Introduction to Part VI
Nocturnal avian migration monitoring

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 VI: Nocturnal avian migration monitoring

Oceans and other large bodies of water can act as barriers to migrating birds. Some species will not pass over these obstacles; however, many will stop over to rest and refuel before making long overwater flights (Delingat et al. 2008, Faaborg et al. 2010). Large bodies of water like the Mediterranean Sea or the Gulf of Mexico are regularly crossed by even small songbirds (Bruderer and Lietchi 1999, Gauthreaux and Belser 1999). Within the study area for this project, Cape May and Delaware Bay are both known areas where large numbers of migrants stop over during migration (Clark et al. 1993, Moore et al. 1995). While there is some evidence of passerine migration over the northwestern Atlantic for some species (Williams et al. 1977, Faaborg et al. 2010, DeLuca et al. 2015), oceanic flyways and migrant use of offshore regions of the mid-Atlantic are poorly known.

There are two chapters in Part VI of this report, focused on the use of different monitoring technologies to understand the movement patterns and species composition of nocturnal avian migrants off the Eastern Seaboard of the United States:

Chapter 26.	Passive acoustics pilot study: nocturnal avian migration in the mid-Atlantic.
Chapter 27.	Utility of WSR-88 weather radar for monitoring nocturnal avian migration in the offshore environment.

The project team investigated the species composition, spatial patterns, and weather-dependent variation in offshore bird migration through a combination of acoustic and radar data collection. Both the nocturnal passive acoustic avian monitoring from the survey boat (Chapter 26) and the analysis of WSR-88 radar data, also known as NEXt generation RADar (NEXRAD, Chapter 27) were undertaken to determine the utility of these approaches for examining avian migration in the offshore environment. Acoustic monitoring techniques were tested in the marine environment and used to begin developing a list of songbird and shorebird species that migrate over the study area. NEXRAD was used to improve our understanding of patterns in migratory activity in the offshore environment on the Atlantic coast of the U.S.

Passive acoustics

Passive acoustic detectors can be useful for documenting nocturnal migration of low-flying songbirds and shorebirds, which migrate at night and emit short vocalizations during flight (Farnsworth 2005). Many bird species can be identified by their vocalizations, so nocturnal acoustic monitoring stations can provide species-specific presence-absence data and indices of activity for birds that vocalize during migration. To determine whether passive acoustic detectors could be successfully deployed in the offshore environment from a boat platform, and, if so, what species are flying over the Mid-Atlantic continental shelf, we deployed an acoustic detector on the survey vessel (Chapter 26). When the boat stayed overnight on the water (seven total occasions over two years, located 25-46 km from shore), we documented what birds passed overhead. Migratory flight calls were detected from at least fifteen species, including both passerines and shorebirds, mostly during a single September survey when the boat was located 40 km off the coast. Our limited sampling effort makes inference difficult, but this pilot study suggests that a diverse range of landbirds migrate over the Mid-Atlantic continental shelf at low altitudes, at least on occasion. This design appears to be an effective means to monitor the number and type of avian species that migrate offshore, though a more extensive effort is warranted before making broader conclusions.

Weather radar

Developed as a tool to monitor meteorological phenomena, weather surveillance radars regularly detect flying animals in the atmosphere, and are being increasingly incorporated into biological studies of migration patterns and movements (Bridge et al. 2011, Chilson et al. 2012). Open water areas often have poorer radar coverage than terrestrial areas of the United States. In this study, we examine the utility of WSR-88D (NEXRAD) weather radar for studying migration offshore, and specifically off the

Atlantic coast of the U.S. from New York to North Carolina (Chapter 27). We also compare migratory activity at sites over land and up to 80 km out to sea, controlling for variables that could affect measured levels of migratory activity, and we identify the environmental variables correlated with offshore activity, as well as specific geographic locations that may represent offshore migration pathways.

The high level of altitudinal overlap between our measurements and turbines heights suggests that our predictions of migratory activity in the offshore environment are highly relevant to migration occurring at rotor-sweep heights. After controlling for biases in measured levels of migratory activity due to distance from the radar, site elevation, and other factors, we found that in fall, there was no correlation between migratory activity and distance from shore, and no significant difference in predicted activity levels at offshore vs. terrestrial sites across the study area. This suggests that migration over open water areas may be quite common in the mid-Atlantic during this season. There is also a strong weather-related component to offshore fall migration; though responses varied by topographic location along the coast, offshore activity was particularly high under west winds. There were high levels of daily variation in activity at our study sites, but some offshore areas had consistently higher predicted activity levels, most notably the New York Bight (south of Long Island) and offshore of North Carolina. In spring, there still was offshore activity around North Carolina, but levels were fairly minimal in other locations. Westerly winds were less important to offshore activity during this season, with onshore activity aided by both southerly and westerly winds. These data suggest that while birds are less likely to migrate offshore in spring, during the fall, there appear to be multiple “jumping off points” along the coast for tailwind-aided overwater migrations.

