THE SALTMARSH HABITAT & AVIAN RESEARCH PROGRAM

Final Project Report for Agreement Number 50154-0-G004A

A collaborative project of

The Maine Department of Inland Fisheries and Wildlife, the University of Maine, the University of Connecticut, the University of Delaware, the University of New Hampshire, the State University of New York College of Environmental Science and Forestry

In cooperation with

The Connecticut Department of Energy and Environmental Protection, the Delaware Department of Natural Resources and Environmental Control, the Maryland Wildlife and Heritage Service, and Maryland/DC Audubon.

With additional grant funding provided by

U.S. Fish and Wildlife Service, State Wildlife Grant # U2-5-R-1
U.S. Fish and Wildlife Service, Northeast Regional Conservation Needs Grant Program
U.S. Fish and Wildlife Service, Region 5, Division of Wildlife and Sport Fish Restoration
National Science Foundation Grant # DEB-1340008
National Science Foundation Graduate Research Fellowships Program
Connecticut Department of Energy and Environmental Protection
National Park Service, Northeast Temperate Network, Inventory & Monitoring Program
National Park Service, Northeast Coastal and Barrier Network

THE SALTMARSH & AVIAN RESEARCH PROGRAM

Principal Investigators

Brian Olsen, Thomas Hodgman, Chris Elphick, Greg Shriver
Adrienne Kovach, Jonathan Cohen

Graduate Students

Alyssa Borowske, Mo Correll, Chris Field, Becky Kern, Alison Kocek, Kate Ruskin, Jen Walsh, Whitney Wiest

Other Lead Collaborators

Karen Bennett (DE DNREC), Gwen Brewer (MD DNR), Chris Davis (NJ DEP), Dana Filippini (NPS), Min Huang (CT DEEP), Erin King (USFWS), Jillian Liner (Audubon New York), Kate O'Brien (USFWS), Steve Papa (USFWS), Nancy Pau (USFWS), Rhonda Smith (USFWS), Kaytee Steinkerchner Hojnacki (USFWS), and Carol Trocki

Other Partnerships

This project is entirely dependent on a large network of stakeholders and collaborators who have provided access to historical data, logistical support for field work, and permission to access land. Numerous field assistants also helped with data collection, both past and present. Successful completion of the study would not be possible without their cooperation.

BACKGROUND

Tidal marshes are ecotonal systems that dominate the transition zone between terrestrial and marine communities in eastern North America (Reinold 1977, Mitsch and Gosselink 1993). Where they occur, tidal marshes perform many key services for humans. Tidal marsh is critical for absorbing the energy of ocean storms and protecting shorelines (Daiber 1986), improving water quality in bays and estuaries (Heinle and Flemer 1976, Valiela and Teal 1979, Dame et al. 1986, Valiela et al. 2000, Koch and Gobler 2009), providing nutrients to marine foodwebs (Odum 1969), and supplying critical habitat for both the reproduction of a suite of ocean species (Boesch and Turner 1984) and for non-breeding use by an entire community of migratory birds appreciated by birders and sportsmen alike (Master 1992, Erwin 1996, Brown et al. 2002). Furthermore, the shoreline of eastern North America possesses the highest level of vertebrate biodiversity and endemism of any tidal marsh region worldwide (Greenberg and Maldonado 2006).

The global importance of and local services provided by tidal marshes justifies conservationists' attention, but it is their high risk of degradation and loss that necessitates detailed information to prioritize and coordinate conservation actions. Climate change may impact the unique bird assemblage found in tidal marshes by increasing the frequency (Resio and Hayden 1975, Hayden 1981) and intensity (Emanuel 1987, Bacon and Carter 1991, Knutson 1998) of storm surges. Tidal flooding is a well-documented determinant of successful reproduction in tidal marsh birds (Gjerdrum et al. 2005, Greenberg et al. 2006, Shriver et al. 2007, Gjerdrum et al. 2008, Bayard and Elphick 2011); climate change and especially sea-level rise are likely to increase this threat to many tidal marsh endemics, most of which nest on the marsh surface.

In the face of habitat loss and degradation expected to affect tidal marshes given climate change predictions, a group of academic, government, and non-profit ecologists have formed the Saltmarsh Habitat and Avian Research Program (SHARP) to gather information to aid the conservation of this ecosystem. The project will determine each state's responsibility for the conservation of tidal marsh bird species and provide a platform for long-term monitoring of the tidal marsh bird community within the non-barrier-island Atlantic coastline (corresponding to Bird Conservation Region 30 plus the Maine coast from Cape Elizabeth to Lubec; hereafter BCR30^{+}). Using a multi-tiered approach, we will collect detailed population and demographic data for bird species using tidal marsh habitat in BCR30^{+} and use these data to prioritize the importance of tidal marshes at state and regional scales.

This report describes in detail the work conducted by SHARP from 2011-2013 as funded by the USFWS Region 5 Division of Migratory Birds as a final report for Agreement Number 50154-0-G004A, “The New England Tidal Marsh Bird Community Project”. Analyses are underway on many components of the research. We anticipate completing many of these analyses and preparation of publications in the coming year. These products will be delivered to the Division office upon completion.

RESEARCH SUMMARIES

Contemporary Surveys of Bird Use of High Marsh Communities

We conducted bird surveys using both passive point count and broadcast/response methods along the coast of $BCR30^{+}$ to map the abundance and distribution of all bird species using high tidal marsh habitat of $BCR30^{+}$ during the breeding season. To give a more complete assessment of tidal marsh birds along the northeast coast and to facilitate comparisons with historical data sets, we extended survey effort geographically beyond BCR30 to encompass marshes from Casco Bay in Maine (the northern limit of BCR 30) to the Canadian border (Figure 1). We divided the entire study area into 9 subregions.

