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Final Report - Let the Birds Guide You

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PROJECT OVERVIEW

Identifying environmental and habitat characteristics associated with specific bird communities can help guide conservation and habitat management efforts. The goal of this project was to quantify and characterize bird communities in the St. Louis River Estuary (SLRE) based on bird-habitat associations. Bird communities are commonly described with respect to their associated cover types (i.e., habitat). However, birds often respond to combinations of local cover types and larger-scale landscape features (e.g., forested wetlands in proximity to emergent wetlands), which are not adequately described by a single attribute such as dominant plant species or aquatic habitat type. Therefore, to understand bird species' ecological needs and habitat preferences, we evaluated community assemblages without initially linking the locations sampled for birds with standard habitat categories.

Bird assemblages were first identified using hierarchical cluster analysis, which revealed relationships among locations sampled within the SLRE based solely on bird species composition. This approach identified assemblages of species that tend to co-occur irrespective of traditionally defined habitat types. We used percent perfect indication (PPI) models to identify which species or groups of species were most strongly associated with specific landscape features. We also assessed habitat availability at the landscape-scale (i.e., within a 400m buffer from the shoreline) to identify specific features that are under-represented in the SLRE but likely important to a species or group of species. We also quantified species relative abundance, richness, and diversity throughout the SLRE to identify locations of high use and diversity. Once those locations were identified, we summarized local-scale habitat data define vegetation characteristics at locations with the highest and lowest species richness. Together, these analyses will provide a holistic assessment of the environmental and habitat requirements of migratory and breeding birds at multiple spatial scales. We quantitatively assessed which landscape and habitat characteristics are most likely to be beneficial for birds that use the SLRE and, ultimately, to assist in informing habitat management objectives for current and future projects in the area.

AIMS AND OBJECTIVES

Our first objective was to identify bird community assemblages using bird survey data collected by researchers at Natural Resources Research Institute (NRRI). NRRI has conducted bird surveys throughout the SLRE for a variety of projects since the 1970s. The purpose of these surveys was to document bird use throughout the SLRE, including specific locations identified as targets for current and future habitat restoration (e.g., 21st and 40th Avenues West). These bird data were the basis for our analyses. Our second objective was to quantify spatially explicit environmental variables and habitat characteristics associated with the NRRI bird surveys. Because the SLRE is an important stopover location, where birds rest and forage during migration, it was critical to quantify these associations for migrating birds in addition to breeding birds. To identify which environmental and habitat variables were associated with current bird use, we used data from a variety of regional and local sources, which are described in detail in the Methods section.

The overall aim of this study was to identify how species assemblages relate to specific landscape features and cover types. By combining NRRI's bird surveys with environmental and cover type variables, we were able to quantify current habitat availability and provide management guidelines for restoring habitat that is lacking for the bird communities described, guilds, as well as for individual species of interest. For example, we specify use by species of greatest conservation need (SGCN), defined by the Minnesota Department of Natural Resources (MNDNR) as species whose populations are rare, declining, or vulnerable to decline and below levels desirable to ensure their long-term health and stability (MNDNR 2006). Management recommendations include restoration efforts that promote the long-term maintenance of hemi-marsh condition (ratio of open water to emergent vegetation), planting of native perennial vegetation to provide food and cover for a variety of bird species, and using islands to increase mudflat availability for migrating shorebirds. Based on our findings, additional recommendations are provided at the close of this report. Our results will inform restoration goals aimed at maximizing bird biodiversity, benefiting species of conservation concern and to guide current and future restoration efforts in the SLRE.

METHODS

Study Sites and Data Sources

A total of 107 bird survey point-count locations occurring within the SLRE were included in our analyses. These locations spanned from the Duluth-Superior harbor to up-river locations near Chambers Grove (Fig. 1). The spatial extent of these surveys provided an adequate representation of current bird use in the SLRE. Surveys occurred along a gradient of human disturbance, from highly developed (e.g., Minnesota Slip) to primarily forested (e.g., Pokegama River). There were a variety of land cover types surrounding the point-count locations, with many having a mix of emergent wetlands, forested wetlands, shrub/scrub, upland forest, and developed land.

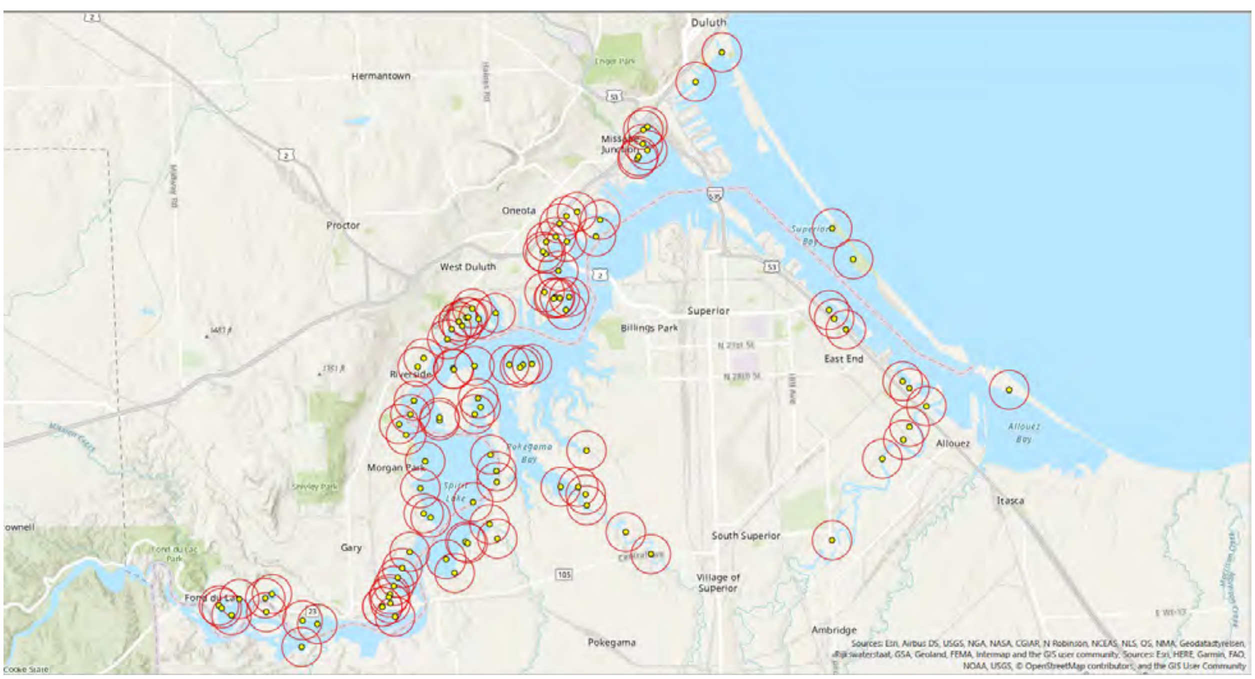

Figure 1. Map of bird point-count locations within the St. Louis River Estuary (*n* = 107). The red circle around each point-count location represents a 500m buffer from which we extracted environmental variables.

