Monitoring Marsh Bird Communities to Support Rapid Wetland Condition Assessments

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INTRODUCTION

Monitoring wetland condition is important for evaluating sources of wetland degradation and to guide restoration efforts. The three-tiered approach to monitoring and assessing wetland condition requires an integrated assessment framework of varying degrees of scale and effort. Delaware's Wetland Monitoring and Assessment Program evaluates wetland condition with broad landscape-level assessments (Level 1), rapid field assessments (Level 2), and intensive site assessments (Level 3). Level 1 studies are almost exclusively conducted remotely and include inventories of wetland acreage and analyses of changes in wetland acreage. Level 2 assessments utilize stressor checklists and simple measures of biotic properties to characterize the condition of wetlands. The most detailed survey type, level 3, includes rigorous measures and on specific aspect of a wetland, such as biota and chemical processes.

The Mid-Atlantic Tidal Rapid Assessment Method (MidTRAM) is a level 2 rapid procedure used to assess the condition of tidal salt marshes. Typically, assessments require only one to two hours of field work and less than one hour of office analyses to produce an overall index of wetland condition. During MidTRAM assessments, information is collected detailing wetland habitat structure and vegetation communities, impacts to wetland hydrology, and the quality of the surrounding buffer. The final index of wetland condition score, ranging from 0 to 100, can then be used compare individual wetlands or aggregated to report on wetland health at the watershed-level.

For these rapid wetland assessments to be useful, field indicators must be supported by intensive measures of wetland condition. Metrics included in MidTRAM have been scaled with data collected on biotic and abiotic characteristics across a gradient of wetland condition and are surrogates for wetland functions. For example, soil bearing capacity is a metric included in MidTRAM which is used to quickly estimate marsh stability. To verify that this metric reflects marsh stability, labor-intensive samples of below-ground biomass were quantified and found to be highly correlated to soil bearing capacity. In the present study, salt marsh bird communities were surveyed to investigate if rapid MidTRAM wetland condition scores were validated by wildlife surveys.

Indices of biotic integrity have been applied successfully to aquatic ecosystems as a way of characterizing the influence of disturbance on assemblages of wildlife. Birds are commonly

used as biological indicators of habitat quality because they are relatively easy to identify and many species exhibit strong habitat preferences. Following the index of marsh bird community integrity (IMBCI) proposed by DeLuca et al. (2004), multiple life history attributes were considered and reflect a species' dependence on salt marshes. For example, a wetland system comprised of obligate salt marsh species has high community integrity and is likely representative of a high condition wetland. Conversely, a highly disturbed salt marsh may be dominated by habitat generalist species displaying low community integrity. Of particular interest was the relationship between habitat condition and marsh bird assemblages, so the relative influence of MidTRAM habitat variables was also examined to investigate how habitat complexity effects bird community composition.

METHODS

Study Area

MidTRAM wetland assessments and marsh bird surveys were conducted in the Leipsic River watershed in Kent County, Delaware (Figure 1). Tidal wetlands in this watershed are typical mesohaline and polyhaline salt marshes of the Delaware Bay and are dominated by smooth cordgrass (*Spartina alterniflora*), big cordgrass (*S. cynosuroides*), saltmeadow cordgrass (*S. patens*), saltgrass (*Distichlis spicata*), marsh elder (*Iva frutescens*), and common reed (*Phragmites australis*). Approximately 9,500 ha of the Leipsic River watershed (29% of the total land area) is covered by salt marshes on both private and public property, notably within Bombay Hook National Wildlife Refuge and Little Creek Wildlife Management Area. Inland land use within the watershed is primarily agricultural, with few forest tracts and rural housing.

