

Long Island Sound License Plate Program

Anthropogenic effects on the distribution and abundance of breeding salt marsh
birds in Long Island Sound and New England

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Final Report



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INTRODUCTION

Coastal wetlands in North America are unique ecosystems dominated by endemic halophytic vegetation spatially limited to the thin interface between marine and terrestrial ecosystems. Salt marshes are unique coastal habitats that provide an important exchange in nutrients between marine and freshwater ecosystems (Bertness 1999). Salt marshes are critical nursery grounds for many commercially valuable fisheries and many worldwide coastal fisheries are significantly correlated with salt marsh area. Coastal marshes buffer shorelines from flooding and storm damage by intercepting runoff and limiting storm-induced erosion and enhance of water quality. Salt marshes also support highly diverse wildlife populations and provide valuable breeding and migratory stopover habitat for numerous species of shorebirds, waterfowl, colonial waterbirds, and passerines (Bertness 1999).

Even though the ecological services and biological diversity of salt marshes are well documented, these ecosystems have been altered, degraded, and lost throughout the coastal United States. Human population density is highest in coastal habitats putting severe pressure on coastal ecosystems to maintain ecological integrity and ecosystem functions. Nearly a quarter of the population in the United States, 60 million people, lives in coastal counties along the Atlantic Ocean. Human population growth in United States coastal counties increased by 41 % from 1960, slightly higher than the national average (<http://www-orca.nos.noaa.gov/projects/population/population.html>). Most salt marshes in the Northeast have been altered to some degree by agriculture, mosquito control, and development. Losses of coastal wetlands in the United States have been substantial, ranging from 30 – 40 % (Horwitz 1978) and salt marsh habitat in New England is particularly imperiled (Tiner 1984). For example, Neiring and Bowers (1966) in Connecticut estimated that 50 % of tidal wetlands have been lost.

Despite the magnitude of these habitat changes, neither New England's salt marshes nor their avifauna have been systematically surveyed across the region, leaving essential information about species occurrence, relative abundance, and density of these wetland obligates unknown. For many habitat specialists, such as salt marsh breeding birds with their intrinsic patchy distributions, the North American Breeding Bird Survey (BBS) does not provide adequate coverage (Sauer et al. 2000) and, therefore, distributions and most importantly, population trends, are poorly estimated. For these reasons habitat and guild-specific avian surveys on a regional scale are important to establish. Furthermore, inadequate information on salt marsh obligate populations and their status and distribution is the primary reason for many salt marsh bird species to be listed as high conservation priorities on continental prioritization schemes (Pashley et al. 2000).

In recent years, multiple avian conservation ranking schemes (Partners in Flight, National Audubon Society) have indicated that Salt Marsh breeding birds are species of high conservation priority in the Northeast, due mainly to the lack of information about the distribution, abundance, and breeding ecology of these wetland dependent birds. Specifically, the Salt Marsh Sharp-tailed Sparrow is of

high global importance for New England conservationists as over 90 % of the entire breeding population occurs in the Northeast.

Herein we report the results of a regional survey of breeding salt marsh birds coordinated across all New England states. These data were collected using methods developed in Maine and Connecticut and have been incorporated into a geo-referenced regional database for all New England states. The primary objectives of this survey were to; 1) establish fixed radius points within salt marsh habitat to sample breeding birds from southern Connecticut to the Lubec, Maine, 2) determine if salt marsh bird communities responded to different vegetation communities, especially invasive *Phragmites*, 3) determine the landscape level influences on salt marsh bird communities, and 4) build partnerships with federal, state, non-governmental organizations, and land managers to increase the exchange of information regarding salt marsh breeding bird communities.

METHODS

We used aerial photography and USFWS National Wetland Inventory maps to identify potential estuarine emergent survey sites (Cowardin et al. 1979, Wilen and Bates 1995). Only sites greater than 2.5 ha were considered for this survey. We used 100 m radius point counts with a 10-minute listening period to estimate avian abundance, species richness, and an index of species diversity (Ralph et al. 1995). Points were located systematically in each marsh such that they were greater than 300 m from any other point center and 25 m from a non-salt marsh edge. All analyses in this report are based on the number of individuals (seen and/or heard) within a 100 m radius of the point center. All points were visited at least two times from 1 June – 15 August in 1997 - 2000. Surveys were conducted from dawn to 12 p.m. on days with low wind and at most, a light rain. All observers were trained in bird species identification by sight and sound prior to the field season and ran at least two practice surveys before collecting data.

Vegetation was sampled at each point using a 100 m line transect bisecting the center of the point. The distance (in cm) each vegetation type contacted the measuring tape was recorded. The total length of each vegetation type was summed across the 100 m line transect to give an estimate of the cover within a point (Brower and Zar 1984).

Landscape level variables were collected from GIS coverages available within each state. Several geographic information system data sets were obtained from several sources. Digitized maps of estuarine emergent vegetation in Rhode Island, New Hampshire, and Maine were obtained from the U.S. Fish and Wildlife Service (1981-1992) National Wetland Inventory (<http://www.nwi.fws.gov>). In Massachusetts, digitized Orthophotoquads were obtained from the MASSGIS webpage (<http://www.state.ma.us/mgis/massgis.htm>) and used to create a statewide coverage of salt marsh habitat. The Long Island Sound Office of the Connecticut Department of Environmental Protection provided a salt marsh data layer digitized from 1995 aerial photographs. Patch Analyst in Arc/View 3.2 (Arc/View

Version 3.2, Environmental Systems Research Institute, Redlands, CA) was used to calculate patch variables used in analyses (Table 1). We followed the methods of Gustafson and Parker (1994) to calculate a salt marsh Proximity Index by summing the ratio of area / distance for each marsh within a 1 km buffer around the focal marsh. We first determined the area (in ha) for all marshes in New England. We then generated a 1 km buffer around each surveyed marsh and measured (in m) the shortest linear distance from the edge of the surveyed marsh to the edge of each marsh within the 1 km buffer. A 1 km buffer was chosen to cover the average home range size of all breeding species and to quantify the available marsh habitat within a short flight of the focal marsh. We divided the area of a marsh by the distance that marsh was from the surveyed marsh and summed these values across all marshes within the 1 km buffer of the surveyed marsh. The resulting Proximity Index ranged from 0 for isolated marshes where no marshes were within the 1 km buffer of the surveyed marsh, to 10, for surveyed marshes close to many other large marshes. We defined and calculated a Road Density Index to estimate aggregate anthropogenic effects surrounding a salt marsh. We calculated the Road Density Index by creating: (1) a 500 m buffer around each marsh, (2) counting the number times the buffer bisected a road, and (3) dividing the number of road / buffer intersections by the perimeter of the buffer to control for marsh size. US Geological Survey 1998 TIGER/Line Files of roads were used as the road data layer.

STATISTICAL ANALYSIS

We used analysis of variance to test for effects of marsh size, isolation, proportion of marsh within 1 km, and road density on obligate wetland bird richness (Zar 1999). We used independent t-tests to determine the difference between vegetation and landscape variables in used and unused marshes for 12 Salt Marsh bird species. All tests should be considered with caution as we conducted 14 tests per species and Bonferroni adjusted alpha levels = 0.004. However, to avoid Type II error, we used a liberal interpretation of these results and considered patterns of habitat use based on alpha = 0.05. We realize the risk of Type I error, and have presented P-values for all tests to allow more conservative interpretation of the same analyses. We then used a multiple variable logistic regression using the same variables in the univariate analysis (Hosmer and Lemeshow 1989). We therefore used the univariate tests to explore the effect of each variable had on a given species occurrence and used the multiple variable logistic regression to determine which variables remained significant when considered together. We used correlation analysis to determine the relationship among the independent variables and the relative abundance for each species (Zar 1999). We used principle components analysis (PCA) to reduce the landscape and vegetation variables to latent variables (factors) that explained some percentage of the total variation (Reyment et al. 1984). We controlled for site size and sampling effort when estimating species richness by taking the average number of species detected per point within a given marsh. This minimizes the problem of having higher species richness in larger marshes,

as there is an increasing probability of detecting a new species with each new sample point. Relative abundance was determined by taking the maximum number of individuals detected for a given species and dividing by the number of points surveyed in the marsh. This, once again, controls for the greater number of survey points in larger marshes.

RESULTS

We surveyed a total of 240 salt marshes from southern Connecticut to eastern Maine (Table 2, Figure 1). In Connecticut, Marsh Wrens and Snowy Egrets were the most common species detected on 77 surveyed marshes. In Connecticut, marshes were smaller and more isolated than the rest of New England (Table 2). Connecticut salt marshes had the most marshes within 1 km of the focal marsh but these marshes were small as indicated by the low average value for the isolation index. *Phragmites* cover in Connecticut was more than 14% higher than the New England average (Table 2). In Rhode Island, 35 marshes were surveyed; Snowy Egret and Great Egret were the most common species. Rhode Island had the highest isolation index and smallest average marsh size, indicating that marshes were smaller and further from each other than in Connecticut (Table 2). Road density, an index of human disturbance, was greatest in Rhode Island (Table 2). In Massachusetts, 55 marshes were surveyed; Willet and Marsh Wren were the most common species. Massachusetts had the largest salt marshes and they were less isolated than in other states. In New Hampshire, marshes were larger than the New England average, but the sample size in NH was small and these marshes are associated with the complex along the north shore of Massachusetts. Maine and New Hampshire had the lowest road densities in New England (Table 2).

