White-winged Scoter both have a Conservation Status of Least Concern from the International Union for Conservation of Nature (IUCN) 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 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).

Related sea duck species have demonstrated avoidance at several offshore wind facilities in Europe (Larsen and Guillemette 2007, Petersen and Fox 2007), causing effective habitat loss of feeding or roosting areas. There is some evidence for habituation or re-initiation of habitat use several years after construction (possibly in relation to changes in prey distributions; Petersen and Fox 2007). Scoters are also known to be disturbed by vessel activity, with displacement effects varying by species (Schwemmer et al. 2014, Williams et al. 2015).

CONTEXT

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

TAKE HOME MESSAGES

- Telemetry and survey data for scoters indicated strong nearshore distribution patterns, which held true across species and were largely driven by water depth.
- 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.

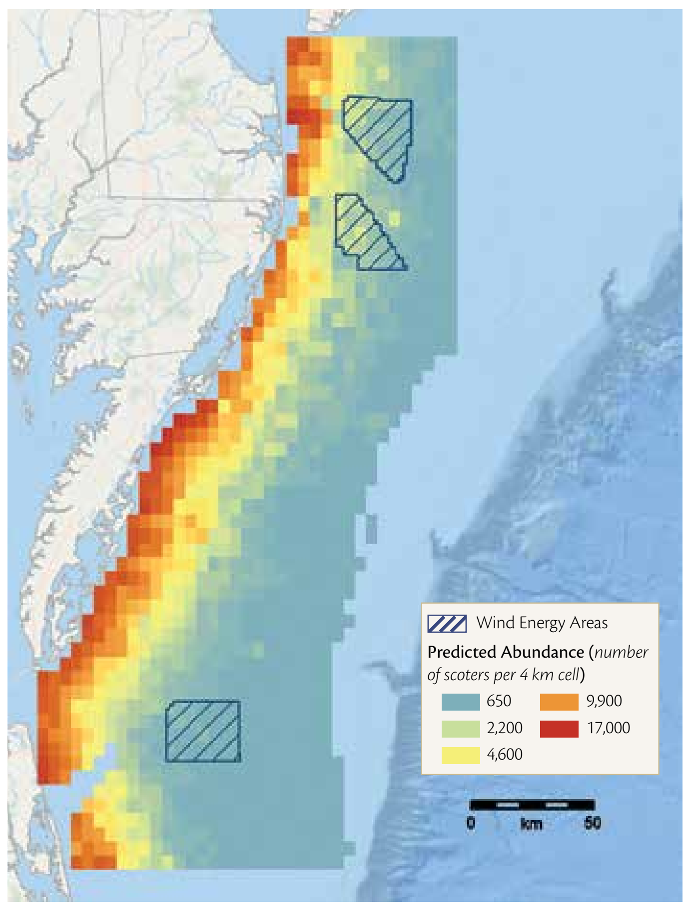


Figure 9: Predicted abundance of scoters (including White-winged Scoter, Black Scoter, and Surf Scoter) for a given day during winter of 2012-13. Model outputs combine observation data from boat-based surveys with environmental covariate data to predict scoter abundance across the study area. The highest abundance of scoters was predicted to occur close to shore and in regions with high primary productivity.

STUDY FINDINGS

- Scoters were the most abundant avian genus observed over the course of the study, with 43,339 individuals observed (25% of all wildlife observations). 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.
- Scoters were most abundant in the mid-Atlantic between October and May (Figure 10). Satellite tagged Surf Scoters spent an average of 133 days in the region during winter, generally arriving in the study area between mid-October and mid-December.
- Satellite tagged Surf Scoters departed the study area between early January and mid-May, and followed the coastline north to stage briefly in the St. Lawrence Estuary before continuing on to breeding and molting areas in northern Canada. This route was reversed during fall migration as birds returned to wintering areas in or near the mid-Atlantic.
- Large aggregations of scoters were most consistently observed at the mouth of Chesapeake Bay and just south of the mouth of Delaware Bay, within roughly 30 km of shore (Figure 9). Satellite tagged Surf Scoters spent >50% of their time in the study area within or at the mouths of the bays (Figure 11).
- Core use areas identified by satellite telemetry of Surf Scoters may have been heavily influenced by capture locations. However, survey and telemetry data both showed that scoters used habitat characterized by shallow nearshore waters with high primary productivity.
- The rotor-swept zone for offshore wind turbines may include altitudes between approximately 20 m and 200 m (Willmott et al. 2013). In the digital aerial survey video, 77% of flying scoters (all species) were below this range; 19% were between 20 m and 200 m.

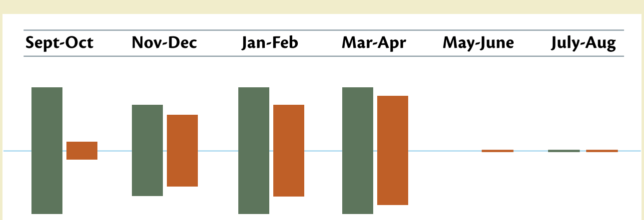


Figure 10: Temporal changes in relative abundance for Surf Scoters. This chart shows the year-round relative abundance of Surf Scoters observed by boat (■) and video aerial surveys (■) in two-month periods. Surf Scoters were most commonly observed in winter and none were observed in May-August.

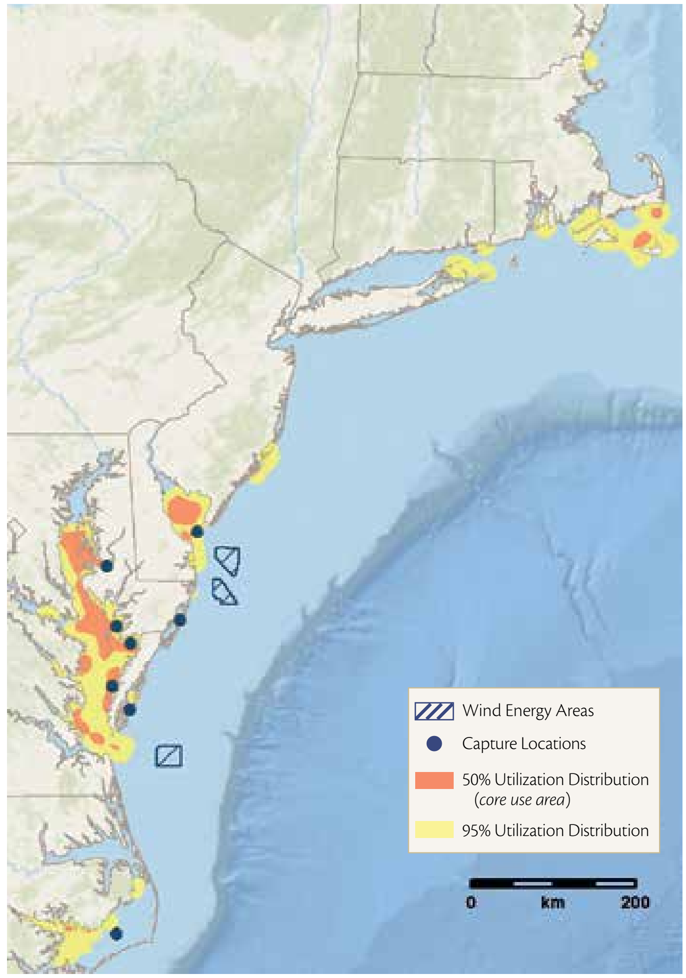


Figure 11: Winter utilization distribution for satellite-tagged Surf Scoters (n=101; data are preliminary). Additional capture locations in Labrador, Québec, and New Brunswick are not shown on this map.

