Sea Duck Joint Venture
Annual Project Summary – FY 2009

Project Title: Spatial and temporal distributions of wintering sea ducks on the Atlantic coast of the United States and Canada: population trends and relation to habitat (SDJV Project #121).

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Project Description:

Little is known about the population trends and habitat preferences of sea ducks wintering along the Atlantic coast of the U.S. and Canada. The difficulty in gathering information on sea ducks during the winter is due not only to the relative inaccessibility of their wintering sites, but also their high mobility and patchy, aggregated distributions. In this project, we are analyzing the spatial and temporal wintering distributions of five sea duck species (Black Scoters, Surf Scoters, White-winged Scoters, Common Eiders and Long-tail Ducks) using the historical Atlantic Flyway Wintering Sea Duck Survey (1991-2002), which have not been previously examined in detail. We built statistical models to relate observed nearshore distributions of sea ducks to important habitat characteristics to determine wintering preferences and distribution trends along the eastern Canadian and U.S. coast.

Objectives *(should identify how the project addresses SDJV priorities*):
1) Determine spatial and temporal trends in sea duck distributions (specifically Black Scoters, Surf Scoters, White-winged Scoters, Common Eiders and Long-tail Ducks) along the nearshore of the eastern coast of the U.S. and Canada;
2) Relate observed distributions of each sea duck species to habitat characteristics including annual winter temperatures and bathymetry measurements of the nearshore;
3) Characterize the nature of aggregation for each species in terms of landscape characteristics to examine the extent of clustering across large and small spatial scales;
4) Use the above results to help improve the design of ongoing winter sea duck surveys currently conducted by the USFWS.

Preliminary Results:

The Atlantic Flyway Winter Sea Duck Survey was flown between mid-January and mid-February along the east coast of the United States and Canada in 1991, 1992, 1994, 1995, and 1997-2002. A single aerial transect was flown parallel to the coast, a quarter mile offshore in 10 nautical mile segments and all sea ducks within 250 meters on each side of the route were counted and binned into a segment. We used hand drawn maps of the survey course (the only maps available) to digitally recreate the route and identify the start and stop points for each segment in ArcGIS. The digitally created line was buffered by 250 meters on each side using GIS to create the segments. We validated the digital route using GPS track data that were available for flights in 2001 and 2002, the only years in which GPS was onboard, to ensure that our recreated segments included the areas in which sea ducks had been observed. We then gathered relevant, remotely sensed habitat data including yearly values for the North Atlantic Oscillation (NAO), sea surface temperature (SST, which varied by segment and year), mean bottom depth per segment, and maximum slope (change in bottom depth) within a segment.

Because the survey produced highly aggregated counts of sea ducks, we modeled the population using a negative binomial distribution, which allows for high variances and thus explicitly accounts for over-dispersion. We define $y_{i,j,t}$ as the count of species *i* at survey segment *j* in year *t* such that $y_{i,j,t} \sim NegBinom\left(r_i, p_{i,j,t}\right)$ where the estimated mean count for species *i* in segment *j* at time *t* is $\mu_{i,j,t} = \dfrac{r_i\left(1 - p_{i,j,t}\right)}{p_{i,j,t}}$ with a variance of $\sigma^2{}_{i,j,t} = \dfrac{r_i\left(1 - p_{i,j,t}\right)}{\left(p_{i,j,t}\right)^2}$. Since the survey was not designed to accommodate the specific geographic ranges of each species, we included a zero inflation term to estimate the probability that a given segment should be included in the model by assuming that $\mu_{i,j,t} = \lambda_{i,j,t} \cdot z_{i,j}$ where λ is the estimated mean count and $z_{i,j} \sim Bernoulli\left(\psi_{i,j}\right)$ is a parameter that indicates whether or not a segment should be included in the model (variable by species and segment, but constant over time). We hypothesized that *z* would vary by latitude so we set the probability of inclusion to $\psi_{i,j} = \beta 0_i + \beta 1_i \cdot lat_j$ where $\beta 0$ and $\beta 1$ are estimable parameters that allow the inclusion parameter to either increase or decrease (or remain constant) by latitude. We modeled sources of variation in the mean count $\left(\lambda\right)$ using a log-link function:

