Characterizing critical habitat for saltmarsh sparrows (*Ammospiza caudacuta*) and other vulnerable tidal marsh birds in New Hampshire

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2022-12-06

Introduction

Salt marshes are among the world's most productive ecosystems, providing coastline protection, water filtration, carbon storage, and wildlife habitat (Barbier et al. 2011, Gedan et al. 2009; NHDES 2016). While New England has a history of salt marsh degradation and loss, accelerated rates of sea-level rise present an unprecedented threat to marsh persistence and associated ecosystem services (Gedan et al. 2011; Crosby et al. 2016; FitzGerald et al. 2021). The effects of accelerated sea-level rise are already being observed in New England (FitzGerald et al. 2021; Langston et al. 2020). Marsh composition and structure is changing, as the rate of high marsh accretion fails to keep pace with sea-level rise, converting high marsh (infrequently flooded salt marsh) to low marsh systems (salt marsh flooded at every tide) (Payne et al. 2019; Valiela et al. 2018; Raposa et al. 2017).

At the same time, avian tidal marsh specialists are declining, with negative trends seen in the community as a whole (Correll et al. 2016; Klingbeil et al. 2021). Within this community the saltmarsh sparrow (*Ammospiza caudacuta*) has been identified as a focal species (Correll et al. 2016; Hartley and Weldon 2020). It is listed as IUCN endangered and is a species of conservation priority for NH, the US Fish and Wildlife Service, and the Atlantic Coast Joint Venture (BirdLife International 2020; NHFG 2015; USFWS 2020; Hartley and Weldon 2020). With range wide population declines of 9% a year, saltmarsh sparrow extinction is projected by 2060, with a loss of habitat for 85% of its current population by 2050 (Corell et al. 2016; Field et al 2017; Klingbeil et al. 2021). Saltmarsh sparrows are tidal marsh obligates making them particularly vulnerable to sea-level rise and loss of habitat (Bayard and Elphick 2011; Gjerdrum et al. 2005). Saltmarsh sparrows nest in high marsh vegetation, timing their reproduction with the tidal cycle to avoid nest flooding at high marsh inundation, which occurs ~ every 28 days (Shriver et al. 2007). Their reproductive cycle (23-26 days) once fit within the tidal cycle but is now threatened by sea-level rise and high marsh decline as the window for breeding success closes (Field et al. 2017; Benvenuti et al. 2018). Population declines for other species that nest in the high marsh, including willets (*Tringa semipalmata*), are predicted with sea-level rise as well (Klingbeil et al. 2021).

In New Hampshire coastal managers are exploring ways to prioritize habitat conservation for vulnerable tidal marsh birds and site salt marsh restoration activities. Tools that predict saltmarsh sparrow habitat and/or saltmarsh resiliency include Great Bay National Estuarine Research Reserve's (GBNEER) Habitat Prioritization Tool, the Atlantic Coast Joint Venture's Habitat Prioritizaion Tool, and GBNERR's Marsh Mapping Tool. These tools are being used by NH managers for planning, yet have not been ground truthed with tidal marsh bird data and may not include all of the features/factors necessary to predict their habitat. Understanding the distribution of tidal marsh birds and their habitat associations is key to future sea-level rise planning for wildlife habitat conservation in NH and a recognized research need of NH Fish and Game (NHFG 2015b). The overarching goal of this project is to assess the factors that predict the resilience of NH salt marshes for saltmarsh sparrows and other tidal marsh birds. The project will investigate the research question: How well do existing tools, which rank marshes based on habitat availability and likelihood of resilience to sea-level rise, and additional habitat-level factors predict saltmarsh sparrow occupancy, relative abundance, and productivity in New Hampshire? In investigating this question, the following objectives will be addressed:

1. Assess the current occupancy and relative abundance of tidal marsh birds across NH salt marshes and assess saltmarsh sparrow reproduction at a subset of occupied NH marshes.

2. Identify if and how a marsh's ranking by the GBNERR's Marsh Prioritization Tool, GBNERR's Habitat Prioritization Tool, and/or ACJV's Habitat Prioritization Tool predict saltmarsh sparrow occupancy, relative abundance, and reproduction.

3. Document current marsh condition through vegetative surveys and other fine-scale habitat metrics, and determine their relationship with saltmarsh sparrow occupancy, relative abundance, and reproduction.

For this report and portion of the project, I intend to focus on creating summary statistics from the results of the 2022 field season which will begin to address Objective 1 above. The data collected in this field season is described below in the *Methods*, but briefly includes point counts, vegetation surveys, and rapid demographic surveys. I will also prepare to identify relationships between saltmarsh sparrow relative abundance and habitat metrics from our field data, starting to address Objective 2 above. These steps will help build my R skillset, while working with some of my Masters dataset. The objectives for this report are as follows:

1. Clean the datasets for effective use in R.

2. Create summary statistics for the 2022 field season to provide managers with an assessment of current tidal marsh bird occupancy and relative abundance.

3. Create maps to reflect site specific totals from the point count, vegetation, and rapid demographic surveys in the 2022 field season.

4. Determine the distribution of vegetative cover classes across the point count locations. If the sample sizes (number of survey points in each cover class) are relatively equal, I will begin identifying relationships between the relative abundance of sharp-tailed sparrows and the vegetative cover classes. If the sample sizes are unequal, however, analyses will not be run and I will use this assignment as an opportunity to learn about poisson regressions and reflect on future study design to address my research's overall objectives.

Methods

Field Data Collection

The full suite of tidal marsh bird data to be used in this portion of the research includes avian point counts and vegetation data collected from surveys at 88 locations throughout New Hampshire in 2022. Survey points included historical SHARP survey points and new ones added for greater areal coverage in Rye, Hampton, and Seabrook, NH. New points were identified in collaboration with GBNERR, NHFG, and NH Audubon partners. SHARP (the Saltmarsh Habitat and Avian Research Program) is a collaboration of government, academic, and private entities supporting 'the science behind tidal marsh bird conservation' throughout the saltmarsh sparrow's range (www.tidalmarshbirds.org). For all of our point count, vegetation, and rapid demographic surveys we followed established SHARP protocols (see www.tidalmarshbirds.org for greater detail).

Point counts consisted of a passive five-minute bird count followed by a five-minute broadcast series with playback calls for Black Rail, Least Bittern, Sora, Virginia Rail, and Clapper Rail to ensure more secretive birds were counted. The second point count survey for each point was spaced at least 10 days apart. We conducted surveys between sunrise and 11am, while avoiding weather that could influence detection, including rain, fog, and heavy wind. Each species observation was recorded according to the distance from the point center, in the following distance bands: within 50 meters, 50-100 meters, and over 100 meters. Due to high hybridization between Nelson's and saltmarsh sparrows in NH for the purposes of data analysis, observations of these species will be grouped together as sharp-tailed sparrows (Hodgman et al. 2002).