Bird Data

We included only current bird survey data collected by NRRI researchers (2011–2018). We restricted our analyses to include only these years because they are most representative of current conditions in the SLRE, and therefore will be most useful for informing current restoration and management efforts. Additionally, many of the bird surveys conducted prior to 2011 either used different sampling methodologies, did not have enough metadata to determine spatial extent or effort, or had no existing land cover or habitat data available.

We used point-count surveys to determine bird use in the SLRE. These surveys are a tally of birds detected by sight and sound at a fixed location during a specified period of time by a trained observer. Bird surveys were conducted during spring (April – early May) and fall (August – November) migration as well as during the breeding season (May 25 – July 10). We combined data collected by NRRI researchers from three sources: 1) Minnesota Pollution Control Agency St. Louis River AOC R2R Support Project: Ecological Monitoring and Assessment (Bracey et al. 2016); 2) Minnesota Land Trust Avian Surveys for the St. Louis River Natural Areas Project (Liljenquist et al. 2019); and 3) the Great Lakes Coastal Wetland Monitoring Program (CWM; https://www.greatlakeswetlands.org/Home.vbhtml). See Bracey et al. (2016) for detailed information about how bird surveys were conducted for both migration and breeding season counts.

Landscape and Local Vegetation Data

We quantified landscape- and local-scale variables from the following sources: 1) The National Oceanic and Atmospheric Administration (NOAA) C-CAP Regional Land Cover; 2) the U.S. Fish & Wildlife Service (USFWS) National Wetland Inventory; and 3) The St. Louis River Estuary Vegetation Database (Danz et al. 2017). Large-scale environmental variables (NOAA C-CAP and USFWS National Wetland Inventory) were quantified within a 200m and 500m circular buffer placed around the center of each bird survey location. We chose 200m and 500m buffers because this adequately captured the scales at which birds select resources and observations were made. The local habitat variables (Danz et al. 2017) were restricted to vegetation surveys conducted within a 200m buffer around each bird survey location, a spatial extent that appropriately described the wetland habitat within each survey location and that is also useful for restoration projects.

Patch Analyst (Rempel et al. 2012) in ArcGIS (ESRI 2019) was used to extract NOAA C-CAP land cover and USFWS National Wetland Inventory wetland classes within each 500m buffer around point-count locations. Extracted area values were converted to percent area per buffer. Land cover and wetland classes used in the analyses are listed in Appendix A. The same process was used to extract land cover occurring within the SLRE from Allouez Bay to Chamber's Grove. We chose to delineate this spatial extent of the river because it encompasses the wetland areas most likely to be chosen for restoration. Land cover and wetland classes were extracted from a 400m buffer (200m on land and 200m in the river) along the shoreline of the SLRE on both the MN and WI sides (Fig. 2).

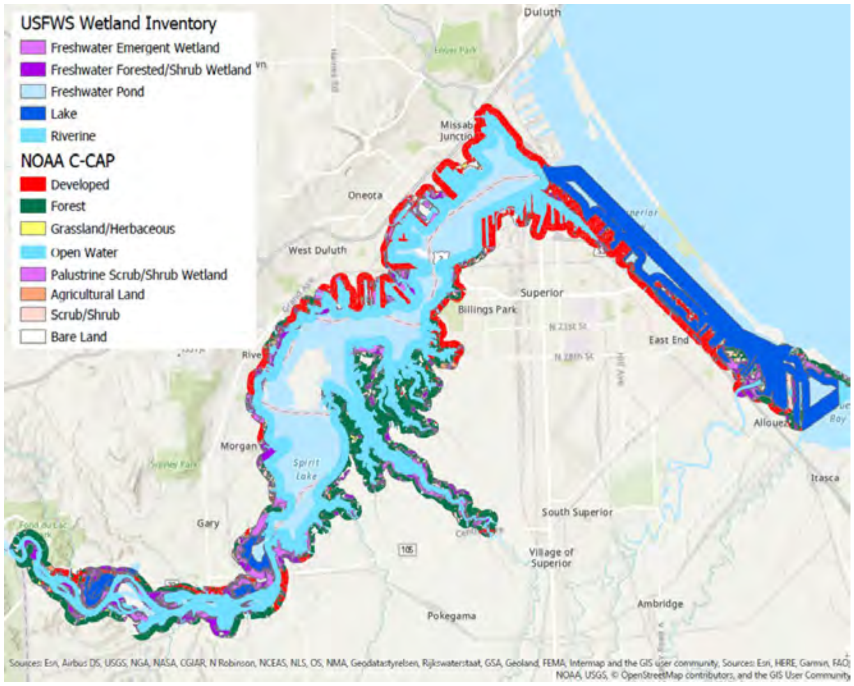

Figure 2. Map of land cover and wetland cover types from USFWS Wetland Inventory and NOAA C-CAP data. Calculations of cover types were restricted to a 400m buffer along the shoreline of the SLRE, from Allouez Bay to Chambers Grove.

We restricted local vegetation variables (Danz et al. 2017) to those that fell within a 200m buffer around each point-count location. Because of the magnitude of the 2012 flooding, we used the following rules to select local vegetation data that aligned best (temporally) with the bird data: 1) if a bird survey year was < 2012: select closest year before 2012; 2) if a bird survey year was ≥ 2012: select closest year after 2011; if no data matching were found in 2 or 3: select closest year ignoring 2012; and 4) select a sample at random if more than one is available from the selected year. Descriptions of local vegetation variables included in the summaries can be found in Appendix B.

Analytical Methods

For all analyses, unknown bird observations and flyovers were excluded. A total of 36,540 individual birds of 169 species were detected for all surveys and seasons combined. The number of bird surveys conducted and species detected varied by season (Table 1). All analyses were conducted independently by season using R version 3.6.1 (R Core Team 2019).