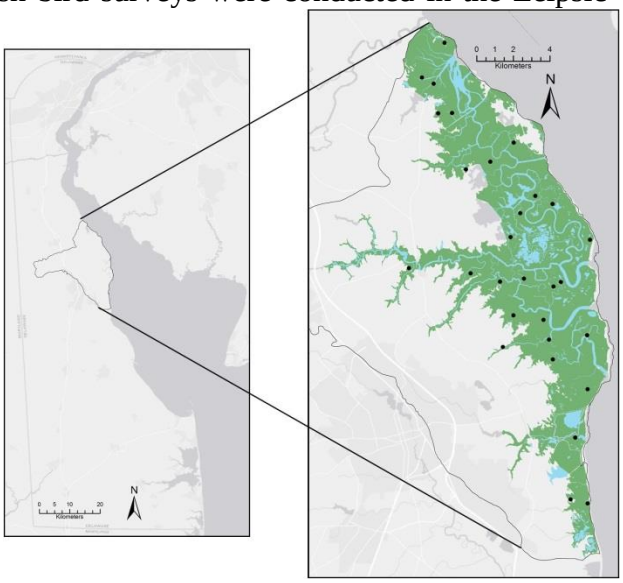

Figure 1. Map of the study area in the Leipsic River watershed in Delaware. Watershed boundaries are delineated by black lines, study sites are represented as black dots. Map includes estuarine wetlands (green) and

MidTRAM Condition Assessments

A Level 2 wetland condition assessment was performed at 30 randomly selected points throughout the watershed in July-September 2013 utilizing the Mid-Atlantic Tidal Rapid Assessment Method (MidTRAM v3.0). During MidTRAM site visits, observers estimated the percent cover of each plant community in the wetland as well as habitat features, including open water, ditches, creeks, and pools in the 50m assessment area. Assessments also included the composition of each plant height layer in the wetland assessment area (50m radius circle). Plant strata were classified as floating/aquatic, short (< 0.3m), medium (0.3–0.75m), tall (0.75–1.5m),

and very tall (>1.5m). MidTRAM metrics are grouped into three discrete wetland attributes: habitat condition, hydrology impacts, and buffer condition. These three attribute scores are then averaged to produce a final condition score, ranging from 0 to 100.

Bird Surveys

We surveyed marsh bird communities with passive and callback, fixed point counts centered at 29 of the 30 MidTRAM assessment points in the Leipsic River watershed. Bird surveys were conducted at 20 MidTRAM sites in 2013 and nine sites in 2014. Bird surveys were not conducted at one of the 30 MidTRAM sites due to problems with accessibility. Surveys followed the Standardized North American Marsh Bird Monitoring Protocols (Conway 2009) and were conducted during three discrete sampling periods at each site to account for variations in breeding phenology: once at beginning of the breeding season (May 1-14), once in the middle of the season (May 15-31), and once late in the season (June 1-15). Observers navigated to study sites using a GPS and recorded any bird that was flushed or observed in the assessment area upon approach. Surveys included a 5-minute passive listening period and 6 minutes of broadcast calls at 80 dB for secretive marsh birds, played in order of increasing intrusiveness: black rail (*Laterallus jamaicensis*), least bittern (*Ixobrychus exilis*), virginia rail (*Rallus limicola*), king rail (*R. elegans*), clapper rail (*R. longirostris*), and American bittern (*Botaurus lentiginosus*). One observer recorded species using the four-letter American Ornithological Union acronym, whether the bird was seen and/or heard, and the birds' estimated distance away from the point center (0-25m, 25-50m, 50-75m, 75-100m). Birds were only recorded if they were observed utilizing the wetland, so individuals observed only in adjacent upland habitats or flying over the assessment area were not recorded.