Vegetation surveys collected information on habitat features including percent cover of community habitat class and the percent coverage by species of vegetation covering more than 5% in a given 50 meter radius circle plot. Cover classes were divided into the following percent ranges: 0%, <1%, 1-5%, 6-10%, 11-25%, 26-50%, 51-75%, and 76-100%. Cover class categories included: low marsh, high marsh, salt marsh or brackish terrestrial boarder, invasive species, panes/pools/creeks, open water, upland, and wrack. All vegetation surveys were conducted during the second point count survey at each survey point.

Rapid demographic surveys were also conducted at nine locations twice throughout the breeding season in the summer of 2022. While no analysis of these data will be conducted for this report, a map of the survey locations with associated data for each site will be produced. Briefly, a rapid demographic survey consists of five individual survey techniques: 1). point count (see above), 2). vegetation survey (as above and a 100 meter vegetation transect), 3). transect walk, recording all birds seen, 4). systematic mist netting at the survey point (and targeted netting as time allows) to capture all sharp-tailed sparrow juveniles and adults, and 5). recording of any and all breeding behavior(s) observed and any nests found. Greater detail is available at www.tidalmarshbirds.com.

Analysis

Data analysis was conducted in R. Maps were created using the package *leaflet* to show the point count locations and rapid demographic study locations, with accompanying data for each. Summary statistics were created for the 2022 field season using the point count and vegeation data. This included the total number of occurrences across the two survey visits and distance bands for the following species or bird groups: Virginia rail, purple martin, glossy ibis, marsh wren, yellowlegs, great blue heron, osprey, Eastern willet, great egret, snowy egret, and sharp-tailed sparrows (including Neslson's, saltmarsh, and hybrid sparrows). These birds of focus were selected based on habitat requirements, conservation status, and/or specific interest from project stakeholders including New Hampshire Fish and Game and New Hampshire Audubon (NHFG 2015; ACJV 2019). Nelson's sparrow, saltmarsh sparrow, Eastern willet, and purple martin are all species of special concern for NH (NHFG 2015). The marsh wren is also a species of greatest conservation need for NH (NHFG 2015).

Data analysis also included the total number of sharp-tailed sparrow occurrences, subset into Nelson's and saltmarsh sparrow categories to compare the number of confirmed Nelson's and saltmarsh sparrow identifications to the general sharp-tailed sparrow category, where differences could not be distinguished in the field or hybridization had occurred. Summary statistics also included the percent of sites occupied by sharp-tailed sparrows, wading birds, and Eastern willets and the mean number of occurrences per survey point for each of the bird groups.

The total number of survey points in each percentage category was also identified for the following cover class types: high marsh, low marsh, pannes/pools/creeks/ and *Phragmites australis*, to determine whether poisson regressions could be used to examine the relationship between habitat features and saltmarsh sparrow relative abundance.

Results

2022 Point Count and Rapid Demographic Surveys Summary

In the 2022 field season we recorded 4609 bird occurrences, across two survey visits to each of the 88 point count locations in New Hampshire, and conducted two rounds of rapid demographic surveys at 9 sites. Total occurrences for our species of focus varied greatly from 9 Virginia rail to 155 sharp-tailed sparrows (Figure 1). For New Hampshire species of special concern or greatest conservation need, total occurrence counts were 116 Eastern willets, 16 marsh wrens, and 10 purple martins (Figure 1).

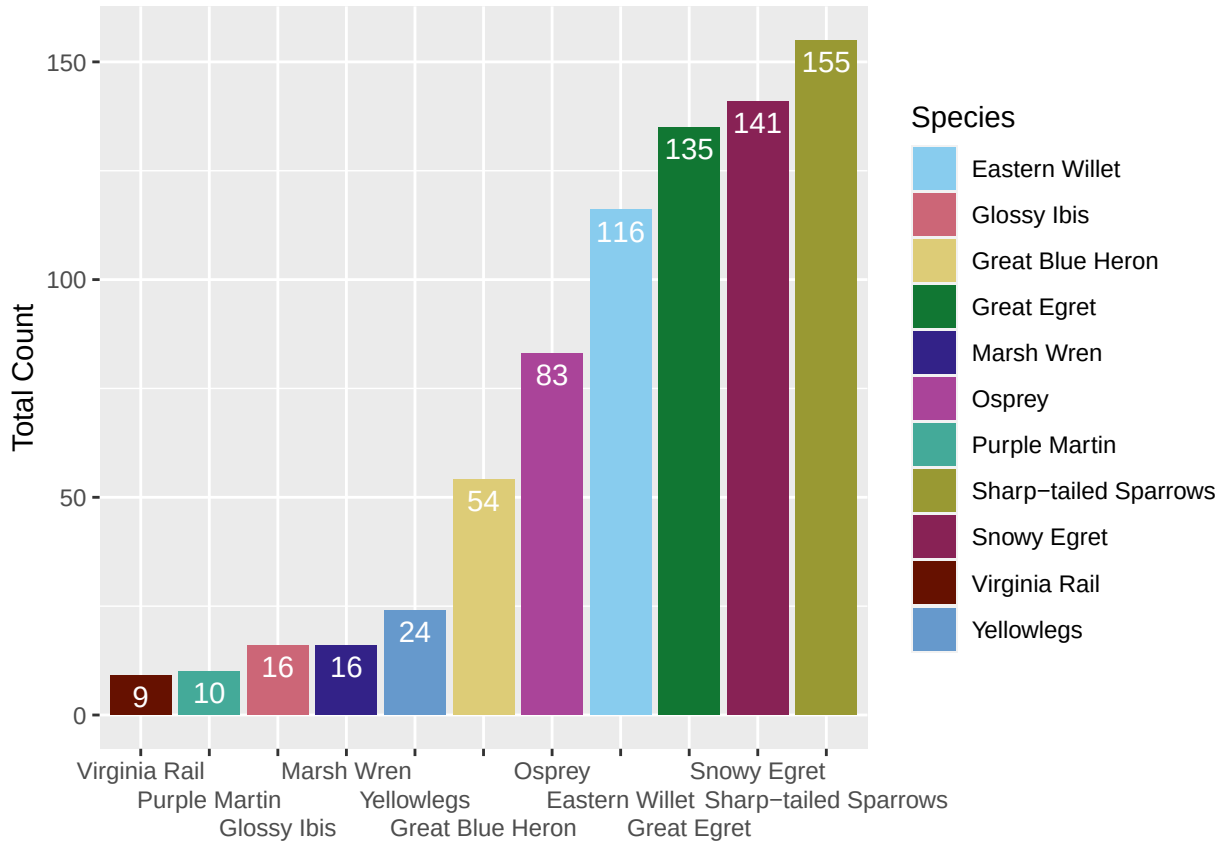


Figure 1: Total number of occurrences for the following species or bird groups: Virginia rail, purple martin, glossy ibis, marsh wren, yellowlegs, great blue heron, osprey, Eastern willet, great egret, snowy egret, and sharp-tailed sparrows. Totals reflect counts from two, 10 minute point counts across 88 points surveyed in New Hampshire. Point count surveys conducted as part of the Saltmarsh Habitat and Avian Research Program in 2022 (www.tidalmarshbirds.org).