Table 1. The number of individual birds of known species detected during each season (spring migration, breeding season, fall migration) is provided along with the number of species detected, number of point-count surveys conducted, number of point-count locations, and years in which surveys were conducted.

Season	Number of Individuals	Number of Species	Number of Surveys Conducted	Number of Point-Count Locations	Years Surveyed
Spring Migration	8,725	134	174	40	2014 – 2015, 2018
Breeding Season	13,102	120	400	91	2011 – 2019
Fall Migration	14,713	130	312	52	2013 –2015, 2018

Guilds and community metrics

Each bird species was categorized within three different group types based on broad taxonomic groups (11), family (43), and foraging behavior (12; Appendix C). Information for categorizing species was obtained primarily from Cornell Lab of Ornithology (2019). Bird communities were summarized for each site by season using three metrics: species richness, Shannon–Wiener index of diversity, and Shannon evenness to assess bird use among sites and between seasons. We used t-tests to compare differences in environmental variables (cover types) within 200m and 500m buffers of sites with highest and lowest species richness.

To identify local-scale vegetation characteristics associated with diverse bird communities, we used linear regression models to assess the relationship between bird species richness and five vegetation metrics; vegetation species abundance (restricted to species with at least 10 detections), exotic cover, native species richness, water depth, and weighted mean C (Appendix B; refer to Danz et al. 2017 for additional details). Single vegetation metric (e.g., vegetation species abundance) models were fit, and best models were identified using both forward and backward stepwise AIC model selection (Burnham and Anderson 2003), using R package MASS (Venables and Ripley 2002).

Hierarchical cluster analysis

We calculated relative abundance (RA) for each species by aggregating individual counts at each point-count location, summing observations for each species detected and dividing by the number of surveys conducted at each site by season. We then used R package vegan (Oksanen et al. 2019) to identify site clusters. Environmental variables at the 200m and 500m scales were summarized to characterize clusters of sites. Percent Perfect Indicator analysis (see details below) was applied to clusters to identify bird species representative of associated bird communities.

PPI

We used Percent Perfect Indicator (PPI) models to determine associations between environmental variables and bird RA by season (Dufrêne and Legendre 1997). This modeling approach identifies the proportion of a given species detected in a given land cover type (e.g., developed) or wetland type (e.g., freshwater emergent) relative to the proportion of sites in that cover type or wetland type that were occupied by the species. This value can be used as an indicator for how important a landscape characteristic is to a given species (i.e., how strongly the species is associated with given characteristic).

Within each 200m and 500m buffer around point-count locations we calculated percent dominant habitats, after excluding the riverine category, as it comprised 43% of sites and was not useful in these analyses. The C-CAP categories Forested Wetland and Emergent Wetland were also removed because their definitions overlapped with the Wetland Inventory categories of Emergent Wetland and Forested Shrub Wetland. Any land cover type or wetland type categories that were dominant in less than 1% of sites were excluded. We also limited calculations of PPI to species that were detected in at least 10 sites. In addition to species RA, we also calculated PPI values for guilds to identify general patterns in cover type associations for similar species. The *P*-value for PPI indicates whether a species or group of species is a significant indicator of a given land cover type or wetland type. Non-significant values are still informative, as they identify which cover type or wetland type is most frequently used by a given species. PPI models were fit using R package labdsv (Roberts 2019).

RESULTS AND DISCUSSION

Overall

Spring migration: A total of 8,725 individuals of 134 species were observed over three survey years (2015, 2016, and 2018) during 174 point counts (*n*= 40) in the SLRE during spring migration (Table 1). The most common species included Lesser Scaup (1,187), Red-winged Blackbird (1,061), Canada Goose (751), Ring-necked Duck (661), and Mallard (486). Annual relative abundance for each species observed during spring migration can be found in Appendix D.

Breeding season: A total of 13,102 individuals of 120 species were observed over nine survey years (2011–2019) during 400 point counts (*n*= 91) in the SLRE during the breeding season (Table 1). The most common species detected during the breeding season included Red-winged Blackbird (3,043), Canada Goose (2,050), Ring-billed Gull (1,261), Yellow Warbler (795), and Song Sparrow (646). Annual relative abundance for species observed during the breeding season can be found in Appendix E.

Fall migration: A total of 14,713 individuals of 130 species were observed over four survey years (2013, 2014, 2015, and 2018) during 312 point counts (*n*= 52) in the SLRE during fall migration (Table 1). The most common species included Canada Goose (3,996), American Coot (2,298), Mallard (2,104), Common Grackle (1,093), and European Starling (652). Annual relative abundance for each species observed during fall migration can be found in Appendix F.

Land Cover Types

To determine the availability of different land cover types within the SLRE, we calculated the percentages of each land cover type from the NOAA C-CAP and USFWS Wetlands Inventory datasets (Appendix A). Because of differences in land use between MN and WI, we calculated percentages both independently for each state and with states combined (Fig. 2; Tables 2 and 3).

Table 2. Percent area of NOAA C-CAP land cover types found within a 400m buffer along the shoreline of the St. Louis River Estuary (SLRE). Values are provided separately ("Independent") for shoreline occurring in Minnesota (MN) and Wisconsin (WI), as well as in reference to availability within the entire SLRE (confined to 400m buffer around shoreline). See Appendix A for a description of land classifications. "Independent" values were calculated by dividing the land cover area by the total wetland area in the state. "Relative to SLRE" values were calculated by dividing the land cover area by the combined 400m buffer area in the SLRE.

	Independent (%)		**Relative to entire SLRE (%)**		
C-Cap Land Classification	***WI***	***MN***	***WI***	***MN***	***Total***
Developed	13.7	22.0	8.8	7.9	16.7
Agricultural Land	0.2	0.3	0.1	0.1	0.3
Grassland/Herbaceous	0.3	0.4	0.2	0.2	0.4
Forest	19.7	5.2	12.7	1.9	14.5
Scrub/Shrub	3.5	3.4	2.3	1.2	3.5
Palustrine Forested Wetland	4.3	2.0	2.8	0.7	3.5
Palustrine Scrub/Shrub Wetland	4.3	9.6	2.8	3.5	6.2
Palustrine Emergent Wetland	2.7	4.6	1.8	1.7	3.4
Bare Land	0.2	1.0	0.1	0.4	0.5
Open Water	51.0	51.6	32.7	18.5	51.2
Totals	100.0	100.0	64.1	35.9	100.0

Table 3. Percentages of USFWS Wetland Inventory wetland cover type found along the shoreline of the St. Louis River Estuary (SLRE). Values are provided separately ("Independent") for shoreline occurring in Minnesota (MN) and Wisconsin (WI), as well as in reference to availability of total wetland area and availability within the entire SLRE (confined to 400m buffer around shoreline). See Appendix A for a description of land classifications. "Independent" values were calculated by dividing the land cover area by the total wetland area in the state. "Relative to SLRE" values were calculated by dividing the land cover area by the combined 400 m buffer area in the SLRE.