Male Surf Scoter with implanted satellite tag (note antenna visible above tail).

[CASE STUDY] Red-throated Loons

The Red-throated Loon is the most widespread member of the loon family, with a circumpolar distribution. Similar to larger loon species, Red-throated Loons are long-lived (25-30 years) and experience high adult survival (Barr et al. 2000, Schmutz 2014).

In North America, these loons breed primarily on freshwater or brackish ponds and small lakes on the Arctic tundra. They likely form monogamous pairs, exhibiting elaborate courtship rituals (Kaufman 1996), and often returning to the same nest site over multiple years. Young move onto the water one day after hatching; both parents feed the young, and chicks can fly after seven weeks (Kaufman 1996). They spend the winter in temperate coastal ocean waters, and are known to migrate singly or in small groups within a few kilometers of the coast (Barr et al. 2000, Kaufman 1996).

Red-throated Loons swim at the surface with their heads partially submerged to search for prey before diving. They primarily eat fish, including cod and herring, on their wintering grounds, and char, trout, and salmon on the breeding grounds, in addition to aquatic invertebrates and the occasional frog (Kaufman 1996). Many Red-throated Loons forage in marine habitats year-round, the only loon species to do so (Barr et al. 2000, Kaufman 1996).

The Red-throated Loon has an IUCN Conservation Status of Least Concern due to the species' broad range and large population size, despite population trends indicating a decline across much of the species' range (Barr et al. 2000, BirdLife International 2015). In the U.S., fisheries are the major source of adult mortality, via bycatch of birds in nets (Barr et al. 2000). Red-throated Loons have exhibited long-term and possibly permanent displacement from areas around offshore wind energy facilities in Europe (Petersen and Fox 2007, Langston 2013), making disturbance and effective habitat loss the primary concern for this species in relation to offshore development (Furness et al. 2013).

CONTEXT

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

TAKE HOME MESSAGES

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

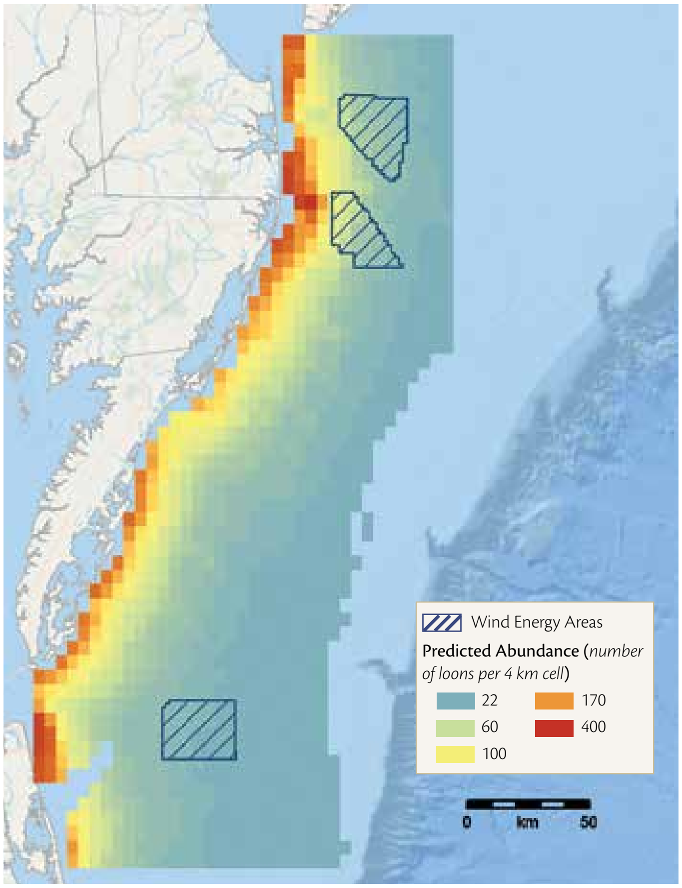


Figure 12: Predicted abundance of Red-throated Loons for a given day in winter of 2013-14 (Nov.-Jan.). Model outputs combine observation data from boat-based surveys with environmental covariate data to predict Red-throated Loon abundance across the study area. The highest abundance of Red-throated Loons was predicted to occur close to shore, and in regions with cooler water and high primary productivity.

STUDY FINDINGS

- During boat and aerial surveys, 1,770 Red-throated Loons were observed (1% of all wildlife observations from surveys). In many cases, however, Red-throated Loons and Common Loons could not be distinguished in digital video aerial surveys.
- Red-throated Loons were most commonly observed between November and May (Figure 13).
- During surveys, Red-throated Loons were most consistently observed within approximately 20 km of shore (Figure 12). This differed from Common Loons, which were more widely distributed across the study area in winter.
- Telemetry data showed that Red-throated Loons preferentially used shallow nearshore waters over flat sandy substrates while wintering in the mid-Atlantic region, particularly around the mouth of Chesapeake Bay and south along the Virginia and North Carolina coasts, close to original capture locations (Figure 14). Modeled boat survey data indicated that proximity to shore was the strongest predictor of Red-throated Loon abundance, followed by relatively cold sea surface temperature, and primary productivity (low in spring, high in winter).
- Satellite tagged individuals left the study area between late March and early May, and largely followed the coast north to breeding grounds. Greatest offshore movements occurred during this departure from the study area. During fall migration, loons arrived in the study area between mid-November and late December. Most individuals stopped over in Hudson Bay, and then moved either to the Gulf of St. Lawrence or to the Great Lakes before flying to Delaware Bay and following the coastline south.
- The rotor-swept zone for offshore wind turbines may include altitudes between approximately 20 m and 200 m (Willmott et al. 2013). In the digital aerial survey video, 70% of flying loons (both species) were below this range; 28% were between 20 m and 200 m.

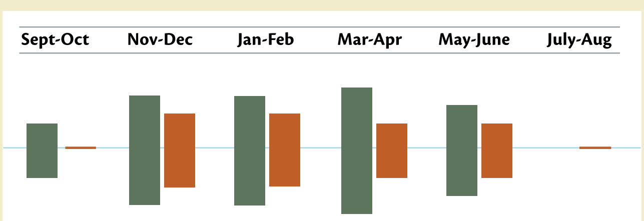


Figure 13: Temporal changes in relative abundance for Red-throated Loons. This chart shows the year-round relative abundance of Red-throated Loons observed by boat (■) and video aerial surveys (■) in two-month periods. Red-throated Loons were most commonly observed in winter. No individuals were observed in July-August by either survey method.