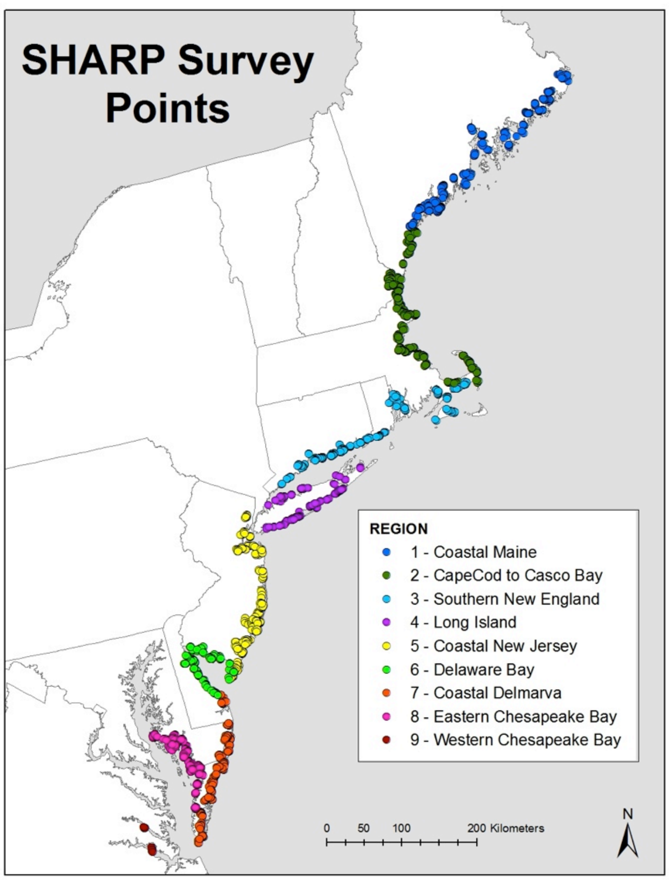

Figure 1. Distribution of survey effort within nine subregions of $BCR30^{+}$ for the Saltmarsh Habitat and Avian Research Program (SHARP).

Point count surveys consisted of a five-minute passive period followed by a series of broadcast calls for secretive marsh birds. The total time to complete a point count ranged from 8 to 13 min, depending on the number of species included in broadcast calls for a given subregion. During this time, we recorded all bird species detected by sight or sound that were using tidal marsh habitat. Surveys were completed between one half hour before sunrise and 1100 h.

We partnered with several agencies and conservation organizations to accomplish these surveys. Adrienne Kovach and Jen Walsh (University of New Hampshire) collected point count data at 21 points in New Hampshire. Luanne Johnson (BiodiversityWorks) collected data at 13 points on Martha's Vineyard that were otherwise inaccessible to SHARP staff due to their island location. Dana Fillipini (National Park Service) collected data at 5 points in Boston Harbor and Cape Cod National Seashore. Erin King (USFWS) conducted point counts at 55 points in coastal Rhode Island. Point count data for 108 points on Long Island and portions of New York were collected by Steve Papa (USFWS), Lauren Puccia (Town of Babylon), Derek Rogers (The Nature Conservancy), Alison Kocek (SUNY-ESF), Michael Farina (Town of Hempstead), and Lindsey Ries (National Park Service). In New Jersey, Paul Castelli (USFWS) conducted point counts at 26 points in E.B. Forsythe National Wildlife Refuge (NWR). In Delaware, Susan Guiteras and Annie Larson (USFWS) collected data at 25 points in the Coastal Delaware NWR Complex (Bombay Hook and Prime Hook NWRs). These various collaborations resulted in an additional 193 points visited 2-3 times over the 2013 field season. Many other collaborators supported SHARP efforts through field and logistic support, including USFWS, NPS, the University of New England, New Hampshire Fish and Game Department, Marine Biological Laboratory, Massachusetts Audubon, New York City Audubon, Maryland Ornithological Society, and the Smithsonian Migratory Bird Center.

We conducted surveys at a total of 1,499 points (Table 1), 208 less than in 2012. All of the points visited in 2013 also were surveyed in 2011 and 2012. Each point was surveyed on at least two occasions and most were visited three times throughout the survey period. At least 10 days elapsed between consecutive surveys at individual points.

Raw occurrence data are summarized by year in Tables 1-3, illustrating the frequency with which each focal species was detected in each state each year. Additional analysis of survey data will be conducted during 2013-14.

Table 1. Number of survey points visited in 2013 and proportion of those points where each of the focal high marsh species was detected, for each of the ten states in the SHARP sampling scheme.

State	Survey points	Occurrence (% points where detected)					
		American Black Duck	Clapper Rail	Willet	Nelson's Sparrow	Saltmarsh Sparrow	Seaside Sparrow
ME	309	19.4	0.0	21.7	42.1	10.0	0.0
NH	62	0.0	0.0	29.0	6.5	29.0	1.6
MA	254	8.3	0.0	42.9	1.6	28.0	1.2
RI	54	0.0	0.0	59.3	0.0	66.7	7.4
CT	81	4.9	9.9	49.4	4.9	7.4	12.4
NY	110	9.1	39.1	57.3	0.9	30.0	22.7
NJ	259	9.3	65.6	64.5	0.0	28.6	45.6
DE	89	5.6	75.3	66.3	0.0	25.8	71.9
MD	130	32.3	56.2	50.8	0.0	7.7	75.4
VA	151	3.3	95.4	87.4	0.0	12.6	34.4
Total	**1499**	**9.2%**	**56.9%**[1]	**52.9%**	**9.3%**[1]	**24.6%**	**27.3%**[1]

[1]Mean occurrence (%) calculated only across states within species geographic range.

Table 2. Number of survey points visited in 2012 and proportion of those points where each of the focal high marsh species was detected, for each of the ten states in the SHARP sampling scheme.

State	Survey points	Occurrence (% points where detected)					
		American Black Duck	Clapper Rail	Willet	Nelson's Sparrow	Saltmarsh Sparrow	Seaside Sparrow
ME	305	13.1	0	21.6	45.9	13.4	0
NH	62	0	0	33.9	8.1	12.9	0
MA	256	4.3	0.4	45.7	5.5	28.5	1.6
RI	54	0	1.9	59.3	0	59.3	3.7
CT	90	5.6	26.7	58.9	0	36.7	14.4
NY	111	0.9	45.0	64.9	0	41.4	27.0
NJ	339	11.5	70.5	65.2	0.3	39.8	56.3
DE	93	5.4	62.4	59.1	0	16.1	63.4
MD	221	30.8	57.0	52.9	1.8	30.8	76.9
VA	176	8.0	92.0	69.9	2.3	25.0	35.2
Total	**1707**	**10.7%**	**38.7%**	**51.4%**	**9.9%**	**29.0%**	**31.1%**

Table 3. Number of survey points visited in 2011 and proportion of those points where each of the focal high marsh species was detected, for each of the ten states in the SHARP sampling scheme.