Sharp-tailed sparrow occurrences (155) included 6 Nelson's sparrows, 47 saltmarsh sparrows, and 102 hybrid or unidentified sharp-tailed sparrows (Figure 2). The mean number of occurrences for the focal bird groups ranged from 1.76 sharp-tailed sparrows to 3.97 wading

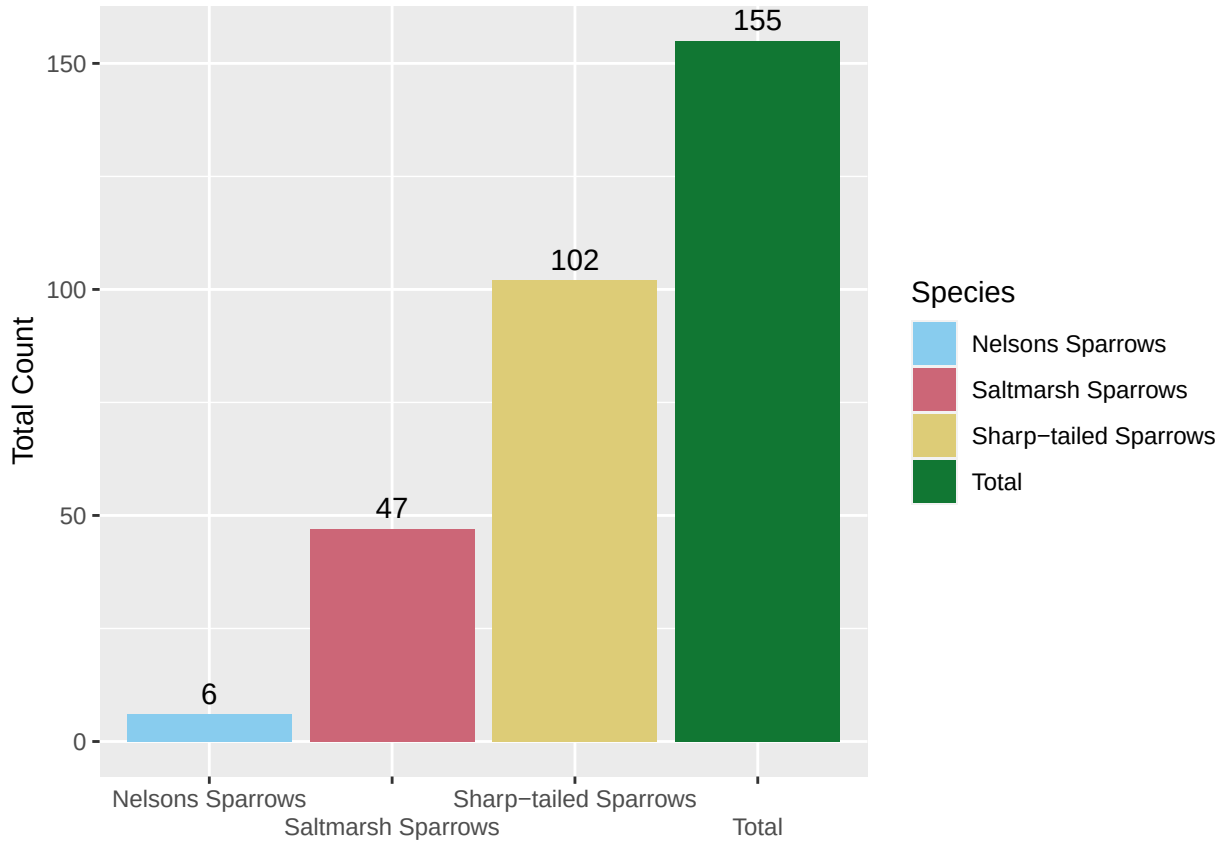


Figure 2: Total count of saltmarsh sparrow (*Ammospiza caudacuta*), Nelson's sparrow (*Ammospiza nelsoni*), and unidentified sharp-tailed sparrow occurrences. Green colomn represents the total count of all sharp-tailed sparrow occurrences. Total count determined from two, 10 minute point counts across 88 points surveyed in New Hampshire. Point count surveys conducted as part of the Saltmarsh Habitat and Avian Research Program in 2022 (www.tidalmarshbirds.org).