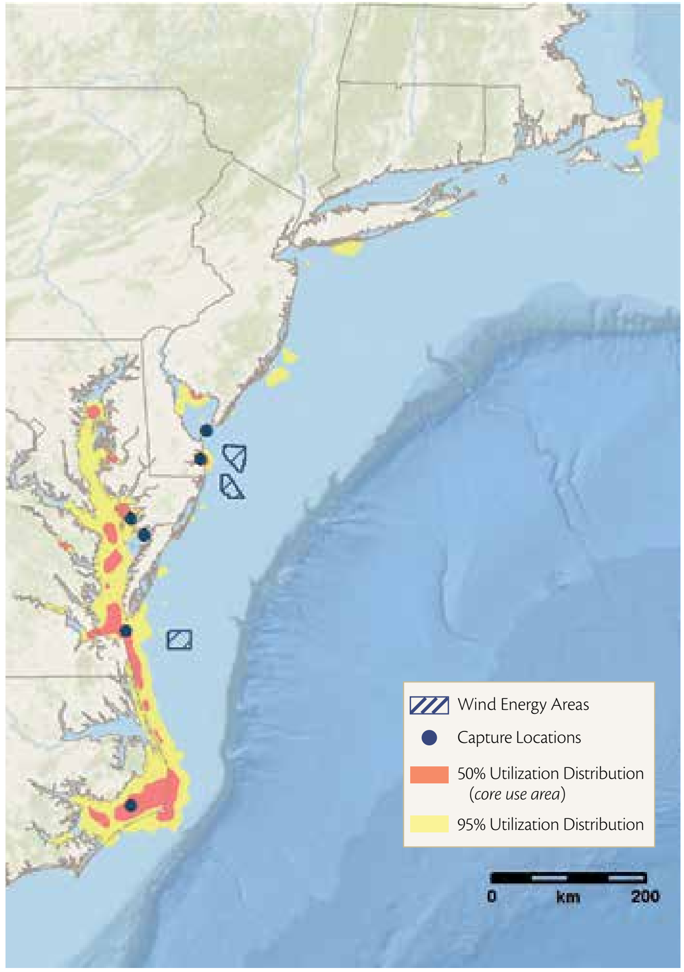


Figure 14: Winter utilization distribution for satellite-tagged Red-throated Loons (n=23; data are preliminary).

Red-throated Loon in winter plumage with implanted satellite tag (antenna visible above tail).

[CASE STUDY]

Northern Gannets

Northern Gannets are the largest seabirds to breed in the North Atlantic Ocean, wandering widely over continental shelf waters. They forage on surface-schooling fishes in dramatic plunging dives from the sky; they also dive directly from the ocean's surface (Garthe et al. 2000, Montevecchi 2007).

Like many seabirds, Northern Gannets are long-lived (20+ years) and exhibit high adult survival. They begin breeding at around five years of age, nesting in dense colonies on remote rocky islands and sea stacks. Females lay only one egg per year and it requires the constant efforts of both parents to raise the chick. Adults can fly hundreds of kilometers from the nest in search of prey (Garthe et al. 2007).

In the Western Hemisphere, Northern Gannets 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 (Nelson 1978, Mowbray 2002). On migration, they 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 (Nelson 1978, Fifield et al. 2014).

The Northern Gannet has an IUCN Conservation Status of Least Concern due to its relatively large population size and its exceptionally large range. 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. Northern Gannets have displayed avoidance of or displacement from some offshore wind facilities in Europe (Lindeboom et al. 2011, Vanermen et al. 2015) and are also considered to be at high risk of collision mortality (Furness et al. 2013).

CONTEXT

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

TAKE HOME MESSAGES

- The broad-scale distribution 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 foraging and habitat use areas appear to be defined by a wide variety of habitat characteristics. Construction and operations of offshore wind energy facilities, including associated vessel traffic, could potentially cause localized displacement anywhere in the study area, but this is most likely within about 30-40 km of shore where Northern Gannets were more abundant.

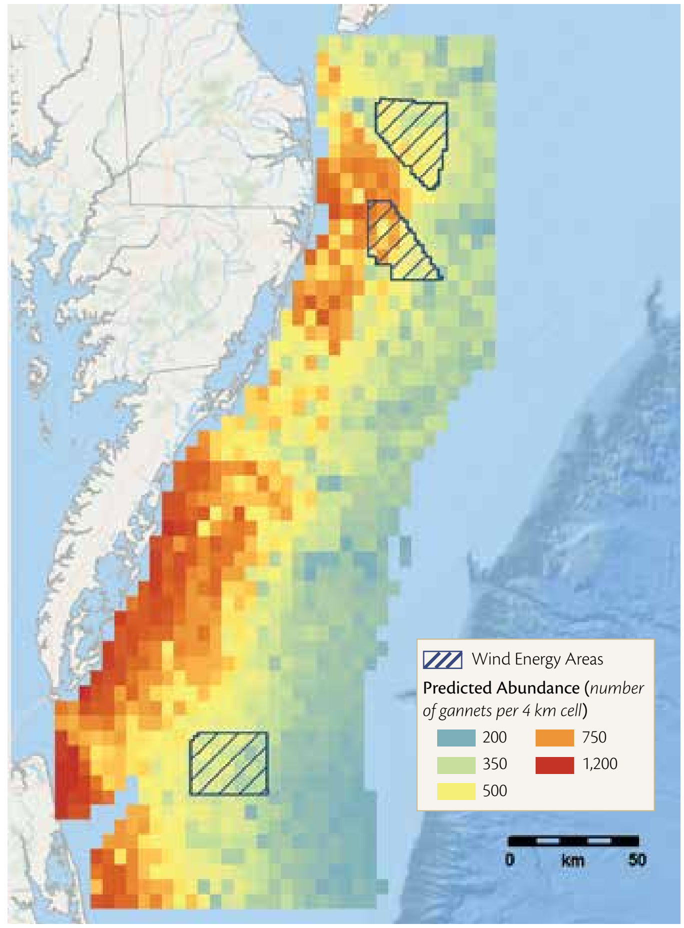


Figure 15: Predicted abundance of Northern Gannets for a given day in winter of 2013-14. This model used observation data from boat-based surveys and remotely sensed environmental covariate data to predict abundance across the study area. The highest abundance of Northern Gannets was predicted to occur closer to shore in regions with high primary productivity.

STUDY FINDINGS

- 21,345 Northern Gannets were observed during the boat and aerial surveys (17% of all wildlife observations).
- Northern Gannets were most commonly observed in the study area between October and April (Figure 17).
- 35 Northern Gannets were captured and satellite tagged in the study area during the winters of 2012 and 2013.
- Northern Gannet migration was highly asynchronous and widely dispersed across the continental shelf. In general, individuals worked their way up the east coast in March-April, often pausing in large bays. In the fall, birds left the breeding colonies in September and either followed the coast or took a more direct route south by following the continental shelf edge. They arrived in the wintering area mostly in November-December.
- Individual Northern Gannets roamed widely across the region in winter and often visited several areas, showing low site fidelity. The general locations used by wintering Northern Gannets, however, were relatively consistent across years.
- The rotor-swept zone for offshore wind turbines may include altitudes between approximately 20 m and 200 m (Willmott et al. 2013). In the digital aerial survey video, 55% of flying Northern Gannets were below this range; 43% were between 20 m and 200 m.
- Northern Gannets were most consistently observed in nearshore waters along the length of the study area (Figure 15), but satellite data also showed that they regularly ranged up to 50 km out onto the continental shelf (Figure 16).
- Telemetry and survey data showed that Northern Gannets in the mid-Atlantic generally used habitat characterized by highly productive, shallower waters and lower sea surface salinities, especially areas closer to shore and over fine sandy substrate.
- Northern Gannet behavioral patterns indicated that they foraged roughly 67% of the time during winter. Within the habitat use areas described above, birds preferred to forage in relatively deeper waters, and in areas with high densities of sea surface temperature fronts (e.g., boundary areas between water masses of different temperatures).

