Chapter 20: Wintering movements and habitat use of Surf Scoter (*Melanitta perspicillata*) in the mid-Atlantic U.S.

Final Report to the Department of Energy Wind and Water Power Technologies Office, 2015

Dustin Meattey[1], Lucas Savoy[1], Andrew Gilbert[1], Jeffrey Tash[1], Carrie Gray[1], Alicia Berlin[2], Christine Lepage[3], Scott Gilliland[4], Tim Bowman[5,8], Jason Osenkowsi[7], and Caleb Spiegel[6]

[1]Biodiversity Research Institute, Portland, ME
[2]USGS Patuxent Wildlife Research Center, Laurel, MD
[3]Canadian Wildlife Service, Québec, QC, Canada
[4]Canadian Wildlife Service, Sackville, NB, Canada
[5]U.S. Fish and Wildlife Service, Anchorage, AK
[6]U.S. Fish and Wildlife Service, Hadley, MA
[7]Rhode Island Division of Fish and Wildlife, West Kingston, RI
[8]Sea Duck Joint Venture, Anchorage, AK

Project webpage: www.briloon.org/mabs

Suggested citation: Meattey D, Savoy L, Gilbert A, Tash J, Gray C, Berlin A, Lepage C, Gilliland S, Bowman T, Osenkowski J, Spiegel C. 2015. Wintering movements and habitat use of Surf Scoter (*Melanitta perspicillatai*) in the mid-Atlantic U.S. In: 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. Williams KA, Connelly EE, Johnson SM, Stenhouse IJ (eds.) Award Number: DE-EE0005362. Report BRI 2015-11, Biodiversity Research Institute, Portland, Maine. 24 pp.

Acknowledgments: This material is based upon work supported by the Department of Energy under Award Number DE-EE0005362. Funding for this work came from the Department of Energy, the Bureau of Ocean Energy Management (BOEM), and Sea Duck Joint Venture (SDJV). This chapter includes data from field studies supported by the U.S. Department of Energy as well as numerous other collaborating principal investigators and agencies studying the movement patterns of Surf Scoters along the Atlantic coast using satellite telemetry. Surf Scoter movement data were collected between 2000-2014 by lead investigators and study partners from the U.S. Department of Energy (DOE), Biodiversity Research Institute (BRI), USGS Patuxent Wildlife Research Center, Canadian Wildlife Service, U.S. Fish and Wildlife Service, SDJV, BOEM, Maryland Department of Natural Resources, Virginia Department of Game and Fisheries, Rhode Island Division of Fish and Wildlife, University of Rhode Island, Delaware Division of Fish and Wildlife, and North Carolina Wildlife Resource Commission. The authors would like to thank Dr. Glenn Olsen from USGS Patuxent Wildlife Research Center and Scott Ford from Avian Specialty Veterinary Services for performing countless implant surgeries, Doug Howell from North Carolina Wildlife Resources Commission and Brian Rogers for logistical support and area knowledge.

Chapter 20 Highlights

Wintering movements and habitat use of Surf Scoters in the mid-Atlantic U.S.

Context[1]

Wintering habitat use and migratory pathways are key issues facing sea ducks in the mid-Atlantic U.S. and elsewhere due to the potential for offshore wind energy development. A comprehensive understanding of important winter habitats and environmental characteristics determining sea duck abundance and distribution is paramount in advising marine spatial planning efforts in the region and identifying key resource areas for sea ducks to minimize potential threats posed by offshore wind energy development. This chapter explores spatial patterns and movement of Surf Scoters using satellite telemetry data to identify migratory chronology and pathways, as well as determine utilization distributions and core-use areas during the wintering period. Remotely-collected environmental covariate data were also incorporated to develop resource selection models to help identify valuable scoter habitat. Similar studies were conducted on Red-throated Loons and Northern Gannets, and are discussed in Chapters 21 and 22, respectively. Additionally, time variant kernel density models were developed using movements of all three species to examine broad scale movement patterns throughout the year (Chapter 23).

Study goal/objectives

Investigate the spatial patterns, temporal patterns, and environmental variation in Surf Scoter migration and winter habitat use through a combination of satellite telemetry data and remotely collected environmental covariate information.

Highlights

- Surf Scoters in core-use areas utilized shallow (<40 m) areas within 4.5 km from shore.
- Resource selection models suggest that other dynamic variables such as sea surface temperatures, productivity, and salinity (and selected interactions among them) may also be important in determining valuable scoter habitat.
- Migration chronology of birds tracked in this study suggests that Surf Scoters wintering and migrating throughout the mid-Atlantic region could encounter future offshore wind energy facilities between mid-October and early May.

Implications

This analysis indicates Surf Scoters tagged along near-shore areas of the mid-Atlantic have a minimal likelihood of overlapping with current mid-Atlantic Wind Energy Areas (WEAs). Activities associated with construction within WEAs, such as installation of transmission lines or vessel traffic within nearshore areas, would have a higher likelihood of overlapping with wintering Surf Scoters in the mid-Atlantic.

[1] For more detailed context for this chapter, please see the introduction to Part V of this report.

Abstract

Wintering habitat use and migratory pathways are key issues facing sea ducks in the mid-Atlantic U.S. and elsewhere due to the potential for offshore wind energy development. A comprehensive understanding of important winter habitats and environmental characteristics determining sea duck abundance and distribution is paramount in advising marine spatial planning efforts in the region and identifying key resource areas for sea ducks. We captured and tracked 101 Surf Scoters to investigate the spatial patterns, temporal patterns, and environmental variation in migration and winter habitat use through a combination of satellite telemetry data and remotely collected environmental covariate information. We found that Surf Scoters in core-use areas utilized shallow (<40 m) areas within 4.5 km from shore. Resource selection models suggest that other dynamic variables such as sea surface temperatures, productivity, and salinity (and selected interactions among them) may also be important in determining valuable scoter habitat. Migration chronology of birds tracked in this study suggests that Surf Scoters wintering and migrating throughout the mid-Atlantic region could encounter future offshore wind energy facilities between mid-October and early May. Our analyses indicate Surf Scoters tagged along near-shore areas of the mid-Atlantic have a minimal likelihood of overlapping with current Wind Energy Areas (WEAs) in the mid-Atlantic, though activities associated with construction within WEAs, such as installation of transmission lines or vessel traffic within nearshore areas, or possible development of wind farms closer to shore and outside currently designated WEAs, may have a higher likelihood of overlapping with wintering Surf Scoters in the mid-Atlantic.

Introduction

As development of renewable energy sources such as offshore wind power progresses towards large-scale development in the United States, the need for effective pre-construction surveys and site planning is paramount. Several development sites along the mid-Atlantic Outer Continental Shelf of the United States have been proposed for large offshore wind energy facilities. To date, commercial wind energy leases have been issued for offshore areas in Massachusetts, Rhode Island, Delaware, Maryland, and Virginia. These areas coincide with important staging and wintering habitat for several sea duck species (Silverman et al. 2013), for which habitat use, migration pathways, and general biology has only recently been studied (Sea Duck Joint Venture 2014). Population declines in several species of North American sea ducks (Bowman et al. 2015, Sea Duck Joint Venture Management Board 2014) have led to increased research on how environmental and anthropogenic factors in various stages of the annual cycle may affect survival, productivity, habitat use, and site fidelity (Provencher et al. 2014, Perry et al. 2007, Skerratt et al. 2005, Merkel 2004).

No operational offshore wind energy facilities currently exist in U.S. waters, however the Deepwater Wind project located off the coast of Block Island, RI is currently under construction. Although planning for offshore wind energy and assessing its potential effects on wildlife is a recent development in the U.S. (Loring et al. 2014, Goodale and Milman 2014), European nations have been developing offshore wind energy and studying its impacts on wildlife for several decades (Guillemette and Larsen 2002, Desholm and Kalhert 2005, Langston 2013). The main concerns regarding potential interactions between birds and wind farms involve collision risk, disturbance, and indirect effects such as impacts to habitat and prey base (Fox et al. 2006). European studies have demonstrated that collision risk is probably minimal for sea ducks in many locations (Desholm and Kahlert 2005), but avoidance behaviors may have an effect. Common Eiders (*Somateria mollissima*) at a wind farm in Denmark were found to avoid flying close to or amongst turbines, determining that habitat use within and around wind farms may be greatly reduced (Larsen and Guillemette 2007). These avoidance behaviors may be trivial when considering the energetic costs of a long-distance migration, but the cumulative effects of multiple developments along a migration route could be significant (Madsen et al. 2009).

Sea ducks feed primarily on mollusks and benthic invertebrates in shallow, subtidal areas where wind farms are likely to be developed, at least initially. A study at the Horns Rev 1 wind facility in Denmark found a short-term (three year) displacement of Common Scoter (*Melanitta nigra*) followed by a return to the wind farm area (Petersen and Fox 2007). It is unclear whether habituation, changes in prey distribution, or other factors initiated the birds' return. This potential loss of foraging habitat (temporary or otherwise) in areas with large congregations of wintering sea ducks could have detrimental population-level effects. Recent studies have suggested that habitat conditions and prey availability during the wintering period may have strong impacts on reproductive success and productivity during the subsequent breeding season (Camphuysen et al. 2002, Oosterhuis and van Dijk 2002). A recent study tracking Black Scoters (*Melanitta americana)* through the migratory and wintering period in southern New England found considerably larger home range sizes in scoters than other sea duck species (Loring et al. 2014). That study also demonstrated the tendency for scoters to occasionally venture outside near shore core-use areas to locations further offshore, suggesting an increased likelihood of encountering offshore wind energy facilities scattered throughout coastal areas.