	Independent (%)		**Relative to entire SLRE (%)**		
Wetland Inventory Land Classification	***WI***	***MN***	***WI***	***MN***	***Total***
Lake	31.7	22.3	11.7	5.3	17.0
Riverine	49.5	54.9	18.3	13.0	31.3
Freshwater Emergent Wetland	9.6	13.1	3.6	3.1	6.7
Freshwater Forested/Shrub Wetland	8.7	8.3	3.2	2.0	5.2
Freshwater Pond	0.6	1.4	0.2	0.3	0.5
Total	100.0	100.0	37.0	23.7	60.7

Land cover type summary: Based on the wetlands inventory data, there are approximately 3,100 hectares of 'wetland habitat' in the SLRE, including lands classified as riverine and lakes. Approximately 1,900 hectares are located in WI and 1,200 hectares are in MN. The three most abundant land cover types in the SLRE, after excluding riverine and lake, are developed, forest, and emergent wetland, respectively. As shown in Figure 2, the majority of developed land is located in the lower SLRE, in both MN and WI, while the majority of forested land is south of Billings Park in the Superior Municipal Forest, WI.

Minnesota: The three main land cover types in MN, excluding riverine and lake, are developed (covered by varying amounts of constructed materials), forest (dominated by trees generally greater than 5 meters tall and greater than 20% of total vegetation cover), and scrub/shrub wetland (dominated by woody vegetation less than 5 meters in height and total vegetation cover > 20%). Lands classified as wetlands comprise 66% of the 400m buffer area. Relative to size, there is more scrub/shrub and emergent wetland habitat (dominated by persistent emergent vascular plants, emergent mosses or lichens and total vegetation cover > 20%) located in MN than in WI.

Wisconsin: The three main land cover types in WI, excluding riverine and lake, are developed, forest, and emergent wetland. Lands classified as wetlands comprise 58% of the 400m buffer area. Compared to MN, there is more forested land in WI along the shore of the SLRE.

Discussion: An important takeaway from this summary is that while emergent wetland is a relatively common cover type, it primarily occurs in small patches throughout the SLRE. For example, less than 15% of the survey sites had more than 30% emergent cover at the 200m scale, and only two sites had more than 30% emergent wetland cover at the 500m scale. In general, increasing the amount and quality of emergent wetland habitat in the SLRE would be beneficial for bird communities. Long-term conservation efforts should focus on protecting the existing emergent wetland habitat and identifying restoration activities that enhance the connectivity between the small patches to provide quality habitat.

<u>Guilds and community metrics</u>

Bird community metrics (species richness, Shannon–Wiener index of diversity and Shannon evenness) were summarized by site and season for all bird guilds and groups, the full set of figures can be found in Appendix G. The results for the overall bird community metrics (i.e., all species; Fig. 3a) show that high diversity locations differ between seasons (spring migration, breeding, and fall migration), but in general, diversity and richness are higher in up-river sites compared to those in the lower part of the estuary and are highest near the Riverside the Spirit Lake areas (Table 4). Maps focusing on SGCNs (Fig. 3b) show a similar pattern (Table 5).

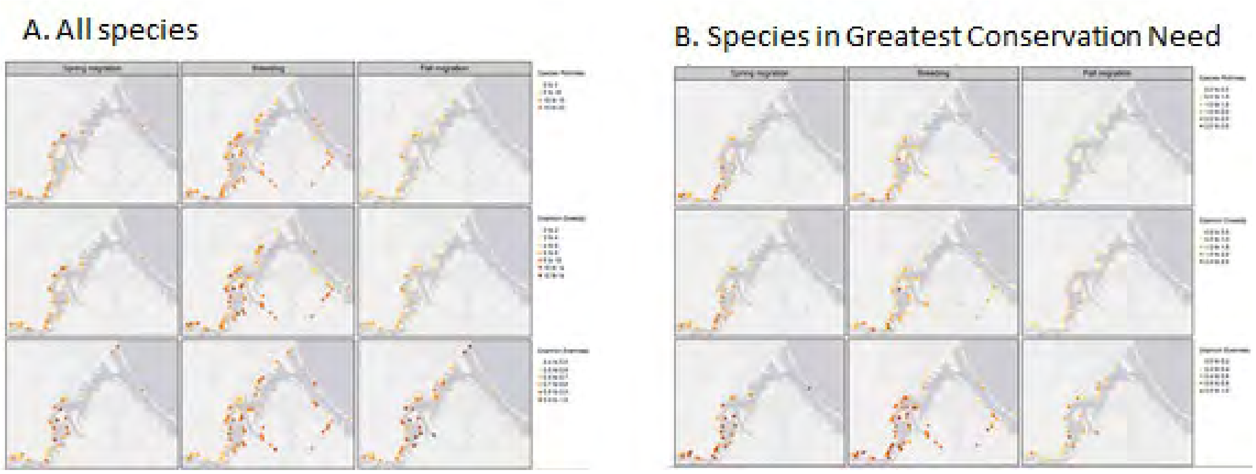

Figure 3. Maps of community metrics by season in the SLRE. A. shows the community metrics for all species observed each season, and B. shows community metrics for those designated as Species in Greatest Conservation Need by the Minnesota Department of Natural Resources.

Table 4. List of bird survey point-count locations within the St. Louis River Estuary (SLRE) where the highest and lowest mean species richness (SR) were detected during each season (spring migration, breeding, fall migration). We restricted sites to include the five highest and lowest values.