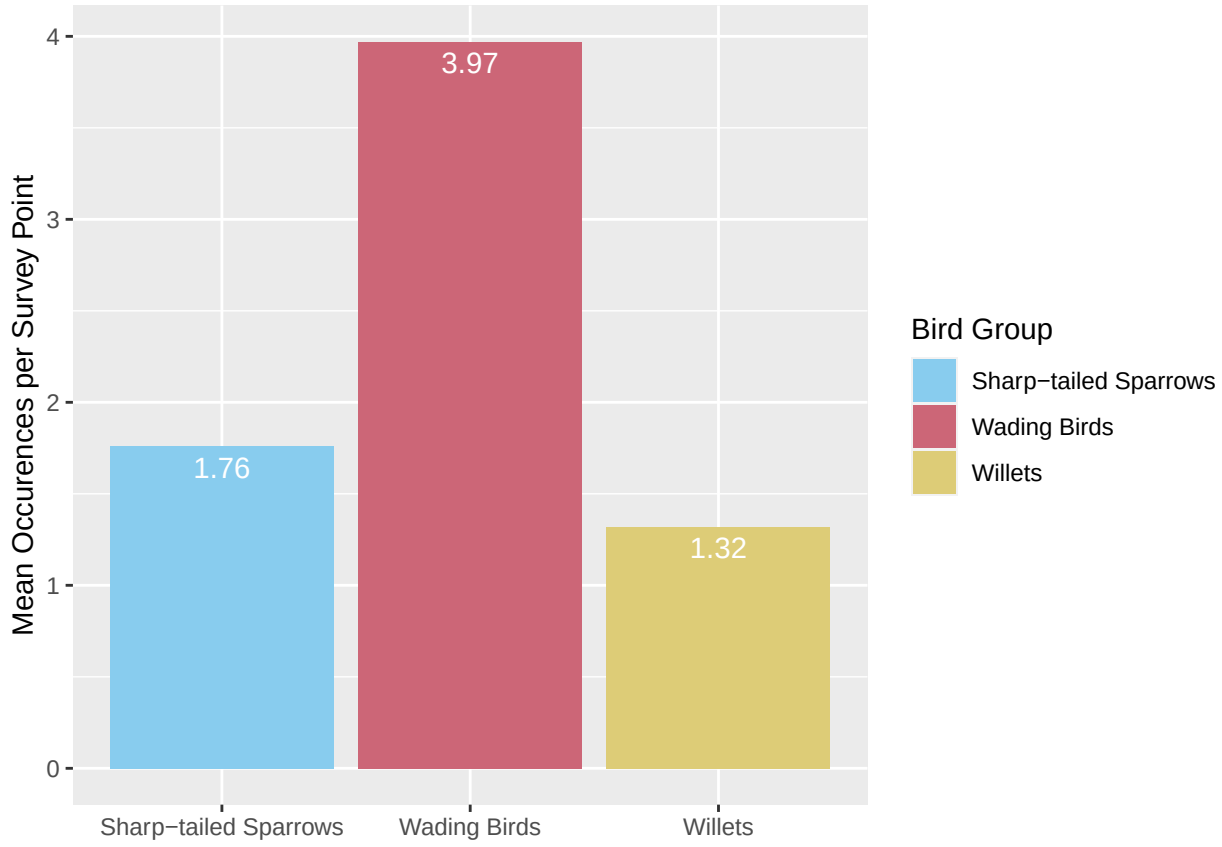


Figure 3: Mean total count of sharp-tailed sparrows, wading birds, and Eastern willets (*Tringa semipalmata*) at 88 point count locations in New Hampshire across two surveys. Sharp-tailed sparrows included saltmarsh sparrows (*Ammospiza caudacuta*), Nelson's sparrows (*Ammospiza nelsoni*), and hybrids. Wading birds included great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), green heron (*Butorides virescens*), and glossy ibis (*Plegadis falcinellus*). Point count surveys conducted as part of the Saltmarsh Habitat and Avian Research Program in 2022 (www.tidalmarshbirds.org).

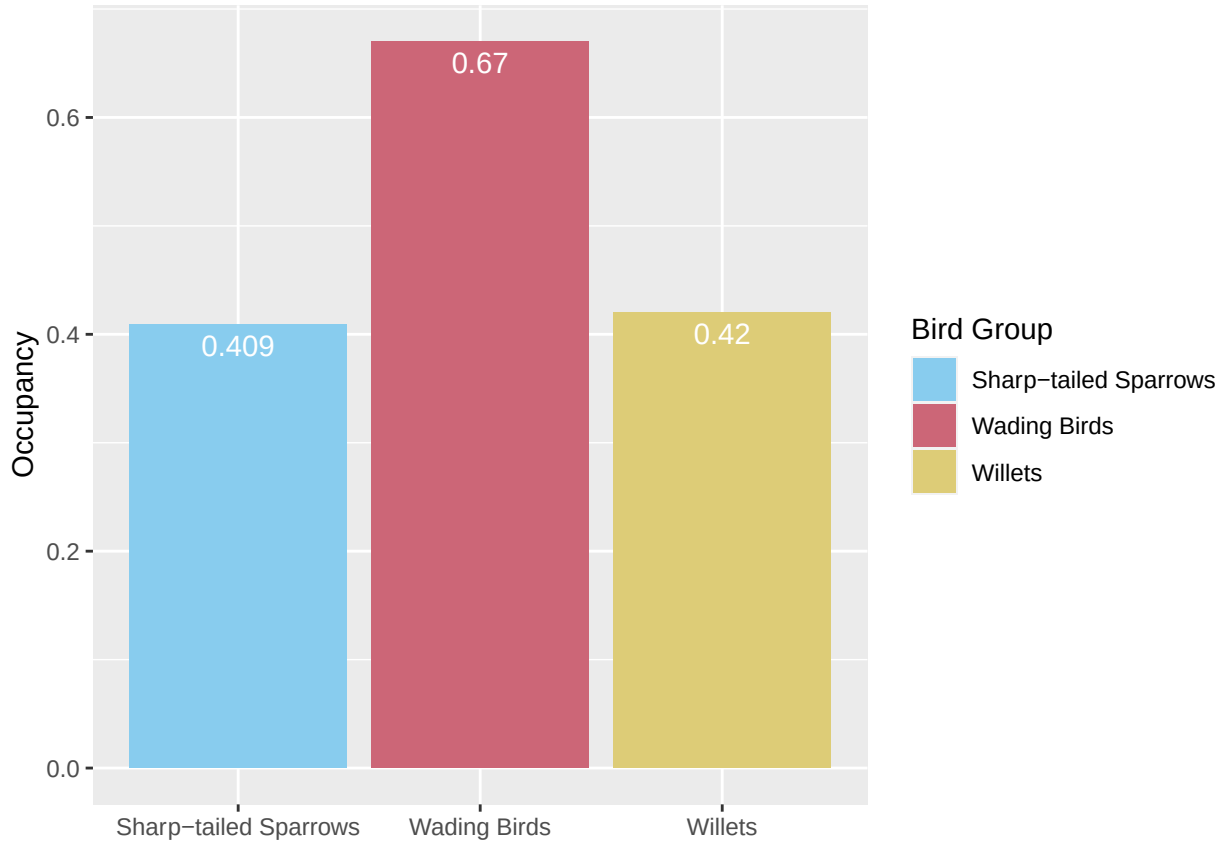
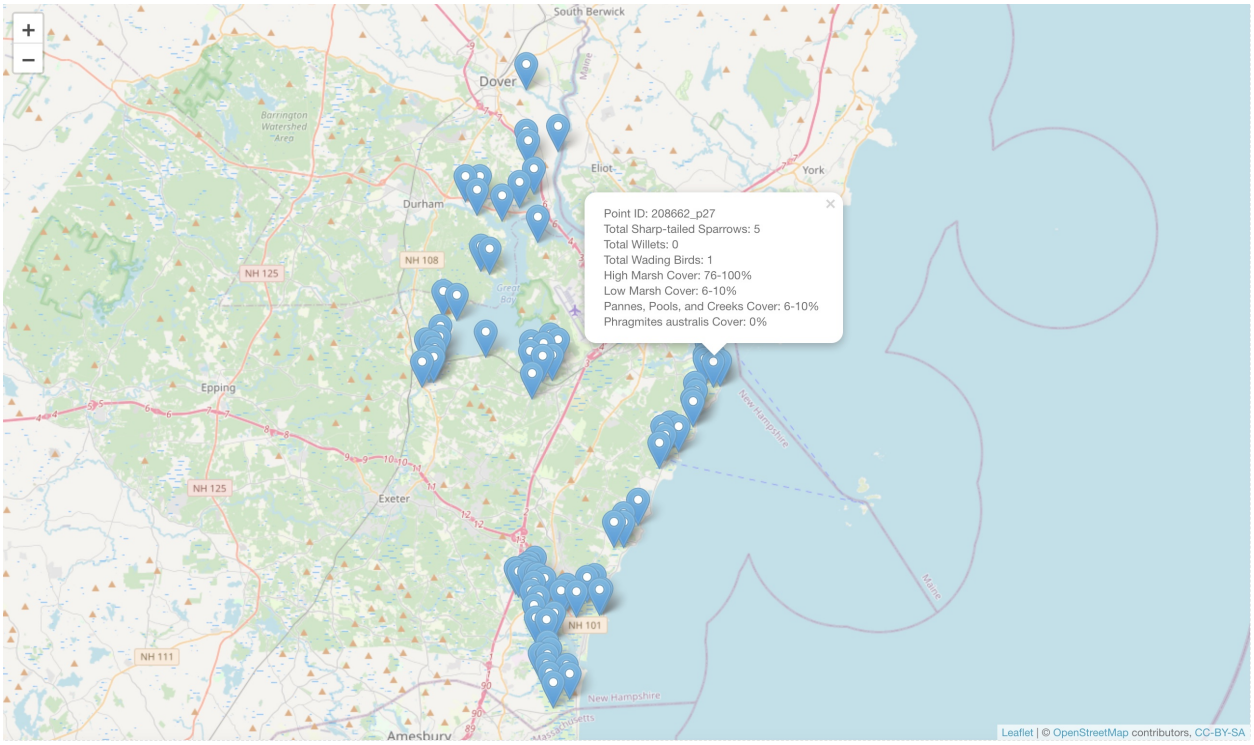