$$\log\left(\lambda_{i,j,t}\right) = \alpha 0_i + \alpha 1_i \cdot NAO_t + \alpha 2_i \cdot SST_{j,t} + \alpha 3_i \cdot depth_j + \\ \alpha 4_i \cdot slope_j + \alpha 5_i \cdot bays_j + \alpha 6_i \cdot NAO_t \cdot SST_{j,t} + a7_i \cdot \log\left(y_{i,j,t-1} + 1\right) + \log\left(offset_j\right)$$

where $\alpha 0$ is the intercept and $\alpha 1$ through $\alpha 6$ are the effects of each of the covariates (NAO, sea surface temperature, mean bottom depth, maximum slope, location in a bay, and an interaction effect between sea surface temperature and NAO) on the estimated count for species *i*. We incorporated temporal correlation into the model at the segment-level by estimating an effect $\left(\alpha 7\right)$ of the observed count in the previous year. The temporal effect was only estimated when data were available in the previous year (e.g., years 1991, 1994, and 1997 were excluded). The offset term was included to account for differences in the count due to variation in segment length. We analyzed the model and estimated each of the species specific parameters using a Bayesian framework with the programs R and WinBUGS.

The model estimated significant temporal correlation in the expected count and a spatial effect in the inclusion parameter for all five species of sea ducks (see Figures 1-5 for trend maps). There was a positive relationship at the segment-level between expected count in year *t* and observed count in the previous year $(\alpha 7)$ for all species, with White-winged Scoters, followed by Black Scoters, having the highest estimated site fidelity. Not unexpectedly, there was also a consistent and positive relationship for the latitude inclusion parameter, $(\beta 1)$ indicating that the probability of observing all species increased from the south to north, with Common Eiders followed by Long-tailed Ducks having the strongest effects.

NAO $(\alpha 1)$ had a significant negative effect on all three scoter species and a significant positive effect on the Common Eiders and Long-tailed Ducks. This implies that the scoter species are observed in higher abundances in the nearshore during cold, snowy winters while Common Eiders and Long-tailed Ducks are more frequently observed in the nearshore during wet, mild winters. Sea surface temperature $(\alpha 2)$ had a significant negative effect on Long-tailed Ducks and White-winged scoters counts. Both species, as well as Long-tailed Ducks, had positive NAO/SST interaction effect$(\alpha 6)$.

All species, except for the White-Winged scoters (which had a similar, although not significant response), had increased expected counts with decreasing bottom depth $(\alpha 3)$. Maximum slope $(\alpha 4)$ had a negative effect on the three scoter species (but was only significant for Surf Scoters) while the other two species had positive effects (but again, significant only for Common Eiders), suggesting that the scoters may prefer areas with flat topography compared to the other species. Black Scoters had a significant negative bay effect $(\alpha 5)$ while White-winged Scoters had a significantly positive effect, suggesting that Black Scoters prefer coastal areas outside bays and White-winged Scoters prefer bay habitats.

Project Status:

We spent most of the last year collecting relevant covariate data and developing, testing, and fitting our models. We are currently working on processing and interpreting our model results and developing a manuscript for publication submission later this year. The final step will be to provide input to USFWS on potential improvements to ongoing winter sea duck surveys.

Figure 1. Map indicating the temporal and spatial trends (percent change) of Black Scoters from 1991 to 2002.