Implications

While there may be fewer overwater migrants in the mid-Atlantic as compared to smaller ecological barriers such as the Gulf of Mexico or Mediterranean Sea, there still appears to be both overwater songbird and shorebird migration in the region. This may be particularly true during fall migration; evidence in a variety of species (including bats as well as landbirds; Chapters 25-27; Hatch et al. 2013) suggest that overwater migration in the northwestern Atlantic is much more common in fall than in spring, when animals presumably migrate preferentially over water due to consistent tailwinds from the northwest (e.g., Morris et al. 1994, Hatch et al. 2013, DeLuca et al. 2015). Trans-oceanic migrations, once thought to be extreme events only undertaken by few individuals or species with extreme physiological adaptations (DeLuca et al. 2015), are perhaps more commonplace than previously thought in this region.

Offshore structures, particularly those with full-spectrum nighttime lighting, have been known to cause mass mortality events to migrating passerines in low visibility weather conditions (Hüppop et al. 2006). Given the levels of migratory activity predicted in offshore locations, regulators for offshore wind energy development may want to consider potential impacts to terrestrial species (passerines, shorebirds, bats, etc.) in offshore wind development scenarios. This may be particularly important in locations with consistently higher levels of migratory activity, such as the New York Bight and areas offshore of North Carolina. Predicted levels of activity in many other parts of the study area were also intermittently high, however, suggesting that offshore migration is a widespread phenomenon, and should be regarded as such during planning activities.

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Literature cited

Bridge, E. S., K. Thorup, M. S. Bowlin, P. B. Chilson, R. H. Diehl, R. W. Fléron, P. Hartl, R. Kays, J. F. Kelly, W. D. Robinson, and M. Wikelski. 2011. Technology on the Move: Recent and Forthcoming Innovations for Tracking Migratory Birds. BioScience 61:689–698. doi: 10.1525/bio.2011.61.9.7.

Bruderer, B., and F. Lietchi. 1999. Bird migration across the Mediterranean. Pages 1983–1999 *in* N. J. Adams and R. H. Slotow, editors. Proceedings of the 22nd International Ornithological Congress. Durban, Johannesburg, South Africa.

Chilson, P. B., W. F. Frick, J. F. Kelly, K. W. Howard, R. P. Larkin, R. H. Diehl, J. K. Westbrook, T. A. Kelly, and T. H. Kunz. 2012. Partly cloudy with a chance of migration weather, radars, and aeroecology. Bulletin of the American Meteorological Society 93:669–686. doi: 10.1175/BAMS-D-11-00099.1.

Clark, K. E., L. J. Niles, and J. Burger. 1993. Abundance and distribution of migrant shorebirds in Delaware Bay. The Condor 95:694–705. doi: 10.2307/1369612.

Delingat, J., F. Bairlein, and A. Hedenström. 2008. Obligatory barrier crossing and adaptive fuel management in migratory birds: The case of the Atlantic crossing in Northern Wheatears (Oenanthe oenanthe). Behavioral Ecology and Sociobiology 62:1069–1078. doi: 10.1007/s00265-007-0534-8.

DeLuca, W. V, B. K. Woodworth, C. C. Rimmer, P. P. Marra, P. D. Taylor, K. P. McFarland, S. A. Mackenzie, and D. R. Norris. 2015. Transoceanic migration by a 12 g songbird. Biology Letters 11. Retrieved from http://rsbl.royalsocietypublishing.org/content/11/4/20141045.abstract.

Faaborg, J., R. T. Holmes, A. D. Anders, K. L. Bildstein, K. M. Dugger, S. a. Gauthreaux, P. Heglund, K. a. Hobson, A. E. Jahn, D. H. Johnson, S. C. Latta, D. J. Levey, P. P. Marra, C. L. Merkord, E. Nol, S. I. Rothstein, T. W. Sherry, T. S. Sillett, F. R. Thompson, and N. Warnock. 2010. Recent advances in understanding migration systems of New World land birds. Ecological Monographs 80:3–48. doi: 10.1890/09-0395.1.

Farnsworth, A. 2005. Flight calls and their value for future ornithological studies and conservation research. The Auk 122:733–746.

Gauthreaux, S. A., and C. G. Belser. 1999. Bird migration in the region of the Gulf of Mexico. Pages 1931–1947 *in* N. J. Adams and R. H. Slotow, editors. Proceedings of the 22nd International Ornithological Congress. BirdLife South Africa, Durban, Johannesburg, South Africa.