Obligate wetland bird species richness increased with increasing marsh size, proximity to other marshes, and proportion of marsh habitat within 1 km (Fig. 2). This pattern was consistent in Connecticut and throughout New England, however the pattern was significant only for Connecticut marshes (size, $F = 5.36$, $P = 0.02$; isolation, $F = 10.66$, $P = 0.00$; proportion, $F = 6.17$, $P = 0.02$). Obligate wetland bird richness in Connecticut was significantly positively correlated with the proportion of marsh within 1 km, isolation index, and negatively correlated with road density (Table 3).

Using principle components analysis, we found that three factors explained 70% of the variation in landscape and vegetation variation throughout New England salt marshes (Table 4). The first factor explained 29% of the variation and was positively associated with marsh isolation, the proportion of marsh within 1 km, and size (Table 4). Factor 2 explained 21% of the variation and showed a clear contrast between *S. patens* and *S. alterniflora*. Negative values were associated with *S. alterniflora* while positive values were associated with *S. patens*. Factor 3 explained 20% of the variation and revealed a clear contrast between *Phragmites* cover on the negative axis and panne cover on the positive axis (Table 4).

To determine if there were general patterns in habitat occupancy, we plotted occurrences for four species of wading birds (Great Egret, Snowy Egret, Glossy Ibis, Willet) on the three PCA factors. We found that these four species formed a cluster on all three axes (Fig. 4). These species were positively associated with large marshes (Factor 1), *S. alterniflora* (Factor 2), and pannes (Factor 3; Fig. 4). None of these species were strongly associated with the *S. patens* or *Phragmites* (Fig. 4).

We then plotted occurrences for four passerine species and found a strong relationship for three of four species (Fig. 3). Nelson's Sharp-tailed sparrow was neutral in association with Factor 1 (Fig. 3). Nelson's Sharp-tailed sparrow was positively associated with the *S. patens* end of Factor 2. Seaside Sparrow showed the greatest variation in all factors and had the highest value on the size and isolation gradient, indicating that this species is sensitive to the size of the marsh, proximity to other marshes and location within a salt marsh complex (Fig. 3). Marsh Wrens were positively associated with *Phragmites* (Fig. 3).

We developed incidence functions for these four species, using logistic regression to determine the influence of marsh size, isolation, and road density on species occurrences. Of the three species, Salt Marsh Sharp-tailed Sparrow was least sensitive to area (Fig. 5A). Seaside Sparrows showed the greatest sensitivity to area, with a 60% chance of occurrence on marshes at least 500 ha in size (Fig 5B). Marsh Wren occurrence showed a linear relationship with marsh size (Fig. 5C). Salt Marsh Sharp-tailed Sparrows were also less sensitive to isolation than Seaside Sparrows and Marsh Wrens (Figs. 6A-C). All three species showed a positive relationship with increasing proximity to other marshes (Figs. 6A-C), but showed a negative relationship with road density (Figs. 7A-C).

American Bittern

American Bitterns occurred on 17 (22%) of surveyed salt marshes in Connecticut (Table 5). Throughout New England, American Bitterns were detected on 26 marshes (9%), only two more than were detected in Connecticut (Table 5). Based on univariate t-tests, in Connecticut bitterns used larger, less isolated marshes with lower road density. When all variables were considered together in a logistic regression model, bitterns were positively associated with marsh size, *Phragmites* and panne cover (Table 6). On a regional scale, bitterns selected sites with a greater number of patches and pannes, greater amounts of *Phragmites*, and a lower perimeter to area ratio (Table 5).

Great Egret

In Connecticut, Great Egrets occurred on 35 salt marshes (45%). Throughout New England, Great Egrets were detected on 102 (43%) of the surveyed marshes. Based on univariate t-tests, Great Egrets preferred larger marshes with lower road density (Table 7). When all variables were considered simultaneously in a logistic regression model, none of the variables significantly predicted Great Egret occurrence in Connecticut (Table 6). On a regional scale, this species preferred large marshes with lower perimeter / area ratio, a greater number of patches and pannes and greater amount of *S. alterniflora* cover (Table 7).

Snowy Egret

Snowy Egrets were detected on 43 salt marshes (56%) in Connecticut. Throughout New England, Snowy Egrets were detected on 125 (53%) of the surveyed marshes. Based on univariate t-tests, Snowy Egrets preferred larger marshes with a greater proportion of salt marsh habitat within 1 km, lower road density, greater amounts *S. alterniflora* and panne cover, and less *Phragmites* cover (Table 8). When all variables were considered together in a logistic regression model, Snowy Egrets were positively associated with the proportion of marshes within 1 km (Table 6). On a regional scale, this species preferred larger marshes with other marshes in close proximity. They also preferred marshes with greater proportions of *S. alterniflora* and panne cover (Table 8).

Green Heron

Green Herons occurred on 22 salt marshes (29%) in Connecticut. Throughout New England, Green Herons were detected on 63 (27%) of the surveyed salt marshes. Based on univariate t-tests, Green Herons used large marshes with more numerous, larger patches (Table 9). When all variables were considered together in a logistic regression model, none of the variables used in this analysis significantly predicted the occurrence of Green Herons in Connecticut (Table 6). On a regional scale, these herons preferred large marshes with a greater number of patches and more *S. alterniflora* cover (Table 9).

Glossy Ibis

Glossy Ibis occurred on 12 salt marshes (16%) in Connecticut. Throughout New England, Glossy Ibis were detected on 39 marshes (17%). Based on univariate t-tests, ibis selected large marshes with less road density and more panne cover (Table 10). When all variables were considered together in a logistic regression model, Glossy Ibis preferred large marshes and greater panne cover (Table 6). On a regional scale, ibis preferred large marshes with less road density, and more panne cover (Table 10).

Clapper Rail

Clapper Rails occurred on 24 (31%) of the surveyed marshes in Connecticut (Table 11). Throughout New England, Clapper Rails were only

detected on 2 marshes outside of Connecticut (11% of all surveyed marshes). Based on univariate t-tests, rails selected large marshes with less road density and greater *S. alterniflora* (Table 11). When all variables were considered together in a logistic regression model, no significant variables predicted Clapper Rail occurrence in Connecticut (Table 6). On a regional scale, these rails preferred marshes with numerous patches and greater *Phragmites* cover, but lesser amounts of *S. patens* (Table 11).

Willet

Willetts occurred on 29 salt marshes (38%) in Connecticut. Throughout New England, Willetts were detected on 90 (38%) of the surveyed salt marshes. Based on univariate t-tests, Willetts selected large marshes that had more salt marsh habitat within 1 km, were less isolated, had more near neighbors, and less *Phragmites* cover (Table 12). When all variables were considered together in a logistic regression model, we found a negative relationship between Willet occurrence and *Phragmites* cover (Table 6). On a regional scale, Willetts preferred large, less isolated marshes with numerous, larger patches and panes within the marshes. They also preferred sites with lower road density and lesser amounts of *Phragmites* cover (Table 12).

Marsh Wren

Marsh Wrens occurred on 38 salt marshes (49%) in Connecticut. Throughout New England, Marsh Wrens were detected on 61 (26%) of the surveyed marshes. Based on univariate t-tests, wrens selected larger marshes with a lower perimeter / area ratio, a greater proportion of salt marsh habitat within 1 km, were closer to other marshes, and had lower road density but greater *Phragmites* cover (Table 13). When all variables were considered together in a logistic regression model, in Connecticut, wrens preferred marshes with greater *Phragmites* cover (Table 6). On a regional scale, wrens preferred larger marshes with a greater proportion of marsh within 1 km, shape index, *S. patens* and *Phragmites* cover were significantly different between used and unused marshes (Table 13).

Salt Marsh Sharp-tailed Sparrow

Salt Marsh Sharp-tailed Sparrows occurred on 44 salt marshes (57%) of the surveyed marshes in Connecticut. Throughout New England, Salt Marsh Sharp-tailed Sparrows were detected on 131 (56%) of the surveyed marshes. Based on univariate t-tests, Salt Marsh Sharp-tailed Sparrows preferred larger marshes that had more *S. patens* and less *Phragmites* cover (Table 14.). When all variables were considered together in a logistic regression model, none of the variables used in this analysis significantly predicted Salt Marsh Sharp-tailed Sparrow occurrence in Connecticut (Table 6). On a regional scale, these sparrows preferred large marshes with a lower perimeter / area ratio. They also preferred sites that had other marshes within 1 km and greater amounts of panne cover (Table 14).

Seaside Sparrow

Seaside Sparrows occurred on 11 salt marshes (14%) in Connecticut. In New England, Seaside Sparrows were detected on 23 (10%) of the surveyed marshes. Based on univariate t-tests, Seaside Sparrows selected larger marshes that had more marsh habitat within 1 km, greater number of patches and lower road density (Table 15). When all variables were considered together in a logistic regression model, Seaside Sparrow preferred large marshes (Table 6). On a New England scale, their preference pattern was similar to Connecticut, but in addition, they preferred increased panne cover (Table 15).