State	Survey points	Occurrence (% points where detected)					
		American Black Duck	Clapper Rail	Willet	Nelson's Sparrow	Saltmarsh Sparrow	Seaside Sparrow
ME	312	6.7	0	18.0	41.7	4.5	0
NH	62	1.6	0	25.8	3.2	9.7	0
MA	253	2.3	0	34.8	2.4	18.2	2.8
RI	50	2.0	2.0	34.0	0	52.0	2.0
CT	97	2.1	14.4	37.1	2.1	22.7	12.4
NY	100	4.0	20.0	45.0	0	25.0	27.0
NJ	269	1.1	52.0	46.1	0.7	9.7	32.0
DE	102	2.9	47.1	61.8	0	9.8	59.8
MD	210	23.3	41.4	54.8	0.5	25.2	76.2
VA	205	6.3	81.5	62.9	0	9.8	23.4
Total	1660	6.2%	28.7%	41.5%	8.6%	14.9%	24.2%

Changes in Marsh Bird Abundance and Distribution Based on Comparisons with Historical Data

The goal of this research is to repeat surveys in the area studied extensively by Hodgman et al. (2002) and Shriver et al. (2004) to estimate changes in bird distribution and abundance over time across sites where historical data exist. Our approach here uses the same sampling frame as our contemporary surveys. However, our analyses differ in that we will use historical data as reference points for the dynamics of the saltmarsh bird community.

For our entire BCR30^{+} study area, we have assembled historical saltmarsh bird data from 14 sources, spanning 10 states, and totaling 3,006 points (Figure 2). During the three field seasons, 425 of our survey points were consistently at locations for which historical bird counts are available (28% of the contemporary survey points; Table 2). Analyses including historical data are underway and we anticipate completing all analyses by the end of 2014.

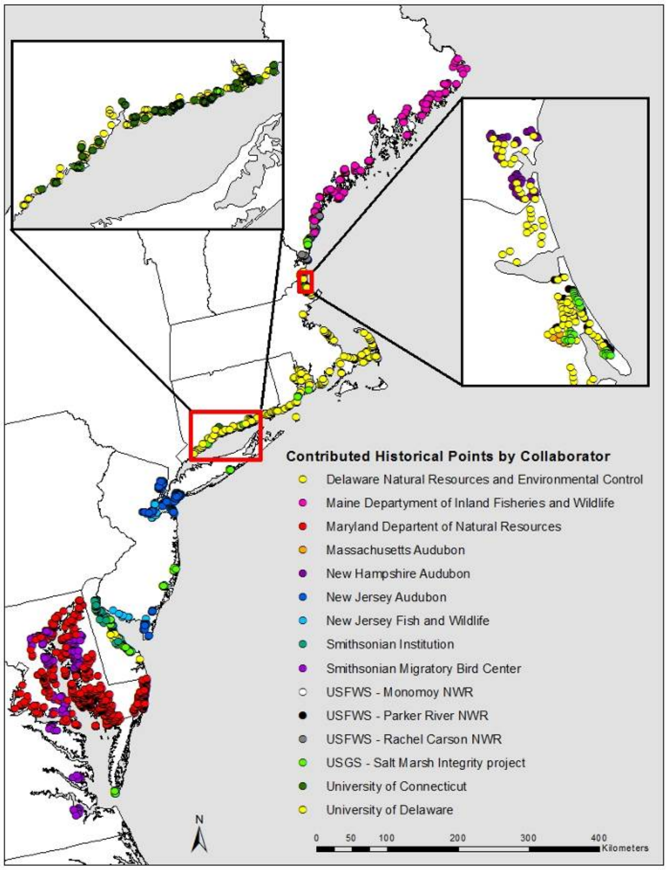

Figure 2. Distribution of historical survey points for saltmarsh birds for which data have been provided to the Saltmarsh Habitat and Avian Research Program (SHARP). A subset of these points have been surveyed during our current research (28% of the contemporary SHARP survey points) to allow comparisons between current and historical abundance and distribution.

Table 4. Summary of historical point count data available for analysis and number of historical points resurveyed by SHARP during the 2011-2013 field seasons.

State	Historical points contributed	Historical points resurveyed (2011)	Historical points resurveyed (2012)	Historical points resurveyed (2013)
ME	698	123	122	123
NH	22	19	19	19
MA	296	47	48	48
RI	64	18	19	19
CT	287	56	57	52
NY	32	8	8	8
NJ	481	25	32	24
DE	181	57	53	52
MD	617	73	86	70
VA	328	14	13	10
Total	**3006**	**440**	**457**	**425**

Initial comparisons of bird counts during the historical and contemporary surveys in New England indicate that all specialist tidal marsh species surveyed (those species that are restricted to tidal salt marshes) have shown significant declines (Fig. 3). Species with tidal-marsh populations that are found elsewhere, however, show no trends in counts over the fifteen years of the study (Fig. 3). Continuous data from the Connecticut coast over a similar period (2000-2012) confirm significant declines in the three specialist species over the same period (Fig. 4-6). It should be emphasized that these initial results are of raw counts (uncorrected for detection bias). We are in the process of developing more sophisticated Bayesian n-mixture models to confirm these general patterns. These results were presented by Maureen Correll at the 2014 meeting of the American Ornithologists' Union in Estes Park Colorado and by Brian Olsen at the 2014 joint meeting of the Northeast and Southeast chapters of Partners in Flight in Virginia Beach, Virginia.

