Introduction to Part IV
Integrating data across survey platforms

Report structure

The chapters in this report represent a broad range of study efforts and goals. Some chapters are purely methodological in nature, while others present a variety of analyses and results. Generally speaking, however, chapters fall into two categories: efforts focused on population distributions, and those focused on individual movements (Figure I).

Part I of this report (the Executive Summary and Chapters 1-2) summarizes and synthesizes project results. The 25 subsequent chapters and their relationships to each other are shown in Figure I. In Parts II (Chapters 3-6) and III (Chapters 7-12), we describe methods and results for high resolution digital video aerial surveys and boat surveys, respectively. Part IV of this report (Chapters 13-19) combines data from both survey approaches to develop a comprehensive understanding of marine wildlife populations that use the mid-Atlantic study area. Part V (Chapters 20-25) focuses on individual movements and habitat use of focal avian species, tracked via satellite telemetry; and Part VI (Chapters 26-27) focuses on population-level migratory movements over the oceans, using several approaches for studying nocturnal avian migration. An additional study effort, which further explores statistical approaches for combining boat and aerial survey data to develop joint models of wildlife distributions and abundance, will be published as an addendum to this final report.

Part IV: Integrating data across survey methods

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

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

There are seven chapters in Part IV of this report, focused on the comparison and integration of data from boat surveys and digital video aerial surveys to examine wildlife distributions and relative abundance in the mid-Atlantic:

Chapter 13. A standardized comparison study of boat-based and digital video aerial surveys for marine wildlife in the U.S.

Chapter 14. A general comparison of results from boat surveys and digital video aerial surveys in the mid-Atlantic (2012-2014).

Chapter 15. Density modeling with environmental covariates for marine mammals and turtles.

Chapter 16. Modeling species assignment in strip transect surveys with uncertain species identification.

Chapter 17. Integrating data across survey methods: persistent hotspots and temporal changes in observed abundance.

Chapter 18. Comparison of boat and aerial models of abundance with environmental covariates for seabirds.

Chapter 19. Integrating aerial and boat data with environmental covariates to develop joint predictions of abundance for seabirds.

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

Comparisons of the two survey approaches

In order to test the utility of high resolution digital video aerial surveys in the U.S., and to integrate new digital aerial survey data with historical data, we compared the digital aerial data to boat-based surveys using experimentally controlled methods (Chapter 13). This comparison indicated largely complementary strengths of the two survey approaches, though it also highlighted their respective weaknesses (namely, the need for additional analytical development for digital surveys, and the issue of disturbance to wildlife populations caused by the boat during surveys). The two survey methods found similar distribution patterns for scoters (sea ducks; *Melanitta* spp.), but were poorly correlated for highly mobile Northern Gannets (*Morus bassanus*), which at the density of transects in the comparison study were not adequately surveyed by the plane's relatively narrow transect strip width.

In addition to this formal comparison of methods, project collaborators also pursued other methods of comparing and contrasting the two survey datasets (Chapter 14). Species identification rates, as well as detection rates, varied considerably between methods for some taxa. Aquatic species, such as sea turtles, rays, sharks, and fishes, were observed in much higher numbers in the aerial data than the boat data. While some of these animals were also observed in the boat survey, the aerial surveys provided an excellent platform for detecting and identifying animals within the upper reaches of the water column. In particular, higher counts and species diversity of sea turtles and mammals were detected on the aerial surveys than from the boat. A similar efficiency in detecting and identifying sea turtles and marine mammals from high resolution digital aerial platforms (as compared to visual aerial or boat surveys) has also been observed elsewhere (Normandeau Associates Inc. 2013). In contrast, boat survey observers detected larger numbers of more species of birds than the aerial survey, which may be partially due to differences in detectability between the two survey types. Northern Gannets and larger gulls, for example, were visible at great distances from the boat survey, as observers could look from the vessel all the way to the horizon. Reviewers of aerial survey data, in contrast, could only see animals present in the narrow strip of the transect onscreen, and aerial survey speed was roughly 13.5 times that of the boat, potentially limiting onscreen appearances by highly mobile animals (Chapter 13; Figure II).

Rates of identification of animals to species were lower for many taxa in digital video aerial surveys than boat surveys. The exhaustive quality assurance and audit protocol followed by aerial video reviewers, as well as characteristics inherent to the video review process itself (such as the use of multiple levels of "certainty" criteria in identifications), ultimately led to fewer definitive identifications than were afforded by direct observational approaches. This may not be as much of a disadvantage of the digital video aerial survey approach as it seems; in some cases, species misclassification in visual surveys may actually lead to less reliable density estimates than classifying animals as "unknown" (Conn et al. 2013). The detailed and exhaustive quality assurance process applied to digital video aerial survey data (Chapter 4) recognized the inherent uncertainty in the identification process, which is generally under-recognized in visual surveys, as it can be difficult to measure. The limitation of many aerial identifications to the family or genus level is also likely due in part to image quality, however. The current generation of cameras being used in Europe have much higher resolution and color rendition than the cameras used in this study, with better identification rates as a result (A. Webb pers. comm.). In the mid-Atlantic, gulls and terns (Laridae), loons (Gaviidae), and auks (Alcidae) all had much higher identification rates to the species level from the boat surveys than in aerial video (Chapter 14). Aerial video observers were better at identifying the most common avian family, Anatidae (scoters, ducks, and geese), to species than were boat observers, and observers from both survey types had similarly high identification rates of shearwaters (Procellariidae). Identification rates of toothed whales (Odontoceti) were higher on boat surveys, but baleen whales (Mysticeti) had higher rates of identification from aerial surveys.