Index of Marsh Bird Community Integrity

The IMBCI developed for this study is a modified index proposed by DeLuca et al. (2004). Each bird species was ranked based on their foraging habitat, nesting substrate, migratory status, breeding range, and local conservation status. For example, species of conservation concern with life history strategies unique to salt marshes and narrow breeding ranges score higher than habitat generalists with broad breeding ranges. Scores for each species recorded at a wetland was used to calculate IMBCI score for each wetland site using the formula:

$$\text{IMBCI} = [(\sum S_{\text{IMBCI}}/S_n) + O_n] - 5$$

whereas S_{IMBCI} is the score for each species detected at the specific wetland site, S_n is the total number of species detected at that specific wetland, and O_n is the number of salt marsh obligates detected at that specific wetland. The equation is subtracted by five to produce a scoring system that begins at zero. IMBCI species scores for the Leipsic River watershed are listed in Table 2.

Data Analysis

Birds recorded greater than 75 m from the plot center were excluded from analyses to avoid variables influencing community composition not measured during MidTRAM site

assessments. Bird survey data from 2013 and 2014 were pooled into a single dataset for analyses. A bird species was considered present at a wetland if it was observed at least once during the three replicate surveys. Since it is possible that birds nesting or defending territories in assessment sites were observed during replicate surveys, relative species abundance was considered as the maximum number of individuals of a given species observed during any of the three surveys. Statistical analyses were performed in R (R Core Team 2012).

MidTRAM wetland condition scores and marsh bird community composition were explored using linear regression models. Simple linear regression models were created to determine if MidTRAM condition scores were supported by the IMBCI. Species richness was also compared to MidTRAM scores using separate linear regression models created with the Buffer, Hydrology, and Habitat attribute scores, as well as the overall MidTRAM site scores, as dependent variables.

To determine the influence of habitat heterogeneity on marsh bird species richness, the sum of the number of herbaceous plant strata found in the wetland (0-5 plant layers), the presence of shrubs (marsh elder), the presence of pannes or pools, and the presence of creeks or ditches was used as a surrogate for habitat complexity. A generalized linear model with a Poisson distribution was used to investigate the relationship between species richness and the number of habitat features found in the wetland. A multiple linear regression model was then created to measure the effects of each habitat variable on overall marsh bird species richness. Model selection started with a null model and followed a stepwise forward selection process based minimizing Akaike's Information Criterion values with the *step* function in R. The relative importance of each variable in the final model was estimated with the *relaimpo* package in R, based on the metric created by Lindeman et al. (1980). Creeks and ditches were excluded from multiple regression analyses because they were recorded in every wetland site.

A canonical correspondence analysis (CCA) from the R package *vegan* was used to explore species-specific responses to environmental variables. CCA is a multivariate statistical procedure which combines a species-site correlation matrix and associated environmental variables into two linear axes. To visually represent the CCA, a bi-plot was produced with wetland sites and bird species as symbols on the bi-plot, and environmental variables as vectors. The length of a vector, and its proximity to a bird species symbol, indicates its relative importance in predicting species abundance based on that particular environmental variable. Statistical significance of the CCA ordination was investigated by performing a Monte Carlo randomization test with 999 permutations. To increase the strength of the ordination procedure, species that were documented at only one site (14 species) were excluded from the CCA ordination.

RESULTS

Wetland Habitats and Condition

Salt marshes in the Leipsic River watershed varied from monotypic stands of *S. alterniflora* to diverse habitats of low marsh and high marsh plant species with multiple pannes, pools, and creeks (Table 1). On average, study sites contained 3.8 ± 1.2 plant strata/habitat

features. Wetlands containing invasive *P. australis* occurred throughout the watershed (15 of 29 sites) but the plant typically covered only a small portion of the wetland, with only 1 site dominated by *P. australis*. Woody shrub species were also found throughout the watershed (12 of 29 sites) generally only as a few plants along the wetland-upland boundary and on spoil piles along ditches. Pannes and pools were also found in six of the wetland sites. Most of these aquatic features appear to be natural, while some of the pools were created as a result of open marsh water management practices for mosquito control. Wetlands in the Leipsic River watershed were generally in good condition, with MidTRAM condition scores ranging from 47 to 91 (mean = 79 ± 11).