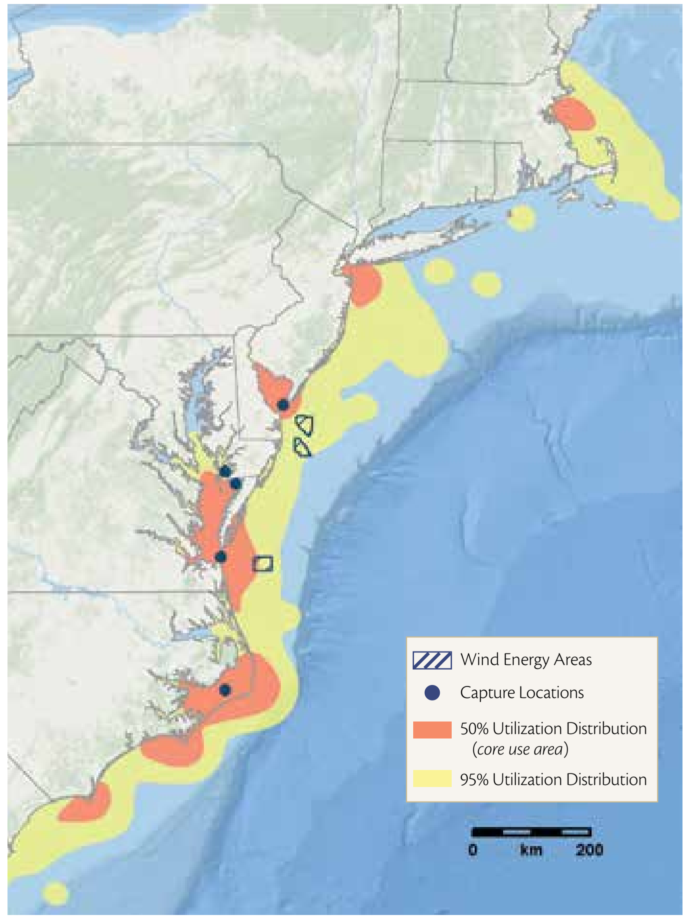


Figure 16: Winter utilization distribution of Northern Gannets tracked via satellite telemetry (n=17; data are preliminary).

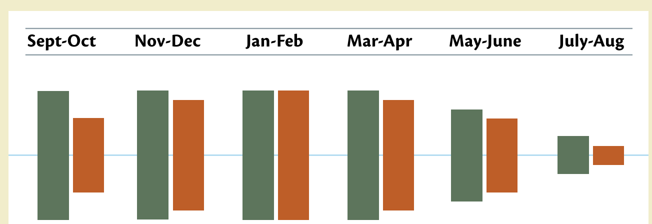


Figure 17: Temporal changes in relative abundance for Northern Gannets. This chart shows the year-round relative abundance of Northern Gannets observed by boat (■) and video aerial surveys (■) in two-month periods. Gannets were observed year-round, but were present in greatest numbers during winter.

[CASE STUDY]

Cetaceans

Cetaceans include two major types of aquatic mammals, both of which breathe air and birth live young. Toothed whales, such as dolphins and porpoises, have rows of teeth and eat fish and other large prey. They use sound to sense objects around them ("echolocation"). Baleen whales, including many of the large endangered whale species, eat krill, copepods, and small fish by filtering them through bristles or plates on their jaws. While baleen whales do not echolocate, they do use sound for communication.

There are two genetically distinct ecotypes of Bottlenose Dolphins in the western North Atlantic. The "offshore" ecotype inhabits colder, deeper waters on the Outer Continental Shelf and shelf edge, while "coastal" dolphins occur in more nearshore areas (Waring et al. 2014). In the mid-Atlantic, the coastal ecotype is thought to include at least two different migratory stocks, or subpopulations, whose migration may be partially related to water temperature (Waring et al. 2014). Many other cetaceans also migrate seasonally between wintering and breeding grounds. Migratory routes are poorly defined for many species, though several are known to migrate through the mid-Atlantic region.

All cetaceans that occur in the U.S. are protected under the Marine Mammal Protection Act. The North Atlantic Right Whale, among the rarest of all marine mammals, is of particular interest to regulators, and very little information exists on their movements and habitat use in the mid-Atlantic.

Acoustic disturbance from construction and operation of offshore wind facilities may affect all marine mammals (Bergström et al. 2014). European studies have shown displacement of Harbor Porpoises during construction (Teilmann et al. 2006, Thomsen et al. 2006), though displacement during operations has been variable in duration and degree (Teilmann and Carstensen 2012, Scheidat et al. 2011).

There is evidence for disturbance of large whales by other anthropogenic activities (e.g., McCauley et al. 2000, Tyack et al. 2011), but no information is available about their interactions with offshore wind facilities, as large whales are not common in European waters where development has occurred to date.

CONTEXT

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

TAKE HOME MESSAGES

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

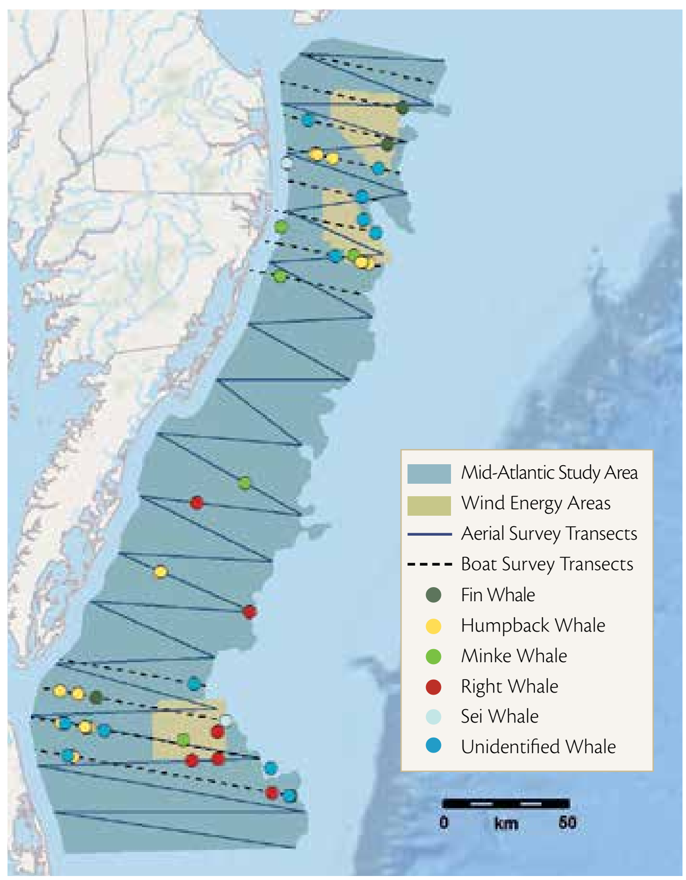


Figure 18: Large whale observations (Mysticeti) from boat and video aerial surveys (March 2012-May 2014). Aerial surveys were also conducted at high transect densities within certain areas (Figure 1).