Season	Site	High SR		Site	Low SR
Spring migration	Grassy Point 2	16.33		Slip C 1	4.33
	Kingsbury Bay KB.2	15.20		Minnesota Slip 1	4.25
	Mud Lake ML.1	14.67		Clough Island 2	4.00
	Rask Bay RB.1	14.50		Spirit Lake West 3	3.00
	North Bay NB.1	13.83		Clough Island 1	2.00
Breeding	Clough Island 1	16.00		7073 4 (Kingsbury Bay)	6.50
	North Bay 1	15.80		7049 2 (21st Ave W)	6.17
	Kingsbury Bay 2	15.50		Minnesota Slip 1	5.60
	Perch Lake 1	14.67		7073 1 (Kingsbury Bay)	4.50
	Tallas Island TI.1	14.67		7074 1 (Grassy Point)	4.00
Fall migration	Kingsbury Bay KB.2	13.33		40th Avenue West 2	2.00
	Sargent Creek Floodplain SF.1	11.83		Spirit Lake West 3	1.83
	Spirit Lake SL.2	11.00		Spirit Lake East 2	1.67
	North Bay NB.1	10.67		Slip C 1	1.56
	Mud Lake ML.1	10.33		Spirit Lake East 1	1.20
	Mud Lake ML.1	10.33		Spirit Lake East 1	1.20

Table 5. List of bird survey point-count locations within the St. Louis River Estuary (SLRE) where the highest and lowest mean species richness (SR) were detected for species of greatest conservation need (SGCN), during each season (fall migration, breeding, spring migration). We restricted sites to include the five highest and lowest values. When sites had equal SR values, both were included; therefore, some seasons have more than five sites listed.

Season	Site	High SR	Site	Low SR
Spring migration	Rask Bay 2	3.00	Slip C 1	0.67
	Mud Lake ML.1	2.33	Spirit Lake East 1	0.67
	Spirit Lake SL.3	2.20	Sargent Creek Floodplain SF.2	0.60
	Mud Lake ML.2	2.00	Spirit Lake East 2	0.33
	Radio Tower Bay 1	2.00	Minnesota Slip 1	0.25
	Rask Bay RB.2	2.00		
	Spirit Lake West 1	2.00		
Breeding	7064 2 (Mud Lake)	2.50	1191 1 (Wisconsin Point Bay)	0.25
	Radio Tower Bay 1	2.33	7048 1 (40th Ave West)	0.25
	North Bay 1	2.20	Minnesota Slip 1	0.20
	Clough Island 1	2.00	1194 1 (inlet near Barker's Island)	0.17
	Kingsbury Bay 2	2.00	7049 2 (21st Ave West)	0.17
			7049 1 (21st Ave West)	0.13
Fall migration	Spirit Lake SL.2	1.17	Perch Lake 1	0.18
	Rask Bay RB.2	0.83	Grassy Point GP.1	0.17
	Spirit Lake SL.3	0.83	Kingsbury Bay 1	0.17
	40th Avenue West 3	0.80	Kingsbury Bay 2	0.17
	Little Pokegama Bay 2	0.75	Little Pokegama Bay 1	0.14

Based on linear regression models, there were no significant vegetation characteristics associated with species richness during any season, which may be a consequence of inadequate sample sizes for some metrics each season and high within group variability. However, the best model for the breeding season was nearly significant ($p = 0.07$) and showed that breeding bird species richness was positively correlated with native richness of plant communities. Some of the sites with the lowest species richness did not contain any vegetation (e.g., Minnesota Slip), and therefore there are no values to compare. Although we were unable to identify specific differences in local-scale vegetation metrics and species richness based on sites with highest and lowest species richness, we summarize the local-scale vegetation metrics for the sites identified in Table 4, including most abundant species of plants observed at sites where data are available, though note the small sample sizes (Appendix H). Although local-scale vegetation metrics were not significantly associated with species richness, landscape-scale environmental variables summarized for the sites with highest and lowest diversity show differences by season (Appendix I). During spring migration, species richness was significantly higher at sites with emergent wetland at the 500m scale and at sites with forested shrub wetlands, at both scales (Appendix I). During the breeding season, the amount of developed land is significantly lower in sites with highest species richness, at both spatial scales (Appendix I). During fall migration, the amount of emergent wetland was significantly greater in sites with highest species richness (Appendix I). These results suggest that breeding birds in the SLRE are more sensitive to human development than are birds during migration, which makes sense given migrating birds are using the habitat for short-term needs associated with rest and foraging, while migrating birds tend to use sites that are more sheltered and surrounded with vegetation (Appendix I).

Discussion: The results of these analyses suggest that pursuing opportunities for wetland restoration in the highly developed areas (i.e., those in the lower SLRE, closer to Lake Superior) would likely benefit birds. An expected outcome would be an overall increase in bird richness and diversity throughout the year and an increase in breeding and stop-over habitat use by SGCNs. A coordinated long-term monitoring program that temporally and spatially tracks changes in both bird and plant communities is recommended for the SLRE. This type of monitoring program will allow us to assess and make specific recommendations regarding plant community composition that will aid habitat restoration teams in identifying, targeting, and mitigating issues associated with biodiversity loss related to habitat quality in a timely manner. At a local scale, restoration plans should focus on the vegetation characteristics that benefit both breeding and migratory bird communities. Specifically, we recommend that restoration plans promote diverse native plant communities and account for ecological processes that will promote resiliency after disturbance.

Hierarchical cluster analysis

Hierarchical cluster analysis illustrated relationships among survey points conducted in each season based on bird associations alone (i.e., ignoring the assigned habitat categories). The relationships between the bird communities and site characteristics paint a complex picture of bird community composition within the SLRE. The relative abundance of species by cluster and results of the PPI for the clusters can be found in Appendix J.

Spring migration: Spring bird communities split the sites into three groups. At the 200m scale, the first group, “Spring A,” had a relatively high proportion of emergent and shrub wetland, and high proportion of developed land at the 500m scale. Based on the results of the PPI analysis, the bird species that were characteristic of this group included Tree Swallow, Swamp Sparrow, Hooded Merganser, Blue Jay, American Robin, and Belted Kingfisher (Appendix J). The second group, “Spring B,” had a high proportion of the lake cover type at the 200m and 500m scales. Species characteristic of this cluster included Ring-necked Duck and Redhead (Appendix J). Both species are surface divers and were likely responding to the deeper areas associated with the lake cover type. The third group, “Spring C,” was a mix of cover types at both scales (Fig. 4), and the only characteristic species for this cluster was Common Tern (Appendix J).