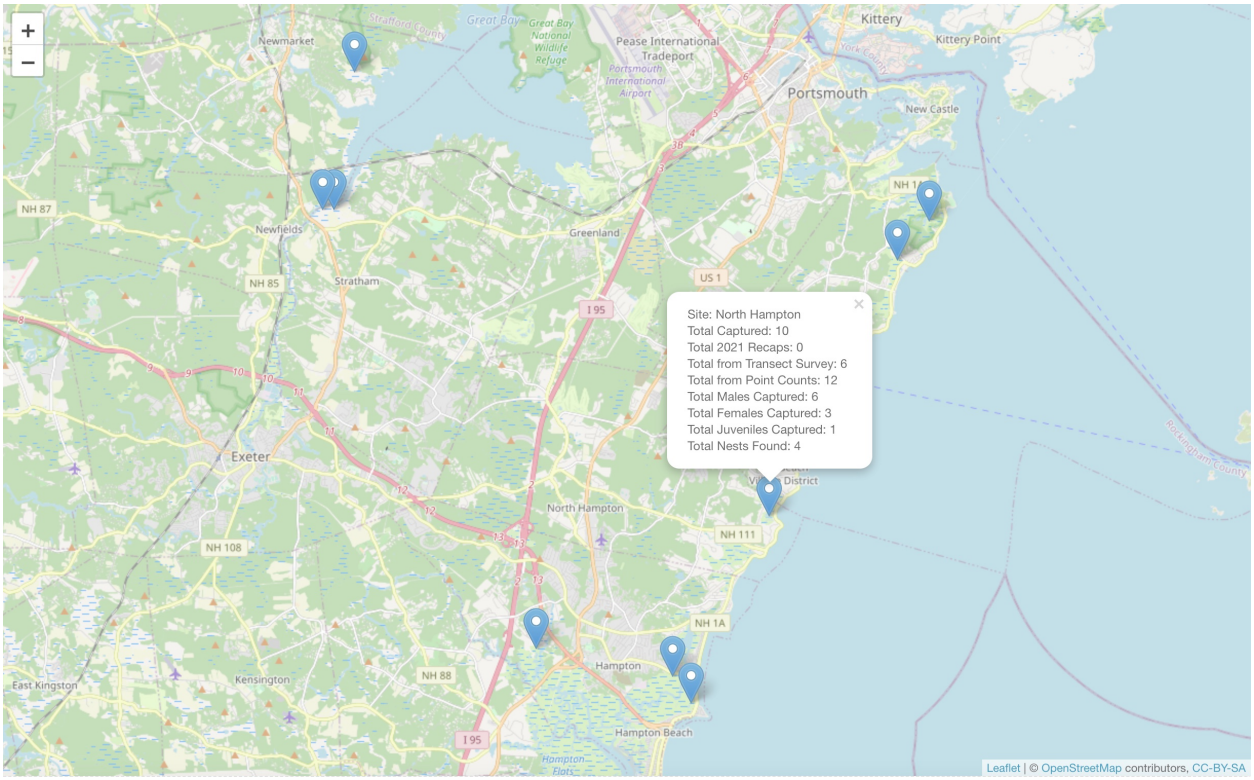
Figure 4: Proportion of points occupied by sharp-tailed sparrows, wading birds, and Eastern willets (*Tringa semipalmata*) during two rounds of point count surveys at 88 points in New Hampshire. Sharp-tailed sparrows included saltmarsh sparrows (*Ammospiza caudacuta*), Nelson's sparrows (*Ammospiza nelsoni*), and hybrids. Wading birds included great blue heron (*Ardea herodias*), great egret (*Ardea alba*), snowy egret (*Egretta thula*), green heron (*Butorides virescens*), and glossy ibis (*Plegadis falcinellus*). Point count surveys conducted as part of the Saltmarsh Habitat and Avian Research Program in 2022 (www.tidalmarshbirds.org).

birds (Figure 3). Occupancy across the 88 points was 0.409 for sharp tailed sparrows, 0.67 for wading birds, and 0.42 for willets (Figure 4).

Below are two interactive maps detailing the findings of our 2022 field season, including the point count, vegetation, and rapid demographic surveys. Coastal managers can view these maps to get information specific to each site or marsh. These maps can be used to inform ongoing restoration projects at Fairhill Marsh in Rye and Philbrick's Pond in North Hampton, among other examples. Coastal managers can see which point count locations had sharp-tailed sparrows (Map 1) and how many nests were found on a given marsh during the rapid demographic surveys (Map 2). Please note that they are represented as still images in this report but when viewed in R, the interactive map is available.