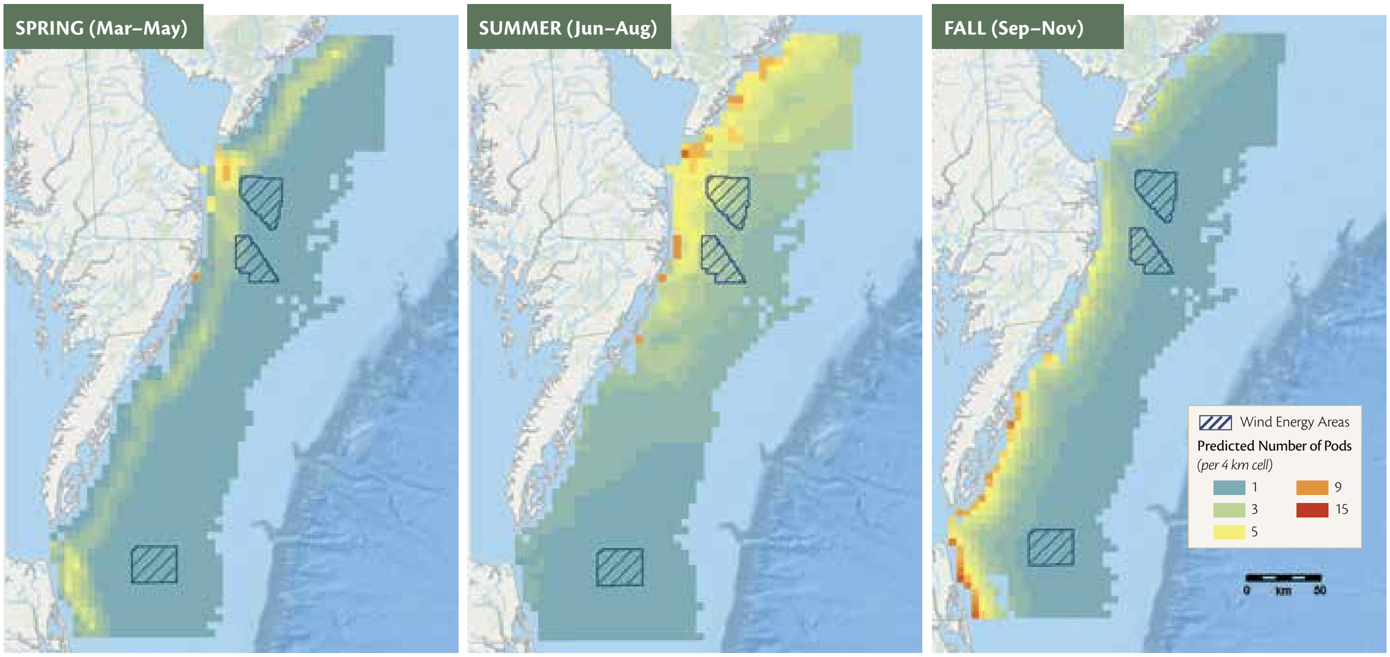
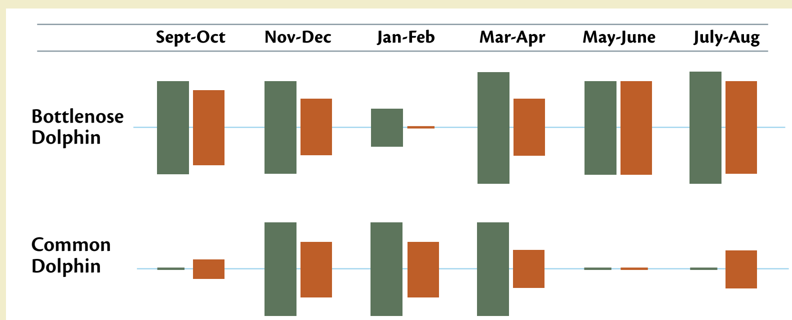


Figure 19: Predicted numbers of Bottlenose Dolphin pods by season, based on two years of boat survey data (2012-2014). Models used observation data from boat-based surveys and remotely sensed environmental covariate data to predict numbers of pods across the study area. Strong nearshore distributions were predicted in spring and fall, likely driven by the species' resident coastal ecotype. Dolphins were predicted to be more evenly distributed longitudinally in summer.

Figure 20: Temporal changes in relative abundance of dolphins from surveys.
This chart illustrates the relative abundance of dolphins observed by boat (■) and video aerial surveys (■) in two-month periods. Bottlenose Dolphins were most common in the spring, summer, and fall, while Common Dolphins were most abundant from late fall to early spring.



STUDY FINDINGS

- We observed 3,289 marine mammals in boat and aerial surveys. The majority (99%) were dolphins and porpoises (from at least five species), but the data included 51 baleen whales, also from at least five species.
- We observed nine North Atlantic Right Whales (Figure 18), which is notable for this species in the mid-Atlantic region. We also observed endangered Humpback Whales and Fin Whales.
- Baleen whales were most frequently observed in winter, although present in small numbers year-round (Figure 6).
- Bottlenose Dolphins, the most abundant delphinid in surveys, were observed primarily in spring, summer, and fall (Figure 20). Models suggest minimal presence of Bottlenose Dolphins within mid-Atlantic WEAs during cooler months.
- Cold-tolerant Common Dolphins were most frequently observed in offshore areas in winter and early spring.
- 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 Bottlenose Dolphins 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 (Figure 19), possibly due to an influx of transient populations during the warmer period.

[CASE STUDY]
Sea Turtles

Sea turtles are long-lived animals with a world-wide oceanic distribution. Five species occur in our study area: the Loggerhead, Leatherback, Kemp's Ridley, Hawksbill, and Green Sea Turtles. All are listed as threatened or endangered under the Endangered Species Act.

Female sea turtles lay clutches of tens to hundreds of eggs that they bury in sandy beach nests. After an incubation period, tiny hatchlings emerge and head to the sea, where they forage in floating sargassum seaweed mats and travel thousands of miles offshore as they grow (Mansfield et al. 2014). They take many years to reach maturity, and can grow to be enormous; adult Leatherbacks grow up to 2 m (6.5 feet) and 900 kg (2,000 lbs).

Adults migrate seasonally, with some migrations up to 10,000 km (James et al. 2005). Their body temperatures vary considerably with their environment, limiting them to waters in specific temperature ranges (Gardner et al. 2008, Epperly et al. 1995). Sea turtle foraging strategies are varied: Leatherbacks dive up to 1,000 m in search of jellyfish (Eckert et al. 1988), while herbivorous Green Sea Turtles graze on seagrasses on shallow sea floors.

CONTEXT

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

TAKE HOME MESSAGES

- There may be species-specific differences in habitat use or movements that were not distinguishable in this study.
- Digital aerial surveys seem to have higher detection rates of sea turtles than other survey approaches, but application of newer technologies with improved species differentiation is needed.
- Construction of offshore wind energy facilities in mid-Atlantic WEAs is likely to occur in warmer months and sea turtles will be present during these periods.

The mid-Atlantic region has large populations of a high diversity of turtles, but there are many existing threats that could cause population declines (Wallace et al. 2011). These 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).

In addition to vessel traffic, potential concerns from offshore wind energy development include the effects of noise and vibrations from seismic profiling, pile driving, and trenching (Read 2013).