In this study, we captured and outfitted Surf Scoters (*Melanitta perspicillata*) with abdominally-implanted satellite transmitters to track daily and seasonal movements during the wintering and migratory periods off the mid-Atlantic coast of the U.S. Data collected from satellite-tagged Surf Scoters from Sea Duck Joint Venture (SDJV) collaborative studies, dating as far back as 2000, are also included in this report. To assess the extent of potential exposure to proposed offshore wind energy development, we determined median arrival dates, departure dates, and length of stay in the mid-Atlantic study area. We also performed habitat utilization analyses and determined prominent biotic and abiotic characteristics of core-use areas. This information is invaluable in delineating offshore areas that have the habitat and environmental characteristics associated with high densities of wintering sea ducks. These data can be used to ensure that currently-proposed and future offshore wind farms are sited in areas where we would predict minimal negative impacts to sea ducks.

Methods

Study area

Surf Scoters were captured and tagged by several principal investigators and agencies between 2000 and 2014 (Sea Duck Joint Venture 2014). Captures and satellite transmitter deployments occurred at various locations in Canada and the US. These locations include Labrador, Québec (Forestville and Chaleur Bay), New Brunswick (Chaleur Bay), Rhode Island, Delaware Bay, Chesapeake Bay, and North Carolina (Pamlico Sound and Swanquarter Bay; Figure 20-1).

Satellite deployment and individual tracking

Scoters were captured during molting, fall and spring staging, and wintering periods (Table 20-1). Scoters were captured using a variety of techniques based on location, seasonal timing, and effective capture approaches in different habitats. These techniques included floating mist-nets (Brodeur et al. 2008), net-gunning from a boat, night-lighting, and gill-netting of molting birds (Sea Duck Venture 2014). Sea Duck Joint Venture (SDJV) partners deployed most of the transmitters prior to the initiation of the DOE- and BOEM-funded studies, and priority was placed on tagging adult female birds to delineate breeding populations. At some sites, however, males and second-year birds did receive transmitters, depending on the study objectives. This dataset encompasses scoters captured and tagged between 2000 and 2014 by several collaborative study partners including U.S. Department of Energy, Biodiversity Research Institute (BRI), USGS Patuxent Wildlife Research Center, Canadian Wildlife Service, U.S. Fish and Wildlife Service, Sea Duck Joint Venture, Bureau of Ocean Energy Management, Ducks Unlimited, Maryland Department of Natural Resources, Virginia Department of Game and Fisheries, Rhode Island Division of Fish and Wildlife, University of Rhode Island, and North Carolina Wildlife Resource Commission.

Platform transmitting terminal satellite transmitters (PTTs) were implanted into the abdominal cavity by a trained veterinarian using sterile surgery procedures and techniques described by Korschgen et al. (1996). PTTs weighed 26 or 38 g with an estimated 450-1400 hours of data transmission at an average internal bird body temperature (105^0 F; Figure 20-2). Transmitters were wrapped in a sterile mesh to provide additional surface area for adhesion to the body wall and anchor points to stabilize the PTT within the abdominal cavity. All efforts were made to closely monitor the recovery of the birds and return them as quickly as possible to the area of capture. During recovery and transport, birds were held separately in small crates. Each crate was equipped with a raised mesh floor platform that allowed the birds to remain clean and dry. Crate doors were also covered with soft padding to avoid bill damage. Each bird was held for a minimum of one hour following surgery and released at the discretion of the veterinarian when it was judged that the bird had fully recovered from anesthesia and was showing no signs of complications. In some cases birds were subcutaneously hydrated with Lactated Ringers Solution during recovery. Birds were released at or near their capture site (Figure 20-3).

Individual location data, body temperature, and PTT operational information were transmitted according to pre-determined duty cycles. Most PTTs deployed on wintering areas were programmed to transmit more frequently during fall and winter months (4 hours ON, 13 hours OFF) to determine spatiotemporal movements and habitat use in areas of proposed large-scale offshore wind power development during periods of peak migration and staging. PTTs deployed in Surf Scoters as part of the BOEM study (2012-2013) used a duty cycle designed to yield two locations per day during the migratory and wintering periods, and a less frequent duty cycle during the rest of the year to preserve battery power. To conserve PTT battery life, transmission periods were greatly reduced during the breeding season (2 hours ON, 120 hours OFF) when birds were primarily sedentary. All PTTs provided through SDJV were programmed with duty cycles that represented a compromise between PTT longevity and frequency of location data. This was intended to allow PTTs to last at least one year, but possibly up to three years, and enable an analysis of annual variation in timing of migration, habitat use, and site fidelity. Exceptions to these duty cycles were made for partners who customized transmitters to meet specific local objectives that required different (usually more frequent) duty cycles (e.g., daily movements during winter to evaluate potential conflicts with proposed offshore wind projects).

Telemetry data from PTTs are available via the Argos system of satellites. Argos records data for known PTTs and stores these data for one year on its servers, but makes available only the last ten days of data to the end-user. BRI's process for handling Argos data management and mapping tasks for the SDJV and BOEM studies included nightly downloads by telnet process of the last five days of data using a customized program written in the Python programming language (Python 2.7[2]). All active programs were cycled through to download data, and any active tags that transmitted during this period provided data for download that were archived for later use. BRI archived ds, diag, and last message data from Argos telnet servers. Argos data from this study were stored or archived at several locations including MoveBank[3] and servers at the USGS Patuxent Wildlife Research Center. Specific subsets of the location data were also uploaded to *wildlifetracking.org* or *seaturtle.org*, free online services that host animal tracking projects and update maps of individual birds' movements with new daily location data (on a fairly coarse scale).

Once data were archived, they were compiled and filtered to remove redundant data and errant points using the Douglas Argos Filter[4] (DAF). The DAF is a threshold filter that has several user-defined parameters to flag improbable locations in satellite tracking data (Douglas et al. 2012). The parameters are adjustable based on species' movement behaviors and the scale of the area under observation. With the DAF, data are retained if they pass (1) a spatial redundancy test and/or (2) a movement rate and turning angle test. Since bird data contain both short-distance, local movements and long-distance migratory events, we employed the hybrid filter of both the distance, angle and rate (DAR) and minimum redundant distance (MRD) filters. This achieved the best of both filters and in practice has produced very clean data with few erroneous points. Using DAF, we also identified the best representative point per duty cycle for each animal to reduce redundant daily positional information.

A database of deployment and life-history data was built for every PTT tag that was deployed or archived by the SDJV project (2000-2014). Data were stored in a shared Google spreadsheet accessible by all project investigators. The database contained information about the PTT tags themselves as well as data on the capture and deployment history of all birds. Furthermore, life-history period start and end dates were noted for every animal, following species-specific life-stage criteria defined by the SDJV (Sea Duck Joint Venture 2014). We identified the following periods: breeding, molting, fall-staging, wintering, and spring-staging, for every year that the animal was alive and transmitted locations.

Final dispositions and the date of disposition were assigned for all non-active tags. Sensor data were assessed for every tag to identify confirmed mortality (by internal temperature sensor or mortality sensor) or battery/tag failure due to low voltage. We listed the day after last transmission as the last date of disposition for all birds with tags that stopped transmitting for either low voltage or unknown

[2] http://www.python.org/
[3] www.movebank.org
[4] http://alaska.usgs.gov/science/biology/spatial/douglas.html

reasons. Tag duration dates were then calculated from the deployment start date and the final disposition date. The DAF filter works off of deployment dates to correctly parse PTT data. Since PTT Argos ID numbers can be deployed multiple times, it was necessary to re-run DAF filters once final dispositions were determined to allow the DAF filter to correctly parse the data. Maps presented in this report include DAF-filtered data through 21 October 2014.

BRI wrote a custom script in Python 2.7 for ArcGIS to automate map production. This script used the DAF-filtered data and the corresponding life-period data from the deployment database to map locations for each individual. Only one year's worth of data per life period per animal was included in analyses in order to avoid biasing the dataset towards individuals with more years of data due to tag longevity or mortality. As the movement patterns of birds may be adversely affected in the first year following capture and implant of satellite tags (S. G. Gilliland, unpublished data), we chose Year 1 data if only one year of data existed, and Year 2 data preferentially over Year 3 data. Only birds that transmitted >60 days after release were included to reduce bias from birds that could have been negatively affected by transmitter implantation and handling.

In order to determine if, and during what time periods, Surf Scoters may be exposed to offshore wind facilities in the mid-Atlantic, we calculated arrival date, departure date, and average length of stay for all birds wintering within the study area. Arrival date was determined by finding the date the bird arrived and subsequently remained in the wintering area, typically between October and November. Scoters included in this analysis consisted of birds marked outside of the wintering areas or birds marked originally on the wintering area and returning in subsequent years after marking. Departure date was determined by finding the date the bird made significant movements away from the wintering area, typically between March and April (Sea Duck Joint Venture 2014). A one-way analysis of variance (ANOVA) was used to test significance between arrival and departure dates between sexes. If significance was determined, non-parametric Wilcoxon multiple comparison or Tukey-Kramer HSD tests were used to compare fall arrival dates, spring departure dates, and total length of stay in the study area by age, sex, year, and capture location. Results of statistical tests were considered significant at $p<0.05$.