Swamp Sparrow

Swamp Sparrows occurred on 6 (8%) of the surveyed marshes in Connecticut. Throughout New England, Swamp Sparrows occurred on 23 (10%) of the surveyed marshes. Based on univariate t-tests, Swamp Sparrows selected larger marshes (Table 16). In a logistic regression model, Swamp Sparrow preferred large marshes (Table 6). On a regional scale, this species was not affected by marsh size, but it did prefer marshes with smaller patches and fewer pannes (Table 16).

DISCUSSION

We have shown that salt marsh bird communities in New England are strongly influenced by landscape-scale parameters. For example, species richness was positively related to patch size and proximity to other patches at two different landscape scales. Similarly, in freshwater wetlands in Iowa, marsh size and isolation accounted for 75 % of the variation in the species richness and were important for marsh bird management and conservation (Brown and Dinsmore 1986). Patterns of avian species richness associated with landscape structure have also been demonstrated for forest and grassland birds (Fauth et al. 2000, Askins et al. 1990, Faaborg et al. 1995).

Our analysis revealed that the patterns of salt marsh bird occupancy were influenced by extrinsic and intrinsic factors, but that extrinsic factors in the landscape around salt marshes seemed to have a stronger effect at both community and species levels. Three of the four extrinsic variables (proportion of marsh within 1 km, isolation, road density) but none of the intrinsic variables were significantly correlated with obligate wetland bird species richness. On a regional scale, community level dynamics were more strongly influenced by the amount and quality of the habitat in the salt marsh complex rather than the specific habitat components within a given marsh. Marsh size positively influenced the abundance of six of the 12 species we analyzed. Benoit (1997) found the densities of four species (Virginia Rail, Willet, Salt Marsh Sharp-tailed Sparrow, Seaside Sparrow) to be significantly, positively correlated with marsh area, indicating that similar to patterns found in forest and grassland birds, some salt marsh birds require large habitat patches to support breeding populations. The patterns landscape structure had on obligate wetland bird species richness was consistent across the region. Both in Connecticut and throughout New England,

obligate wetland bird species richness was greater on large marshes situated within a marsh complex than on small, isolated marshes. Wetlands that are in close proximity to other wetlands have greater diversity of species that depend on wetland habitat for some portion of their life history requirements.

Incidence functions developed for the effects of extrinsic variables on three passerine species. All species were more likely to occur in marsh complexes and less likely to occur in marshes with high road density. Seaside Sparrows were more strongly influenced by area than the other passerines. Benoit (1997) also found that, regardless of the definition of marsh area, Seaside Sparrows were consistently area sensitive. Connecticut marshes clearly support the majority of Seaside Sparrows in New England; 50% of the marshes where they occurred were in Connecticut. Because Seaside Sparrows are a species of high conservation concern throughout their range, and especially in the Northeast, the 23 marshes where this species was detected should be given high conservation priority.

Salt Marsh Sharp-tailed Sparrows occurrence did not show the same strong positive relationship with marsh size as Seaside Sparrows. Sharp-tailed sparrows occurred on more than 50% of the marshes in Connecticut and throughout the extent of their New England range. Marsh Wrens were the only passerine species that had a positive relationship with *Phragmites* cover in a marsh. Marsh Wrens either maintain some level of relative density in marshes invaded by *Phragmites*, or actually colonize marshes after *Phragmites* has invaded.

Connecticut marshes were higher in *Phragmites* cover than marshes in the rest of the New England states. Marshes used by most species showed a lower percent cover in *Phragmites* than unused marshes and obligate wetland bird species richness was lower on marshes with high levels of *Phragmites* cover. Connecticut marshes also had greater road densities than the New England average, and were second only to Rhode Island. Increased disturbance created by more roads in close proximity to Connecticut marshes did not seem to limit obligate wetland bird species richness compared to the other New England states. Obligate wetland bird species richness did not differ between Connecticut and the rest of New England. This could be due to the inverse relationship between species richness and latitude. A few of the species detected in this survey were limited to the coasts of Connecticut and Rhode Island (i.e. Clapper Rail), which may confound and detection of the main effects for the human disturbance variables at the community level however, for the 12 species we analyzed 7 were less likely to occur on disturbed marshes with high road density or *Phragmites* cover.

This survey has established baseline information for salt marsh breeding birds in Connecticut, and throughout New England, and has created a framework from which long-term monitoring programs can be developed and implemented to detect trends in populations of these species.

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Table 1. Description of landscape variables and AOU species codes for the 12 species used in the analyses.

Variable / AOU Code	Definition / Species
Proportion marsh	Proportion of salt marsh habitat within 1 km of focal marsh (excluding area of focal marsh)
Isolation index	Sum of the area / distance ratio to all salt marsh patches within 1 km of focal marsh (low values = isolated marshes, high values = marsh complexes)
Marsh Size (ha)	Area of focal salt marsh site surveyed
Number of patches	Number of salt marsh patches within 1 km of focal marsh (number of near neighbors)
Mean perimeter-area ratio	Sum of each patches perimeter/area ratio comprising a focal marsh divided by the number of patches
Mean patch size	Average size of all patches within a site
Mean shape index	Shape complexity; sum of each patch perimeter divided by the square root of patch area
Road density	Total number of road intersections with a 500 m buffer line surrounding each focal marsh (controlled for area by dividing by buffer perimeter)
AMBI	American Bittern
CLRA	Clapper Rail
GLIB	Glossy Ibis
GREG	Great Egret
GRHE	Green Heron
GRYE	Greater Yellowlegs
MAWR	Marsh Wren
SESP	Seaside Sparrow
SNEG	Snowy Egret
SSTS	Salt Marsh Sharp-tailed Sparrow
SWSP	Swamp Sparrow
WILL	Willet

Table 2. Descriptive statistics for landscape and vegetation variables within each state and for all of New England.

Parameter	Connecticut (77)		Massachusetts (57)		Maine (67)		New Hampshire (4)		Rhode Island (35)		New England (240)	
	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>	<u>Mean</u>	<u>SD</u>
Proportion Marsh (%)	0.13	0.10	0.19	0.13	0.11	0.08	0.18	0.17	0.07	0.04	0.13	0.11
Isolation Index	0.21	0.36	1.21	1.94	0.37	0.90	0.89	1.39	0.11	0.13	0.48	1.15
Size (ha)	49.40	65.72	184.54	353.93	128.30	184.05	519.28	755.87	22.08	17.93	105.45	224.99
Number Patches	7.99	4.56	6.76	4.73	0.63	0.95	4.67	3.51	5.51	3.30	5.20	4.77
Perimeter / Area	305.12	205.13	559.85	346.42	691.78	174.34	392.76	192.32	6.06	2.51	431.56	324.61
Mean Patch Size	6.87	7.80	30.28	37.27	5.11	3.00	15.84	8.35	7.46	5.92	12.03	21.22
Shape Index	1.88	0.38	2.67	1.08	1.83	0.27	2.01	0.11	2.58	1.00	2.16	0.79
Road Density	0.90	0.81	0.33	0.32	0.26	0.31	0.16	0.11	1.13	1.76	0.61	0.91
<i>Spartina alterniflora</i>	22.14	30.16	32.99	36.18	13.10	23.27	26.57	6.87	56.20	39.25	27.23	34.06
<i>Distichlis spicata</i>	6.86	18.48	7.02	20.41	1.68	4.38	0.00	0.00	11.91	29.23	6.07	18.56
<i>Juncus gerardi</i>	2.82	11.17	0.11	0.76	10.38	16.71	0.00	0.00	3.68	15.88	4.37	12.98
<i>Spartina patens</i>	16.43	29.85	29.96	36.77	37.92	28.71	34.01	8.03	11.49	26.21	25.21	32.10
<i>Phragmites</i>	22.18	35.64	6.66	23.24	0.00	0.00	0.00	0.00	0.00	0.00	8.70	24.97
Panne	3.51	7.37	3.42	6.92	4.84	6.75	3.03	6.06	4.36	8.93	3.98	7.30

Table 3. Correlation between relative species abundance and independent variables on 77 salt marshes surveyed in Connecticut. Sign indicates direction of correlation and asterisks indicate level of significance (* = P<0.05, ** = P<0.01, *** = P<0.001, OBL = obligate wetland bird species richness, PAS = passerine species richness).

Parameter	Species													
	AMBI	CLRA	GLIB	GREG	GRHE	GRYE	MAWR	SESP	SNEG	SSTS	SWSP	WILL	OBL	PAS
Proportion Marsh	0.148	0.060	0.046	0.129	0.239*	0.024	0.444**	0.180	0.053	0.103	0.008	0.383**	0.344**	0.209
Isolation	0.136	0.020	0.035	0.198	0.110	-0.011	0.376**	0.273*	0.089	0.135	0.047	0.369**	0.340**	0.183
Size	0.248*	0.153	0.297**	0.121	0.122	0.001	0.221	0.582**	0.077	0.298**	0.317**	0.309**	0.192	0.049
Road Density	-0.138	-0.129	-0.207	-0.092	-0.131	-0.100	-0.242*	-0.248*	-0.081	-0.150	-0.166	-0.225*	-0.241*	-0.168
<i>Spartina patens</i>	0.053	-0.117	0.002	0.043	-0.091	-0.073	-0.144	0.014	0.098	0.130	0.085	0.165	0.032	-0.028
<i>Spartina alterniflora</i>	-0.160	0.345**	0.028	-0.042	0.128	0.057	-0.121	0.011	0.239*	0.084	-0.078	0.000	0.090	0.179
<i>Phragmites</i>	0.281*	-0.105	-0.020	-0.025	-0.031	0.036	0.414**	-0.069	-0.195	-0.342**	-0.107	-0.299**	0.005	0.096
Panne	-0.001	0.108	0.232*	0.057	-0.036	0.089	-0.177	0.166	0.051	0.186	-0.077	0.192	0.083	0.166

Table 4. Results of principle components analysis for all salt marshes surveyed in New England 1997-2000.