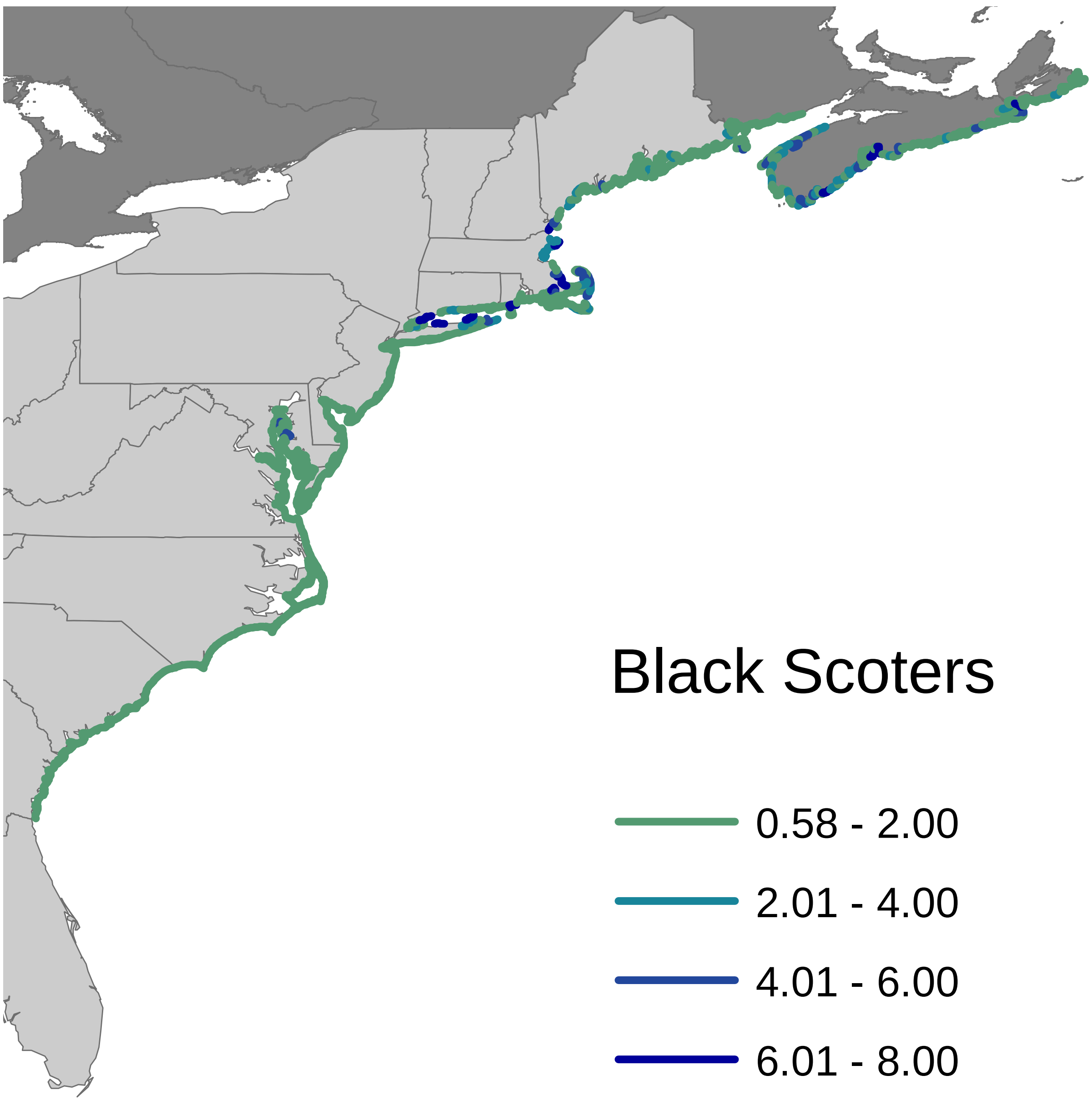

Figure 2. Map indicating the temporal and spatial trends (percent change) of Surf Scoters from 1991 to 2002.