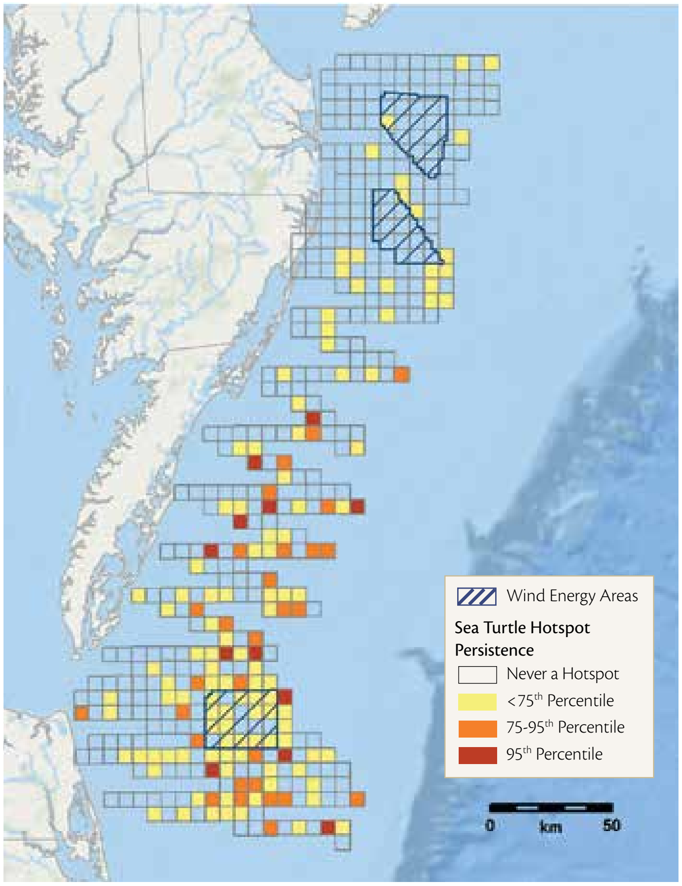


Figure 21: Persistent abundance hotspots for turtles (Testudines spp.) observed in video aerial surveys, March 2012–May 2014. Data are split into only three persistence classes as the 75th and 85th percentile of persistence fell at the same value.

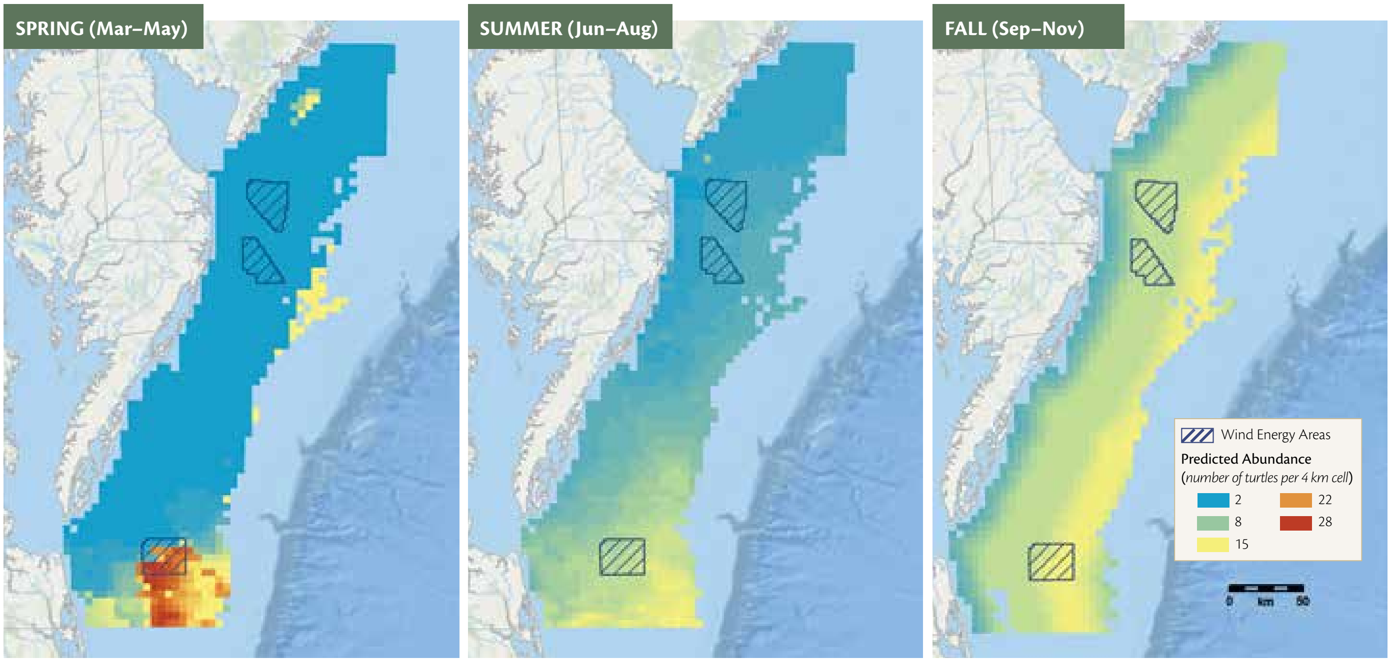


Figure 22: Predicted relative abundance of sea turtles by season, based on two years of digital video aerial survey data (2012–2014). Models used observation data from aerial surveys and remotely sensed environmental covariate data to predict abundance across the study area. Turtles had a dense southerly distribution in the spring, and were dispersed more broadly in the summer. By the fall, they were distributed fairly evenly across the mid-Atlantic in offshore areas.

STUDY FINDINGS

- There were 1,862 sea turtles observed in boat and aerial surveys (1.5% of all wildlife observations).
- Turtles were more frequently observed in digital aerial surveys than in boat surveys, likely in part because they could be detected even when fully submerged. Because of these high detection rates, we used only aerial data to identify persistent hotspots (Figure 21) and develop predictive models of sea turtle distributions (Figure 22).
- We detected all five species of sea turtles that occur in our study area. Loggerhead and Leatherback Sea Turtles were most frequently observed.
- Sea turtles were most abundant from May to October (Figure 23), with very few individuals present in winter.
- Models predicted highest turtle densities in areas far from shore off of Virginia in spring, and in areas with warmer sea surface temperatures (Figure 22). In summer, sea turtles were predicted to be distributed across a broader range, as females moved to shore to lay eggs on sandy beaches. Sea turtles were most widely distributed across the study area in fall, predominantly in offshore areas.
- In addition to water temperature, primary productivity and distance from shore were important influences on sea turtle densities.
- There was substantial overlap between sea turtle distributions and areas of planned offshore wind energy development, particularly in the southern mid-Atlantic (Figure 21).