Parameter	Factor 1 (Size and Isolation)	Factor 2 (<i>S. patens</i> vs. <i>S.</i> <i>alterniflora</i>)	Factor 3 (<i>Phragmites</i> vs. Panne)
Proportion Marsh	0.858		
Isolation	0.824		
Size	0.674		
<i>S. patens</i>		0.891	
<i>S. alterniflora</i>		-0.769	
<i>Phragmites</i>			-0.849
Panne			-0.573
Variance	29 %	21 %	20 %
Explained			
Total: 70%			

Table 5. Characteristics of salt marshes occupied and unoccupied by American Bittern in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 58		Used n = 17			Unused n = 215		Used n = 20		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.11	0.10	0.17	0.10	0.03	0.13	0.11	0.16	0.10	0.22
Isolation Index	0.16	0.30	0.38	0.51	0.03	0.50	1.20	0.33	0.49	0.55
Size (ha)	33.40	42.88	103.98	96.59	0.00	106.63	233.59	92.81	93.06	0.79
Number Patches	7.62	4.50	9.41	4.70	0.16	4.88	4.66	8.70	4.77	0.00
Perimeter / Area	329.00	218.25	223.65	125.70	0.06	453.90	328.01	191.34	139.77	0.00
Mean Patch Size	5.93	7.83	10.45	6.86	0.03	12.30	22.12	9.71	6.75	0.60
Mean Shape Index	1.87	0.38	1.91	0.38	0.69	2.18	0.82	1.90	0.36	0.13
Road Density	1.01	0.85	0.51	0.49	0.02	0.60	0.91	0.65	0.91	0.83
<i>S. alterniflora</i>	23.11	31.77	16.13	19.07	0.39	27.27	34.59	24.21	28.67	0.70
<i>Distichlis spicata</i>	8.27	20.95	2.85	5.33	0.30	6.49	19.51	2.42	5.00	0.35
<i>Juncus gerardii</i>	3.30	12.65	1.53	4.35	0.57	4.75	13.61	1.30	4.03	0.26
<i>S. patens</i>	16.62	30.73	17.69	28.85	0.90	26.39	32.67	16.54	27.21	0.19
<i>Phragmites</i>	18.87	33.40	36.06	41.88	0.08	6.77	22.34	30.65	40.64	0.00
Panne	2.71	5.74	6.45	11.33	0.07	3.69	6.54	7.74	13.04	0.02

Table 6. Results of logistic regression models to predict species occurrence on 77 salt marshes in Connecticut. Signs indicate the direction of significant relationship between species occurrence and a parameter. Numbers in parenthesis indicate the overall classification rate for each model.

Parameter	Species											
	AMBI (84%)	CLRA (76%)	GLIB (84%)	GREG (64%)	GRHE (76%)	GRYE (68%)	MAWR (73%)	SESP (96%)	SNEG (80%)	SSTS (61%)	SWSP (93%)	WILL (79%)
Proportion Marsh									+			
Isolation												
Number Patches												
Size	+		+					+			+	
Road Density												
<i>Spartina patens</i>												
<i>Spartina alterniflora</i>												
<i>Phragmites</i>	+											+
Panne	+		+									

Table 7. Characteristics of salt marshes occupied and unoccupied by Great Egret in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 40		Used n = 35			Unused n = 133		Used n = 102		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.10	0.08	0.15	0.12	0.06	0.11	0.08	0.16	0.13	0.00
Isolation Index	0.14	0.20	0.29	0.48	0.09	0.34	0.96	0.66	1.35	0.03
Size (ha)	27.41	36.02	74.53	81.81	0.00	70.31	100.25	151.27	316.86	0.01
Number Patches	7.48	4.15	8.66	5.01	0.27	3.79	4.16	7.05	4.93	0.00
Perimeter / Area	286.67	202.79	326.22	208.70	0.41	495.91	303.77	347.64	333.11	0.00
Mean Patch Size	6.86	8.78	7.06	6.66	0.91	9.72	17.50	15.15	25.08	0.05
Mean Shape Index	1.85	0.39	1.92	0.38	0.44	2.03	0.63	2.33	0.94	0.00
Road Density	1.07	0.96	0.70	0.56	0.05	0.63	0.99	0.58	0.81	0.68
<i>S. alterniflora</i>	18.35	29.49	25.16	29.31	0.32	21.25	31.32	34.51	36.18	0.00
<i>Distichlis spicata</i>	6.38	16.04	7.79	21.56	0.75	5.05	16.19	7.57	21.63	0.31
<i>Juncus gerardii</i>	4.25	14.55	1.35	5.57	0.27	5.58	14.32	3.00	11.22	0.13
<i>S. patens</i>	15.00	29.47	18.99	31.15	0.57	28.63	33.66	21.55	30.15	0.10
<i>Phragmites</i>	23.30	36.81	22.16	35.41	0.89	7.68	23.81	10.25	26.96	0.44
Panne	2.03	5.49	5.31	8.98	0.06	2.76	5.15	5.71	9.27	0.00

Table 8. Characteristics of salt marshes occupied and unoccupied by Snowy Egret in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 32		Used n = 43			Unused n = 110		Used n = 125		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.09	0.07	0.15	0.12	0.00	0.10	0.08	0.15	0.12	0.00
Isolation Index	0.18	0.37	0.23	0.36	0.54	0.37	1.04	0.58	1.24	0.17
Size (ha)	25.44	35.14	67.23	77.04	0.01	56.35	72.33	148.66	294.80	0.00
Number Patches	7.22	4.27	8.63	4.75	0.19	4.21	4.42	6.08	4.93	0.00
Perimeter / Area	253.74	193.06	343.36	207.66	0.06	470.29	323.19	397.47	323.30	0.09
Mean Patch Size	6.89	7.43	7.01	8.17	0.95	10.91	19.73	13.10	22.53	0.43
Mean Shape Index	1.87	0.37	1.89	0.39	0.83	2.10	0.68	2.21	0.87	0.30
Road Density	1.15	1.00	0.72	0.59	0.02	0.63	0.78	0.59	1.02	0.73
<i>S. alterniflora</i>	13.44	26.90	27.54	30.05	0.04	21.57	33.22	31.78	34.24	0.02
<i>Distichlis spicata</i>	5.55	17.33	8.15	19.78	0.56	4.67	17.37	7.44	19.85	0.26
<i>Juncus gerardii</i>	1.78	5.67	3.73	14.14	0.46	4.44	12.23	4.48	13.87	0.98
<i>S. patens</i>	13.77	29.94	19.17	30.41	0.45	29.22	35.92	22.33	28.53	0.10
<i>Phragmites</i>	33.34	42.10	14.90	28.58	0.03	12.15	30.07	5.85	19.61	0.06
Panne	1.51	3.63	5.08	9.10	0.04	2.17	3.40	5.68	9.29	0.00

Table 9. Characteristics of salt marshes occupied and unoccupied by Green Heron in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 53		Used n = 22			Unused n = 172		Used n = 63		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.11	0.08	0.16	0.13	0.03	0.12	0.09	0.15	0.14	0.05
Isolation Index	0.17	0.32	0.32	0.44	0.11	0.43	1.04	0.63	1.42	0.24
Size (ha)	39.39	55.99	73.50	81.20	0.04	73.20	95.64	193.50	393.78	0.00
Number Patches	7.34	4.03	9.68	5.44	0.04	4.77	4.70	6.40	4.83	0.02
Perimeter / Area	295.50	197.34	328.31	225.96	0.53	456.06	323.77	364.66	319.93	0.06
Mean Patch Size	5.50	4.79	10.46	11.83	0.01	10.69	20.37	15.85	23.23	0.10
Mean Shape Index	1.85	0.36	1.95	0.44	0.31	2.12	0.77	2.26	0.83	0.25
Road Density	0.99	0.87	0.69	0.61	0.14	0.57	0.78	0.70	1.20	0.34
<i>S. alterniflora</i>	19.53	29.10	26.34	30.27	0.36	22.65	32.04	38.89	36.83	0.00
<i>Distichlis spicata</i>	6.63	18.40	8.02	19.81	0.77	6.52	19.56	5.12	16.43	0.61
<i>Juncus gerardii</i>	1.88	5.40	5.36	19.22	0.23	4.62	11.77	4.03	16.29	0.76
<i>S. patens</i>	18.37	31.70	13.23	26.27	0.51	27.05	32.60	21.49	31.40	0.24
<i>Phragmites</i>	23.14	36.94	21.87	34.18	0.89	9.22	26.17	7.64	22.50	0.67
Panne	3.88	8.45	2.80	4.32	0.57	3.84	7.26	4.58	7.66	0.50

