Obligate Grassland Breeding Bird Ecology on Islands and Mainland Habitats in the St. Lawrence River Corridor

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Abstract

The decline of obligate grassland breeding birds in North America over the past 40 years has resulted in focused grassland management and conservation efforts, including in New York State. Thus, there is a need for knowledge of obligate grassland breeding bird habitat preferences and high-quality grassland bird habitat. The primary objective of my study was to evaluate the quality of two large islands in the St. Lawrence River, Galop Island and Ogden Island, as obligate grassland breeding bird habitat, by comparing their grassland bird communities to those present at two mainland sites, the Green Landowner Incentive Program (LIP) site and Whitehouse Point. I conducted double-observer bird point counts, and vegetation and arthropod surveys in 2015 and 2016. Bobolinks (*Dolichonyx oryzivorus*) and Savannah Sparrows (*Passerculus sandwichensis*) were the most abundant obligate grassland bird species across the four sites, and were two of five obligate grassland breeding bird species observed over both years. Total obligate grassland breeding bird and Bobolink abundance were higher at the Green LIP site, Ogden Island, and Whitehouse Point, and lower at Galop Island. Savannah Sparrow abundance was similar across all four sites during both years of study. I found that percent graminoid cover was the best predictor of total obligate grassland breeding bird and Bobolink abundance in both years, though it was a weaker predictor of Savannah Sparrow abundance. Variability in arthropod biomass appeared to have little effect on obligate grassland breeding bird abundance, but was high across all sites during both years. Ogden Island supported an abundant obligate grassland breeding bird community, but Galop Island requires focused management to facilitate conversion of shrubland and early successional forest to high-quality grassland habitat. The Green LIP site's high obligate grassland breeding bird abundance highlights the importance of private land management in the conservation of obligate grassland breeding birds. My study indicates that large islands in the St. Lawrence River may provide high-quality obligate grassland breeding bird habitat if are managed to retard or prevent succession of grasslands into shrubland and forest habitat.

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Introduction

Over the last 40 years, obligate grassland breeding birds have declined throughout North America (Vickery and Herkert 2001). Breeding Bird Survey data indicate that 92 percent of grassland breeding bird species in the lower Great Lakes/St. Lawrence Plain of North America region display negative trend estimates, while none show positive trend estimates (Sauer *et al.* 2017). Between the first and second breeding bird atlases in New York (1980-1985, 2000-2005), the statewide distribution of obligate grassland breeding birds declined, with the distribution of five of the 13 species that breed in the state declining by over 50 percent (McGowan and Corwin 2008).

Widespread alteration of native grassland habitat and change in agricultural practices has been implicated in the general decline of grassland birds in North America (Askins 1997, Vickery and Herkert 2001, Murphy 2003, McGowan and Corwin 2008). Furthermore, land-use trends, such as abandonment of agricultural lands and their succession to shrublands and early-growth forests, have facilitated grassland bird declines (Askins 1999, Murphy 2003, McGowan and Corwin 2008). Land-use changes in the surrounding landscape and construction of more roads have resulted in highly fragmented grassland habitat and smaller habitat patches (Askins 1999, Norment 2002).

Focused management aimed at conserving grassland habitats has increased in response to the decline in obligate grassland breeding birds in the Northeastern United States (Norment 2002, Ochterski 2005, Morgan and Burger 2008). The New York State Department of Environmental Conservation (NYSDEC) established best management practices (BMPs) for grassland habitats on appropriate Wildlife Management Areas (WMAs) and other state lands, while implementation of Landowner Incentive Programs (LIP) and Conservation Reserve Programs (CRP) in New York State has incentivized farmers to follow BMPs for grassland breeding birds (McGowan and Corwin 2008, Morgan and Burger 2008). Further, NYSDEC, Audubon New York, The College at

Brockport, SUNY, and other partners have spearheaded a working group to develop a statewide plan to guide grassland bird conservation efforts. Such efforts must take into account the habitat requirements of obligate grassland breeding birds, which vary across species and region (Norment *et al.* 1999, Norment 2002).