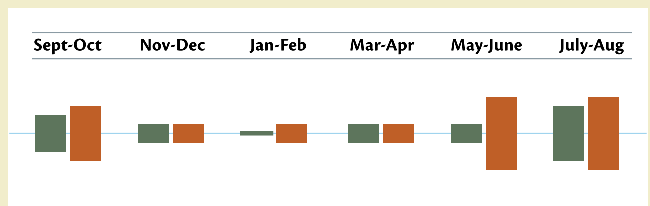
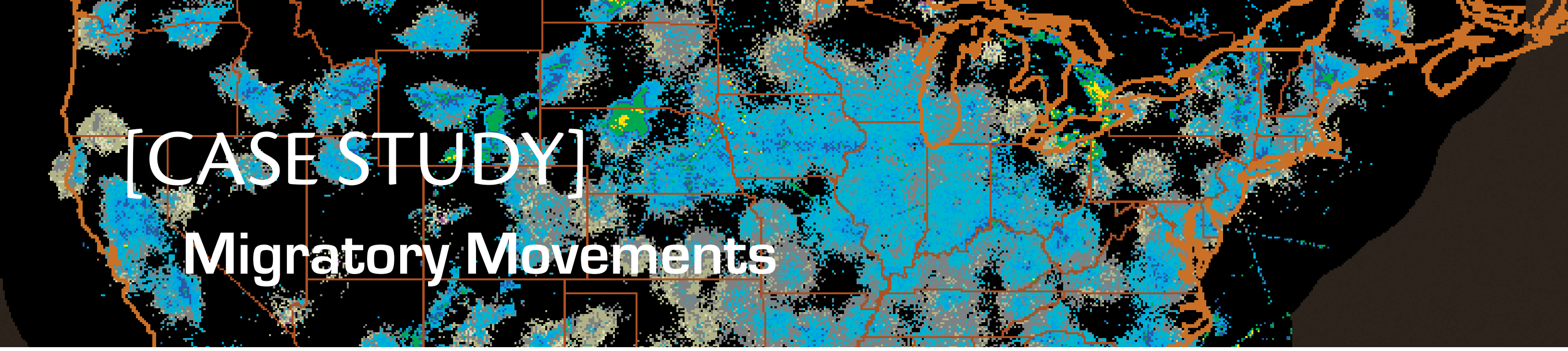


Figure 23: Temporal changes in relative abundance for sea turtles. This chart illustrates the relative abundance of sea turtles observed by boat (■) and video aerial surveys (■) in two-month periods. Sea turtles were most common in the early spring, summer, and fall, and were more commonly observed in aerial surveys.

Surfacing Loggerhead Turtle observed during boat-based surveys.



[CASE STUDY]
Migratory Movements

Seasonal variation in the environment has led to the development of migratory behavior in many taxa, in which they undertake seasonal long-distance movements between ecosystems. The migratory journey can take many weeks and is often an arduous and risky undertaking. Migrants face challenges on their seasonal routes, including inclement weather, lack of food, and hungry predators.

Migration is a difficult phenomenon to study, particularly in offshore areas, but a wide range of taxa move over or through open water habitats during migration. If we are to understand the potential effects of offshore activities on wildlife populations, we must determine when and where this phenomenon occurs.

We employed several methods to document the timing and routes of animal migration through the mid-Atlantic region, including analysis of weather radar (Next Generation Radar, or NEXRAD) data, the use of avian passive acoustic recorders, satellite telemetry, and boat and aerial surveys.

CONTEXT

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

TAKE HOME MESSAGES

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

RAYS

The Cownose Ray is a species of eagle ray that primarily eats mollusks and shellfish. In large groups, these rays migrate north and into inland bays, such as the Chesapeake, to breed during the summer (Goodman et al. 2011). While their breeding habits are reasonably well known, the migratory period is poorly understood. However, digital video aerial surveys recorded immense migratory schools near the water's surface in the mid-Atlantic, up to 75 km from shore. We observed almost 48,000 rays in the summer and fall of 2012-2013. The unexpected detection of these massive migrations is a reminder of how little we truly know about the migratory lives of many ocean creatures.

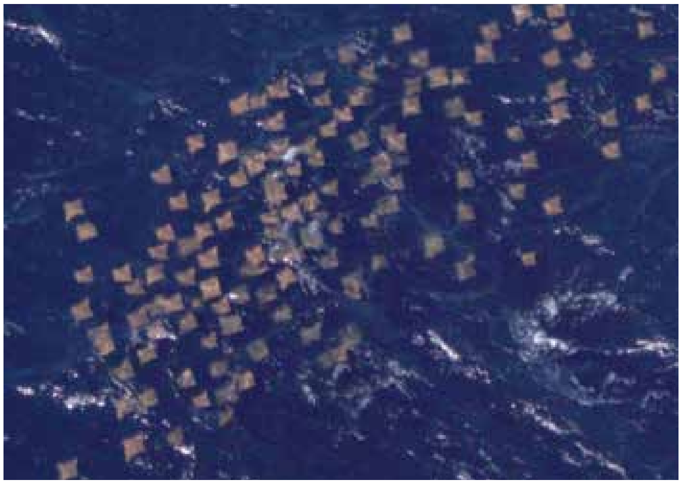


Image of a migratory school, or "fever," of Cownose Rays extracted from the high resolution digital video recorded during aerial surveys.

BATS

Bats are not commonly thought of as offshore migrants, although anecdotal observations of migrating bats over the Atlantic Ocean (particularly during fall migration) have been reported since at least the 1890s (Hatch et al. 2013). In September of 2012 and 2013, a total of two bats were documented during boat-based surveys and 15 in high resolution video aerial surveys, all between approximately 16 and 70 km from shore.

Most of these bats were identified as Eastern Red Bats, a tree-roosting species that migrates long distances and sometimes collides with land-based wind turbines. Most bats seen in digital aerial surveys were estimated to be flying several hundred meters above sea level (Hatch et al. 2013). Despite generally nocturnal habits, all bats were observed during the day. Weather conditions were good at the time of these observations, suggesting that these bats were deliberately migrating offshore and had not been driven offshore by severe weather.

SONGBIRDS

Like bats, the movements of individual songbirds can be difficult to track because of their small body size. Most songbirds also migrate at night, making the study of their migrations particularly difficult. Weather radar can detect migratory activity in the atmosphere (see "Radar Blooms"), which allowed us to document broad-scale geographic and temporal patterns of nocturnal migrants in the offshore environment. Nocturnal acoustic sensors deployed on the survey boat also allowed us to identify some of the species making these flights.

Songbirds regularly flew over open water, particularly in the fall, when offshore migratory activity was often higher than over land (Figure 25). For many birds, expansive areas of open water on the Outer Continental Shelf may not be the barrier to movement that we previously thought.

FALCONS

Peregrine Falcons are the world's fastest animal, and their aerial dexterity allows them to catch birds on the wing. This foraging prowess, among other attributes, allows them to migrate over large expanses of the Atlantic Ocean. They are able to fly for several consecutive days over open water, soar and forage at night, and often roost on offshore structures and vessels (Voous 1961, Cochran 1975, Johnson et al. 2011, Desorbo et al. 2012).