Table 10. Characteristics of salt marshes occupied and unoccupied by Glossy Ibis in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 63		Used n = 12			Unused n = 196		Used n = 39		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.12	0.10	0.16	0.09	0.27	0.12	0.10	0.18	0.14	0.00
Isolation Index	0.19	0.33	0.32	0.52	0.24	0.40	1.02	0.89	1.64	0.02
Size (ha)	41.09	56.71	93.01	91.95	0.01	78.14	135.46	242.69	440.88	0.00
Number Patches	7.78	4.47	9.33	5.12	0.28	4.93	4.68	6.59	5.12	0.05
Perimeter / Area	290.71	188.63	380.83	274.04	0.16	441.64	321.16	380.86	341.18	0.29
Mean Patch Size	6.85	8.08	7.52	6.45	0.79	11.52	21.81	14.88	18.14	0.37
Mean Shape Index	1.91	0.37	1.72	0.43	0.12	2.16	0.77	2.18	0.90	0.89
Road Density	0.98	0.84	0.47	0.40	0.04	0.67	0.98	0.31	0.32	0.03
<i>S. alterniflora</i>	20.17	29.75	28.64	27.66	0.36	25.10	34.04	36.57	33.11	0.05
<i>Distichlis spicata</i>	5.96	17.24	12.70	25.19	0.25	5.76	18.43	8.08	20.40	0.48
<i>Juncus gerardii</i>	2.93	11.81	2.76	8.62	0.96	4.94	14.04	2.04	6.12	0.21
<i>S. patens</i>	17.45	31.00	13.78	26.00	0.70	26.39	33.45	21.36	25.77	0.38
<i>Phragmites</i>	24.80	37.40	12.08	25.53	0.26	9.81	26.70	3.72	14.85	0.17
Panne	2.55	6.46	8.85	10.13	0.01	2.80	5.57	10.26	11.27	0.00

Table 11. Characteristics of salt marshes occupied and unoccupied by Clapper Rail in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 51		Used n = 24			Unused n = 209		Used n = 26		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.11	0.11	0.15	0.10	0.20	0.13	0.11	0.14	0.10	0.51
Isolation Index	0.16	0.25	0.33	0.52	0.06	0.50	1.21	0.31	0.50	0.42
Size (ha)	29.64	39.18	91.37	88.62	0.00	107.66	236.67	87.69	86.02	0.67
Number Patches	8.08	4.57	7.92	4.68	0.89	4.92	4.72	7.50	4.73	0.01
Perimeter / Area	293.15	219.65	330.56	171.80	0.47	440.38	336.25	360.58	199.20	0.24
Mean Patch Size	6.87	8.68	7.14	5.69	0.89	12.65	22.38	7.48	5.81	0.24
Mean Shape Index	1.88	0.38	1.88	0.39	0.96	2.19	0.82	1.89	0.37	0.06
Road Density	1.04	0.88	0.60	0.53	0.03	0.61	0.95	0.60	0.51	0.96
<i>S. alterniflora</i>	15.77	27.45	33.75	30.24	0.01	26.13	34.61	34.03	29.18	0.27
<i>Distichlis spicata</i>	8.63	21.98	3.66	7.55	0.29	6.45	19.70	3.71	7.24	0.48
<i>Juncus gerardii</i>	2.83	12.78	3.05	7.53	0.94	4.66	13.65	2.82	7.27	0.50
<i>S. patens</i>	19.63	33.80	10.98	19.58	0.25	27.33	33.20	11.27	19.04	0.02
<i>Phragmites</i>	24.16	37.40	19.81	33.14	0.63	7.62	24.02	18.28	32.24	0.04
Panne	3.27	8.44	4.18	4.85	0.63	4.04	7.63	3.99	4.70	0.97

Table 12. Characteristics of salt marshes occupied and unoccupied by Willet in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 46		Used n = 29			Unused n = 145		Used n = 90		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.10	0.08	0.17	0.13	0.01	0.10	0.08	0.17	0.13	0.00
Isolation Index	0.13	0.19	0.33	0.52	0.02	0.27	0.78	0.82	1.52	0.00
Size (ha)	30.44	39.51	79.47	85.89	0.00	54.89	78.40	186.91	335.07	0.00
Number Patches	7.17	4.18	9.38	4.92	0.04	4.46	4.43	6.40	5.10	0.00
Perimeter / Area	282.96	200.95	340.28	210.29	0.24	426.90	346.62	439.06	287.33	0.78
Mean Patch Size	6.93	8.89	7.00	5.84	0.97	8.03	10.68	18.59	30.54	0.00
Mean Shape Index	1.87	0.38	1.90	0.39	0.74	2.10	0.68	2.25	0.93	0.16
Road Density	1.07	0.90	0.63	0.55	0.02	0.77	1.08	0.35	0.42	0.00
<i>S. alterniflora</i>	20.98	31.69	22.39	25.89	0.84	27.74	36.75	25.82	29.44	0.67
<i>Distichlis spicata</i>	7.55	19.55	6.22	17.57	0.77	6.32	19.87	5.86	16.87	0.86
<i>Juncus gerardii</i>	3.01	13.38	2.71	7.10	0.91	5.31	15.32	3.08	8.27	0.20
<i>S. patens</i>	12.30	27.86	24.11	32.60	0.10	22.94	32.80	29.77	31.22	0.12
<i>Phragmites</i>	30.37	40.35	10.71	23.44	0.02	11.50	28.96	4.45	16.77	0.04
Panne	2.39	5.49	5.42	9.63	0.09	2.56	4.92	6.42	9.70	0.00

Table 13. Characteristics of salt marshes occupied and unoccupied by Marsh Wren in Connecticut and throughout New England.

Parameter	Connecticut					New England				
	Unused n = 37		Used n = 38		P	Unused n = 174		Used n = 61		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.09	0.06	0.16	0.12	0.00	0.12	0.10	0.16	0.12	0.00
Isolation Index	0.08	0.09	0.34	0.47	0.00	0.42	1.03	0.67	1.44	0.15
Size (ha)	33.68	57.98	64.71	69.85	0.04	83.14	146.68	169.09	360.31	0.01
Number Patches	8.19	4.71	7.87	4.50	0.76	4.91	4.77	6.05	4.74	0.11
Perimeter / Area	375.07	229.44	237.02	152.60	0.00	454.31	342.46	366.64	258.83	0.07
Mean Patch Size	4.13	3.29	9.71	9.78	0.00	11.90	23.06	12.58	15.06	0.83
Mean Shape Index	1.89	0.29	1.87	0.46	0.82	2.24	0.86	1.94	0.51	0.01
Road Density	1.10	0.96	0.70	0.57	0.03	0.63	1.00	0.56	0.61	0.61
<i>S. alterniflora</i>	20.48	30.84	22.55	28.32	0.76	28.35	35.71	23.17	28.87	0.31
<i>Distichlis spicata</i>	11.70	25.51	2.50	4.78	0.03	6.55	19.55	4.98	16.31	0.57
<i>Juncus gerardii</i>	0.90	2.77	4.84	15.51	0.13	4.08	11.60	5.53	16.71	0.46
<i>S. patens</i>	21.12	34.73	12.72	24.61	0.23	29.10	34.18	15.44	23.72	0.00
<i>Phragmites</i>	12.63	27.94	32.63	40.24	0.01	4.24	17.86	21.80	36.39	0.00
Panne	2.74	4.45	4.36	9.52	0.35	3.74	6.66	4.87	9.08	0.30

Table 14. Characteristics of salt marshes occupied and unoccupied by Salt Marsh Sharp-tailed Sparrow in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 31		Used n = 44			Unused n = 104		Used n = 131		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.11	0.09	0.13	0.11	0.46	0.11	0.08	0.14	0.12	0.02
Isolation Index	0.18	0.30	0.23	0.41	0.55	0.30	0.87	0.63	1.32	0.03
Size (ha)	28.82	37.37	63.90	77.05	0.02	63.06	88.08	139.11	287.04	0.01
Number Patches	7.23	3.38	8.59	5.22	0.21	4.19	4.32	6.01	4.99	0.00
Perimeter / Area	321.45	247.12	293.62	171.70	0.57	510.71	323.00	368.72	313.07	0.00
Mean Patch Size	6.75	7.06	7.11	8.37	0.85	8.68	10.17	14.77	26.73	0.03
Mean Shape Index	1.86	0.33	1.90	0.42	0.69	2.06	0.57	2.23	0.92	0.10
Road Density	1.01	0.88	0.82	0.76	0.31	0.65	1.03	0.58	0.81	0.57
<i>S. alterniflora</i>	20.72	32.48	22.09	27.42	0.84	23.70	33.70	29.63	34.29	0.19
<i>Distichlis spicata</i>	6.63	17.51	7.33	19.68	0.87	4.33	15.75	7.59	20.77	0.19
<i>Juncus gerardii</i>	1.48	3.12	3.90	14.52	0.36	4.41	12.42	4.50	13.66	0.96
<i>S. patens</i>	8.49	22.29	22.76	33.61	0.04	27.51	34.63	24.01	30.39	0.41
<i>Phragmites</i>	34.34	42.17	14.61	28.56	0.02	11.97	29.76	6.28	20.66	0.09
Panne	1.95	4.25	4.69	8.95	0.12	2.56	4.14	5.21	8.99	0.01

Table 15. Characteristics of salt marshes occupied and unoccupied by Seaside Sparrow in Connecticut and throughout New England.