Map 1. 2022 point count locations, with accompanying total bird counts from two, ten minute point count surveys conducted as part of the Saltmarsh Habitat and Avian Reserach Program (www.tidalmarshbirds.com). Map also includes relevant percent cover classes from the 50 meter radius vegetation surveys at each point.



Map 2. Nine rapid demographic study locations across New Hampshire salt marshes surveyed in 2022 as part of the Saltmarsh Habitat and Avian Research Program (www.tidalmarshbirds.com). Each study location is accompanied by data collected across two complete surveys. All totals reflect numbers of sharp-tailed sparrows either captured or counted during point count and transect surveys. 2021 recaps are birds that were banded during our 2021 rapid demographic surveys at the same location. Nests found included any nest that had eggs, chicks, or the remains of either when found. Chapman's Landing nest totals reflect intensive demographic work, conducted by a separate field crew over the course of the summer.

2022 Vegetation Summary

The distribution of points in each of the vegetative cover classes was uneven (Figures 5-8). For example, there were only 3 points with 11-25% high marsh cover, compared to 34 with 76-100% (Figure 5). Only a few of the points had low marsh cover above 25% (Figure 6). Sixty-eight of the 88 points had 0% invasive coverage, with no sites having over 50% invasive coverage (Figure 7). Water coverage was also uneven with 25 points having 1-5% invasive cover and only three 51-75% cover (Figure 8).

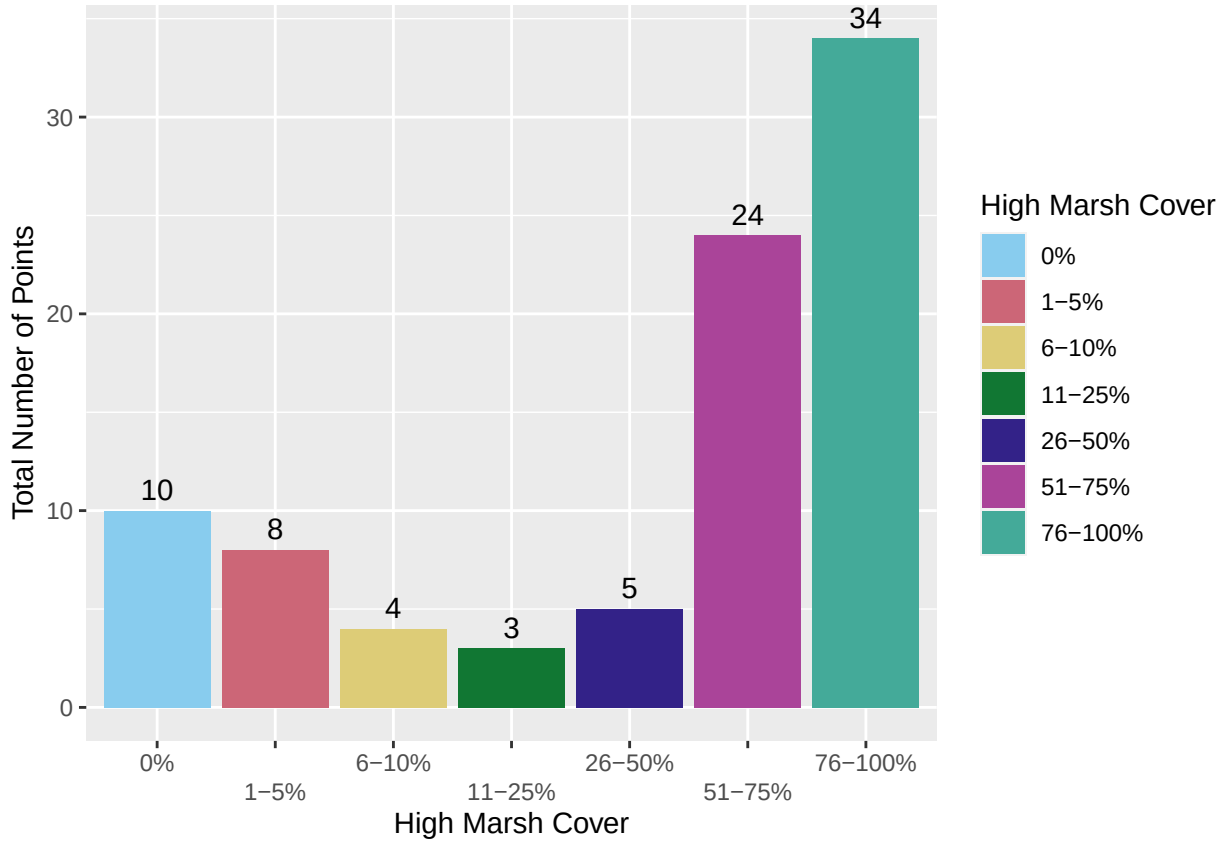


Figure 5: Total number of 2022 point count sites in each category of high marsh coverage, based on Saltmarsh Habitat and Avian Research Program vegetation surveys (www.tidalmarshbirds.com). All point counts were conducted in New Hampshire. Coverage categories reflect the vegetation in a 50 meter radius circular plot centered on the point count location.