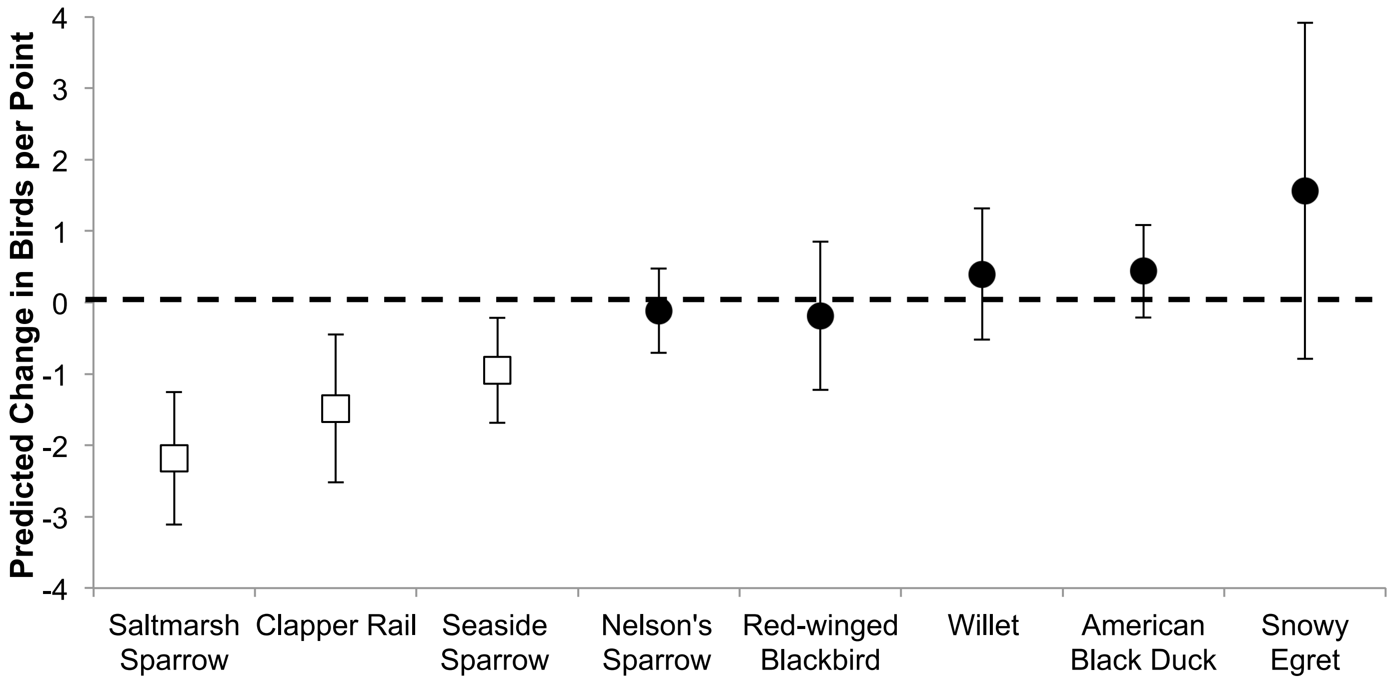

Figure 3. The estimated change in birds detected per point count by species across New England from 1997-2012 (2013 survey data not included). Tidal-marsh specialist species (those species that are mostly constrained to tidal marshes) are shown in the white boxes. Those species with the majority of their populations found outside of tidal marshes are shown in the filled circles. Error bars are 95% confidence intervals.

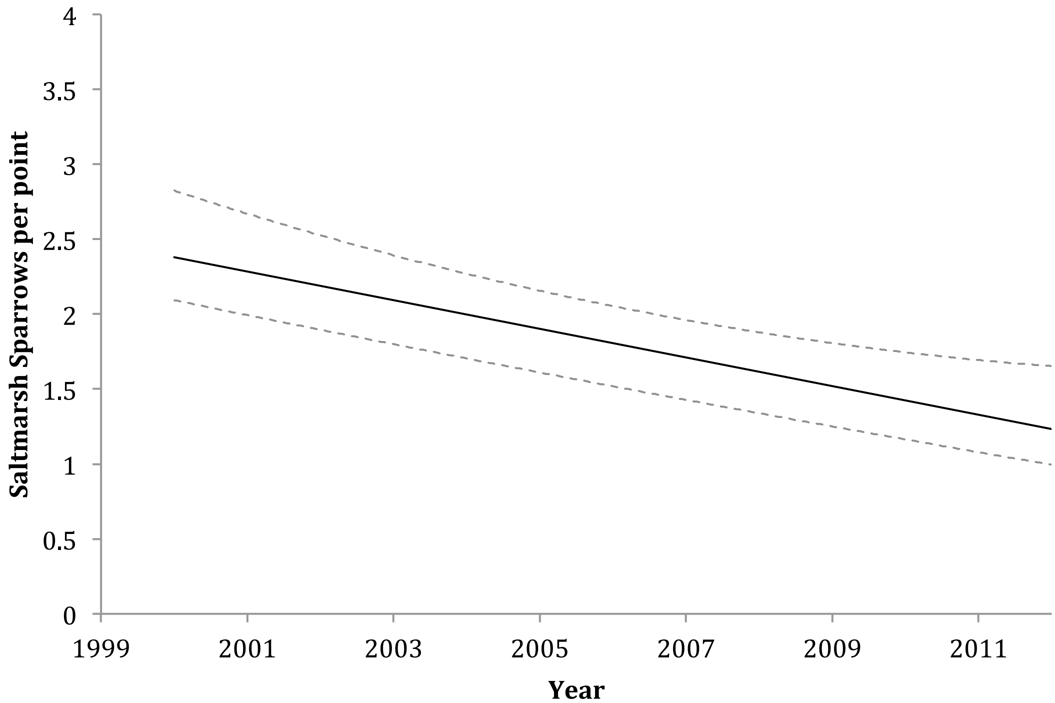

Figure 4. Significant declines in Saltmarsh Sparrows along the Connecticut coast from 2000 to 2012. Dotted lines indicate 95% confidence interval.