Parameter	Connecticut					New England				
	Unused n = 64		Used n = 11		P	Unused n = 212		Used n = 23		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.11	0.10	0.19	0.10	0.02	0.12	0.10	0.18	0.11	0.01
Isolation Index	0.15	0.23	0.58	0.69	0.00	0.44	1.09	0.90	1.59	0.07
Size (ha)	31.54	36.07	153.28	99.26	0.00	81.55	138.83	325.74	545.28	0.00
Number Patches	7.47	4.37	11.27	4.58	0.01	4.82	4.58	8.74	5.25	0.00
Perimeter / Area	309.11	214.97	281.95	139.90	0.69	435.47	321.85	395.51	354.61	0.58
Mean Patch Size	6.25	7.44	11.07	8.98	0.06	11.45	21.09	17.85	22.27	0.17
Mean Shape Index	1.86	0.37	1.99	0.43	0.29	2.14	0.78	2.31	0.91	0.32
Road Density	1.01	0.83	0.27	0.21	0.00	0.64	0.95	0.26	0.28	0.06
<i>S. alterniflora</i>	20.80	30.78	25.74	20.23	0.61	27.26	34.96	24.68	25.01	0.73
<i>Distichlis spicata</i>	7.62	20.04	3.63	6.37	0.52	6.01	18.71	7.35	19.48	0.75
<i>Juncus gerardii</i>	2.93	11.71	2.73	9.05	0.96	4.74	13.61	1.85	6.40	0.32
<i>S. patens</i>	16.16	30.86	20.99	26.35	0.63	25.36	32.37	27.34	32.41	0.78
<i>Phragmites</i>	24.43	37.22	13.09	26.49	0.34	8.65	25.19	10.17	25.78	0.78
Panne	3.00	6.62	6.83	11.05	0.12	3.58	6.69	8.27	11.23	0.00

Table 16. Characteristics of salt marshes occupied and unoccupied by Swamp Sparrow in Connecticut and throughout New England.

Parameter	Connecticut				P	New England				
	Unused n = 69		Used n = 6			Unused n = 212		Used n = 23		P
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Proportion Marsh (within 1km)	0.12	0.10	0.14	0.09	0.68	0.13	0.11	0.13	0.09	0.82
Isolation Index	0.20	0.37	0.32	0.36	0.44	0.50	1.19	0.28	0.65	0.59
Size (ha)	41.16	57.21	144.17	87.72	0.00	93.37	217.57	216.77	264.65	0.69
Number Patches	8.10	4.60	7.17	4.62	0.63	5.44	4.81	3.00	3.92	0.39
Perimeter / Area	306.77	210.46	286.16	141.22	0.82	417.91	331.86	557.30	214.83	0.87
Mean Patch Size	6.85	8.02	8.18	5.03	0.69	12.43	22.27	8.81	5.87	0.01
Mean Shape Index	1.87	0.39	1.97	0.27	0.55	2.18	0.82	1.96	0.36	0.02
Road Density	0.95	0.83	0.34	0.28	0.08	0.64	0.95	0.28	0.32	0.44
<i>S. alterniflora</i>	21.94	30.36	16.81	15.27	0.69	27.61	34.84	21.45	26.02	0.21
<i>Distichlis spicata</i>	6.64	19.21	11.59	11.39	0.54	6.30	19.58	4.66	7.67	0.41
<i>Juncus gerardii</i>	3.11	11.77	0.48	1.17	0.59	4.69	13.69	2.31	4.75	0.79
<i>S. patens</i>	16.05	30.03	26.23	32.42	0.43	25.74	33.00	23.82	25.60	0.07
<i>Phragmites</i>	24.02	37.07	8.38	11.77	0.31	9.09	25.76	6.10	19.49	0.41
Panne	3.68	7.72	2.20	3.18	0.64	4.06	7.61	3.81	4.48	0.05

Figure 1. Map of surveyed salt marshes in New England, 1997-2000.

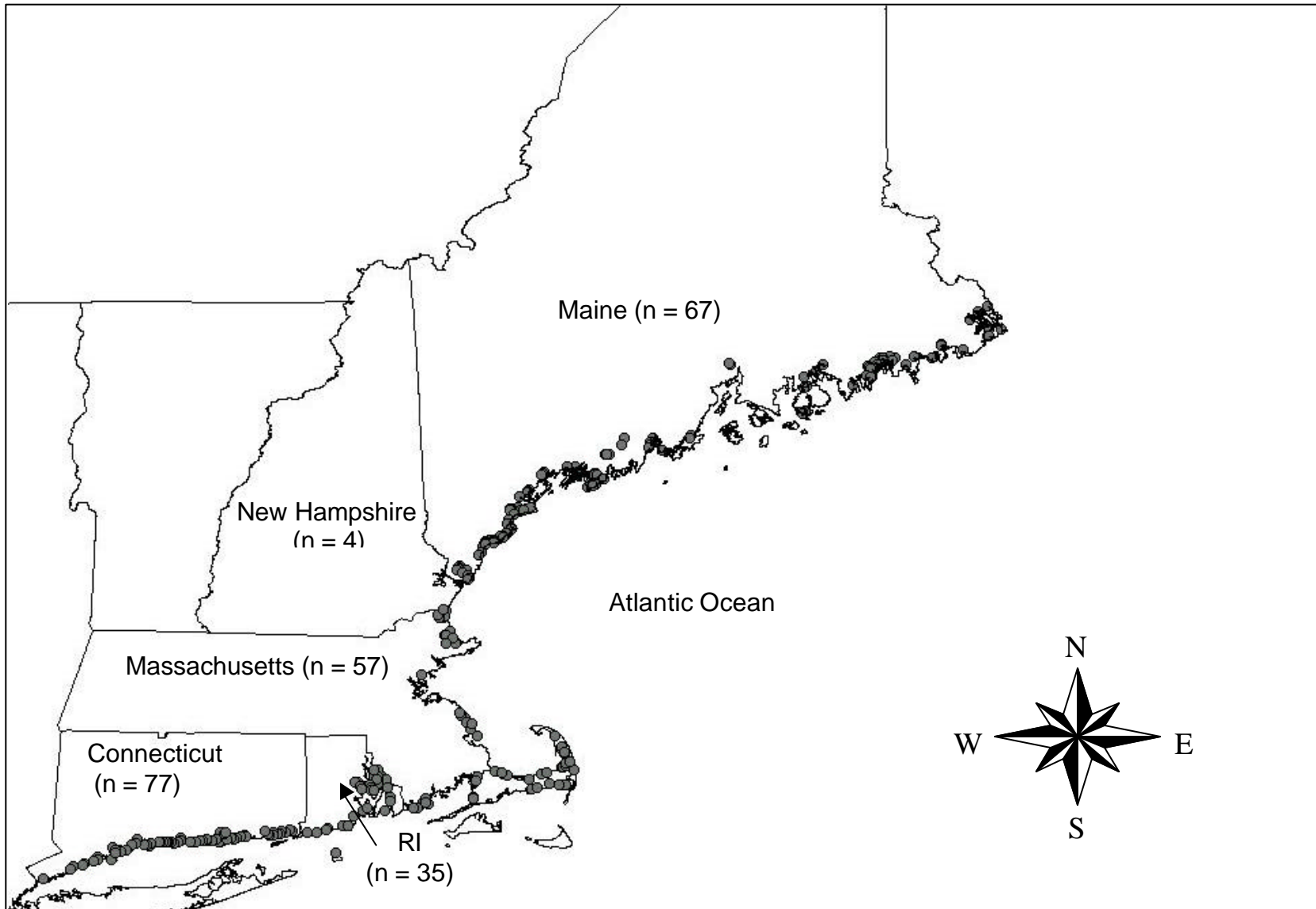


Figure 2. Patterns in obligate wetland bird species richness and marsh size (A), isolation (B), and proportion marsh within 1 km (C). Closed circles = RI, MA, NH and ME, open squares = CT.