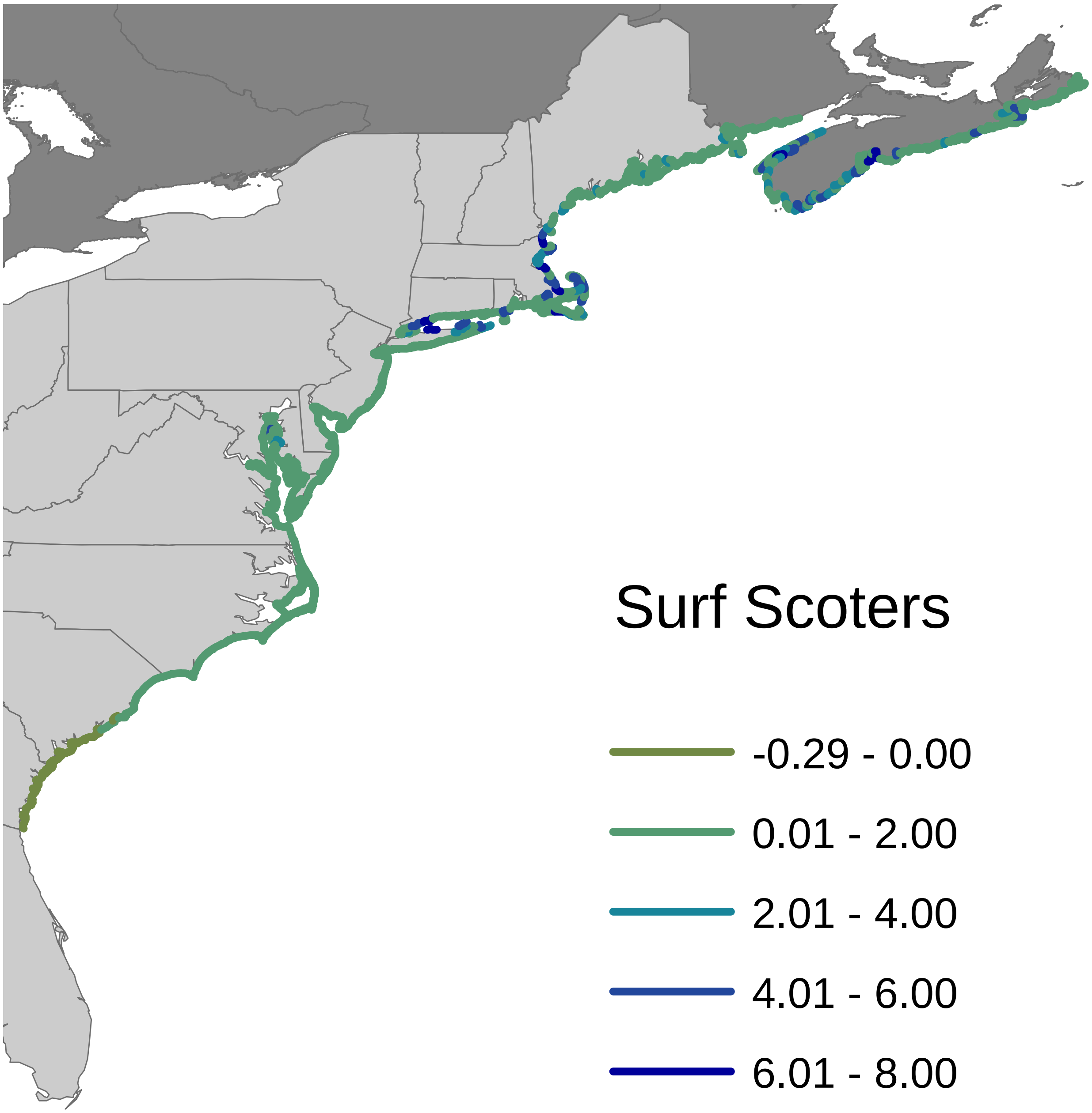

Figure 3. Map indicating the temporal and spatial trends (percent change) of White-winged Scoters from 1991 to 2002.