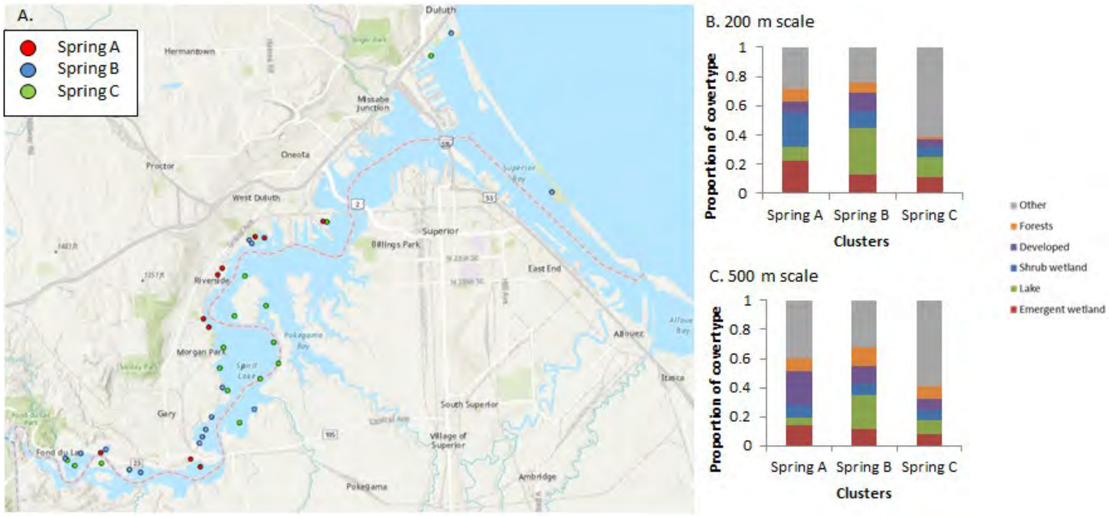

Figure 4. Site groupings based on the results of hierarchical cluster analysis for spring migration. **A.)** map of sites by cluster and summary of cover type variables of sites at the **B.)** 200m and **C.)** 500m scales.

Breeding season: The breeding season bird communities split the sites into four groups; the clusters had a similar proportion of emergent wetland, shrub wetland, and forest cover at the 200m scale (Fig. 5). Breeding group A had a relatively high proportion of developed cover, and characteristic species were those well-adapted to humans and included Ring-billed Gull, Mallard, and European Starling (Fig. 5; Appendix J). Sites in breeding group B had a mix of cover types at the 200m scale, but distinctive features were a high proportion of forests at the 500m scale. There were several characteristic species including European Starlings, Veery, Red-eyed Vireo, Ovenbird, Black-capped Chickadee, White-throated Sparrow, Chestnut-sided Warbler, Northern Flicker, and Black-throated Green Warbler (Appendix J). All characteristic species for this cluster breed in forest habitats with the exception of European Starling. Breeding groups C and D had a mix of land cover types, but sites in breeding group D had a higher proportion of lake cover (Fig. 5). There were no species that were characteristic of Breeding C, but there was high relative abundance of many wetland breeding species such as Yellow Warbler, Common Yellowthroat, Swamp Sparrow, and Marsh Wren. Importantly, this cluster had the highest relative abundance of both Virginia Rail and Sora. Breeding group D also had several wetland-associated species, including Swamp Sparrow and Marsh Wren. Red-winged Blackbird, Canada Goose, and Common Grackle were characteristic species of Breeding D. The results of breeding groups C and D show that these are the sites that are important for breeding wetland birds. The combination of “wetland” habitats including lake, emergent wetland, and scrub-shrub wetlands for these sites are, on average, at least 50% of the 200m scale (Fig. 5).

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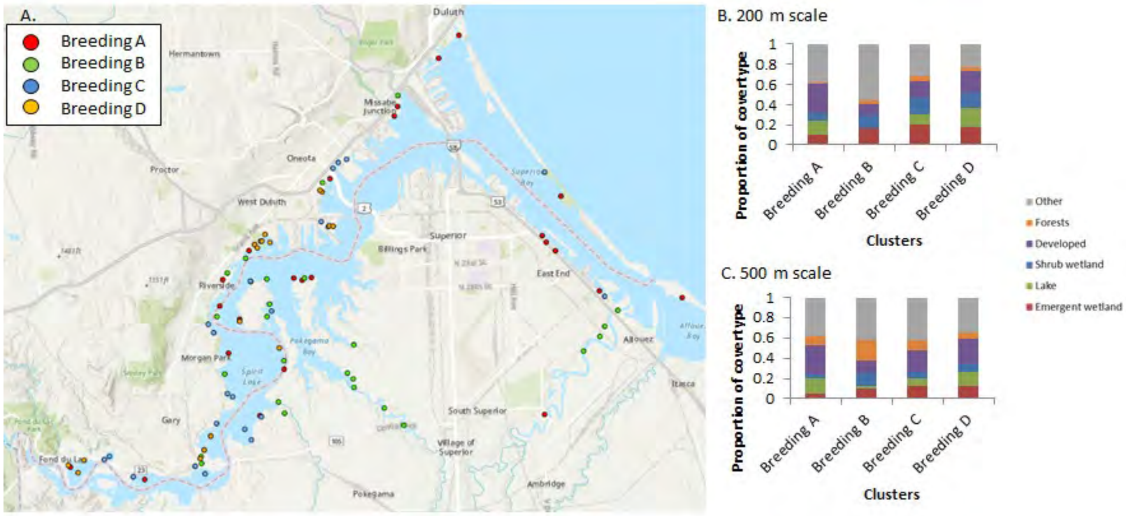

Figure 5. Site groupings based on the results of hierarchical cluster analysis for the breeding season. **A.)** map of sites by cluster and summary of cover type variables of sites at the **B.)** 200m and **C.)** 500m scales.

Fall migration: The fall migration bird communities clustered sites into three groups. Sites in fall group A had a mix of cover types at the 200m scale and a high proportion of developed and lake cover types at the 500m scale (Fig. 6). Sites in the fall group B sites had relatively little lake cover at the 200m scale and high percentage of forest at the 500m scales (Fig. 6). Sites in the fall group C cluster had a high proportion of lake and developed at the 200m scale (Fig. 6). There were no species that had significant associations for the fall migration clusters (Appendix J), although there were patterns in overall relative abundances between groups. For example, Fall A had many species that are tolerant to development such as Canada Goose, Mallard, and Common Grackle. Importantly, this group had the highest relative abundance of Rusty Blackbirds. Fall group B had a mix of waterfowl such as Canada Goose, Mallard, and American Coot, along with wetland species such as Red-Winged Blackbird, and forest species such as Black-capped Chickadees. Fall Group C had several waterfowl species with relatively high abundances such as American Coot, Ring-necked Duck, and Bufflehead (Appendix J).