Table 1. Frequency of wetland habitat features from MidTRAM assessments at each of the bird survey sites in the Leipsic River watershed in 2013. Table also includes examples of plants typically comprising each plant strata.

Wetland Habitat Variable	Example of Typical Community	No. of Sites
Short herbs	*D. spicata/S. patens*	7
Medium herbs	*S. alterniflora*	19
Tall herbs	*S. alterniflora/S. cynocuroides/P. australis*	21
Very tall herbs	*P. australis/S. cynocuroides*	16
Shrubs	*I. frutescens*	12
Pannes and pools	Natural salt pannes or persistent pools	6
Creeks and ditches	Natural creeks, manmade mosquito ditches	29

Example of monotypic stand of medium herbs (*S. altiniflora*)

Example of diverse habitat with shrubs, short, medium, and very tall herbs

Bird Surveys

Twenty seven bird species were documented utilizing salt marsh sites in the Leipsic River watershed during bird surveys in 2013 and 2014. Sites averaged 6.1 ± 1.4 species and ranged from 4 to 9 species per site. The most common species were marsh wrens, red-winged blackbirds, clapper rails, and seaside sparrows (Table 2). The relative abundance of marsh bird

species also varied among sites (Kruskal-Wallis $H = 270$, $p < 0.001$) with these four species most abundant (Mann-Whitney pairwise comparison, all $p < 0.005$; Table 2). Over half of the bird species (14 of 27 species) recorded during surveys were found at only a single site.

Table 2. Frequency and average relative abundance (± 1 SD when applicable) of bird species recorded during marsh bird surveys in Leipsic River watershed during 2013 and 2014. Included are the Index of Marsh Bird Community Integrity (IMBCI) scores for each species recorded.

Species Code	Common Name	Scientific Name	IMBCI Score	No. of Sites	Avg. Relative Abundance at Occupied Sites
MAWR	Marsh wren	*Cistothorus palustris*	12	28	4.07 ± 1.92
RWBL	Red-winged blackbird	*Agelaius phoeniceus*	8	28	5.00 ± 2.23
CLRA	Clapper rail	*Rallus longirostris*	14.5	27	2.96 ± 1.63
SESP	Seaside sparrow	*Ammodramus maritimus*	16	27	4.85 ± 2.49
COYE	Common yellowthroat	*Geothlypis trichas*	11	14	1.57 ± 0.76
TRES	Tree swallow	*Tachycineta bicolor*	8	10	2.30 ± 1.49
WILL	Willet	*Tringa semipalmata*	18	9	1.67 ± 1.32
SALS	Saltmarsh sparrow	*Ammodramus caudacutus*	14.5	6	1.67 ± 0.82
SWSP	Swamp sparrow	*Melospiza georgiana*	12	5	2.00 ± 1.00
BARS	Barn swallow	*Hirundo rustica*	8	4	2.25 ± 1.26
VIRA	Virginia rail	*Rallus limicola*	12.5	3	1
BTGR	Boat-tailed grackle	*Quiscalus major*	10	2	1
SOSP	Song sparrow	*Melospiza melodia*	6.5	2	1.5 ± 0.71
ABDU	American black duck	*Anas rubripes*	9	1	1
AMBI	American bittern	*Botaurus lentiginosus*	12.5	1	1
BCNH	Black-crowned night heron	*Nycticorax nycticorax*	9	1	1
CAGO	Canada goose	*Branta canadensis*	6.5	1	3
EAKI	Eastern kingbird	*Tyrannus tyrannus*	10	1	1
GBHE	Great blue heron	*Ardea herodias*	8	1	1
GRCA	Gray catbird	*Dumetella carolinensis*	8	1	1
GRYE	Greater yellowlegs	*Tringa melanoleuca*	11.5	1	1
NOCA	Northern cardinal	*Cardinalis cardinalis*	6	1	2
NOFL	Northern flicker	*Colaptes auratus*	5	1	1
NOMO	Northern mockingbird	*Mimus polyglottos*	5	1	1
PUMA	Purple martin	*Progne subis*	8	1	3
SNEG	Snowy egret	*Egretta thula*	13.5	1	3
YEWA	Yellow warbler	*Setophaga petechia*	8	1	1