Wintering area distribution

We produced two basic map types: (1) movement maps showing mean location points for each animal per period (i.e., breeding, molt, and winter) connected by approximate migratory path lines and (2) kernel density maps that show broad-scale utilization distribution for all birds. Movement maps were created to show male movements from *winter to molting*, which included spring migration and movements during the breeding and post-breeding periods, and *molting to winter*, which included fall migration. Female movement maps consisted of *winter to breeding,* which included spring migration, and *breeding to winter,* which included post-breeding movements, molt, and fall migration. Different maps were produced for each sex to reliably delineate both breeding and molting locations. Period locational means for winter, breeding, and molting locations were used for these maps, calculated from all best locations per duty cycle available for those periods. Movement lines for each individual were created from all intermediate points between "book-end" periods such as winter and breeding to show the linkage between these periods; increasing line density where tracks were overlaid indicate areas used by multiple birds. Lines are straight-line paths between consecutive points and do not necessarily reflect the true path of each bird; the broadness and semitransparency of the lines used in these maps was intended to illustrate generalized migratory paths.

Kernel density maps were created for various life-history periods. Kernel density estimation involves the use of point data from telemetry to estimate relative spatial use during specified time intervals. For each location, the bird's habitat use was estimated to be greatest directly on the point, and to decrease with distance from the point (reaching zero at a distance specified by the user, after Worton 1989). Seventy DAF-filtered locations were randomly selected from each individual's winter period. The number of locations selected per bird (n=70) was based on the lower quartile of the distribution of location data available for all birds, and was chosen to minimize bias related to varying amounts of available location data among individuals. For maps of wintering and staging in this report, separate kernel density estimates were developed for each individual bird, and those results were summed at each location ("location" meaning a degree of latitude/longitude), to form a composite kernel density map for all birds during these periods. This prevented birds that spent greater time in the wintering area from disproportionately influencing estimates of population utilization. Bandwidth (distance) was calculated for all pooled locations using the likelihood cross-validation estimator (Loring et al. 2014).

Habitat selection and use

We examined winter habitat use by satellite-tagged Surf Scoters by comparing relevant environmental covariates at locations within the core use area (0.5 isopleth) to environmental characteristics available throughout the utilization distribution (0.95 isopleth). Following Loring et al. 2014, habitat data were in raster format and resampled to a standardized cell size of 250m^2 (hereafter: resource units). We then randomly sampled habitat variables from 25% of the resource units within both the available and core-use areas. We measured water depth (m) and slope (degrees) within each resource unit using the NOAA National Geophysical Data Center 3 arc-second Coastal Relief Model for the United States (NOAA 2014a). To estimate distance to shore, the Euclidean distance (m) between scoter locations and the nearest segment of the NOAA Medium Resolution Digital Vector Shoreline (1:70,000; NOAA 2014b) was calculated using the Near Tool in Arcmap 10.2.2 (ESRI, Redlands, CA). For dynamic variables with a temporal component, we relied on Marine Geospatial Ecology Tools to create seasonal and long-term winter mean climatology rasters for sea surface temperature, chlorophyll-*a*, and sea surface salinity (Roberts et al. 2010). We used smoothed daily Sea Surface Temperature (SST; degrees Celsius) estimates based on optimal interpolation of data derived from high resolution satellite imagery and floating buoys (Stark et al. 2007); these data are produced by the UK Met Office on a global scale at a spatial resolution of 0.054 degrees latitude and longitude. Sea surface salinity (in psu – practical salinity units) was estimated using the Hybrid Coordinate Ocean Model (HYCOM) produced by the National Ocean Partnership Program at a spatial scale of 1.5 degrees latitude and longitude (Chassignet et al. 2009). To estimate ocean productivity, we obtained monthly estimates of Chlorophyll-*a* concentration (mg/m^3) produced by the NASA Goddard Space Flight Center's Ocean Data Processing System. These data have a spatial resolution of 4 km and are derived from radiometric measurements of chlorophyll fluorescence made by the Aqua sensor aboard the MODIS satellite system (Mueller et al. 2003). We calculated long-term averages for sea surface temperature (10 years), Chlorophyll-*a* (10 years), and sea surface salinity

(6 years) parameters to best account for the approximately 15 year span of sampling efforts in this study.

Pearson product-moment correlations were performed to test for relationships between pairs of habitat parameters (distance to shore, water depth, slope, long-term chlorophyll-*a* concentrations, sea surface salinity, and sea surface temperature). Variance inflation factors (VIF) were calculated to quantify multicollinearity of variables. Throughout the entire study period, pair-wise correlation among habitat covariates did not exceed 0.31 and VIF values were <1.5. Therefore all variables were included in modeling.

Logistic regression was used to model habitat covariate effects, including interactions between covariates, on used versus available locations throughout the study period. We selected the best of 10 a priori candidate models using Akaike's Information Criterion corrected for small sample size (AIC_c). Models were ranked using AIC_c differences (ΔAIC_c) and AIC_c weights (w_i) to evaluate the relative likelihood of each candidate model (Loring et al. 2014, Žydelis et al. 2006, Burnham and Anderson 2002).

Results

Arrival/departure dates and length of stay

A total of 101 Surf Scoters, tagged by collaborating investigators, were tracked to the study area and made available for data analysis in this report (Table 20-2). The median fall arrival date to the mid-Atlantic study area across all capture years was 8 November (range: 14 Oct – 21 Dec, n=83). We found no significant difference in fall arrival dates based on age ($F_{[1,81]}$=0.0032, p=0.955), sex ($F_{[1,82]}$=1.9211, p=0.169), or capture year ($F_{[5,78]}$=0.7531, p=0.586). Birds captured in Chesapeake Bay and tracked through the subsequent fall migration arrived on the wintering grounds significantly later in the fall than those captured in Pamlico Sound, Labrador, and Forestville (p=0.028, p=0.008, p<0.0001, respectively).

The median spring departure date across all capture years was 5 April (range: 1 Jan – 12 May, n=83). We found no significant difference in spring departure dates based on age ($F_{[1,81]}$=2.4036, p=0.125), sex ($F_{[1,82]}$=0.4539, p=0.502), or capture location ($F_{[6,77]}$=1.2640, p=0.284). Scoters wintering in the study area during the winters of 2002 and 2004 departed on spring migration significantly earlier ($F_{[5,78]}$=3.2618, p=0.010) than in all other years.

Mean (±SD, range) length of stay within the study area for all scoters was 133 days (±28, 60-184) and did not significantly differ based on age ($F_{[1,81]}$=2.1382, p=.0147) or sex ($F_{[1,81]}$=0.0000, p=0.996). Birds wintering in 2002 and 2004 stayed for a significantly shorter period of time ($F_{[5,78]}$=3.7533, p=0.004) than those in other years, while birds captured in Forestville stayed in the study area for significantly longer than those captured in Chesapeake Bay (p=0.047).

Wintering area distribution

Kernel density estimations for both sexes showed that core-use areas during the wintering period encompassed the majority of both Chesapeake Bay and Delaware Bay, with additional smaller core-use areas occurring south of Cape Cod near Nantucket Shoals, in Long Island Sound, and in Pamlico Sound, NC (Figure 20-4). This distribution was similar when broken out by sex, with females (Figure 20-5) demonstrating slightly heavier use of the areas south of Cape Cod than males (Figure 20-6). Composite core-use areas throughout the study area encompassed an area of just over 4400 km^2. Core-use areas for males were much more condensed (~2700 km^2) than for females. It should be noted that core-use areas primarily occurred near mid-Atlantic capture locations (Figure 20-1), which could bias analysis.

Spring migration movement data from satellite-tagged Surf Scoters showed that most birds followed a coastal migration route along the eastern seaboard to staging areas near the Gulf of St. Lawrence and its inner estuary. Most birds then migrated over land to breeding and molting areas in northern Québec, east of Hudson Bay. At least one bird appears to have taken a more direct over-land route, briefly stopping over on Lake Ontario and Lake Huron before continuing north. Other breeding locations west of Hudson Bay in northeastern Manitoba and southeastern Nunavut were also documented (Figure 20-7).

Fall migration data showed that birds used migration routes very similar to their spring migration. Birds left breeding and molting areas in northern Canada and flew east to stage briefly in the St. Lawrence Estuary, before following the eastern seaboard south to wintering areas in the mid-Atlantic region (Figure 20-8).

Winter site fidelity

Surf Scoters appear to exhibit strong site fidelity to wintering areas. However, the vast majority of the satellite transmitters deployed in Surf Scoters contained duty cycles focused on detailed winter movements, and therefore compromised overall battery life longevity. Most marked scoters did not provide satellite locations for multiple (>1) complete winters. A total of 22 marked scoters (9M, 13F) provided satellite locations for two complete winter seasons; 91% (20/22) of the birds occupied the same wintering areas in consecutive winters. Two individuals deviated from their wintering areas slightly, utilizing Chesapeake Bay in the first winter and both Chesapeake Bay and Delaware Bay in the second winter.

There was a high tendency (92% or 36/39) for most marked scoters to return to the same wintering area in which they were originally captured and marked. Most scoters were captured on the wintering areas in March, and transmitters provided locations through the following complete winter, and terminated prior to the third winter. We cannot positively determine if these birds occupied the same wintering area throughout the winter prior to capture and marking.

Habitat selection and use

Surf Scoter core-use areas were closer to shore and in shallower water depths than the rest of the winter utilization areas. Core-use areas also had higher chlorophyll-*a* concentrations and slightly lower salinity (Table 20-3). In both the core-use and utilization distributions, percentage use was highest in areas with mid-range sand grain size; however this percentage use was proportionally larger in core-use areas (Table 20-4). The top model for this study accounted for 0.97 of Akaike weight and included the parameters water depth, distance to shore, sediment type, 10-year mean chlorophyll concentration, 10-year mean sea surface temperature, 6-year mean sea surface salinity, and seafloor slope. Our best fit model also included interactions between sea surface temperature and sea surface salinity, chlorophyll concentration and sea surface temperature, as well as chlorophyll concentration and sea surface salinity. No other models were considered competitive as all had ΔAIC_c values >2 (Table 20-5).