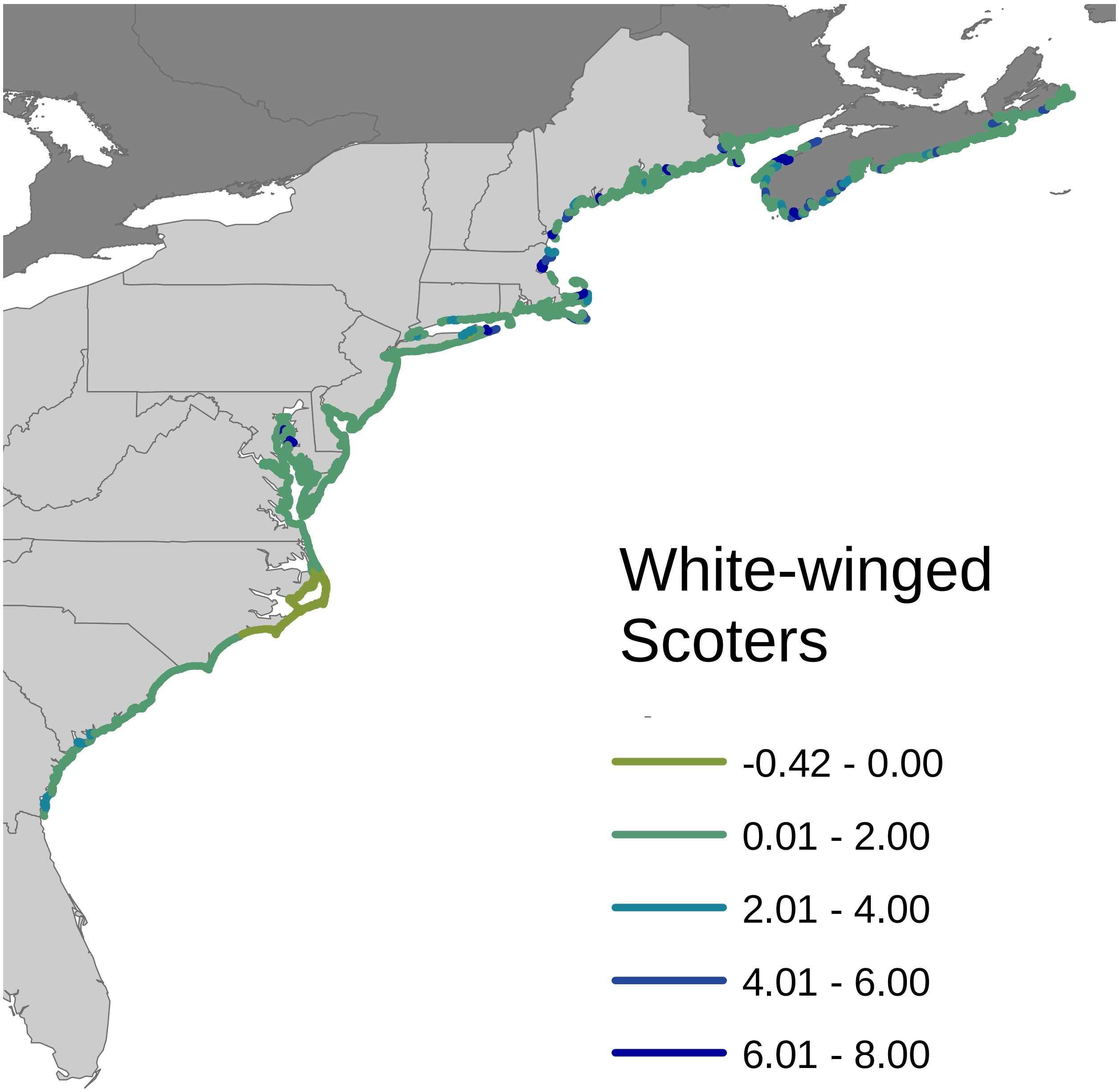

Figure 4. Map indicating the temporal and spatial trends (percent change) of Common Eiders from 1991 to 2002.