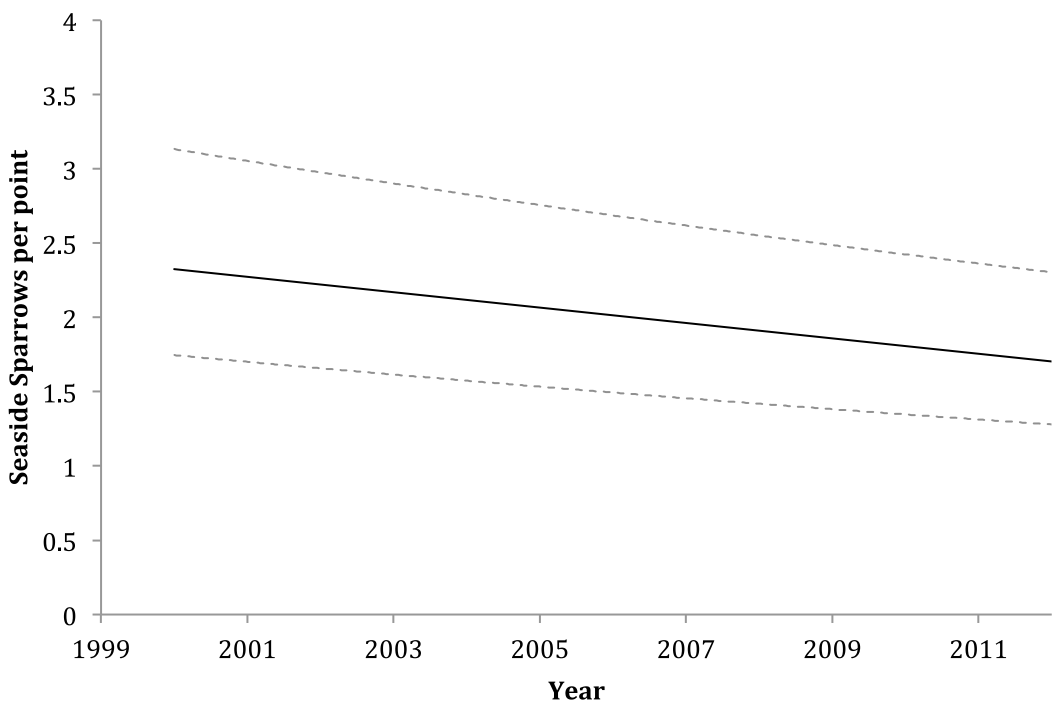

Figure 5. Significant declines in Seaside Sparrows along the Connecticut coast from 2000 to 2012. Dotted lines indicate 95% confidence interval.

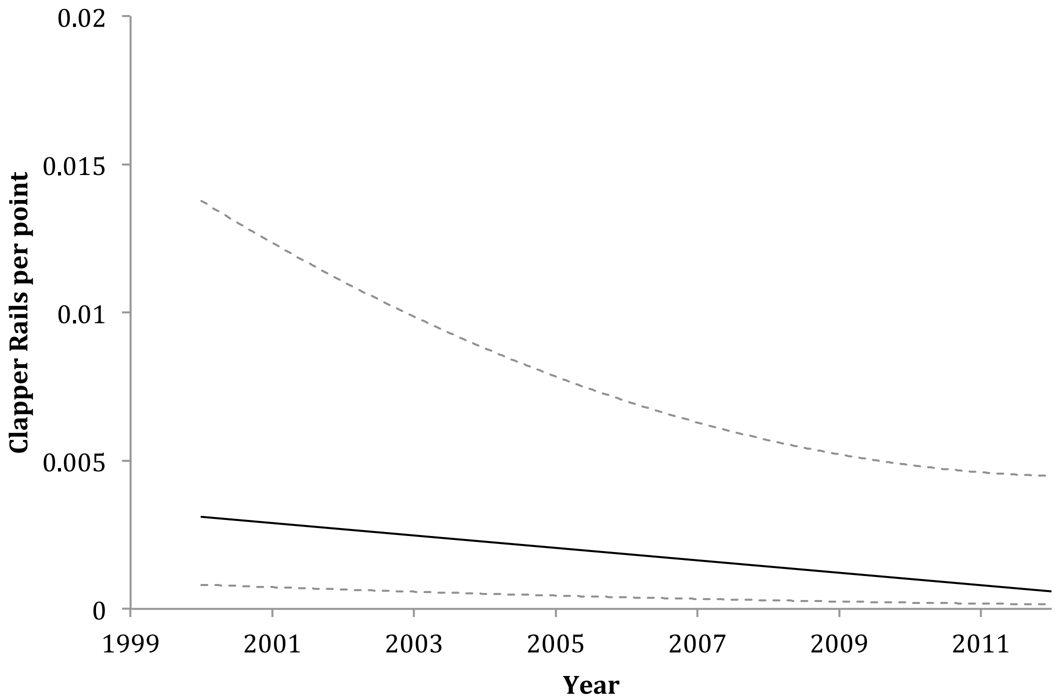

Figure 6. Significant declines in Clapper rails along the Connecticut coast from 2000 to 2012. Dotted lines indicate 95% confidence interval.

Clapper Rail Population Estimates in Bird Conservation Region 30$^+$

We used the 'unmarked' package (Fiske and Chandler 2011) in Program R (R Core Development Team 2010) to estimate Clapper Rail (*Rallus longirostris*) abundance from call-broadcast surveys conducted during the 2011-2012 breeding seasons. We used an N-mixture model (function = 'pcount') to estimate abundance using two site covariates (State and Sub-region) while holding detection constant (Royle 2004). We used the abundance estimates as a measure of Clapper Rail density at each survey point, and then averaged density across the sub-regions within each state. We multiplied these mean density estimates by marsh area, based on National Wetlands Inventory (NWI) Estuarine Emergent marsh, to estimate the total number of Clapper Rails within each state (Table 5). The Maryland and Virginia estimates do not include marshes along western Chesapeake Bay; therefore, these state estimates are specific to marshes on Maryland and Virginia's Delmarva Peninsula. Across BCR30$^+$, we estimated between 253,211 (SE = 20,344) and 265,217 (SE = 18,895) Clapper Rails from Connecticut to Virginia in 2011 and 2012, respectively (Table 5). Estimates of Clapper Rail density and population size varied by year and state. In 2011, our Clapper Rail density and population estimates were greatest in Virginia and lowest in Connecticut (Table 5). In 2012, our clapper rail density estimates were greatest in New Jersey and lowest in Connecticut (Table 5).