We found that the majority of locations within core use areas, for both sexes, occurred in bays (near mid-Atlantic capture locations) rather than open-ocean or tidal rivers. It should be noted, capture location could influence subsequent habitat associations. The majority of marked Surf Scoters were captured in protected bays, which are conducive to scoter capture techniques, rather than turbulent offshore areas. During the study period, scoters utilized areas between 0 and ≥22.2 km from shore. Distances from shore were not influenced by sex. We found a trend of decreasing temperatures when moving from the 0.95 isopleth inward to the core-use areas. We found no significant difference in slope between isopleths or by sex. Both sexes in all locations utilized virtually flat areas with minimal slope.

Discussion

Arrival/departure dates and length of stay

The preliminary results of this study underline the importance of the mid-Atlantic coastal region for migrating and wintering sea ducks. The highest densities of wintering Surf Scoters on the Atlantic coast are located in Chesapeake Bay, Delaware Bay, and along the Maryland-Delaware coast. Smaller concentrations winter in Pamlico Sound and Nantucket Sound, MA (Silverman et al. 2013). Satellite tagged Surf Scoters arrived to the mid-Atlantic region between mid-October and late December (mean: 08 Nov, range: 14 Oct – 21 Dec). Spring departure for satellite tagged Surf Scoters occurred between January through May (mean: 5 April, range: 1 Jan – 12 May). The migration chronology of birds within this study suggests that Surf Scoters wintering and migrating throughout the mid-Atlantic region could encounter future offshore wind energy facilities between mid-October and early May. These dates concur with past research on sea duck migration on the east coast (Loring et al. 2014, Sea Duck Joint Venture 2014, Veit and Petersen 1993). Satellite-tagged scoters in this study spent nearly 40% (mean: 133 days, range: 60-184 days) of their annual cycle on wintering grounds within the study area. This is similar to a recent study in which Black Scoters spent an average of 147 days on wintering grounds in southern New England (Loring et al. 2014). Another study found that King Eiders (*Somateria spectabilis*) in the Bering Sea spent an average of 160 days on their wintering grounds (Oppel et al. 2008).

We found no difference in migration chronology or length of stay on wintering grounds between males and females. Spring departure dates spanned a nearly 5 month period, with no significant differences between sexes. Fall arrival dates were also not significantly different between sexes. This differs from movement data on Black Scoters that documented males arriving on the wintering grounds a week or more earlier than females (Loring et al. 2014, Bordage and Savard 1995).

Wintering area distribution

Composite kernel density estimation core-use areas throughout the study area encompassed an area of just over 4400 km^2. Core-use areas for males were much more condensed (~2700 km^2) than for females. Surf Scoters contained a mean winter utilization distribution of 3,008 km^2 (n=68) and ranged in size of <1.0 to 30,393 km^2. A study on Black Scoters in southern New England found winter utilization distributions ranging from <20 to >10,000 km^2 (Loring et al. 2014) while satellite-tagged King Eiders in the Bering Sea had winter ranges between 13 and >66,000 km^2 (Oppel et al. 2008). Winter ranges for common eiders in Greenland averaged only 67.8 km^2 (Merkel et al. 2006).

We evaluated the potential occurrence of satellite tagged Surf Scoters within the Wind Energy Areas (WEAs) through evaluation of both core use areas (0.5 isopleth) and utilization distributions (0.95 isopleth). Locations of Surf Scoters were not recorded within any WEAs, and 0.2% of all core use and 4.0% utilization distributions were within the mid-Atlantic study area. This analysis indicates Surf Scoters tagged along nearshore areas of the mid-Atlantic have a minimal likelihood of overlapping with current WEAs. Activities associated with construction within WEAs, such as installation of transmission lines or vessel traffic within nearshore areas, or possible construction in nearshore waters outside of currently designated WEAs, would have a higher likelihood of overlapping with wintering Surf Scoters in the mid-Atlantic.

Sea ducks during the wintering period are exposed to several variable factors that can affect movement patterns and distributions. Large winter ranges may allow flexibility in responding to factors such as changing habitat conditions or depleted food sources (Lok et al. 2008, Kirk et al. 2008). The tendency to expand outside the typical utilization distributions, as reported in black scoters (Loring et al. 2014) and king eiders (Oppel et al. 2008), may also increase the probability that wintering scoters will encounter and potentially be affected by wind energy developments scattered throughout the coastal landscape.

While core use areas in this study occurred primarily in bays, this may have been partially influenced by the locations of capture efforts. The majority of marked Surf Scoters were captured in protective bays, which are conducive to scoter capture techniques, rather than turbulent offshore areas.

Habitat selection and use

Surf Scoters in core-use areas utilized shallow (<40 m) areas within 8.5 km from shore. We analyzed distance to shore measurements on an individual level for all scoters within the data set and found a range between 0.16 and 12.8 km. The mean range for individual birds was 8.5 km with a maximum range of 17.5 km. Thirty-six of the scoters sampled had ranges of movement in excess of 10 km, demonstrating the ability and likelihood of scoters to utilize a wide area within the nearshore environment. This concurs with Black Scoter habitat use documented by Loring et al. (2014) where birds generally utilized shallow (<20 m) areas within 5 km from shore. Our resource selection models also suggest that other dynamic variables such as sea surface temperatures, productivity, and salinity (and selected interactions among them) may also be important in determining valuable scoter habitat. Existing literature on scoter species (velvet [*Melanitta fusca*] and common) in Europe document that these species forage mainly on small bivalve mollusks found within the upper layers of sandy substrates less than 20 m deep (Fox 2003). Scoter diet studies along the Atlantic coast have indicated the preferred winter diet is blue mussels and hooked mussels (*Ischadium recurvum*), found among hard substrate (M. Perry unpubl. data). During the wintering period, sea ducks are well known to congregate in areas of high-quality feeding habitat and prey abundance (Lewis et al. 2008, Guillemette et al. 1993). Depending on prey availability, sea ducks are capable of frequent movements between different feeding areas and increased foraging effort (Kirk et al. 2008, Kirk et al. 2007, Larsen and Guillemette 2000). Placement of offshore wind energy facilities in shallow (<40 m) areas in this project's study area could potentially displace wintering sea ducks from high-quality feeding areas. Molluscivorous sea ducks in a similar study were temporarily displaced for at least 3 years after construction of offshore wind energy developments in Europe (Peterson et al. 2007). Flocks of sea ducks began to reappear within the wind farm areas in the fourth year post construction. This potential displacement may necessitate increased flight and foraging efforts, thus increasing energy expenditure during critical periods of the annual cycle.

Next steps

Future analysis of this dataset should include the development of individualized kernel-based home range size estimates, as well as updating current results with data gathered from birds during the 2013-2014 and 2014-2015 winter periods. The inclusion of data from additional consecutive wintering periods will also allow for more thorough and comprehensive analysis of wintering site fidelity. Subsequently, once all movement data from all wintering periods has been obtained, habitat covariate data used in modeling should be updated to include long-term mean values that match the duration of the PTT data. This may improve model fitness or uncover new interactions between covariates not currently recognized in the existing dataset.

Literature cited

Bordage D, Savard J-PL. 1995. Black Scoter (*Melanitta americana*). Account 177 in A. Poole, F. Gill, editors. The Birds of North America. The Academy of Natural Sciences, Philadelphia, Pennsylvania, and The American Ornithologists' Union Washington, D.C., USA.

Bowman TD, Silverman ED, Gilliland SG, Leirness JB. 2015. Status and trends of North American sea ducks: reinforcing the need for better monitoring. pp. 1-27 *in* Savard J-PL, Derksen DV, Esler D, Eadie JM (editors). Ecology and conservation of North American sea ducks. Studies in Avian Biology (in press), CRC Press, New York, NY.

Brodeur S, Mittelhauser GH, Savard J-PL, Thomas PW, Titman RD, Comeau D. 2008. Capture methods for migrating, wintering, and molting sea ducks. Waterbirds 31: 133-137.

Burnham KP, Anderson DR. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer, New York, New York, USA.

Camphuysen CJ, Berrvoets CM, Cremers HJWM, Dekinga A, Dekker R, Ens BJ, van der Have TM, Kats RKH, Kuiken T, Leopold MF, Van der Meer J, Piersma T. 2002. Mass mortality of common eiders (*Somateria mollisima*) in the Dutch Wadden Sea, winter 1999/2000: starvation in a commercially exploited wetland of international importance. Biological Conservation 106: 303-317.

Chassignet EP, Hurlburt HE, Metzger EJ, Smedstad OM, Cummings JA, Halliwell GR, Bleck R, Baraille R, Wallcraft AJ, Lozano C, Tolman HL, Srinivasan A, Hankin S, Cornillon P, Weisberg R, Barth A, He R, Werner F, Wilkin J. 2009. US GODAE: Global Ocean Prediction with the HYbrid Coordinate Ocean Model (HYCOM). Oceanography 22: 64-75.

Desholm M, Kahlert J. 2005. Avian collision risk at an offshore wind farm. Biology Letters 1: 296-298.

Douglas Argos Filter. 2012. Douglas Argos-Filter Algorithm Version 8.20, http://alaska.usgs.gov/science/biology/spatial/douglas.html.