In addition to these general comparisons of survey results, project collaborators compared the estimated effects of habitat on seabird abundance using the boat and digital video aerial datasets. Chapter 18 presents a preliminary analysis of data from four seabird groups (terns, gannets, loons, and alcids), in which remotely-collected environmental data were incorporated into the models. Boat data were analyzed similarly to other chapters (Chapters 11-12), but focused on single species rather than seabird communities; aerial data were analyzed similarly to the approach used for sea turtles in Chapter 15, but utilizing Generalized Linear Models (GLMs) rather than Generalized Additive Models (GAMs). Slightly different formulations of models were used than in these other chapters to facilitate comparison between the two survey approaches. Results were compared to determine if the two sampling methods detected similar patterns in seabird abundance, with the goal of determining how best to combine boat and digital aerial survey data for a joint analysis. Boat vs. aerial survey data did indicate some differences in species-habitat relationships, which suggested that joint modeling approaches that incorporated both sources of data could prove fruitful for describing species distributions, relative abundance, and habitat use throughout the study area.

Integrated analyses of boat and digital video aerial survey data

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

On a small scale, this has led to the publication of a scientific paper on Eastern Red Bat (*Lasiurus borealis*) migration in the offshore environment of the mid-Atlantic (Hatch et al. 2013; Chapter 17). Collaborators also used the two datasets to identify temporal and spatial patterns of species presence and relative abundance in the study area, including the identification of "persistent hotspots," or geographic areas with consistently high numbers of animals or species through time (Chapter 17). These persistent hotspots of abundance and species richness could indicate important habitat use areas

(Santora and Veit 2013). Temporal patterns of observations of different species and groups within the study area can also be used to determine potential exposure to offshore development activities at different times of year (Chapter 17).

A broad geographic and temporal scale of analysis may be required to fully assess exposure to wildlife from proposed development projects, however, including the examination of locations which were not directly surveyed. The incorporation of environmental covariates into modeling efforts allowed for the prediction of relative densities across the study area for many taxa (Chapters 12, 15-16, and 18-19), with one or both survey datasets used to describe populations of interest. In some cases, one survey method was significantly better than the other for surveying a particular taxon (for example, digital aerial surveys for sea turtles; Chapter 15), while in other cases, the two datasets could be combined using recently developed joint modeling frameworks (Chapter 19). Common Loons (*Gavia immer*) and Red-throated Loons (*G. stellata*), which proved difficult to distinguish in aerial video, provided a test case for using boat-based species identifications to inform aerial models and developing spatially explicit species-specific estimates of relative abundance (Chapter 16). In Chapter 19, project collaborators developed an integrated modeling approach in which predictions of marine bird abundance and distribution were jointly informed by aerial surveys (which encompassed a large geographic area), and boat surveys (which allowed for estimation of detection probability). Building on Chapters 12 and 18, Chapter 19 incorporated remotely collected environmental covariate data into the hierarchical modeling structure and produced a single prediction of abundance and distribution across the study area that utilized data from both survey approaches. Integrated models for the four taxa examined (terns, alcids, loons, and gannets) predicted taxon-specific hotspots that generally concurred with the results from Chapters 12 and 17, and in some cases performed better than models developed using data from a single survey approach. While additional exploration and model development is needed, these results indicate that joint modeling approaches may be a fruitful avenue of continued research.

Implications

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

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

  - Informing the siting of future projects, by incorporating wildlife patterns into marine spatial planning and decision making, and by using exposure data as a first step towards defining relative risk by location;
  - Informing the permitting process for projects, by contributing data towards National Environmental Protection Act (NEPA) and other regulatory requirements, and by helping to define target taxa or research priorities on which to focus on during site-specific pre- and post-construction monitoring studies; and
  - Informing mitigation efforts and construction and operations plans, by presenting temporal data on community composition, distributions, and abundance that can be used to time certain activities to coincide with reduced potential for exposure of certain populations.
- Third, digital aerial surveys have some considerable advantages over traditional visual observation approaches, most notably in relation to survey speed and safety, but they also require some different analytical approaches than traditional surveys, which the scientific community is still in the process of developing. We explore statistical models aimed at improving our utilization of digital video aerial survey data, particularly in combination with boat data, to understand wildlife patterns.