Grassland birds as a guild are generally area-sensitive and require habitat patches larger than 5 ha for breeding, highlighting the importance of conserving and managing large patches of grassland habitat (Norment *et al.* 1999, Winter and Faaborg 1999, Johnson and Igl 2001, Balent and Norment 2003, Winter *et al.* 2006, Ribic *et al.* 2009). Larger patches reduce edge habitat, specifically where grasslands border forested land, which reduces nest success in species such as Bobolinks (*Dolichonyx oryzivorus*) (Bollinger and Gavin 2004). Habitat quality increases site fidelity and nest success in grassland birds (Bollinger and Gavin 1989), and is influenced not only by grassland patch area, but also by within-patch variables such as cover by bare ground, grass, dead vegetation, forbs and litter (Fisher and Davis 2010). Management practices that favor low horizontal heterogeneity characterized by few shrubs and trees, varied mixes of grasses and forbs, low vegetation density and shorter vegetation tend to yield greater abundance and nest productivity of grassland birds, especially in the northeastern United States (Norment *et al.* 1999, Fisher and Davis 2010). Intense grazing and hay-cropping during the breeding season also need to be curtailed to ensure high productivity and survival of grassland birds (Bollinger and Gavin 1989, Norment *et al.* 1999, Perlut *et al.* 2006, Perlut *et al.* 2008, Fisher and Davis 2010). However, disturbance, which potentially includes mowing, haying, fire, and low to moderate intensity grazing, is necessary to fight ecological succession and maintain grassland ecosystems, especially in the Northeast (Askins 1997, Hunter *et al.* 2001).

Most species of grassland songbirds nest inconspicuously on the ground or in a clump of forbs or graminoids, with their camouflaged eggs hidden by vegetation above the nest (Elphick *et al.*

2001. Though nests are often well-hidden, nest predation by mammals, such as skunks and raccoons, is common (Bollinger and Gavin 1989, Patterson and Best 1996, Vickery *et al.* 1992, Davison and Bollinger 2000). However, most predation by mammals is random as they are opportunistic predators (Vickery *et al.* 1992). Snakes are also important predators of bird nests in early successional habitats (Thompson *et al.* 1999, Davison and Bollinger 2000, Klug *et al.* 2010). Further, risk of grassland bird nest predation by snakes increases with increased shrub cover and decreased height of forbs and graminoids (Klug *et al.* 2010). Some grassland habitat patches, such as active hayfields, are sinks for grassland birds, since nests and young are destroyed by early-haying practices (Perlut *et al.* 2006, Perlut *et al.* 2008, Norment *et al.* 2010). Thus, nest success is a good indicator of habitat quality (Perlut *et al.* 2006, Norment *et al.* 2010).

Because obligate grassland breeding birds and their habitats are declining across North America, including New England and New York State, it is imperative that wildlife biologists manage for these species, to facilitate their population recovery and viability (Hunter *et al.* 2001, Norment 2002, Morgan and Burger 2008, Norment *et al.* 2010). However, the varied ecological requirements of grassland bird species in New York demand management and conservation of a diverse array of habitats (Norment *et al.* 1999, McGowan and Corwin 2008). A clear understanding of grassland bird habitat preferences, such as vegetation characteristics and patch size, is necessary (Winter *et al.* 2006). This allows wildlife managers to identify areas with suitable habitat for grassland birds to protect and manage. Understanding the predator-prey relationships involving grassland birds is also needed, as these may influence productivity and survivorship of grassland birds.