Habitat Complexity and Community Composition

Marsh bird species richness was not significantly correlated with MidTRAM overall wetland condition score ($p = 0.128$) or the three MidTRAM attribute groups analyzed individually ($p > 0.05$ for habitat, hydrology, and buffer attribute groups). However, IMBCI scores ranged from 7.25 to 13.88 (mean = 10.88 ± 1.69) and was positively correlated with MidTRAM condition scores ($p < 0.005$, $r^2 = 0.27$), with higher condition wetlands supporting marsh bird communities with greater biotic integrity (Figure 2).

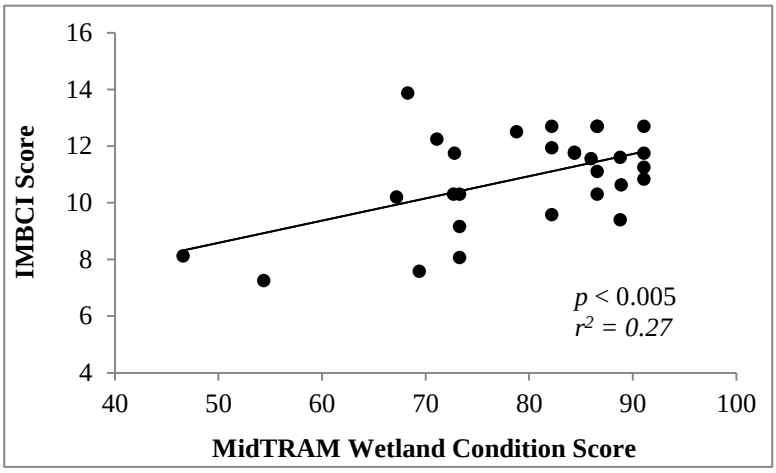

Figure 2. Relationship between the index of marsh bird community integrity (IMBCI) and MidTRAM wetland condition scores for 29 wetlands in the Leipsic River watershed.

There was a significant, positive relationship between the number of habitat features present in the wetland and marsh bird species richness ($p = 0.025$, pseudo $r^2 = 0.16$; Figure 3). The multiple regression model accounted for 62% of the variance in observed marsh bird species richness ($F_{(5,23)} = 7.66$, $p < 0.0001$). The final model retained all of the habitat variables except very tall herbs. The presence/absence of woody shrubs in the wetland had the greatest influence on marsh bird species richness and explained an estimated 39.6% of the variability (Figure 4). The presence of pannes/pools in the wetland, as well as short, medium, and tall herbaceous plant cover, contributed considerably less to predicting species richness (Figure 4).

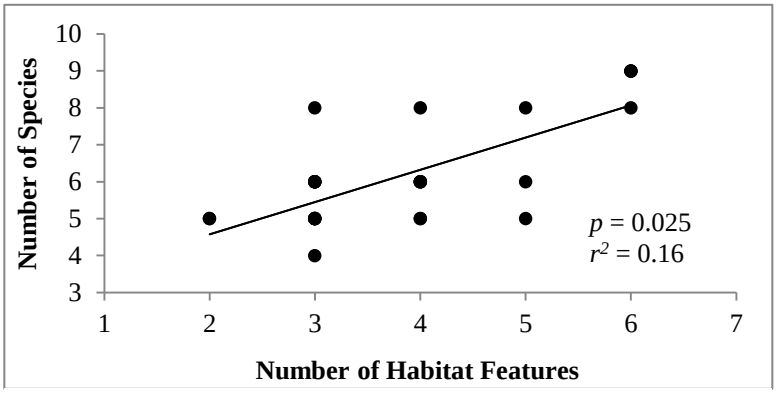

Figure 4. Relationship between the number of biotic and abiotic habitat features and marsh bird species richness in salt marshes in the Leipsic River watershed.