Douglas DC, Weinzieri R, Davidson SC, Kays R, Wikelski M, Bohrer G. 2012. Moderating Argos location errors in animal tracking data. Methods in Ecology and Evolution 3: 999-1007.

Fox AD. 2003. Diet and habitat use of scoters *Melanitta* in the Western Palearctic – a brief overview. Wildfowl 54: 163-182.

Fox AD, Desholm M, Kahlert J, Christensen TK, Peterson IK. 2006. Information needs to support environmental impact assessment of the effects of European marine offshore wind farms on birds. Ibis 148: 129-144.

Goodale MW, Milman A. 2014. Cumulative adverse effects of offshore wind energy development on wildlife. Journal of Environmental Planning and Management. http://dx.doi.org/10.1080/09640568.2014.973483

Guillemette M, Larsen JK. 2002. Post development experiments to detect anthropogenic disturbances: the case of sea ducks and wind parks. Ecological Applications 12: 868-877.

Guillemette M, Himmelman JH, Barette C, Reed A. 1993. Habitat selection by common eiders in winter and its interaction with flock size. Canadian Journal of Zoology 71: 1259-1266.

Kirk M, Esler D, Iverson SA, Boyd WS. 2008. Movements of wintering surf scoters: predator responses to different prey landscapes. Oecologia 155: 859-867.

Kirk MK, Esler D, Boyd WS. 2007. Foraging effort of surf scoters (*Melanitta perspicillata*) wintering in a spatially and temporally variable prey landscape. Canadian Journal of Zoology 85: 1207-1215.

Korschgen C, Kenow K, Gendron-Fitzpatrick A, Green W, Dein F. 1996. Implanting intra-abdominal radiotransmitters with external whip antennas in ducks. Journal of Wildlife Management 60: 132-137.

Langston RHW. 2013. Birds and wind projects across the pond: a UK perspective. Wildlife Society Bulletin 37: 5-18.

Larsen JK, Guillemette M. 2000. Influence of annual variation in food supply on abundance of wintering common eiders *Somateria mollissima*. Marine Ecology Progress Series 201: 301-309.

Larsen JK, Guillemette M. 2007. Effects of wind turbines on flight behavior of wintering common eiders: implications for habitat use and collision risk. Journal of Applied Ecology 44: 516-522.

Lewis TL, Esler D, Boyd WS. 2008. Foraging behavior of surf scoters (*Melanitta perspicillata*) and white-winged scoters (*M. fusca*) in relation to clam density: inferring food availability and habitat quality. The Auk 125: 149-157.

Lok EK, Kirk M, Esler D, Boyd WS. 2008. Movements of pre-migratory surf and white-winged scoters in response to pacific herring spawn. Waterbirds 31: 385-393.

Loring PH, Paton PWC, Osenkowski JE, Gilliland SG, Savard J-PL, McWilliams SR. 2014. Habitat use and selection of black scoters in southern New England and siting of offshore wind energy facilities. The Journal of Wildlife Management 78: 645-656.

Madsen EA, Haydon DT, Fox AD, Furness RW, Bullman R, Desholm M. 2009. Barriers to movement: impacts of wind farms on migrating birds. ICES Journal of Marine Science 66: 746-753.

Merkel FR. 2004. Evidence of population decline in common eiders breeding in western Greenland. Arctic 57: 27-36.

Merkel FR, Mosbech A, Sonne C, Flagstad A, Falk K, Jamieson SE. 2006. Local movements, home ranges, and body condition of common eiders *Somateria mollissima* wintering in southwest Greenland. Ardea 94: 639-650.

Mueller JL, Giulietta GS, McClain CR, Bidigare RR, Trees C, Balch WM, Dore J, Drapeau DT, Karl D, Van Heukelem L, Perl J. 2003. Ocean Optics Protocols for Satellite Ocean Color Sensor Validation, Revision 5, Volume V: Biogeochemical and Bio-Optical Measurements and Data Analysis Protocols. National Aeronautical and Space Administration, Goodard Space Flight Center, Greenbelt, Maryland.

NOAA National Geophysical Data Center, U.S. Coastal Relief Model, Accessed November 2014a, http://www.ngdc.noaa.gov/mgg/coastal/crm.html

NOAA National Geophysical Data Center, Medium Resolution Shoreline, Accessed November 2014b, http://shoreline.noaa.gov/data/datasheets/medres.html

Oosterhuis R, van Dijk K. 2002. Effect of food shortage on the reproductive output of common eiders *Somateria mollissima* breeding at Griend (Wadden Sea). Atlantic Seabirds 4: 29-38.

Oppel S, Powell AN, Dickson DL. 2008. Timing and Distance of King Eider Migration and Winter Movements. The Condor 110: 296-305.

Perry MC, Wells-Berlin AM, Kidwell DM, Osenton PC. 2007. Temporal changes of populations and trophic relationships of wintering diving ducks in Chesapeake Bay. Waterbirds 30: 4-16.

Petersen I, Fox AD. 2007. Changes in bird habitat utilization around the Horns Rev 1 offshore wind farm, with particular emphasis on common scoter. National Environmental Research Institute Report, Aarhus, Denmark.

Provencher JF, Mallory ML, Braune BM, Forbes MR, Gilchrist HG. 2014. Mercury and marine birds in Arctic Canada: effects, current trends, and why we should be paying closer attention. Environmental Reviews 22: 1-12.

Roberts JJ, Best BD, Dunn DC, Treml EA, Halpin PN. 2010. Marine Geospatial Ecology Tools: An integrated framework for ecological geoprocessing with ArcGIS, Python, R, MATLAB, and C++. Environmental Modeling & Software 25: 1197-1207.

Sea Duck Joint Venture. 2014. Atlantic and Great Lakes sea duck migration study: progress report February 2014. Available at: http://seaduckjv.org/atlantic_migration_study.html

Sea Duck Joint Venture Management Board. 2014. Sea Duck Joint Venture Strategic Plan 2014 – 2018. U.S.Fish and Wildlife Service, Anchorage, Alaska, USA; Canadian Wildlife Service, Sackville, New Brunswick, Canada.

Silverman ED, Saalfeld DT, Leirness JB, Koneff MD. 2013. Wintering sea duck distribution along the Atlantic coast of the United States. Journal of Fish and Wildlife Management 4: 178-198.

Skerratt LF, Franson JC, Meteyer CU, Hollmen TE. 2005. Causes of mortality in sea ducks (*Mergini*) necropsied at the USGS-National Wildlife Health Center. Waterbirds 28: 193-207.

Stark JK, Donlon CJ, Martin MJ, McCulloch ME. 2007. OSTIA: An operational, high resolution, real time, global sea surface temperature analysis system., Oceans 07 IEEE Aberdeen, conference proceedings. Marine challenges: coastline to deep sea. Aberdeen, Scotland. IEEE.

Veit RR, Petersen WR. 1993. Birds of Massachusetts. Massachusetts Audubon Society, Lincoln, USA.

Worton BJ. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70: 164-168.

Žydelis R, Esler D, Boyd SW, Lacroix DL, Kirk M. 2006. Habitat use by wintering surf and white-winged scoters: effects of environmental attributes and shellfish aquaculture. Journal of Wildlife Management 70: 1754-1762.