In addition to a general understanding of grassland bird habitat preferences, it is crucial to understand habitat preferences on a local scale (Winter *et al.* 2006). In my study, I evaluated the viability of large islands in the St. Lawrence River in St. Lawrence County, New York, as quality grassland bird habitat. These islands may provide high-quality habitat for obligate grassland breeding birds, not only because they support large patches of suitable habitat, but also because their partial isolation could protect grassland bird nests from some terrestrial mesopredators (Lomolino 1982). Although Bélanger and Picard (1999) evaluated obligate grassland breeding bird populations on large islands of the St. Lawrence River in Quebec, few detailed data are available on grassland breeding bird use of large islands in the St. Lawrence River of New York State. I also evaluated other sites in the surrounding "mainland" landscape to help the multi-agency statewide grassland bird working group determine if the region should be designated as a grassland bird conservation center. Grassland bird conservation centers are priority areas in New York State for allocation of resources dedicated to focused grassland bird management. With limited available resources, it is necessary to identify the most important sites, as well as the most influential habitat characteristics, to best manage for obligate grassland breeding birds. Specifically, I evaluated what habitat factors affect total obligate grassland bird abundance, and abundance of the two most widespread species at my study sites, Bobolink and Savannah Sparrow (*Passerculus sandwichensis*). I compared obligate grassland breeding bird communities across sites to assess viability of the island sites as good grassland habitat. In my study, I tested for differences in obligate grassland breeding bird abundance between island and mainland sites in the St. Lawrence River corridor and for effects of habitat variables on obligate grassland breeding bird abundance.

Methods

Study Area

The study area includes land targeted via habitat improvement projects (HIPs) developed by the New York Power Authority and the New York State Department of Environmental Conservation (NYSDEC) in accordance with the New York Power Authority's license to operate the Moses-Saunders Power Dam on the St. Lawrence River (NYSDEC 2012). The study area includes land on Galop (170 ha; approx. 44.766100, -75.400412) and Ogden (116 ha; approx. 44.868411, -75.222714) islands in the St. Lawrence River, and two nearby mainland sites, Whitehouse Point (52 ha; approx. 44.845485, -75.272442) and the Green Landowner Incentive Program (LIP) site (63 ha; approx. 44.789139, -75.303796), in the towns of Lisbon and Waddington, in St. Lawrence County, New York (Figure 1). At its nearest point, Galop Island is approximately 220 m from the shoreline of the St. Lawrence River, while Ogden Island is approximately 420 m from the shoreline. All sites are managed by the NYSDEC, with authority given by the New York Power Authority at Galop Island, Ogden Island, and Whitehouse Point, and authority granted to the NYSDEC at the Green LIP site. The sites are located in the Lower St. Lawrence River Important Bird Area (IBA), as designated by the National Audubon Society.

Galop Island, Ogden Island, and Whitehouse Point were all expanded with spoils from construction of the St. Lawrence Seaway from 1955-1959 and have many large rock piles and outcrops throughout (Riveredge Associates, LLC 2010). Galop Island was historically grazed until approximately 15-20 y ago (M. Morgan, personal communication) but is now primarily a successional shrubland with some open patches of cool-season grasses, such as redtop (*Agrostis gigantea*), and forbs, such as bedstraw (*Galium* sp.) interspersed with patches of dense trees and shrubs, such as quaking aspen (*Populus tremuloides*), staghorn sumac (*Rhus typhina*), and silky dogwood (*Cornus amomum*). There are also some open areas on Galop Island with rocky substrate with sparse vegetation characterized by patches of red cedar (*Juniperus virginiana*) and unique plants such as shrubby cinquefoil (*Dasiphora fruticosa*). The Green LIP site, Ogden Island, and Whitehouse Point are mostly open pastureland composed primarily of cool-season grasses such as redtop, timothy (*Phleum pratense*), and orchard grass (*Dactylis glomerata*), sedges, and early-successional forbs such as goldenrod (*Solidago* sp.) and tufted vetch (*Vicia cracca*), where grazing is allowed through agricultural agreements; these sites also include some hedgerows, wetland areas, and small patches of open woodland (Riveredge Associates, LLC 2010, NYSDEC 2012). Average vegetation height at the Green LIP site, Ogden Island, and Whitehouse Point varied, but was around 30-40 cm during the early grassland bird breeding season. Aside from those on Galop Island, the open areas have been recently managed using mowing and brush removal techniques (NYSDEC 2012).