Table 5. Clapper rail (CLRA) state population estimates based on tidal marsh bird surveys coordinated and conducted by the Saltmarsh Habitat & Avian Research Program (SHARP), Maine to Virginia, 2011-12.

	2011			2012		
State	**Survey points (n)**	**CLRA density per ha (SE)[1]**	**Total CLRA (SE)**	**Survey points (n)**	**CLRA density per ha (SE)[1]**	**Total CLRA (SE)**
ME	312	0	0	305	0	0
NH	62	0	0	62	0	0
MA	253	0	0	253	0	0
RI	50	0	0	55	0	0
CT	97	0.19 (0.03)	925.0 (157.4)	90	0.08 (0.02)	395.0 (99.2)
NY	100	0.35 (0.04)	3,782.3 (500.4)	124	0.34 (0.03)	3,669.2 (421.6)
NJ	269	0.76 (0.07)	80,322.0 (6,828.3)	338	1.14 (0.08)	122,841.1 (7,782.5)
DE	102	0.59 (0.09)	18,709.3 (2,393.8)	93	0.74 (0.10)	24,973.9 (2,803.4)
MD	210	0.51 (0.05)	32,698.0 (2,956.1)	221	0.36 (0.03)	24,536.0 (2,248.7)
VA	188	2.36 (0.17)	116,774.3 (7,507.8)	169	1.88 (0.13)	88,802.3 (5,539.4)
Total	1,643		253,211.0 (20,343.8)	1,710		265,217.4 (18,894.7)

[1]CLRA density for New York to Virginia is the mean clapper rail density across the sub-regions within each state.

Development of a Remote Sensing Tool for Predicting Tidal Marsh Communities

Up-to-date information about tidal marsh zonation within specific areas of interest is integral to adaptive management of tidal marshes in the northeast for both the Saltmarsh Sparrow and other species of interest. We are comparing remote sensing classification techniques within BCR30^{+} to 1) develop a tool for repeated classification of high- and low-marsh zones within tidal marshes of the northeast, 2) validate the use of this tool across time and high-marsh taxa, and 3) produce a raster of current high and low marsh zonation within our area of interest accurate to 2011. To develop our high/low salt marsh zonation layer, we are using 11 scenes of Thematic Mapper (TM) imagery collected by the Landsat 5 satellite between June and August of 2011. We are attempting classification of our region using both high-marsh quartiles and binary high-marsh/non-high marsh classification schemes. Within these classification schemes, we are comparing Classification Tree (CART) and traditional maximum-likelihood supervised classification techniques using our binned vegetation survey data as ground-truthed data to train and validate the models as appropriate. We are using normalized real band values, calculated Normalized Difference Moisture Index (NDMI) values (Jin and Sader 2005), and Principal Component Analysis (PCA) values as the inputs for our models. We anticipate completing all analyses in early 2014.

Indicators of Climate Change in Long Island Sound

During 2013, members of the SHARP team initiated a series of studies to document the effects of climate change on coastal habitats around Long Island Sound. This work is funded by the Long Island Sound Study, via the Connecticut DEEP and involves both compiling and analyzing existing data sets, plus collecting new data. In addition, we developed a simple protocol for tracking marsh migration into the uplands and set up ~170 transects around the coast of Long Island Sound, randomly-placed in shallow-elevation areas where transgression is predicted to occur. At these sites, we collected baseline data on the presence of saltmarsh plants extending inland from the marsh edge and on tree densities and mortality.

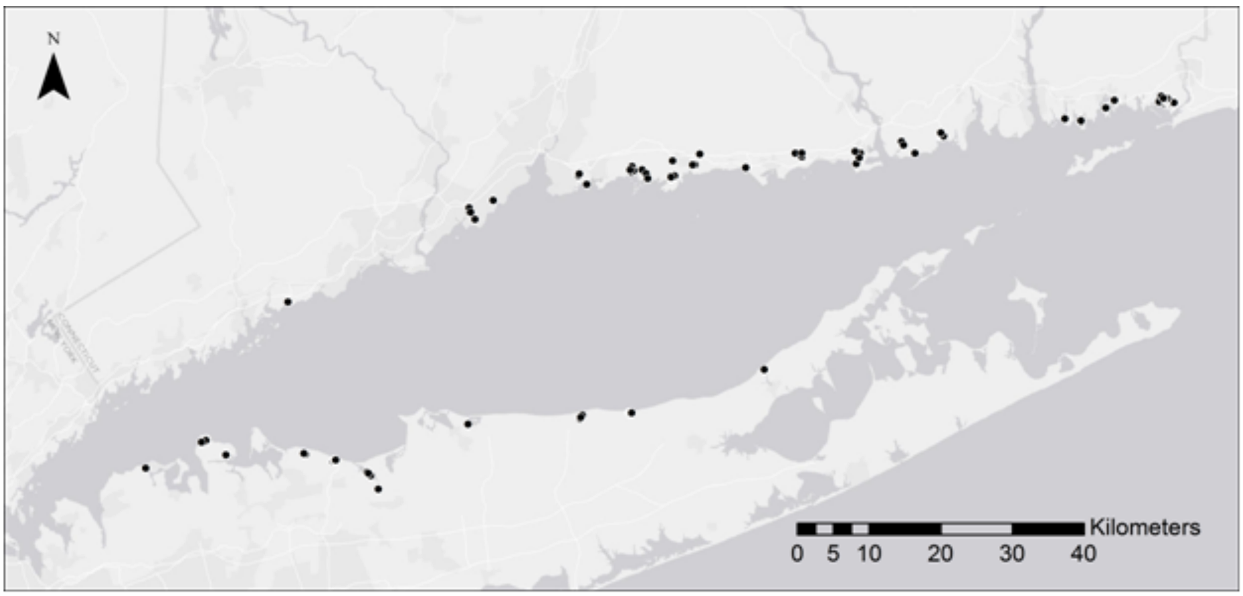

Figure 7. Locations of 55 plots around Long Island Sound where effect of sea level rise on high marsh vegetation was monitored.

