Update on sea duck telemetry analyses
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To date, we have completed two manuscripts for publication as outlined in the original scope of work. The first, a network analysis of annual-cycle sea duck movements and migration, was published in Ecological Applications in August of this year. The second, a comparison of multi-species habitat use and partitioning between seasons, is currently in review at Ecography. This completes our original project objectives.

Earlier this year, we received a one-year project extension to complete three additional objectives: (1) an analysis of transmitter effects on movements of sea ducks using state-space models, (2) analyses of single-species annual-cycle movements, particularly for Black Scoter, and (3) a continent-scale network model of sea duck movements and migration. For objective (1), we have completed data analysis and prepared a draft manuscript for submission to the Wildlife Society Bulletin. For Objective (2), we have begun work outlining a draft of a paper on Black Scoter annual-cycle movements and phenology. For Objective (3), we are in the process of collecting data from West Coast populations of the species included in the AGLSDMS.

In addition to preparing the manuscripts described above, we have presented our work and methods at several conferences, including at the Annual Meeting of the Pacific Seabird Group (February 2019, Kauai, Hawaii), where we presented the network analysis work; the North American Duck Symposium (August 2019, Winnipeg, Manitoba), where we presented both the network analysis and habitat modeling work; and the Annual Meeting of the Waterbird Society (November 2019, Princess Anne, Maryland), where we presented the habitat modeling work. We have also presented our work at local meetings of the Rhode Island Department of Environmental Management, and as part of a webinar by the U.S. Fish and Wildlife Service.

In the coming months, we anticipate completing the second and third objectives of the one-year funding extension and submitting the resulting manuscripts for publication. We look forward to working with the AGLSDMS and new West Coast collaborators to complete these objectives.

Abstracts for completed manuscripts can be found on the following pages. Copies of the three completed articles (published, submitted, or near-submission) are available on request from jslamb@uri.edu.

Abstracts from completed manuscripts

Lamb, J. S., P.W. C. Paton, J. E. Osenkowski, S. S. Badzinski, A. M. Berlin, T. Bowman, C. Dwyer, L. J. Fara, S. G. Gilliland, K. Kenow, C. Lepage, M. L. Mallory, G. H. Olsen, M. C. Perry, S. A. Petrie, J.-P. L. Savard, L. Savoy, M. Schummer, C. S. Spiegel, and S. R. McWilliams. 2019. Spatially explicit network analysis reveals multi-species annual cycle movement patterns of sea ducks. Ecological Applications 00(00):e01919. 10.1002/eap.1919

Conservation of long-distance migratory species poses unique challenges. Migratory connectivity, that is, the extent to which groupings of individuals at breeding sites are maintained in wintering areas, is frequently used to evaluate population structure and assess use of key habitat areas. However, for species with complex or variable annual cycle movements, this traditional bimodal framework of migratory connectivity may be overly simplistic. Like many other waterfowl, sea ducks often travel to specific pre- and post-breeding sites outside their nesting and wintering areas to prepare for migration by feeding extensively and, in some cases, molting their flight feathers. These additional migrations may play a key role in population structure, but are not included in traditional models of migratory connectivity. Network analysis, which applies graph theory to assess linkages between discrete locations or entities, offers a powerful tool for quantitatively assessing the contributions of different sites used throughout the annual cycle to complex spatial networks. We collected satellite telemetry data on annual cycle movements of 672 individual sea ducks of five species from throughout eastern North America and the Great Lakes. From these data, we constructed a multi-species network model of migratory patterns and site use over the course of breeding, molting, wintering, and migratory staging. Our results highlight inter- and intra-specific differences in the patterns and complexity of annual cycle movement patterns, including the central importance of staging and molting sites in James Bay, the St. Lawrence River, and southern New England to multi-species annual cycle habitat linkages, and highlight the value of Long-tailed Ducks (Clangula hyemalis) as an umbrella species to represent the movement patterns of multiple sea duck species. We also discuss potential applications of network migration models to conservation prioritization, identification of population units, and integrating different data streams.