Acknowledgments: This material is based upon work supported by the Department of Energy under Award Number DE-EE0005362. Additional funding support came from the Maryland Energy Administration and Maryland Department of Natural Resources. HiDef Aerial Surveying, Inc. and Capt. Brian Patteson made significant contributions toward the completion of this study.

Literature cited

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

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

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

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

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

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

Normandeau Associates Inc. (2013). High-resolution Aerial Imaging Surveys of Marine Birds, Mammals, and Turtles on the US Atlantic Outer Continental Shelf—Utility Assessment, Methodology Recommendations, and Implementation Tools. *Report prepared under BOEM Contract #M10PC00099*.

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

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

Figure I. Organization of chapters within this final report.

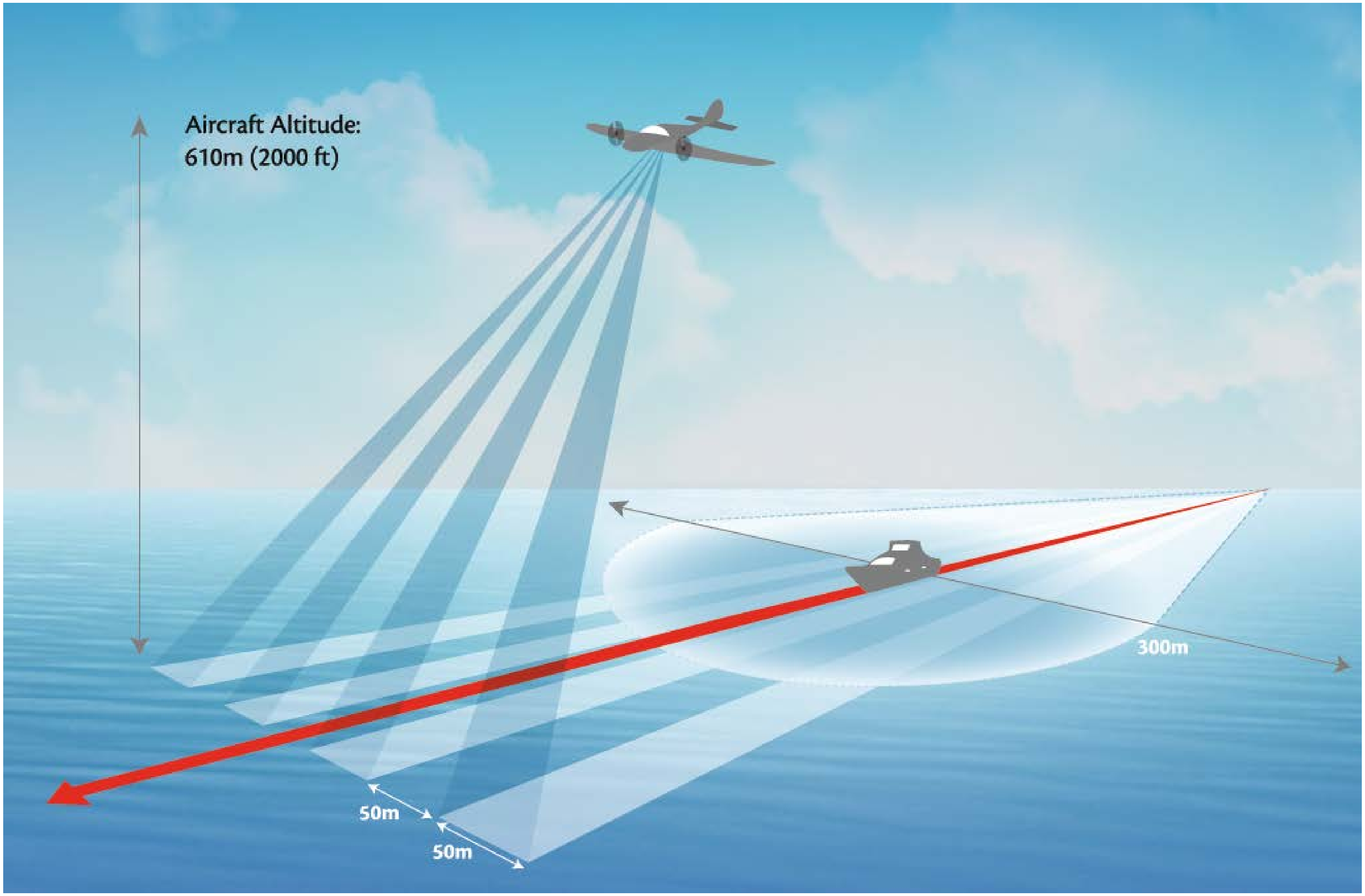

Figure II. Diagram showing the fields of view available during boat surveys and digital video aerial surveys. The combined strip width for the four video cameras is 200 m; the boat transect has an intended minimum strip width of 300 m, although observations of animals were made up to 1,000 m from the vessel. (Note that apart from the experimental comparison described in Chapter 13, the survey boat and planes followed different transect lines; see Chapters 3 and 7).