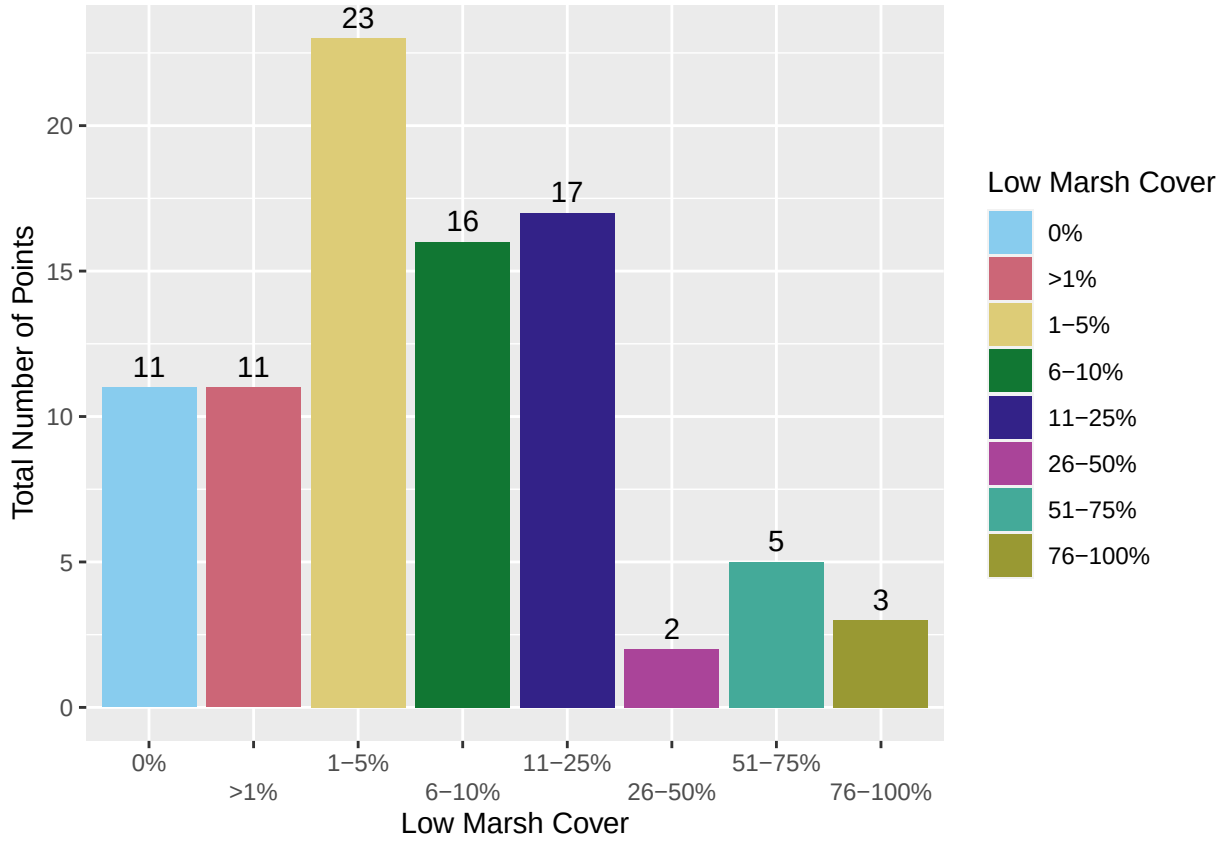


Figure 6: Total number of 2022 point count sites in each category of low marsh coverage, based on Saltmarsh Habitat and Avian Research Program vegetation surveys (www.tidalmarshbirds.com). All point counts were conducted in New Hampshire. Coverage categories reflect the vegetation in a 50 meter radius circular plot centered on the point count location.

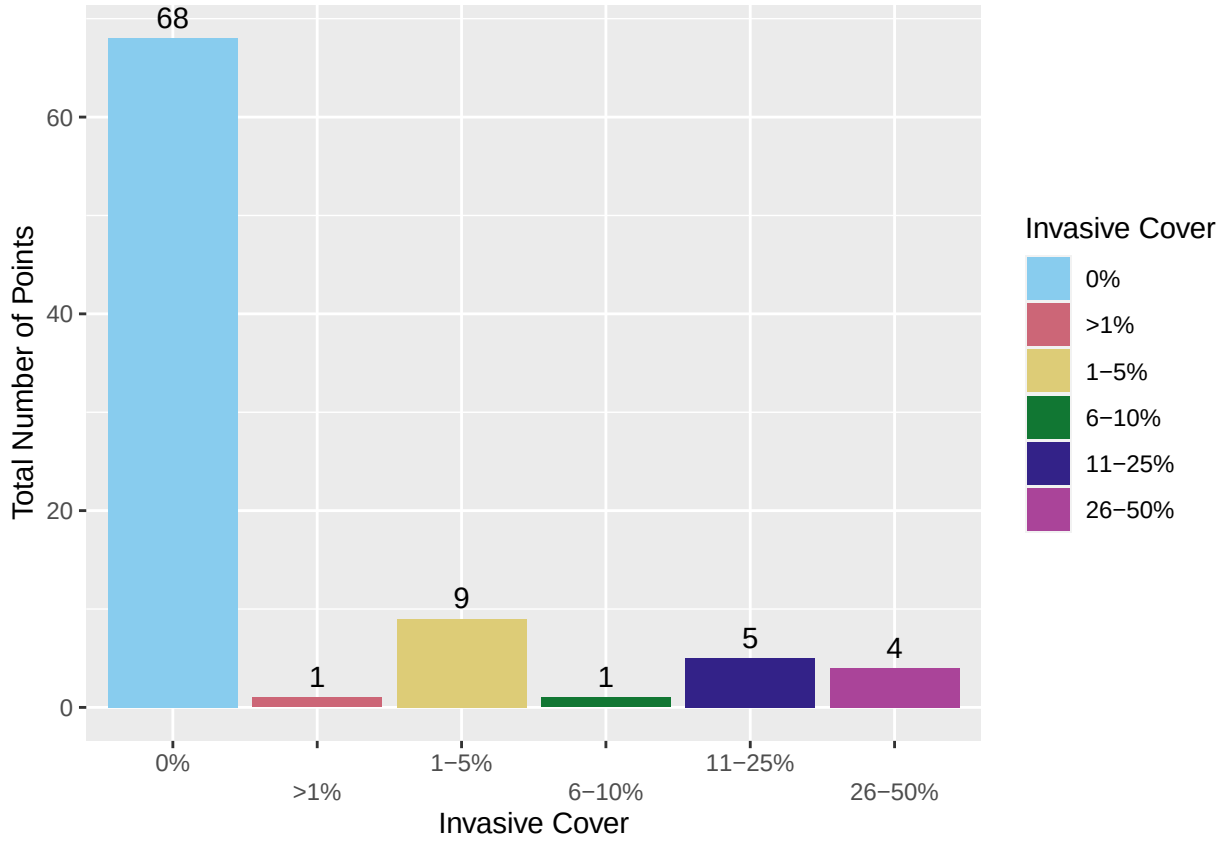


Figure 7: Total number of 2022 point count sites in each category of invasive plant coverage (*Phragmites australis*), based on Saltmarsh Habitat and Avian Research Program vegetation surveys (www.tidalmarshbirds.com). All point counts were conducted in New Hampshire. Coverage categories reflect the vegetation in a 50 meter radius circular plot centered on the point count location.