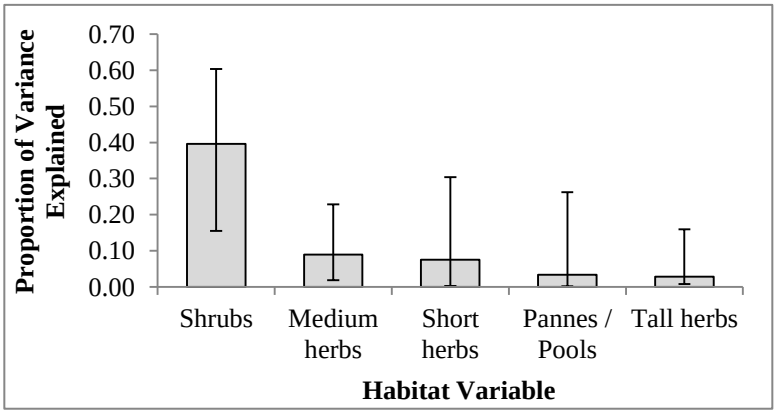

Figure 3. Relative importance of habitat features in predicting marsh bird species richness in the Leipsic River watershed. Error bars represent 95% confidence intervals.

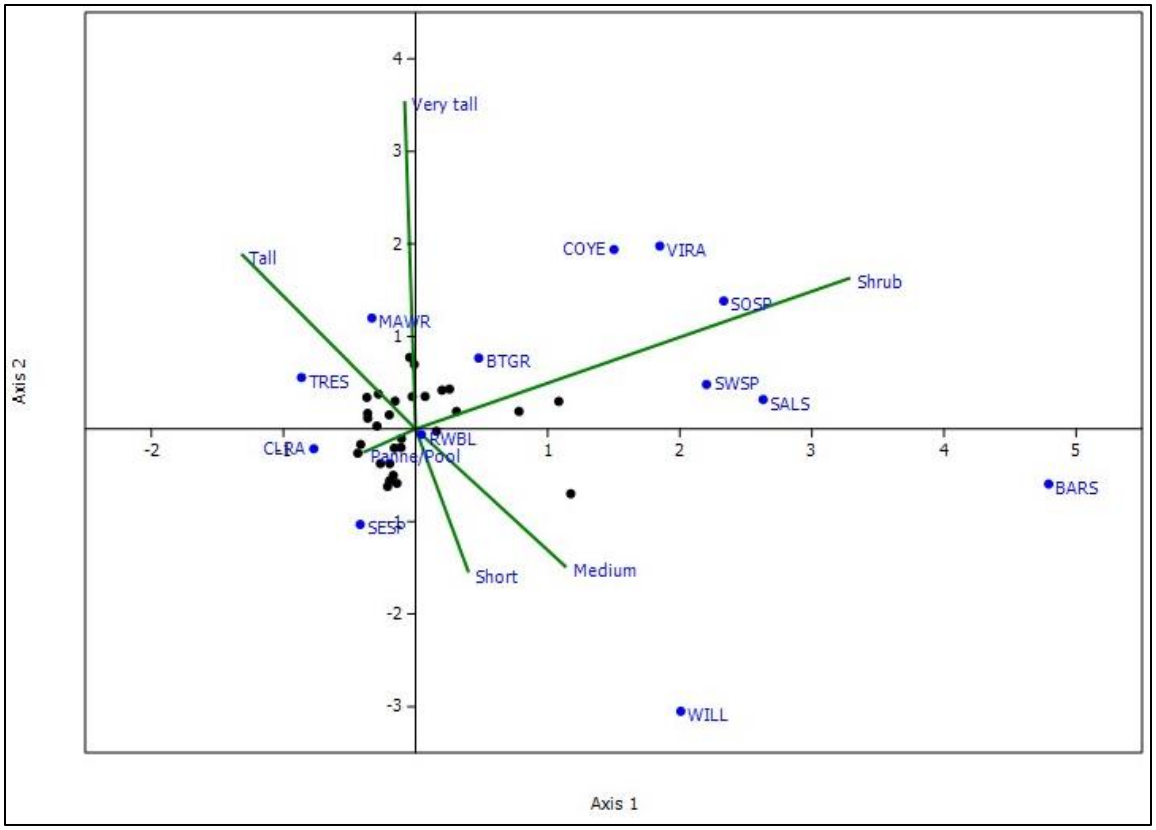

Figure 5. Canonical Correspondence Analysis bi-plot of marsh bird species abundance and six environmental variables from the Leipsic River watershed. Black dots represent the 29 MidTRAM assessment sites. Codes used for bird species are found in Table 2.

Both the primary and secondary axis of the CCA were significantly non-random (both $p < 0.05$), as was the final model ($p = 0.018$). The first axis had a strong positive correlation to the presence of woody shrubs in the wetland. The secondary axis represents extremes in herbaceous vegetation height, with very tall herbs at one end of the axis, opposite short herbs at the other extreme. Song Sparrows, Swamp Sparrows, Saltmarsh Sparrows, and Common Yellowthroats were positively associated with the presence of woody shrubs, while Clapper Rails exhibited a slight negative response to woody shrubs. Along the secondary axis, the abundance of Marsh Wrens aligned positively with the presence of very tall herbaceous plants, while Seaside Sparrows were positively associated with short herbaceous plants.

DISCUSSION

The goal of rapid wetland assessment procedures is to offer a repeatable and scientifically-sound method for estimating wetland condition while minimizing effort. For these methods to be useful, it is important validate rapid procedures with intensive measures of wetland health. The present study demonstrates that MidTRAM wetland condition scores were supported by an intensive study of biological integrity. MidTRAM wetland condition scores, determined by habitat quality, hydrology alterations, and buffer impacts, were supported by estimates of community integrity using marsh birds as a biological indicator. Habitat complexity

within wetlands also influenced salt marsh bird communities, where the number of bird species increased with the number of habitat features present in the wetland.