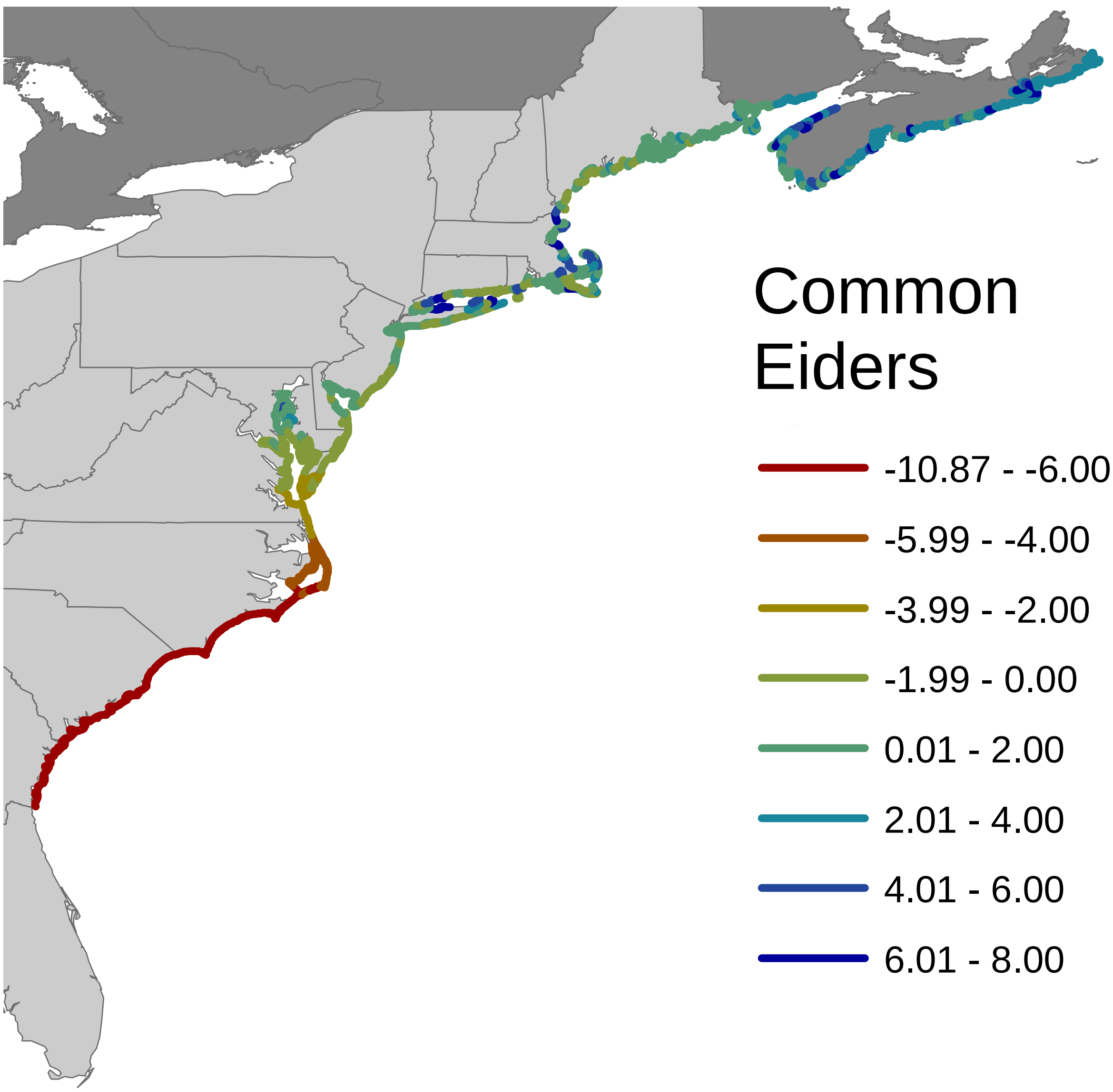

Figure 5. Map indicating the temporal and spatial trends (percent change) of Long-tailed Ducks from 1991 to 2002.