Bird sampling

From late May through late June 2015 and 2016, I conducted four replicate sets of point counts once every c. 7 d to determine the community composition and abundance of obligate grassland breeding birds at each site. Due to variable site size, there were nine point count stations at Galop Island, five at the Green LIP site, 11 at Ogden Island, and four at Whitehouse Point. Points at all four sites were used in previous studies of obligate grassland breeding birds (Riveredge Associates, LLC 2010, NYSDEC 2012). Points were placed ≥400 m apart to prevent double counting of birds (Riveredge Associates, LLC 2010, NYSDEC 2012). Point counts involved 5 min of passive observation and occurred no earlier than 15 min before sunrise and no later than 4 h after sunrise. I recorded birds within a 100 m radius of the point. I recorded each obligate grassland breeding bird observed, its distance from the point, and any breeding behavior it displayed. Using the double-observer method outlined by Nichols *et al.* (2000), my assistant and I alternated between primary and secondary observer, with one calling out birds to the other, who recorded them, along with birds not seen by the other. This method allows for calculating detectability using the program DOBSERV, which is effective in attaining high detection probability to ensure precise counts of bird abundance (Nichols *et al.* 2000). I also recorded ambient temperature, wind speed and direction, and percent cloud cover at each point. I avoided sampling during inclement weather, such as rain or high winds (>15 kph).

Additionally, I monitored Savannah Sparrow nests, since Savannah Sparrow was the most abundant obligate grassland breeding bird species across the four study sites. Starting in late May, I found and monitored nests until young fledged, or the nest was depredated or abandoned. My goal was to find and monitor at least ten nests each at both island and mainland sites during each breeding season. I found nests by actively watching adults visit potential nest sites and by inadvertently flushing females from nests. To mark nests, I placed flagging ≥10 m from the nest to not attract predators, and recorded the direction to the nest. Further, to prevent attracting predators to the nest, I would take a different path each time I visited the nest. My assistants and I attempted to check each nest during every site visit. Initially, I recorded the coordinates of the nest using a GPS, number of eggs or nestlings, litter depth (cm) at the nest, and orientation of the nest opening. During subsequent visits, I recorded the hatching status and development stage of the young until fledging or the nest was depredated.

Vegetation sampling

I sampled vegetation around each point in a circular plot with a 100 m radius. I used a Robel pole to estimate vegetation height and density in each circular plot (Robel *et al.* 1970). I took four Robel pole readings in each plot, one 25 m in each cardinal direction from the point using methods in Robel *et al.* (1970). I averaged the four readings to get the overall Robel pole value for each plot. In each plot, I established 100 m transects in each cardinal direction from the center point. I placed a 1 m x 1 m quadrat at 20 m intervals along each transect, for a total of 20 quadrats per circular plot, except when the circular plot included open water. In each quadrat I recorded litter depth and height of tallest vegetation to the nearest cm using a meter stick, and recorded the total number of unique plant taxa. In each quadrat, I recorded percent cover categories based on the Braun-Blanquet cover-abundance scale (0, >0-5, >5-15, >15-25, >25-50, >50-75, >75-100 percent) for each of the following categories: live graminoid, live forb, live legume, standing dead vegetation, woody vegetation, and bare ground (Braun-Blanquet 1932). These variables, along with litter depth, height of tallest vegetation, total number of taxa, and Robel Pole score, were the ten raw predictor variables used in my data analysis. I also identified and recorded percent cover of the three most abundant taxa in each quadrat using the Braun-Blanquet cover-abundance scale (Braun-Blanquet 1932). I also recorded any presence of exotic species in the quadrats.

Arthropod sampling:

I sampled the arthropod community at three of the four sites (I did not sample arthropods at the Green LIP site since it was private land) to evaluate potential prey biomass for nesting obligate grassland breeding birds. Since obligate grassland breeding birds are almost exclusively insectivorous during the breeding season, but do not feed exclusively on any singular group of arthropods (Martin *et al.* 1951, Wiens and Rotenberry 1979), I used two different sampling methods. A combination of pitfall traps and sweep nets samples a wider range of potential taxa, and provides a more comprehensive estimate of prey abundance and composition, than one method used alone (Norment 1987). I sampled arthropods at five evenly spaced sampling stations at each site, concurrent with points used for bird point counts. I sampled at every other point at Galop and Ogden Island. Since there were four initial bird survey points at Whitehouse Point, I created a fifth arthropod sampling station ≥400 m apart from the others. I conducted sweep net and pitfall trap collection concurrently. I did 50 sweeps of the sweep net while walking in a line from SE to NW straight across each point, not overlapping the pitfall traps. I avoided sampling during inclement weather, such as rain. I processed arthropods collected with sweep nets using ethyl acetate in a kill jar and placed them in a freezer upon immediate return from the field. I placed pitfall traps 25 m in each cardinal direction from the point. I placed a small amount of ethylene glycol in small plastic cups (12.1 cm deep, 9.25 cm diameter) and left them for 24 h before collection. I covered pitfall traps when they were not in use with plastic secured with a rubber band to prevent entrapment of arthropods outside of the sampling period. I placed arthropods collected in pitfall traps in plastic bags in a freezer before analysis. I sampled arthropods twice at each site, beginning when I observed the first nestlings, with ≥10 d between collections. Pitfall traps did not work on Galop Island due to the rocky substrate, but I still used sweep nets there during 2016. However, I used pitfall traps and sweep nets during 2015 and 2016 at Ogden Island and Whitehouse Point.

In the lab, my assistants and I measured each individual insect to the nearest mm from the anterior end of the head to the posterior end of the abdomen and identified them to order. Next, I calculated arthropod biomass from length measurements using formulas in Ganihar (1997). I combined arthropod data from both sampling periods but separated data by year and by sampling method.

Mesopredator (mammal) sampling

To evaluate the abundance of potential predators of grassland bird nests and young, I placed trail cameras at Galop Island, Ogden Island, and Whitehouse Point. I did not place trail cameras at the Green LIP site because the site was on private land. I placed five trail cameras at each site, evenly spaced throughout the area. I installed trail cameras when I observed the first nests with eggs, and left them up for 30 d. I placed trail cameras in 2015, but not in 2016, since I did not have access to any during the field season.

Statistical Analyses

To evaluate bird abundance data, I first calculated detectability using the program DOBSERV, which is based on methods outlined in Nichols *et al.* (2000). Detectability was almost

1.0 for both Bobolink (p=0.9778), and Savannah Sparrow (p=0.9853), so I used the raw data from point counts in my analyses since DOBSERV calculations indicated that nearly all birds present were detected.

I calculated average abundance across four replicates at each point, then found the average abundance across all survey points at each site to assess differences in abundance of Bobolink, Savannah Sparrow, and total obligate grassland breeding birds between sites. I included five obligate grassland breeding bird species in my abundance calculations: Northern Harrier (*Circus cyaneus*), Bobolink, Eastern Meadowlark (*Sturnella magna*), Savannah Sparrow, and Grasshopper Sparrow (*Ammodramus savannarum*). I tested for normality using the Shapiro-Wilk test, and used Levene's test to evaluate homogeneity of variances. I analyzed each response variable by year, and found that, even after transformation, 2016 total obligate grassland breeding bird data, and 2015 and 2016 Bobolink data, did not meet parametric assumptions of normality and equal variances. Since only three datasets met the assumptions of normality, I used a Kruskal-Wallis test in IBM SPSS Statistics 24 (IBM Corp. 2016) to determine differences in abundance across the four sites. I then used a post-hoc Dunn's test to identify which sites accounted for differences in abundance.

I used a principle component analysis (PCA) to consolidate the nine habitat variables into two new predictor variables. I retained the two principle components that explained the highest percent of variance in both 2015 and 2016. I used retained principle components as predictor variables in the generalized linear models (GLMZs). I used a correlation matrix to remove highly correlated variables (r>0.80) (Danz *et al.* 2007). Next, I ran GLMZs using IBM SPSS Statistics 24 (IBM Corp. 2016) to evaluate relationships between response variables and predictor variables. Total obligate grassland breeding bird abundance, Savannah Sparrow abundance, and Bobolink abundance were response variables. I included site as a factor in my analysis. I ran separate GLMZs for 2015 and 2016 data. I used second-order Akaike's Information Criteria (AIC_c) to select the best model, and reported all models with a ΔAIC_c <2.0 (Anderson and Burnham 2002).