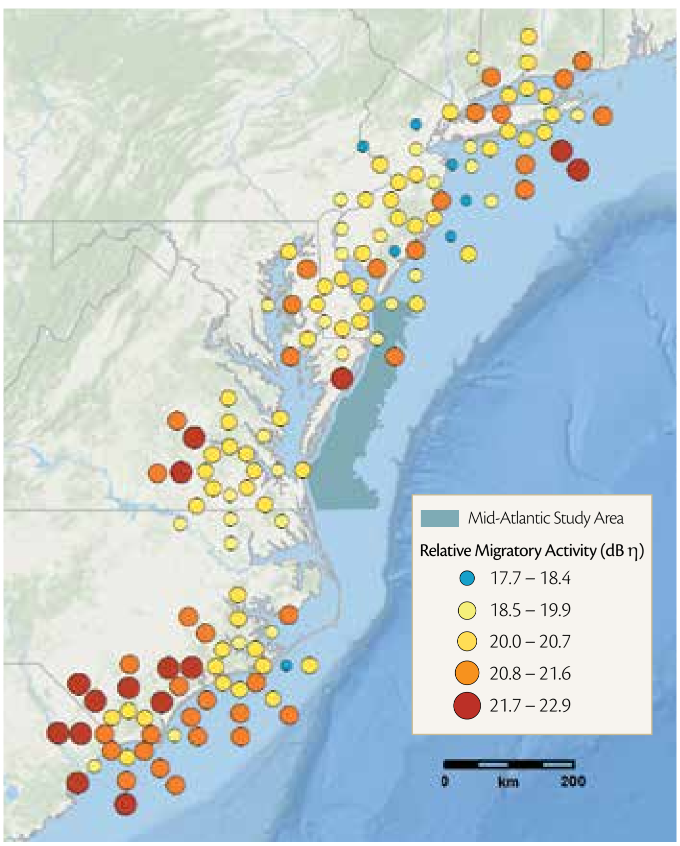
Satellite telemetry data indicated that though peregrines often migrated relatively close to shore, individuals were capable of flying hundreds of kilometers offshore (Figure 26) and staying in those areas for weeks.

During migration, Peregrine Falcons primarily prey on other migrating birds, such as songbirds and shorebirds (White et al. 2002). It is possible that falcon migratory routes in offshore areas are dictated by the migratory paths of their prey.

RADAR BLOOMS

Weather radars send microwaves into the atmosphere to detect precipitation. These microwaves also indicate the locations of flying animals, such as birds, bats, and insects.

During migration, "blooms" of migratory activity can be seen surrounding radar units on unfiltered radar maps (in the radar map depicted in the banner at the top of opposite page, the irregular green and yellow areas represent precipitation, while the more circular blue and gray areas are migratory activity).



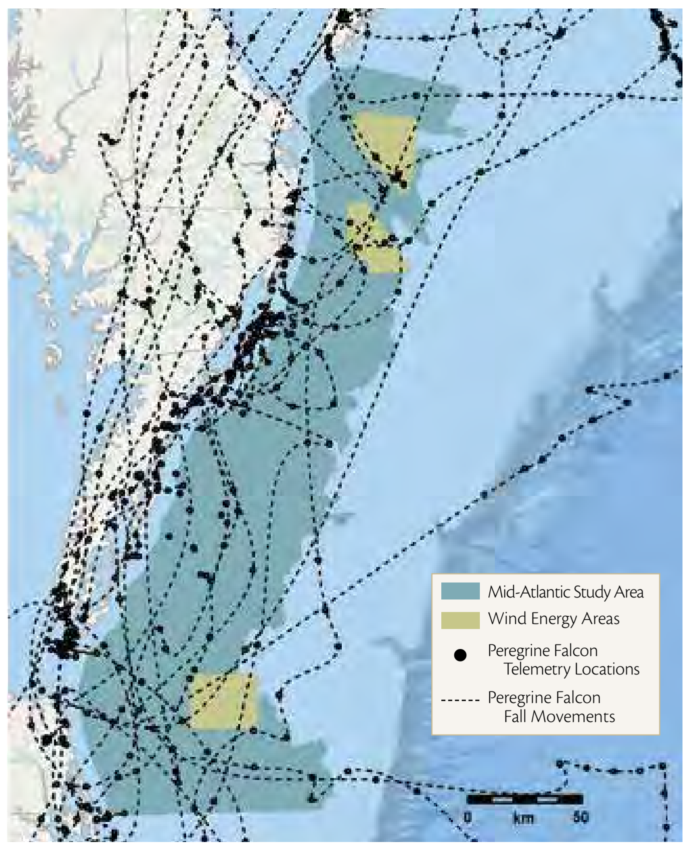


Figure 25 *(left)*: Predicted average levels of nocturnal migratory activity during fall migration at 144 study sites along the eastern seaboard, correcting for nuisance variables like distance from radar unit and elevation. Values are model predictions based on data from six NEXRAD units located between New York and North Carolina (Sept.-Oct., 2010-2012). Red and orange colors show areas of highest migratory activity.

Figure 26 *(right)*: Interpolated movement patterns of Peregrine Falcons with satellite transmitters along the Atlantic U.S. coast during fall migration, 2010–2014 (n=16) indicating extensive use of the offshore environment.

Conclusions

SURVEY AND ANALYSIS METHODS

Study methods and analytical approaches have substantial influences on resulting wildlife distribution and abundance data. Understanding the limitations of these methods is essential in order to interpret results.

In this study, boat and high resolution digital video aerial survey methods each had particular strengths and weaknesses, though technological advances and the development of more sophisticated analytical approaches could help strengthen the digital aerial survey approach.

GEOGRAPHIC AND TEMPORAL PATTERNS

The distributions and relative abundance of wildlife in the mid-Atlantic region were largely driven by environmental variables, including weather, habitat characteristics, prey distributions, and the topography of the coastline. Wildlife responses to these factors varied widely by species and time of year. There were strong seasonal variations in community composition and wildlife distributions. Interannual variation was also substantial, and the results presented in this report should be interpreted with caution when attempting to identify longer-term (e.g., interdecadal) patterns in wildlife distribution, abundance, or movements.

The mid-Atlantic region is important for many species that use the area during breeding and nonbreeding periods. This study also indicated the importance of offshore areas in migratory routes for many taxa, including rays, sea turtles, marine mammals, passerines, shorebirds, and seabirds.

Areas offshore and south of the mouths of Delaware Bay and Chesapeake Bay were consistent hotspots of relative abundance for many species, as well as hotspots of species richness. These areas were likely attractive to a wide variety of species due to gradients in salinity, water temperature, and primary productivity.

More generally, we observed greater abundances of many species in nearshore areas (within approximately 30-40 km of shore). Scoters were one driver of this pattern, as they were highly abundant, and large flocks occurred almost universally in nearshore areas. Red-throated Loons and Bottlenose Dolphins also tended to occur in nearshore areas. This pattern was far from universal, however, with many species widely distributed across the study area, including Common Loons, Northern Gannets, and storm-petrels, while other species occurred primarily in offshore areas, including Common Dolphins, sea turtles, and alcids. Despite the importance of offshore areas for many species, the highest abundance and diversity of species occurred in nearshore areas. This pattern has also been observed elsewhere, and may be driven in part by bathymetry (Paton et al. 2010).

IMPLICATIONS FOR OFFSHORE DEVELOPMENT

Risk to wildlife from offshore development can be thought of as a combination of exposure to construction and operation activities; hazards posed to individuals that are exposed; and the implications of individual-level effects for population vulnerability (Crichton 1999, Fox et al. 2006). The baseline assessment described in this report focused on understanding the potential exposure of wildlife to future offshore development. It will be important to focus future studies on species most likely to be impacted due to their exposure, conservation status, or other factors.

This study is an important first step towards understanding the implications of offshore wind energy development for wildlife populations in the mid-Atlantic United States. Results from this project will be used in combination with data from other recent and ongoing studies along the eastern seaboard (e.g., Bailey and Rice 2015, NEFSC and SEFSC 2011, O'Connell et al. 2009). Collectively, these baseline data can be used to inform the siting of future offshore wind energy projects, address the environmental permitting requirements for current and future projects, and inform the development of mitigation approaches aimed at minimizing potential effects.

Marine wind turbine under construction off the coast of Denmark.

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