Introduction to Part IV
Integrating data across survey methods

Report structure

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

Part IV: Integrating data across survey methods

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

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

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

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

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

Comparisons of the two survey approaches

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

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

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

Integrated analyses of boat and digital video aerial survey data

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

On a small scale, this has led to the publication of a scientific paper on Eastern red bat (*Lasiurus borealis*) migration in the offshore environment of the Mid-Atlantic (Hatch et al. 2013; Chapter 11). Collaborators also used the two datasets to identify temporal and spatial patterns of species presence and relative abundance in the study area, including the identification of "persistent hotspots," or geographic areas with consistently high numbers of animals or species through time (Chapter 11). These persistent hotspots of abundance and species richness could indicate important habitat use areas (Santora and

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

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

Implications

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

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

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Literature cited

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

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

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

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

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

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

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

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

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

Williams, K., I. Stenhouse, E. Adams, E. Connelly, A. Gilbert, and M. Duron (2015). Integrating novel and historical survey methods: a comparison of standardized boat-based and digital video aerial surveys for marine wildlife in the United States. *Wildlife Densities and Habitat Use Across Temporal and Spatial Scales on the Mid-Atlantic Outer Continental Shelf: Final Report to the Department of Energy EERE Wind & Water Power Technologies Office*.

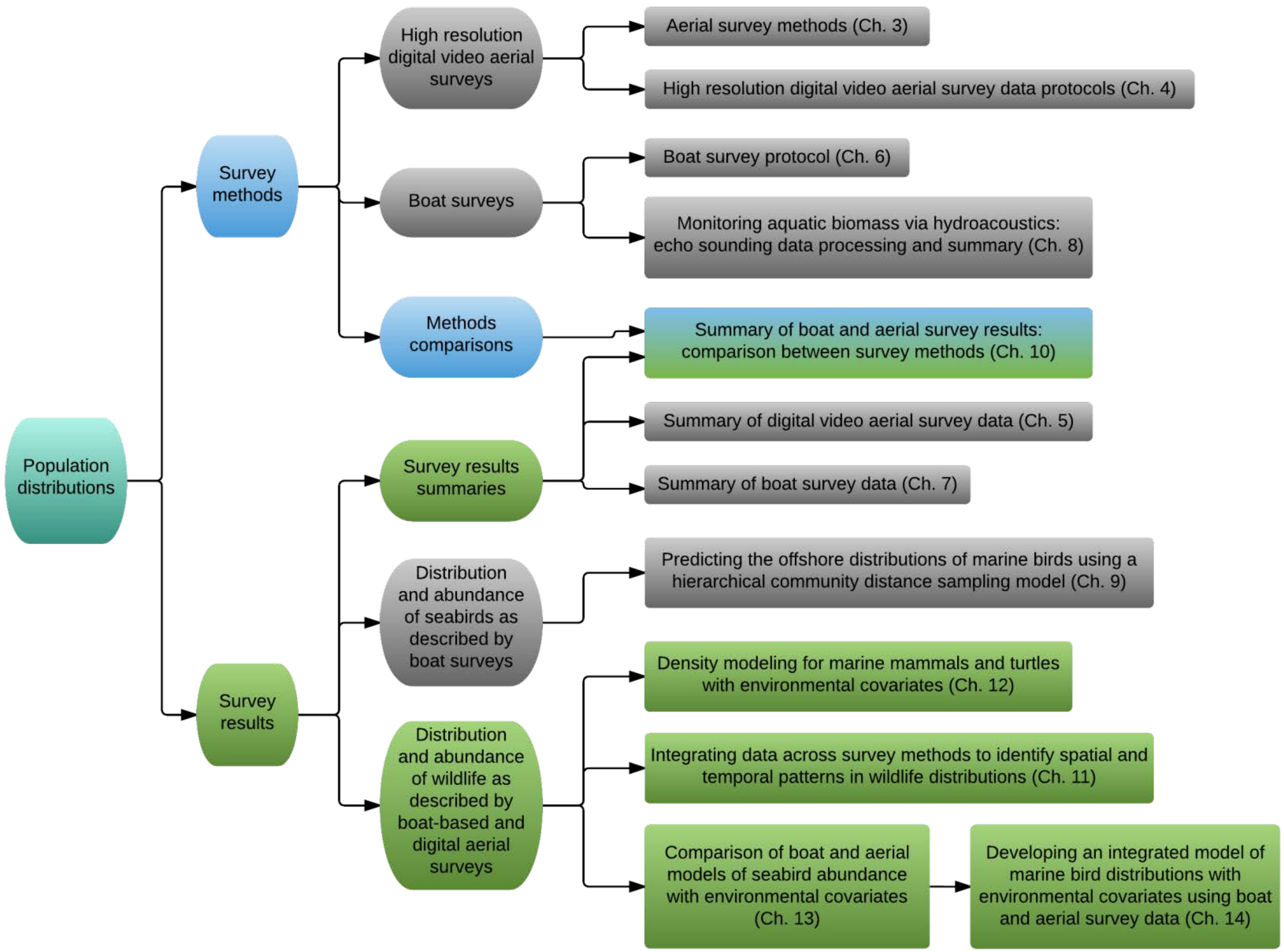

Figure I. Organization of chapters within this final report.