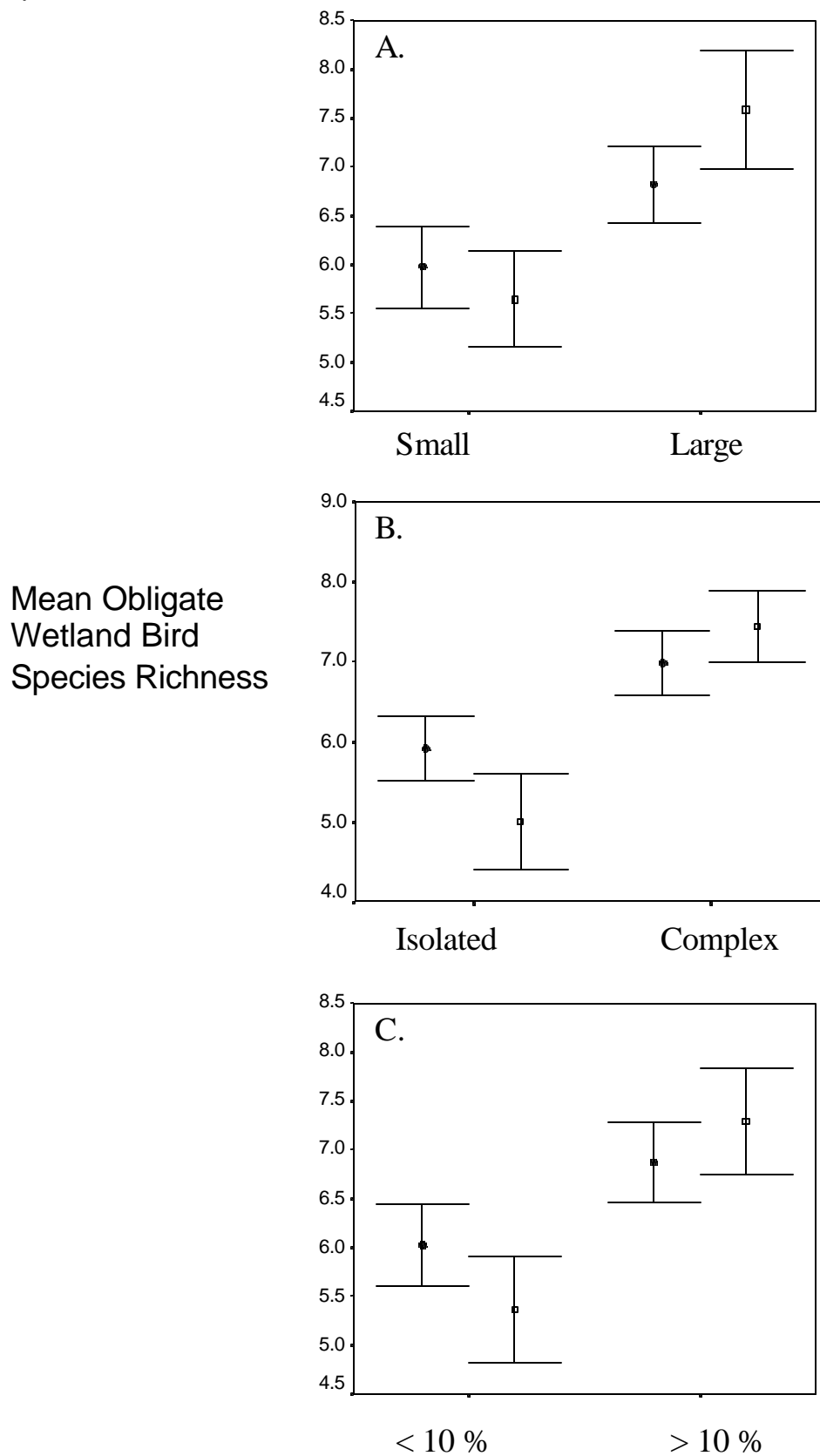


Figure 4. Patterns of species occurrence for selected wading birds based on principle components analysis for all 240 surveyed salt marshes in New England.

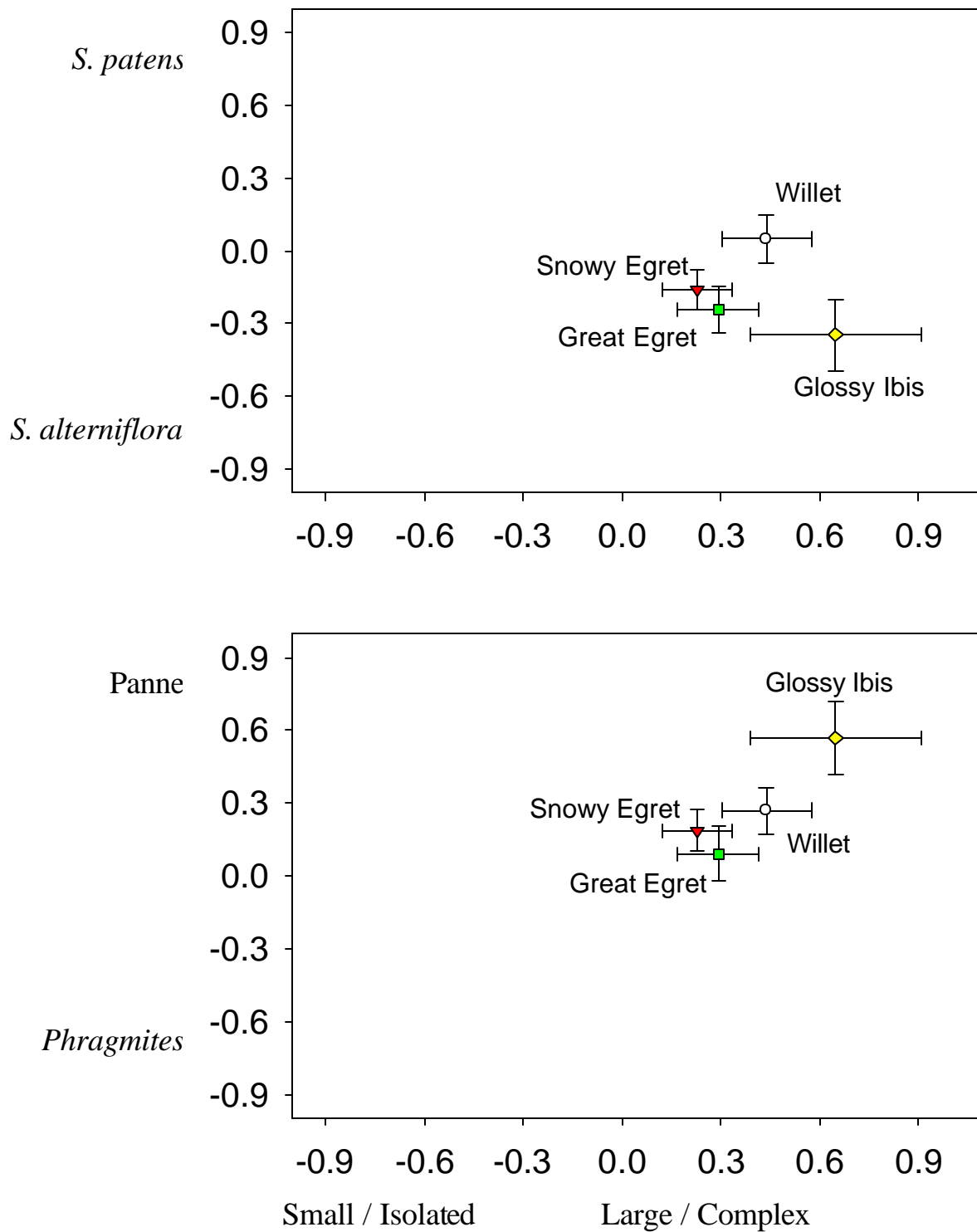


Figure 3. Patterns of species occurrence for selected passerine birds based on principle components analysis for all 240 surveyed salt marshes in New England

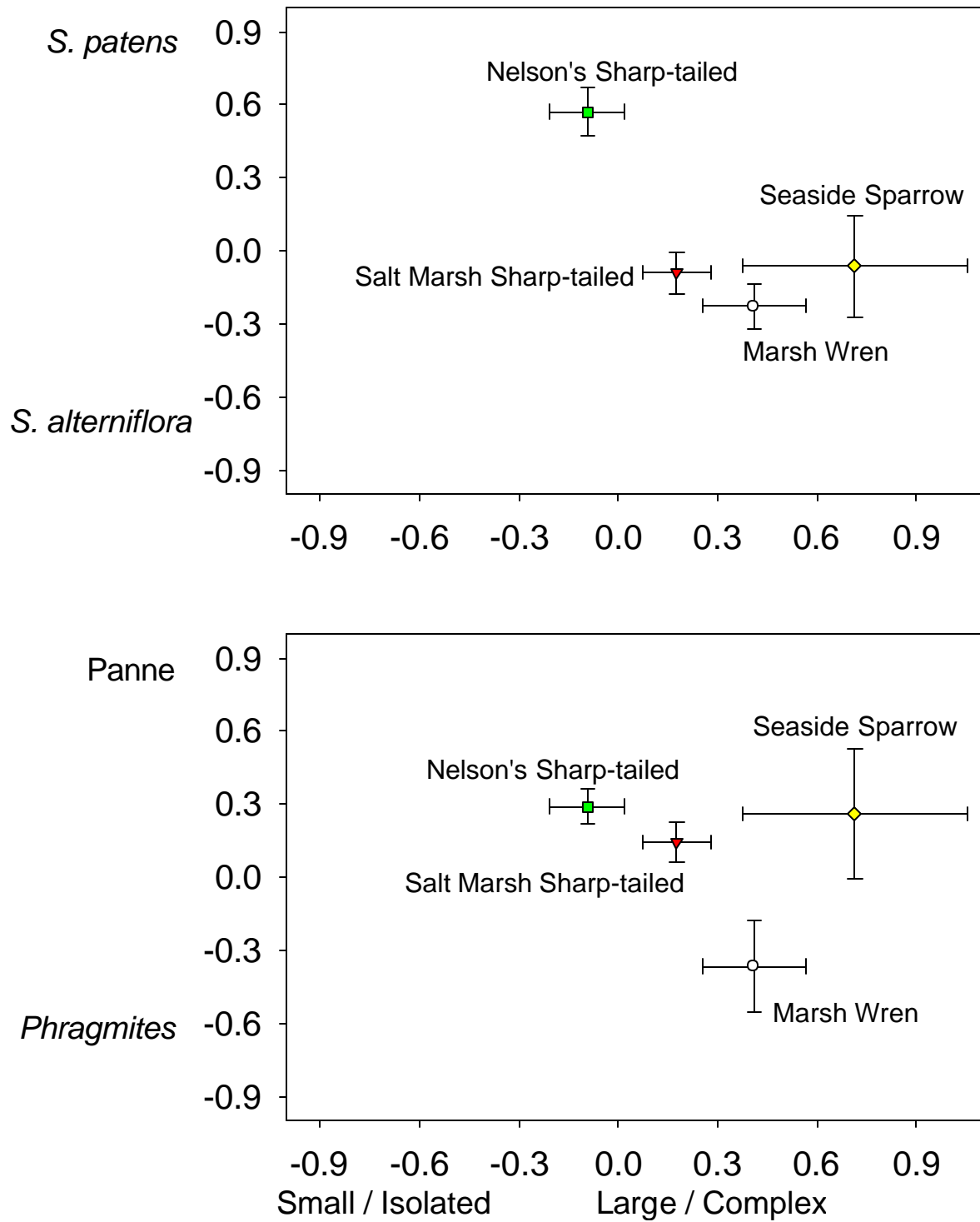


Figure 5. Incidence functions in relation to salt marsh size for (A) Salt Marsh Sharp-tailed Sparrow, (B) Seaside Sparrow, and (C) Marsh Wren throughout New England.