Figures and tables

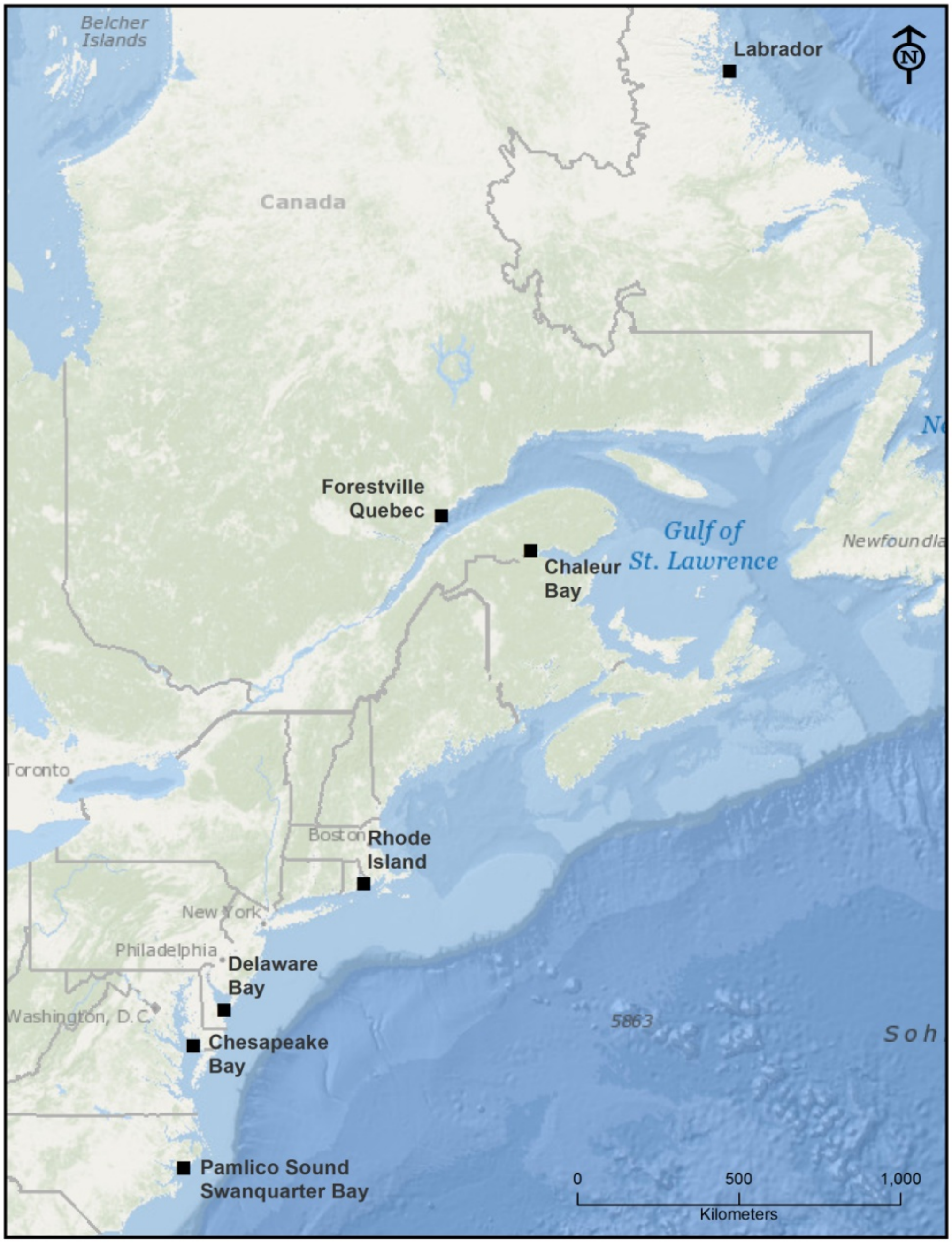

Figure 20-1. Capture locations of Surf Scoters implanted with PTTs between 2000 and 2014.

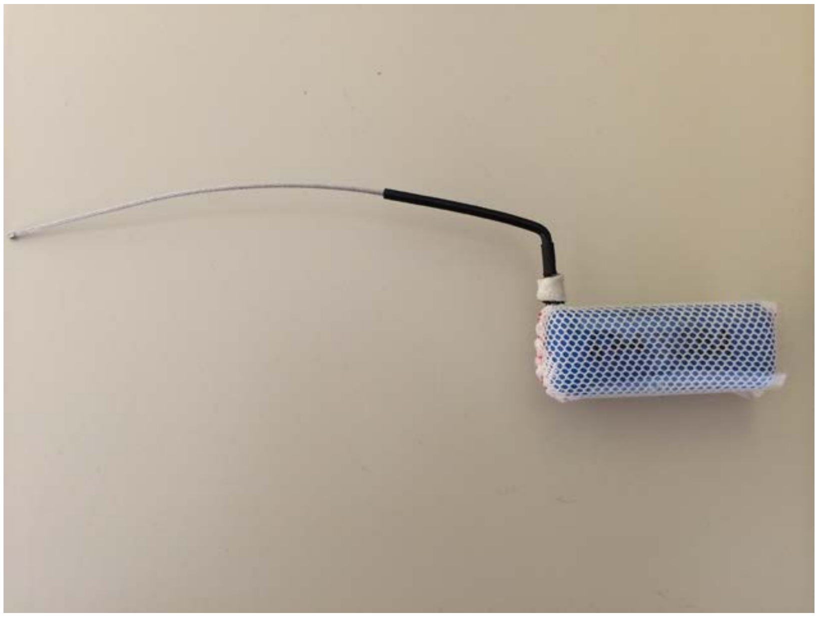

Figure 20-2. Example of implantable PTT transmitter deployed in Surf Scoters. (Photograph: L. Savoy/BRI)

Figure 20-3. Adult male Surf Scoter with implanted PTT prior to release. (Photograph: L. Savoy/BRI)

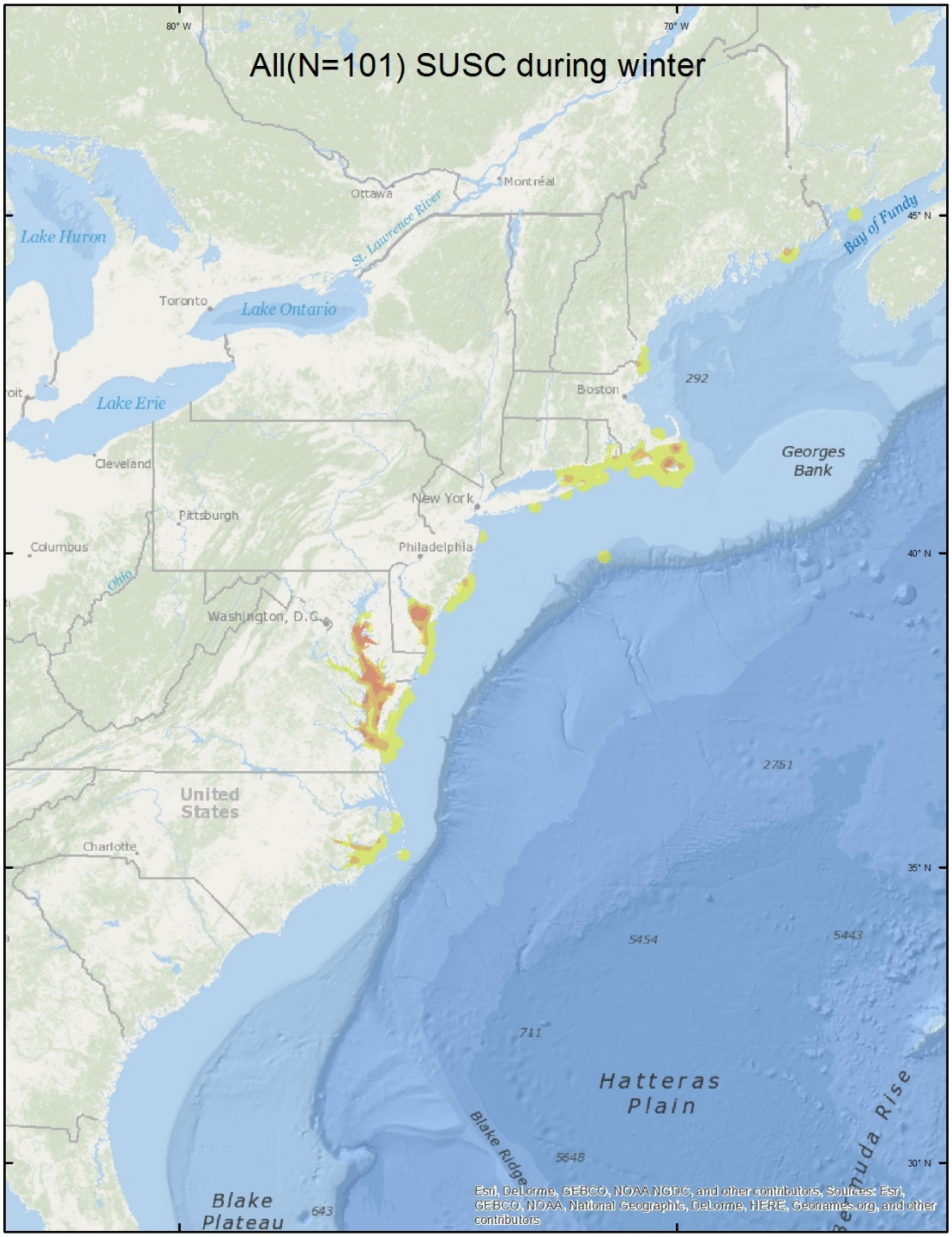

Figure 20-4. Composite kernel density estimations of wintering ground utilization distributions for satellite-tagged Surf Scoters. Intensity of use ranges from lowest (yellow) to greatest (red).