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.

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

Moore, F. R., S. A. Gauthreaux Jr, P. Kerlinger, and T. R. Simons. 1995. Habitat Requirements during Migration: Important Link in Conservation. Pages 121–144 *in* T. E. Martin and D. M. Finch, editors. Ecology and Management of Neotropical Migratory Birds, a Synthesis and Review of Critical Issues. Oxford University Press, New York, NY.

Morris, S. R., M. E. Richmond, and D. W. Holmes. 1994. Patterns of stopover by warblers during spring and fall migration on Appledore Island, Maine. Wilson Bulletin 106:703–718.

Williams, T. C., J. M. Williams, L. C. Ireland, & J. M. Teal. 1977. Autumnal bird migration over the western North Atlantic Ocean. American Birds 31:251:267.

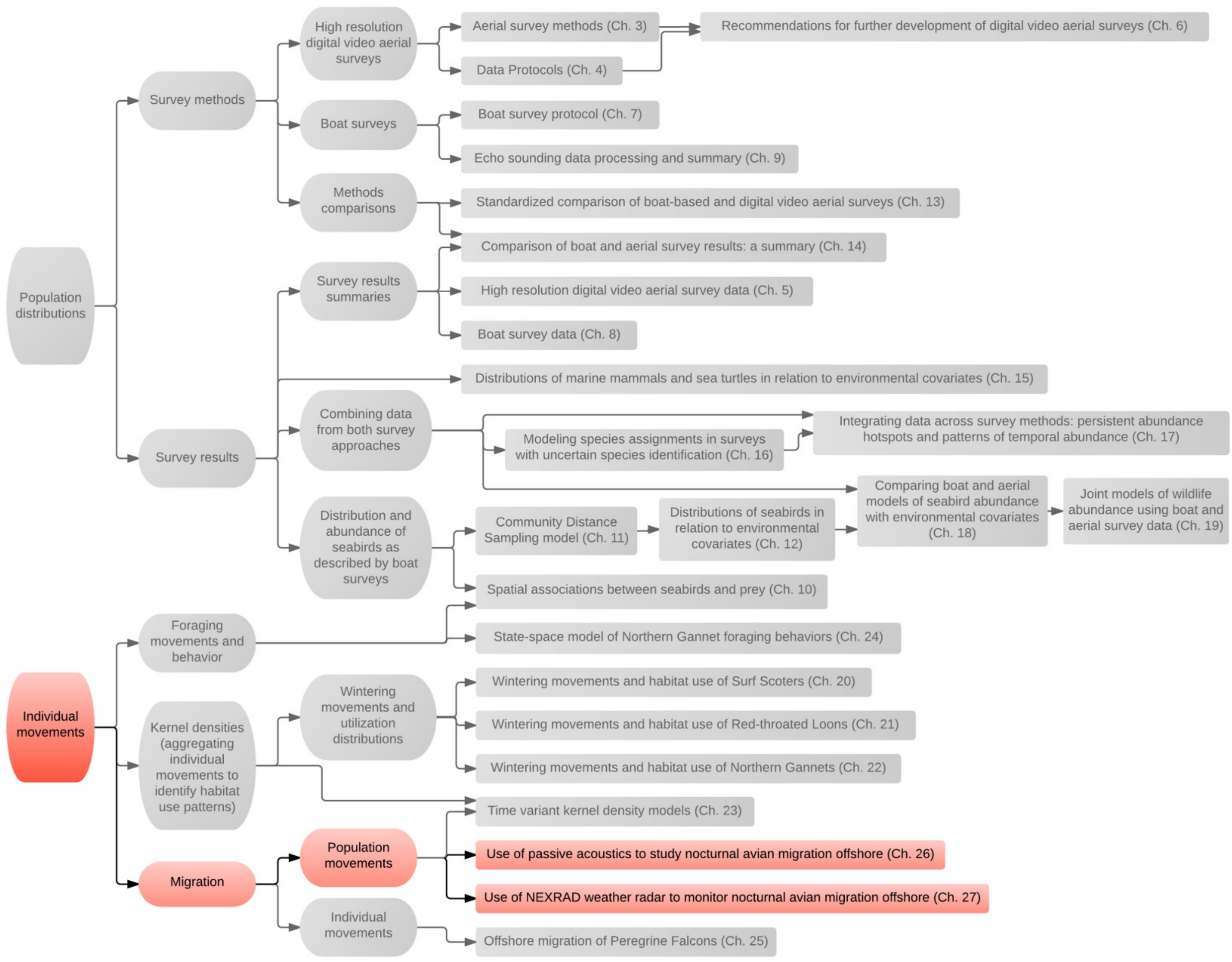

Figure I. Organization of chapters within this final report.