Although analyses are still underway some preliminary results are available. First, by revisiting 55 plots in 12 marsh systems that were sampled in 2002-2004, we have found substantial changes in tidal marsh vegetation all along the Connecticut coast. These changes suggest a decline in the occurrence of *Juncus geradii* and an increase in the occurrence of *Spartina alterniflora* (Fig. 4a). *Spartina patens* also seems to be declining in abundance, further supporting the notion that marshes are getting wetter. Second, by analyzing the survival of Saltmarsh Sparrow eggs and nestlings, we have better quantified the relationship between tide height and reproductive success (Fig. 4b). Third, by comparing precisely georeferenced aerial photographs from 1974, 1990, and 2010, we found no evidence for an overall pattern of forest retreat (Fig. 4c). Additional analysis of this work is ongoing, with a final report due next year.

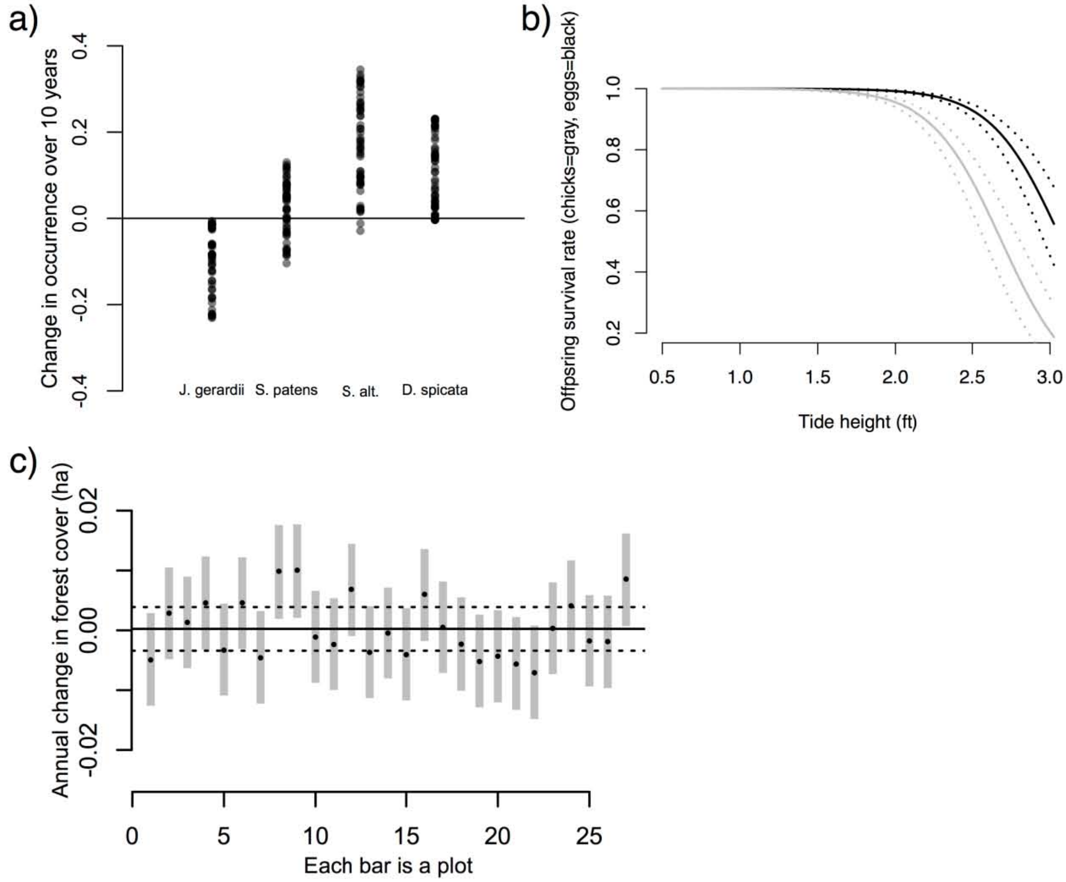

Figure 8. Key results from preliminary analyses for potential indicators of wildlife and ecosystem change in coastal Long Island Sounds. (a) Change in occurrence of key saltmarsh plant species (**Juncus gerardii, Spartina patens, Distichlis spicata*****) in Connecticut tidal marshes between 2002-04 and 2013. Each point represents a single 1-ha plot (n=55); points lying above the horizontal line represent an increase in occurrence, points lying below the line represent a decrease in occurrence. (b) The effect of tide height on the probability of saltmarsh sparrow egg and chick survival. Dotted lines show 95% credible intervals. (c) Estimates of annual change in forest cover at the edge of salt marshes for 27 randomly selected plots. The solid black line is the mean trend across plots, and the dotted lines show the 95% credible interval for the mean. Plots are in no particular order.***

Tidal Marsh Bird Conservation Planning in Response to Predicted Sea Level Rise

We will analyze 2011-2012 survey data to determine the current focal areas (areas of greatest abundance) in BCR 30$^+$ for tidal marsh obligate (TMO) Species of Greatest Conservation Need (SGCN) (i.e., Clapper Rail, Willet, Saltmarsh Sparrow, Nelson's Sparrow, and Seaside Sparrow), as well as identify where we detected other species of concern (i.e., Black Rail, American Black Duck). Based on the geographic distribution of focal areas, we will determine which states and SHARP sub-regions are key areas for the persistence of each species. We will use existing sea level rise models (e.g., SLAMM, NOAA Sea Level Rise and Coastal Impacts Viewer) to evaluate the impacts of different sea level rise scenarios (e.g., 0.5m, 1m, 2m rise by 2100) on current TMO focal areas. We will determine the degree of predicted TMO bird loss in each state and SHARP sub-region and evaluate upland areas adjacent to marsh focal areas for their marsh transgression potential. The landscape configuration of focal areas with marsh migration potential will be combined with present-day bird abundance data to predict future tidal marsh bird hotspots. We will use optimization models to determine the potential of purchasing future hotspots (unprotected marsh areas surviving in the future and non-marsh areas that may facilitate marsh migration) and develop a list of optimal parcels for each state that most efficiently utilizes state conservation funds for land acquisitions that support the long-term persistence of the tidal marsh bird community.