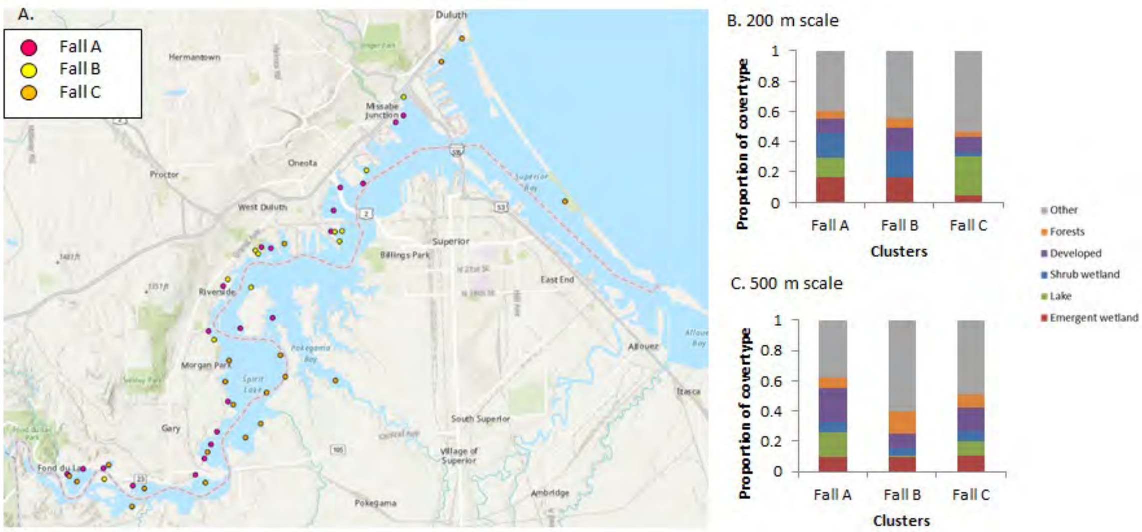

Figure 6. Site groupings based on the results of hierarchical cluster analysis for fall migration. **A.)** map of sites by cluster groupings and summary of cover type variables of clustered sites at the **B.)** 200m and **C.)** 500m scales.

Discussion: The overall results of these analyses show that birds use a combination of scrub-shrub, emergent, and lake habitats, i.e., there are no groups that have a dominant "emergent wetland," "scrub-shrub wetland," or "lake" characteristics. The goal of restoration priorities should be to provide a minimum of 50% of "wetland-associated" cover types to support breeding wetland species. This guideline will also benefit migrating birds.

<u>PPI</u>

Species-specific. The results of the species PPI analysis showed 25 species had significant associations with cover type variables at the 200m and 500m scales (Appendix K). Red-winged Blackbird was the only species that had a significant result during spring migration and was associated with shrub wetlands at the 200m scale. Fourteen (14) species had significant associations with cover type variables at the 200m scale, and 17 species had significant associations at the 500m scale. This result is likely due to the fact that species respond to different scales, particularly during the breeding season, and scale of importance is generally associated with territory size, foraging behavior, and nesting requirements. During fall migration, four species — American Goldfinch, Common Yellowthroat, Hairy Woodpecker, and Red-eyed Vireo — were significantly associated with forested shrub wetland at the 200m scale. These results show the importance of a variety of habitat types in the SLRE used by birds throughout the year.

There were no significant habitat associations for these wetland-obligate bird species including American Coot, Marsh Wren, Pied-billed Grebe, Sora, Swamp Sparrow, and Virginia Rail (Fig. 7). However, the results of the PPI show the relative importance of different habitat types for each species.

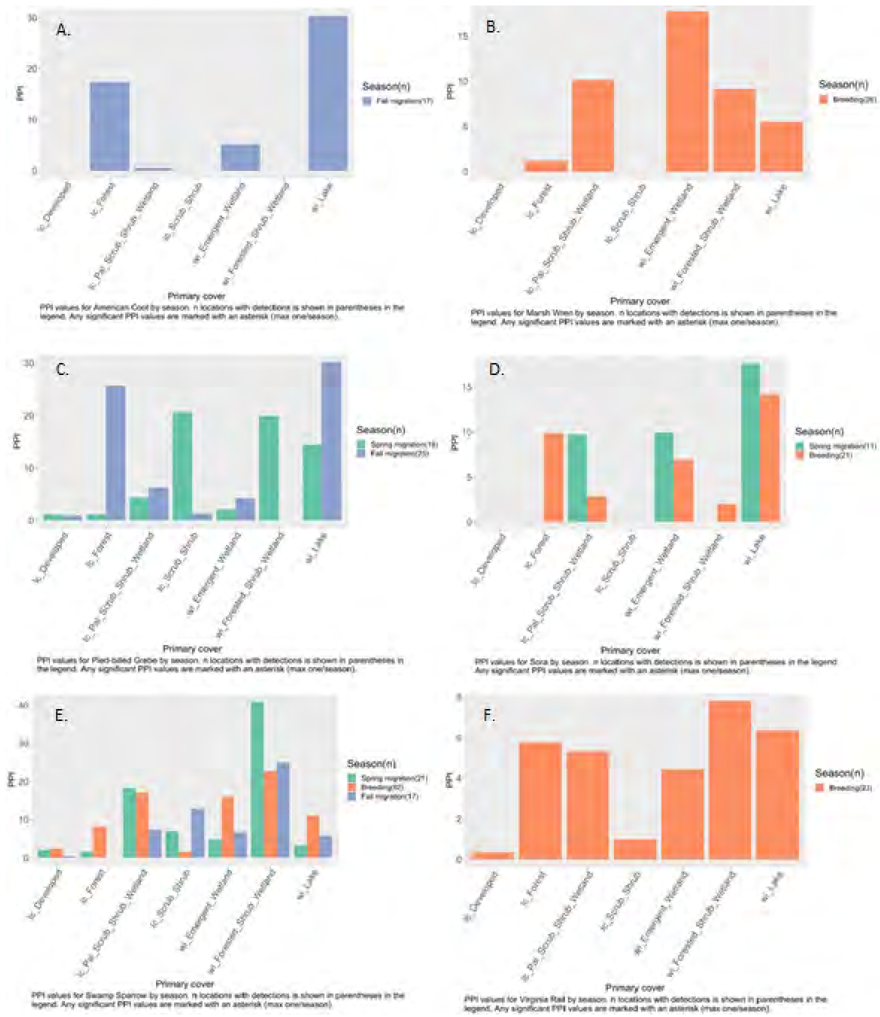

Figure 7. PPI results of cover type associations for wetland obligate bird species including **A.)** American Coot, **B.)** Marsh Wren, **C.)** Pied-billed Grebe, **D.)** Sora, **E.)** Swamp Sparrow, and **F.)** Virginia Rail.