Lamb, J. S., P.W. C. Paton, J. E. Osenkowski, S. S. Badzinski, A. M. Berlin, T. Bowman, C. Dwyer, L. J. Fara, S. G. Gilliland, K. Kenow, C. Lepage, M. L. Mallory, G. H. Olsen, M. C. Perry, S. A. Petrie, J.-P. L. Savard, L. Savoy, M. Schummer, C. S. Spiegel, and S. R. McWilliams. In review. Spatially explicit network analysis reveals multi-species annual cycle movement patterns of sea ducks. Ecography.

Long-distance migration presents complex conservation challenges, and migratory species often experience shortfalls in conservation due to the difficulty of identifying important locations and resources throughout the annual cycle. In order to prioritize habitats for conservation of migratory wildlife, it is necessary to understand how habitat needs change throughout the annual cycle, as well as to identify key habitat sites and features that concentrate large numbers of individuals and species. Among long-distance migrants, sea ducks have particularly complex migratory patterns, which often include distinct post-breeding molt sites as well as breeding, staging, and wintering locations. Using a large set of individual tracking data (N = 476 individuals) from five species of sea ducks in eastern North America, we evaluated multi-species habitat suitability and partitioning across the breeding, post-breeding migration and molt, wintering, and pre-breeding migration seasons. Species selected for common habitat features throughout the annual cycle; however, habitat selectivity and inter-species partitioning varied by season. Sea ducks partitioned shared breeding habitat according to climate conditions, landcover, and distance to water bodies. Wintering sea ducks displayed strong selectivity but weak habitat partitioning, and all species occupied shallow-water aquatic habitats with relatively high productivity, salinity, and temperatures. Selection intensity and partitioning were both strong during post-breeding migration and molt, but weak during pre-breeding migration, suggesting that availability of preferred habitat features is particularly important during the post-breeding period. Our results

highlight the utility of multi-species, annual-cycle habitat assessments in informing conservation strategies for migratory wildlife.

Lamb, J. S., P.W. C. Paton, J. E. Osenkowski, and S. R. McWilliams. In prep. Evaluating short- and long-term effects of coelomic-implanted satellite transmitters in sea ducks. Wildlife Society Bulletin.

Many conservation decisions and predictive models require a detailed understanding of habitat associations at individual and population scales. Telemetry-based studies, which integrate year-round habitat use by known individuals, offer individual- and location-specific information on preferred foraging and wintering habitat, and identify areas of particular conservation importance that might not otherwise be recognized. Telemetry studies also have potential drawbacks, however, in that the energetic cost of carrying a payload can affect multiple aspects of life history in free-living birds. Thus, in order to ensure that data obtained from tracked individuals accurately represent the general population, it is important to measure and account for any sub-lethal impacts of capture and tagging. We evaluated the effects of capture and transmitter attachment on the subsequent movement patterns and breeding propensity for several species of sea ducks, including presence and duration of altered behavior immediately following capture and transmitter attachment, as well as individual attendance at breeding sites over time. Our results suggest that capture and transmitter attachment initially increases dispersive behavior in tagged individuals, but that behavior generally returns to normal within approximately five days of release. This period of altered behavior is considerably shorter than the 14-day post-capture censorship window generally applied to sea duck data. We also observed significantly lower evidence of probable reproductive effort in the first breeding season following transmitter attachment than in the subsequent season, along with a trend toward lower reproductive effort in individuals captured during migration, which had lower reproductive effort in the first breeding season after capture than did individuals captured during winter. This difference was greater in birds captured during spring (i.e., immediately before the breeding season) than those captured in fall (i.e., during the prior calendar year). Finally, younger individuals appear to be more sensitive than adults to effects of tagging, suggesting that limiting captures to adults could help to mitigate long-term impacts of capture and tagging on both behavior and fitness.