Photo Credits
Stone wall, *Juncus gerardii*, Saltmarsh Sparrow by Alyssa Borowske; conducting point count survey by Matt Jones; sparrow nest by Kate Ruskin; Clapper Rail nest by Chris Field; Nelson’s Sparrow by Chris Elphick.

LITERATURE CITED

Bacon, S., and D. J. T. Carter. 1991. Wave climate changes in the North Atlantic and North Sea. International Journal of Climatology 11:545-558.

Bayard, T. S., and C. S. Elphick. 2011. Planning for sea level rise: Quantifying patterns of Saltmarsh Sparrow (*Ammodramus caudacutus*) nest flooding under current sea level conditions. Auk 128:393-403.

Boesch, D. F., and R. E. Turner. 1984. Dependence of fishery species on salt marshes: The role of food and refuge. Estuaries 7:460-468.

Brown, S. C., B. A. Harrington, K. C. Parsons, and E. P. Mallory. 2002. Waterbird use of northern Atlantic wetlands protected under the North American Wetlands Conservation Act. Waterbirds 25:106-114.

Daiber, F. C. (ed) (1986) Conservation of Tidal Marshes. New York, NY: Van Nostrand Reinhold.

Dame, R., T. Chrzanowski, K. Bildstein, B. Kjerfve, H. McKellar, D. Nelson, J. Spurrier, S. Stancyk, H. Stevenson, J. Vernberg, and R. Zingmark. 1986. The outwelling hypothesis and North Inlet, South Carolina. Marine Ecology Progress Series 33:217-229.

Emanuel, K. A. 1987. The dependence of hurricane intensity on climate. Nature 326:483-485.

Erwin, R. M. 1996. Dependence of waterbirds and shorebirds on shallow-water habitats in the Mid-Atlantic coastal region: An ecological profile and management recommendations. Estuaries 19:213-219.

Fiske, I. and R. Chandler. 2011. Unmarked: an R package for fitting hierarchical models of wildlife occurrence and abundance. Journal of Statistical Software 43:1-23.

Gjerdrum, C., C. S. Elphick, and M. A. Rubega. 2005. What determines nest site selection and nesting success in saltmarsh breeding sparrows? Condor 107:849-862.

Gjerdrum, C., K. Sullivan-Wiley, E. King, M. A. Rubega, and C. S. Elphick. 2008. Nest survival during flooding in Saltmarsh Sharp-tailed Sparrows. Condor 110: 579-584.

Greenberg, R. G., and J. E. Maldonado. 2006. Diversity and endemism in tidal marsh vertebrates. *In* Terrestrial Vertebrates of Tidal Marshes: Ecology, Evolution, and Conservation (R. Greenberg, S. Droege, J. Maldonado, and M. V. McDonald, eds.). Studies in Avian Biology 32:32-53.

Greenberg, R. G., C. S. Elphick, J. C. Nordby, C. Gjerdrum, H. Spautz, W. G. Shriver, B. Schmeling, B. Olsen, P. Marra, N. Nur, and M. Winter. 2006. Flooding and predation: trade-offs in the nesting ecology of tidal-marsh sparrows. *In* Terrestrial Vertebrates of Tidal Marshes: Ecology, Evolution and Conservation (R. Greenberg, S. Droege, J. Maldonado, and M. V. McDonald, eds.). Studies in Avian Biology 32:96-109.

Hayden, B. P. 1981. Secular variation in Atlantic Coast extratropical cyclones. Monthly Weather Review 109:159-167.

Heinle, D. R., and D. A. Flemer. 1976. Flows of materials between poorly flooded tidal marshes and an estuary. Marine Biology 35:359-373.

Hodgman, T. P., W. G. Shriver, and P. D. Vickery. 2002. Redefining range overlap between the sharp-tailed sparrows of coastal New England. Wilson Bulletin 114:38-43.

Jin, S., and S. A. Sader. 2005. Comparison of time series tasseled cap wetness and the normalized difference moisture index in detecting forest disturbances. Remote Sensing of Environment 94:364–372.

Knutson, T. R., R. E. Tuleya, and Y. Kurihara. 1998. Simulated increase of hurricane intensities in a CO_2-warmed climate. Science 279:1018-1020.
Koch, F., and C. J. Gobler. 2009. The effects of tidal export from salt marsh ditches on estuarine water quality and plankton communities. Estuaries and Coasts 32:261-275.
Master, T. L. 1992. Composition, structure, and dynamics of mixed-species foraging aggregations in a southern New Jersey salt marsh. Colonial Waterbirds 15:66-74.
Mitsch, W. J., and J. G. Gosselink (eds.) 1993. Wetlands. New York, NY: Wiley.
Odum, E. P. 1969. The strategy of ecosystem development. Science 164:262-270.
R Core Development Team. 2010. R: a language and environment for statistical computing, reference index version 2.11.1. R Foundation for Statistical Computing, Vienna, Austria, http://www.R-project.org.
Reinold, R. J. 1977. Mangroves and salt marshes of eastern United States. *Pages* 157-166 *In* Wet Coastal Ecosystems of the World, (V. J. Chapman, ed.). Amsterdam: Elsevier.
Resio, D. T., and B. P. Hayden. 1975. Recent secular variations in mid-Atlantic winter extratropical storm climate. Journal of Applied Meteorology 14:1223-1234.
Royle, J. A. 2004. N-mixture models for estimating population size from spatially replicated counts. Biometrics 60:108-115.
Shriver, W. G., T. P. Hodgman, J. P. Gibbs, and P. D. Vickery. 2004. Landscape context influences salt marsh bird diversity and area requirements in New England. Biological Conservation 119:545-553.
Shriver, W. G., P. D. Vickery, T. P. Hodgman, and J. P. Gibbs. 2007. Flood tides affect breeding ecology of two sympatric sharp-tailed sparrows. Auk 124:552-560.
Valiela, I., and J. M. Teal. 1979. Nitrogen budget of a salt marsh ecosystem. Nature 280:652-656.
Valiela, I., G. Tomasky, J. Hauxwell, M. L. Cole, J. Cebrian, and K. D. Kroeger. 2000. Operationalizing sustainability: Management and risk assessment of land-derived nitrogen loads to estuaries. Ecological Applications 10:1006-1023.