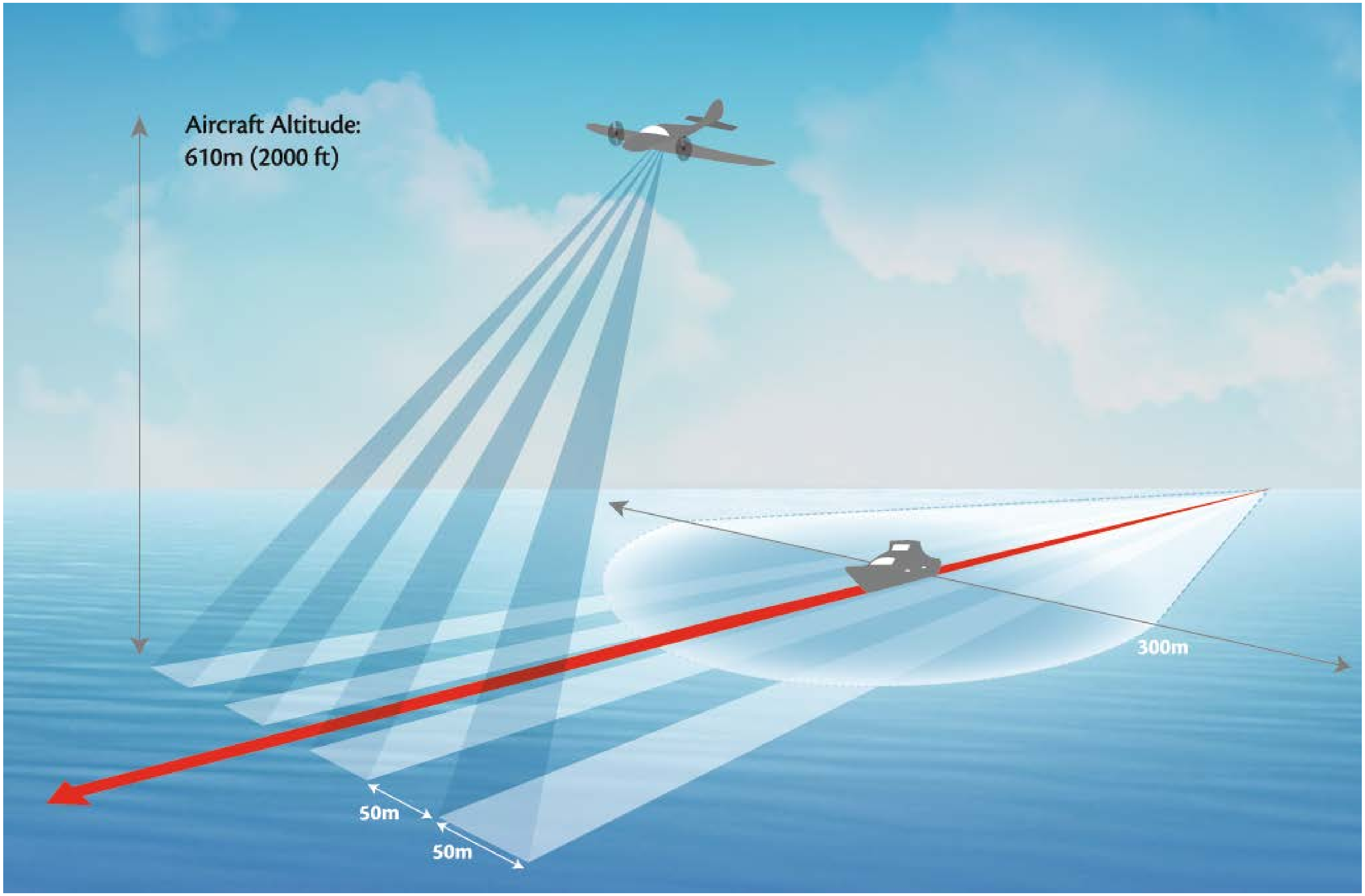

Figure II. Fields of view for boat-based and digital video aerial surveys. Combined strip width for the four video cameras was 200m; the boat had an intended minimum strip width of 300m, though observations of animals were made up to 1,000m away. Apart from an experimental comparison conducted in 2013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