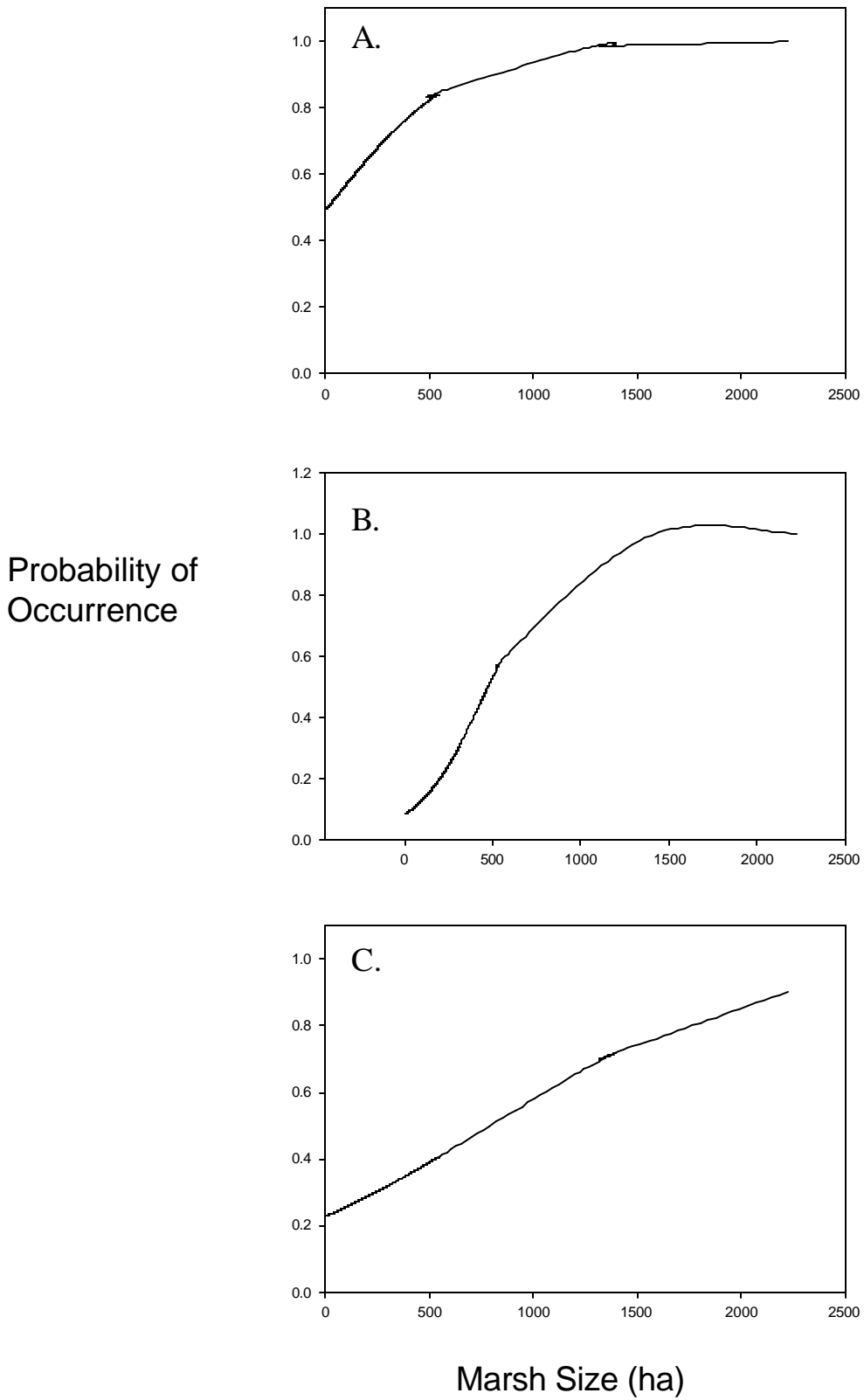


Figure 6. Incidence functions in relation to salt marsh isolation for (A) Salt Marsh Sharp-tailed Sparrow, (B) Seaside Sparrow, and (C) Marsh Wren throughout New England.

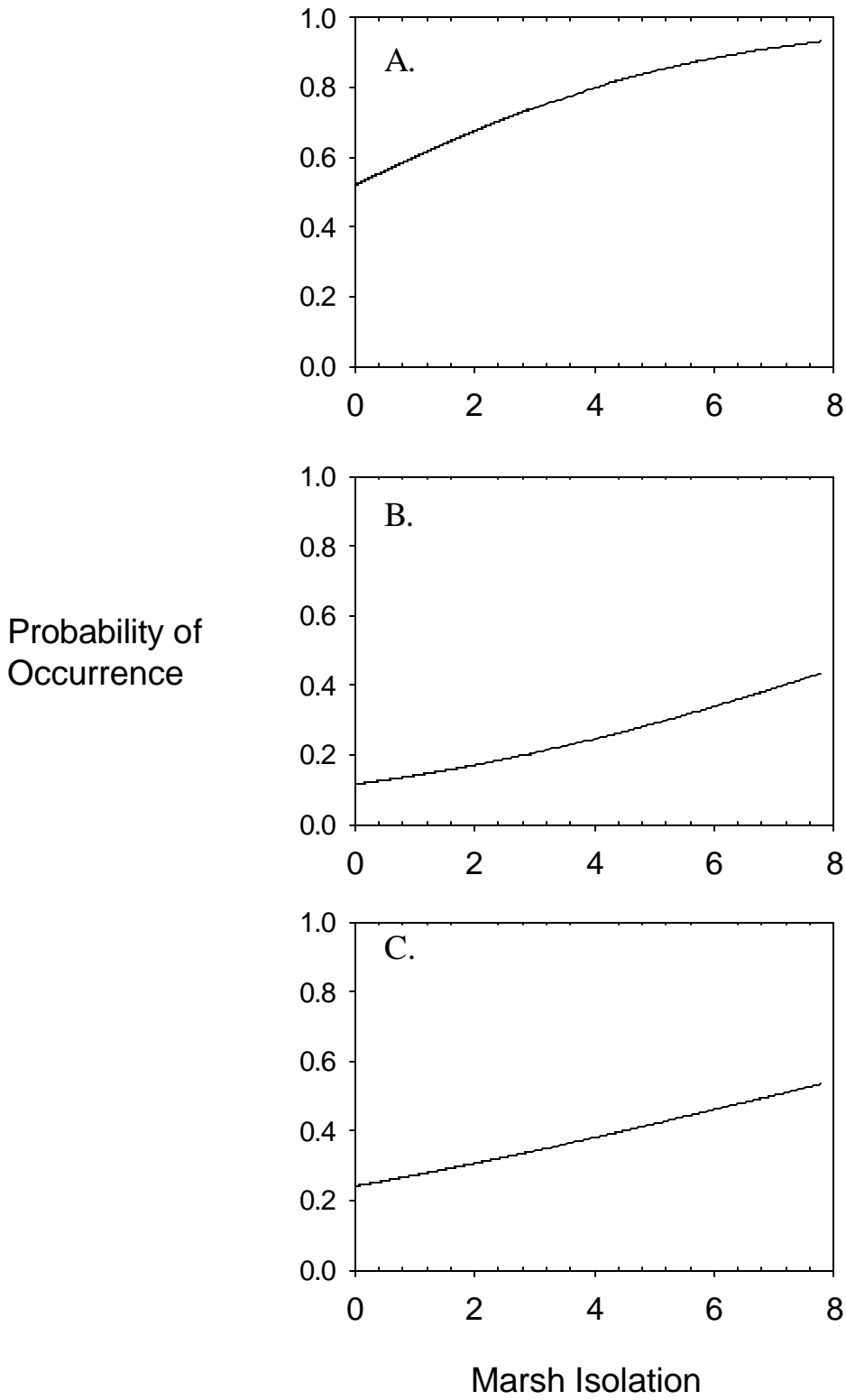


Figure 7. Incidence functions in relation to road density for (A) Salt Marsh Sharp-tailed Sparrow, (B) Seaside Sparrow, and (C) Marsh Wren throughout New England.