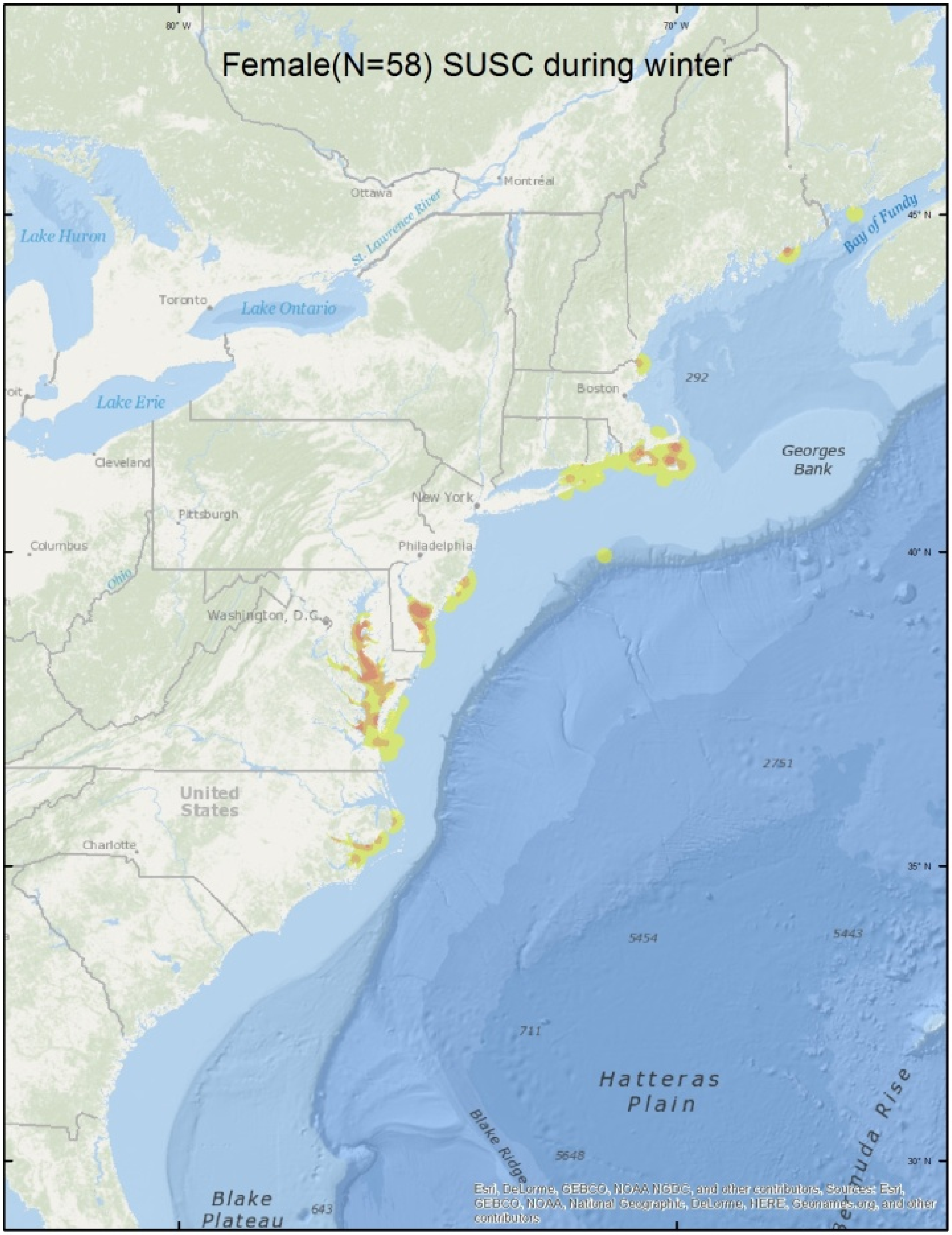

Figure 20-5. Composite kernel density estimations of wintering ground utilization distributions for satellite-tagged female Surf Scoters. Intensity of use ranges from lowest (yellow) to greatest (red).

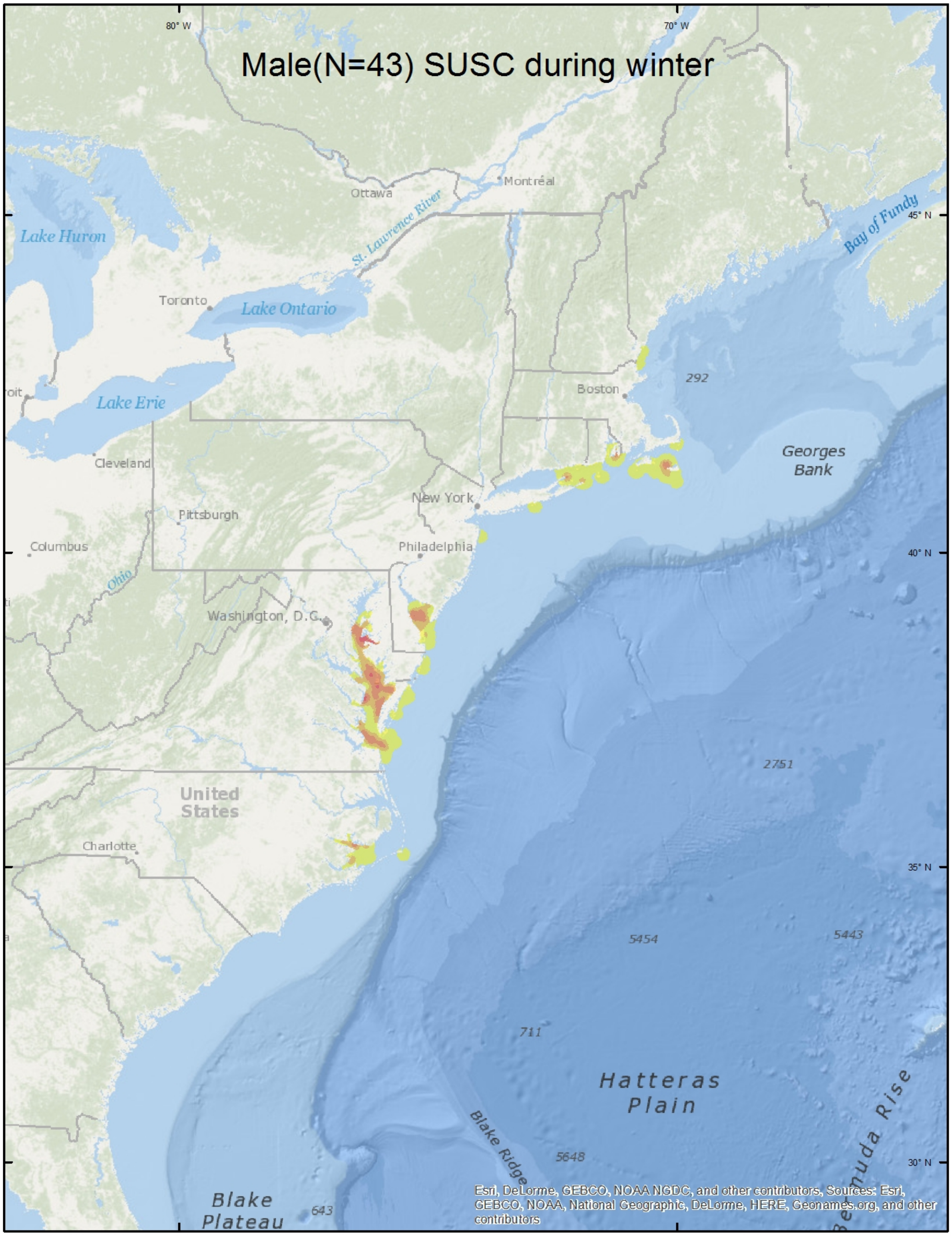

Figure 20-6. Composite kernel density estimations of wintering ground utilization distributions for satellite-tagged male Surf Scoters. Intensity of use ranges from lowest (yellow) to greatest (red).

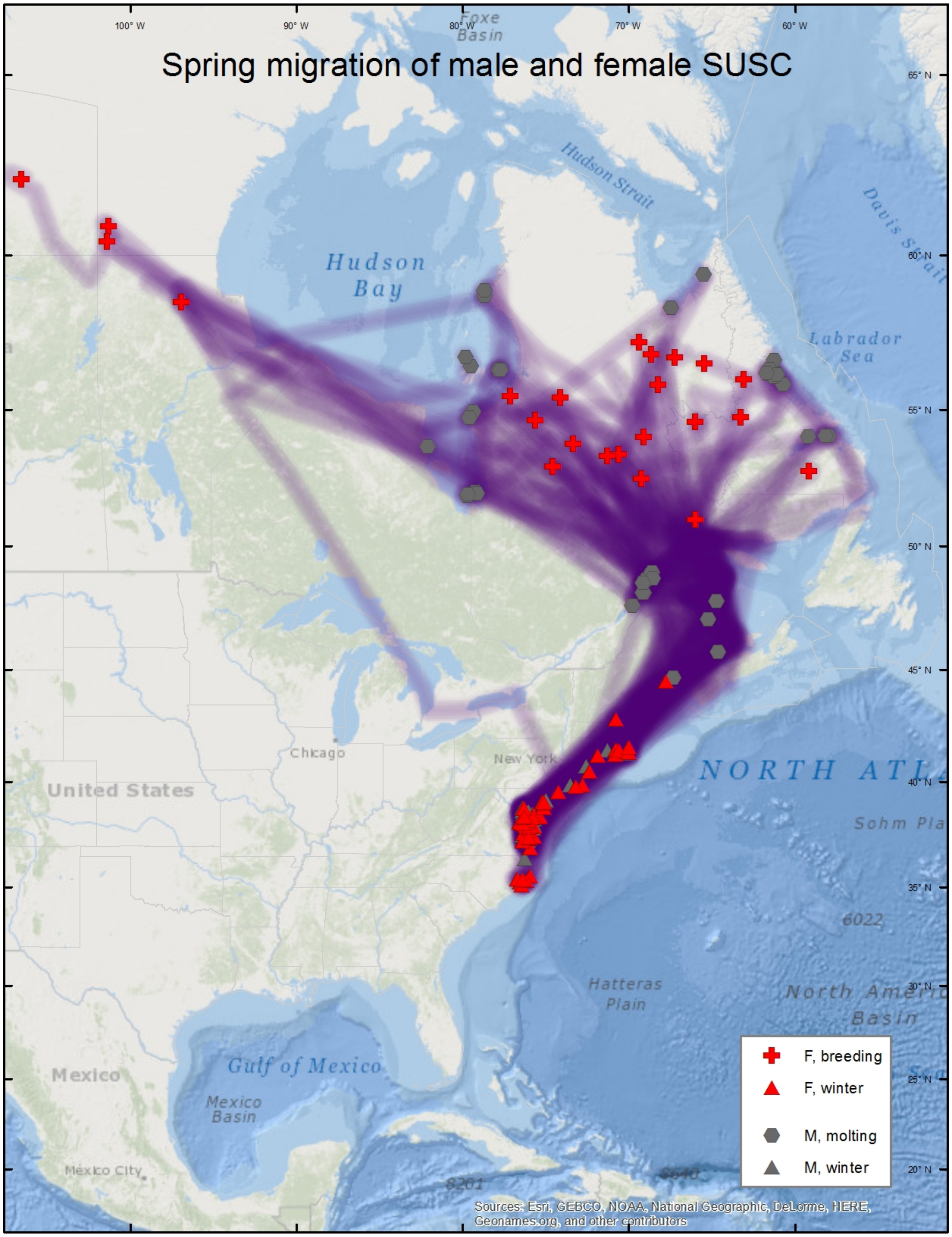

Figure 20-7. Spring migration routes of all satellite-tagged Surf Scoters throughout the study area. Lines do not necessarily represent direct flight paths. Point locations represent mean locations; one per animal per period.