During the development, implementation, and subsequent revisions of MidTRAM, particular metrics have been evaluated and potentially modified or eliminated from the protocol. One of the most scrutinized metrics in MidTRAM is the "Number of Plant Layers" (metric "HAB3") where wetlands with more plant layers present are awarded more points. For example, a study site characterized by a monotypic stand of *S. alterniflora* would receive a lower score than a study site containing short *S. patens*, medium *S. alterniflora*, and the very tall invasive species *P. australis*. The present study highlights the importance of multiple plant layers in a wetland to support diverse assemblages of marsh birds. Most notably, the presence of woody shrubs in a wetland accounted for a largest portion of the variation in species richness, and strongly influenced the abundance of numerous bird species.

While overall species richness was influenced by salt marsh habitat complexity, the CCA bi-plot of species abundance and habitat features highlights life history differences among species utilizing salt marshes. Shrubs were found in fewer than half of the wetlands in the Leipsic River watershed but explained the abundance of a number of species. Swamp Sparrows, Song Sparrows, and Common Yellowthroats, which all nest in woody vegetation, were strongly correlated with the presence of shrubs. Interestingly, the abundance of Saltmarsh Sparrows also trended towards shrub presence despite being a ground nester and ground forager but may be explained by their use of shrubs for calling and territory defense. The secondary axis of the CCA can be interpreted as variation in herbaceous vegetation height. Marsh Wrens, which were observed almost exclusively calling from *P. australis* and *S. cynosiroides*, also build nests in these taller herbs and the CCA bi-plot showed a strong affinity for these habitats. Conversely, Seaside Sparrows and Willets were found in short herbaceous plants, opposite of very tall herbs, which is supported by their life history attributes.

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