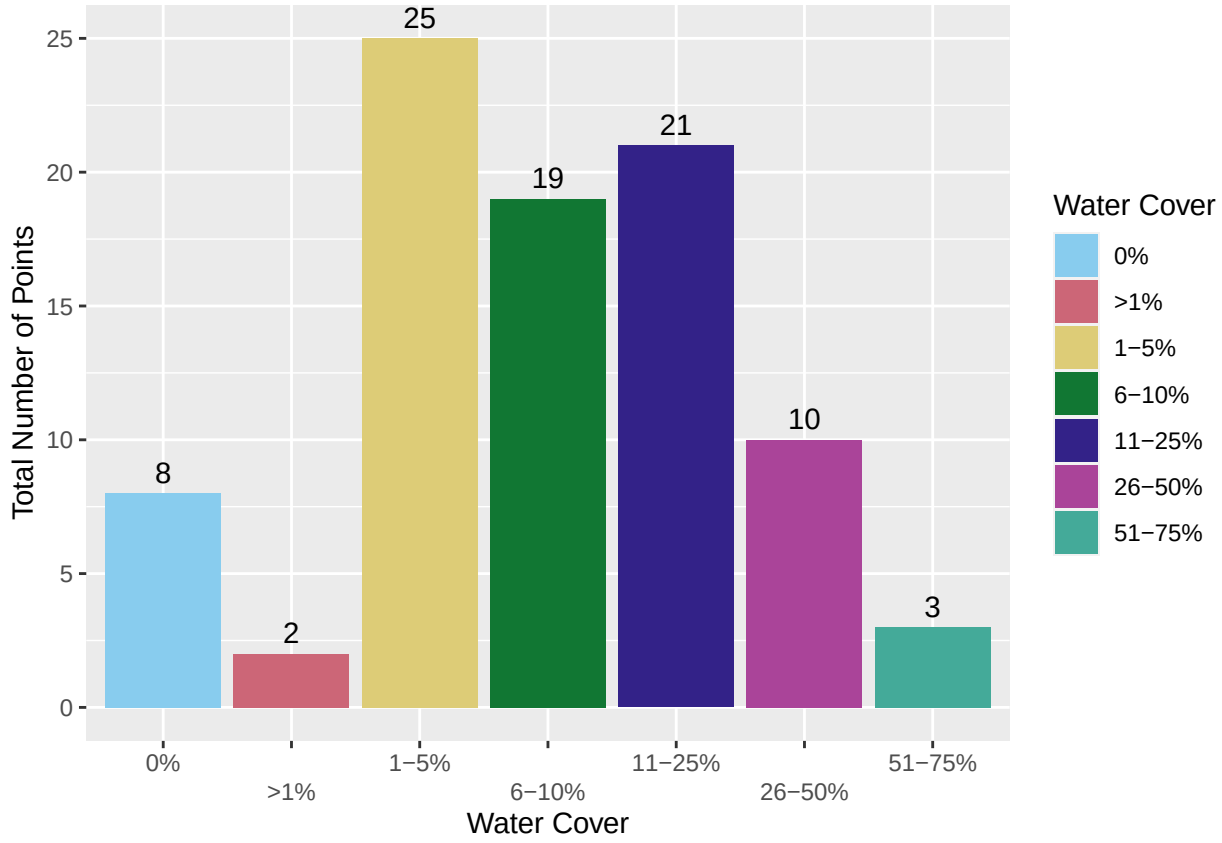


Figure 8: Total number of 2022 point count sites in each category of panness, pools, and creek (aka water) coverage, based on Saltmarsh Habitat and Avian Research Program vegetation surveys (www.tidalmarshbirds.com). All point counts were conducted in New Hampshire. Coverage categories reflect the vegetation in a 50 meter radius circular plot centered on the point count location.

Discussion

The summary statistics showed low sharp-tailed sparrow and Eastern willet occurrence and mean relative abundance (Figures 2 and 3). This was expected as avian tidal marsh specialists decline, with saltmarsh sparrows declining at a rate of 9% a year (Correll et al. 2016), underscoring the continued conservation need for these species in New Hampshire (NHFG 2015). The reason for low Nelson's sparrow occurrence was unclear; a combination of factors are likely at play: New Hampshire is near the southern limit of the Nelson's sparrow's range, high hybridization exists in New Hampshire, and observers may have prioritized sharp-tailed sparrow identification, over identification down to species (Hodgman et al. 2002). It is difficult to draw conclusions from count totals. While the low counts for some species like purple martin and marsh wren, could be seen as cause for concern given their high conservation status (NHFG 2015), the SHARP surveys are designed to monitor long-term population change in a select group of salt marsh obligates (www.tidalmarshbirds.com). Marsh wrens and purple martins also occur in habitats outside of salt marshes (NHFG 2015). Due to these limitations conclusions can not be drawn for the generalist species included in this analysis, despite interest in seeing the results by salt marsh managers. It is, however, encouraging to see high osprey occurrence across just a small portion of the state. Osprey numbers were low in the last century due to DDT, with only eight nesting pairs recorded in New Hampshire in 1981, indicating a significant rebound (Houghton and Rymon 1997).

The relatively high occupancy of saltmarsh sparrows and willets, could lead managers to conclude that these species are wide spread across New Hampshire salt marshes (Figures 3 & 4). This conclusion may be misguided. The vegetation cover classes identified that most of the points had greater than 50% high marsh cover, which may not be representative of the broader marsh complex (Figure 5). It is important to recognize that many of the point locations were selected because SHARP, NH Audubon, and GBNERR partners expected sharp-tailed sparrows to be there, potentially biasing results toward the best saltmarsh sparrow habitat in the state and under surveying other high marsh areas. Saltmarsh sparrows nest in high marsh vegetation, but a threshold proportion of high marsh cover is not known (Bayard and Elphick 2011; Gjerdrum et al. 2005).

Since the distribution of points in each of the vegetative cover classes was uneven, poisson regressions were not conducted to determine the relationship between habitat cover and saltmarsh sparrow relative abundance. Unequal sample sizes would have led to unequal variance, loss of statistical power, and high type 1 error (Seavy 2005). In the future, as I design my study, I will need to make sure that my point count locations are representative of a wide range of vegetation cover classes and that there is a relatively equal number of points for each class. Several poisson regressions are included in the .rmd file, but not in this report. These were conducted for practice in R and will be helpful for analysis in the future, but were not meaningful given the uneven sample sizes. Poisson regressions are commonly used for point count data, where values are from zero to infinity and the majority of observations are right skewed (Seavy 2005).

Despite the project's limitations, it did identify some areas of high sharp-tailed sparrow occurrence, nesting, and breeding activity, where land protection and conservation could

be prioritized. These included Chapmans Landing (Stratham, NH) and Lubberland Creek (Newmarket, NH) and marshes in North Hampton and Hampton. Managers could begin with sites indicated in Map 2. The project also challenges general assumptions in the management community and indicated by the tools. Many of the patches indicated as priority saltmarsh sparrow habitat by the tools were unoccupied, particularly in Seabrook and Rye, New Hampshire. This report provides further support for the need for greater understanding of saltmarsh sparrow habitat in New Hampshire and the careful study design of that research.

Note to the Reader

Please note I am completing this assignment as both my Final R Project and my Graduate Student R Final Assignment. A version history of this project can be found at: https://github.com/GraceMcCulloch/R_Final_Project.

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