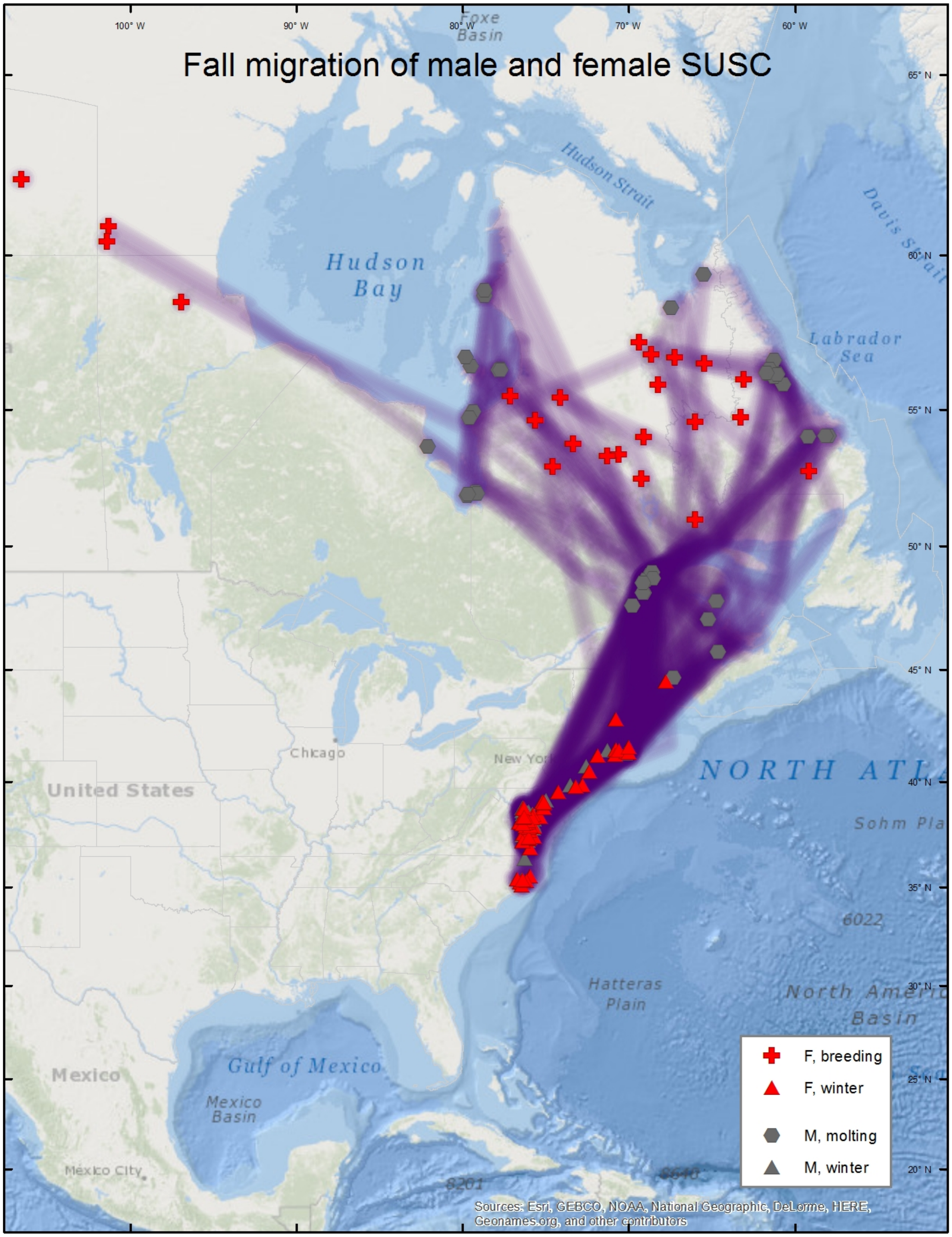

Figure 20-8. Fall migration routes of all satellite-tagged Surf Scoters throughout the study area. Lines do not necessarily represent direct flight paths. Point locations represent mean locations; one per animal per period.

Table 20-1. Life stage criteria used to analyze seasonal migration and distribution data for Surf Scoters (Sea Duck Joint Venture 2014).

Life Stage	Criteria
Breeding	• Stay for ≥ 14 days • Arrive between late May and June • Depart between July and August
Molting	• Stay for ≥ 21 days • Arrive between July and September • Depart between August and October
Wintering	• Arrive between October and November • Depart between late March and early April
Staging	• Along migration, bird stays in same location for ≥ 15 days

Table 20-2. Number of satellite-tagged Surf Scoters tracked within the study area during the wintering periods between 2000 and 2014, listed by capture site, age, and sex. Ages are categorized as second-year (SY), after-second-year (ASY), or unknown (Unk). Sexes are male (M) and female (F).

Capture Site	Winter Period	Capture Timing	SY		ASY		Unk	
			M	F	M	F	M	F
Chesapeake Bay	2000-2001	Winter			1			
	2002-2003	Winter	4		1			
	2004-2005	Winter				3		
	2011-2012	Winter			10	2		
	2012-2013	Winter			8	1		2
	2013-2014	Winter			9	3		
Chaleur Bay, NB	2004-2005	Spring Staging				3		
Labrador	2006-2007	Molting			5			
Rhode Island	2011-2012	Winter			1			
Pamlico Sound, NC	2011-2012	Winter			1	1		
	2012-2013	Winter				1		
Delaware Bay	2012-2013	Winter			2			
	2013-2014	Winter			1			
Forestville, QC	2012-2013	Fall Staging				12		
	2013-2014	Fall Staging				30		
		Total	**4**		**95**		**2**	

Table 20-3. Range, mean ($\bar{x}$) and standard error (SE) of habitat variables at satellite-derived locations for Surf Scoters in the utilization distributions (available; 0.95 isopleth) and core-use areas (0.5 isopleth).

Habitat Variable	Available		Core Use	
	Range	$\bar{x}$ ± SE	Range	$\bar{x}$ ± SE
Long-term				
Chlorophyll-*a* (mg/m^3)- 10 yr Mean	2.0 - 44.8	9 ± 0.02	2.5 - 27.8	13.5 ± 0.02
Sea Surface Temperature (^{0}C) - 10 yr Mean	3.9 - 14.5	6.4 ± 0.01	3.9 - 13.3	5.1 ± 0.004
Sea Surface Salinity (psu) - 6 yr Mean	25.7 - 33.4	32.4 ± 0.005	16.8 - 33.4	29.7 ± 0.03
Physical				
Depth (m)	0.1 - 104.4	10.2 ± 0.03	0.1 - 46.6	7.5 ± 0.02
Slope (degrees)	0.0 - 13.7	0.28 ± 0.001	0.0 - 9.4	0.27 ± 0.002
Distance to Shore (km)	0.1 - 22.2	4.5 ± 13.4	0.1 - 15.5	4.5 ± 14.8

Table 20-4. Proportion of use of different sediment types at satellite-derived locations for Surf Scoters in the utilization distributions (available; 0.95 isopleth) and core-use areas (0.5 isopleth).

Grain Size (mm)	Sediment Type	Available		Core Use	
		n	% Use	n	% Use
0.00 - 0.03	Silt/Mud	80129	13	6112	12
0.03 - 0.17	Sand	20362	25	14122	27
0.17 - 0.35	Sand	20557	26	24604	47
0.35 - 0.36	Sand	7778	10	1952	4
0.36 - 0.48	Sand	5649	7	2992	6
0.48 +	Course Sand - Gravel	15437	19	3109	6

Table 20-5. Logistic model selection results examining the effects of water depth (WD), distance to shore (DS), sediment type (SED), seafloor slope (SL), long-term mean chlorophyll-*a* concentration (2004-2014)(CH10), long-term mean winter sea surface temperature (2004-2014)(SST10), and long-term mean sea surface salinity (2008-2014)(SSS6) on the resource selection of Surf Scoters wintering in the mid-Atlantic U.S. Models are ranked according to Akaike Information Criterion adjusted for small sample size (AIC_c). The table shows the variables included in the model, number of estimated parameters (K), difference between selected model and top-ranked model AIC_c values (ΔAIC_c) and AIC_c weights (W_i).

Model Parameters	K	AIC_c	ΔAIC_c	w_i
WD, SED, DS, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10), (CH10 x SSS6)	14	50404	0	0.97
WD, SED, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10), (CH10 x SSS6)	13	50411	7	0.03
WD, SED, DS, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10)	13	50517	113	0.0
WD, SED, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10)	12	50520	116	0.0
WD^2, SED, DS^2, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10), (CH10 x SSS6)	14	50543	139	0.0
WD^2, SED, DS, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10), (CH10 x SSS6)	14	50703	299	0.0
WD, SED, DS, CH10, SST10, SSS6, SL, (SST10 x SSS6)	12	51328	924	0.0
WD, DS, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10), (CH10 x SSS6)	9	51553	1149	0.0
SED, DS, CH10, SST10, SSS6, SL, (SST10 x SSS6), (CH10 x SST10), (CH10 x SSS6)	13	51570	1166	0.0
Null	1	183036	132632	0.0