Guilds. The results of the PPI analysis showed significant associations for 5 guilds during spring migration, 13 guilds during the breeding season, and 4 guilds during fall migration (Appendices L–N).

Forested shrub wetlands was significantly associated with several guilds. For example, groups that characterize sandpipers (probing, Scolopacidae, shorebirds) were significantly associated with forested shrub wetlands at the 200m scale during spring migration and during the breeding season. Additionally, aerial foragers, kingfishers, and swallows were associated with forested shrub wetlands at the 200m scale during the breeding season. Warblers and bark foragers were significantly associated with forest cover type during the breeding season at the 200m and 500m scales, respectively. During fall migration, forested shrub wetlands were significantly associated with finches and cormorants at the 200m scale and soaring foragers at the 500m scale. Importantly, emergent wetland at the 500m scale was significantly associated with rails during fall migration.

SUMMARY AND MANAGEMENT RECOMMENDATIONS

- The SLRE is critical to birds throughout the year. A consistent, dedicated, long-term bird monitoring program in the SLRE is essential for long-term conservation of biodiversity. We recommend a monitoring program that focuses on bird use in the SLRE throughout the year (spring migration, breeding, and fall migration). The monitoring program should also include an overlapping and coordinated fine-scale vegetation component that allows for classifying native plant communities at the bird survey sites. Annual drone imagery that facilitates monitoring the amount and locations of emergent wetland at the landscape scale would be important for documenting changes in wetland quality over time. Specifically, changes in the availability of emergent wetland habitat from a combination of shrub encroachment, water level changes, and the spread of invasive plant species needs to be monitored.
- Results of cluster and PPI analyses show the importance of having a variety of habitat types in the SLRE, which are used by birds throughout the year. Many bird species and guilds rely on "shrub- scrub" wetlands, maintaining these cover types is recommended.
- Birds that are considered "wetland obligate" species are present but not widespread in the estuary, despite the fact that there is habitat available. While wetland obligate species such as Virginia Rail are often observed in the SLRE, they are found in low densities, thus making site-specific habitat recommendations challenging.
- Our results suggest that pursuing opportunities for wetland restoration in the highly developed areas (i.e., those that are closer to Lake Superior) would likely benefit birds, and an expected outcome would be an overall increase in bird richness and diversity throughout the year and an increase in available breeding and stop-over habitat for SGCN. Based on sites with highest species richness and cluster analyses, increasing the amount and quality of emergent wetland habitat in the SLRE would be beneficial for several bird communities. The goal of restoration priorities should be to provide a minimum of 50% "wetland-associated" cover types to support breeding wetland species. This guideline will also benefit migrating birds.
- Long-term conservation efforts should focus on protecting the existing emergent wetland habitat and identifying restoration activities that enhance connectivity between the small patches that are providing quality habitat.

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LIST OF APPENDICES

Appendices are attached to this document as individual PDF files. Following are descriptions for each appendix:

Appendix A. List of landscape-scale variables included in analyses to identify bird-habitat associations. These variables were calculated within a 200m and 500m buffer around each bird survey point count location. A brief description of each classification is provided for each dataset. A link to additional metadata for each source can be found in the footnotes.

Appendix B. List of local-scale (within wetland) plant community variables included in analyses to identify bird-habitat associations. These variables were calculated within a 200m buffer around each bird survey point count location. A brief description of each classification is provided for each dataset. A link to additional metadata for each source can be found in the footnotes.

Appendix C. List of species detected during point-count surveys in the St. Louis River Estuary. The four-letter alpha code is provided for each species as well as common and scientific name, group it was included in for analysis, family group, foraging behavior, and whether it was identified as a species of greatest conservation need (SGCN) by the Minnesota Department of Natural Resources (DNR). The footnote has a link to the Minnesota DNR listed species that provides additional information about each species.

Appendix D. Relative abundance of each species detected per year during spring migration.

Appendix E. Relative abundance of each species detected by year during the breeding season.

Appendix F. Relative abundance of each species detected by year during fall migration.

Appendix G. Bird community species richness, species diversity, and species evenness maps of the St. Louis River Estuary for spring migration, breeding season, and fall migration.

Appendix H. List of local-scale vegetation metrics included in the species richness linear regression models. The sites with highest and lowest species richness (SR), provided in Table 6, are summarized here. Detailed descriptions of the vegetation metrics can be found in Appendix B and in Danz et al. (2017). The average value of each metric and range of values is provided with the sample size (n). For plot_obs, the most common species are listed, note the sample size of plot_obs is particularly low for all seasons.

Appendix I. Comparison of environmental variables within 200 and 500m buffers around bird survey locations for sites with highest and lowest species richness (see Table 6 for list of sites). Within each season (Breeding, Fall migration, Spring migration), mean percent cover and range are provided. T-test Results are provided by buffer distance and significant values ($p \le 0.05$) and in bold.

Appendix J. Species relative abundance and results of the Percent Perfect Indicator analyses based on the results of the heirarchical cluster analysis.

Appendix K. Percent Perfect Indication (PPI) values for species relative to cover type and season (spring, breeding, and fall). Values are listed at the 200m and 500m scales. Significant values are denoted in bold with an asterisk and the number of locations with detections is included in parentheses.

Appendix L. Percent Perfect Indication (PPI) values for groups of species (behavior, family, general) relative to cover type and season (Spring, Breeding, and Fall). Values are listed at the 200m and 500m scales. Significant values are denoted in bold with an asterisk and the number of locations with detections is included in parentheses.

Appendix M. Percent Perfect Indication (PPI) values for groups of species (behavior, family, general) relative to season (spring, breeding, and fall) and cover type at the 200m scale.

Appendix N. Percent Perfect Indication (PPI) values for groups of species (behavior, family, general) relative to season (spring, breeding, and fall) and cover type at the 500m scale.