Using a Shapiro-Wilk test, I found that arthropod data for both sweep nets and pitfall traps were normally distributed. I separated arthropod data by year and by sampling method, and ran independent sample t-tests to evaluate differences in arthropod biomass from pitfall traps at Ogden Island and Whitehouse Point in both 2015 and 2016. I also used an independent sample t-test to evaluate differences in arthropod biomass from sweep nets at Ogden Island and Whitehouse Point in 2015. I used a one-way ANOVA to test for differences in arthropod biomass from sweep nets at Galop Island, Ogden Island, and Whitehouse Point in 2016. I ran simple regression analyses evaluating the relationship between sweep net and pitfall trap arthropod biomass and total obligate grassland breeding bird abundance.

Lastly, I calculated daily survival probabilities of Savannah Sparrow nests using the program MAYFIELD (Mayfield 1975, Hines 2002) and methods outlined in Bart and Robson (1982). This method accounts for exposure days, which eliminates biases associated with limited nest visits and the discovery of nests after initiation of incubation. I calculated the probability of nest success based on data from multiple visits to nests at both island and mainland sites.

Results

Grassland Bird Communities

In 2015, total obligate grassland breeding bird abundance ranged from 3.2 to 8.4 birds per point across all four sites, and total species richness was three at each site. In 2016, total obligate grassland breeding bird abundance ranged from 3.9 to 7.5 birds per point across all four sites, while total species richness ranged from three to five species across the sites. Savannah Sparrow and

Bobolink, both secondary target species for the Grassland Bird Habitat Improvement Project along the St. Lawrence River (NYSDEC 2015), were the most abundant species observed, while Savannah Sparrow was the most widely distributed. I also observed small numbers of Eastern Meadowlark, also a secondary target species for the Grassland Bird Habitat Improvement Project (NYSDEC 2015). In 2015, I observed Northern Harrier, listed as threatened in New York State and a primary target species for the Grassland Bird Habitat Improvement Project (NYSDEC 2015), at all sites except Whitehouse Point, but did not observe it at any site in 2016. In 2015 and 2016, I observed a single territorial male Grasshopper Sparrow at Galop Island; the species is listed as a species of special concern in New York State, and a primary target species for the Grassland Bird Habitat Improvement Project (NYSDEC 2015). The bird occurred in an area with sparse vegetation, exposed rocks, and some bare ground, and were "on territory" for more than three weeks. I also observed a Grasshopper Sparrow at Ogden Island in 2015. However, I never observed female Grasshopper Sparrows or any evidence of breeding at either locality. I did not observe any other New York State-listed obligate grassland breeding bird species, such as Upland Sandpiper (*Bartramia longicauda*), Sedge Wren (*Cistothorus platensis*), or Henslow's Sparrow (*Ammodramus henslowii*).

The bird communities at the Green LIP site, Ogden Island, and Whitehouse Point were typical of New York grasslands in that they had low species richness, with Bobolink and Savannah Sparrow being the most abundant species. The Green LIP site was wetter than the other three and I frequently observed Wilson's Snipe (*Gallinago delicata*), which often nest in wet meadows. Since the site has not been grazed or otherwise disturbed in 15-20 years (M. Morgan personal communication), shrubland and early successional forest habitat is widespread. Shrubland birds such as Gray Catbird (*Dumetella carolinensis*), Yellow Warbler (*Setophaga petechia*), Song Sparrow (*Melospiza melodia*), Field Sparrow (*Spizella pusilla*), and Indigo Bunting (*Passerina cyanea*) dominated the Galop Island bird community. Further, at Galop Island, I also observed uncommon successional habitat specialists such as Brown Thrasher (*Toxostoma rufum*), Clay-colored Sparrow (*Spizella pallida*), and Orchard Oriole (*Icterus spurius*) (Appendix 1). A full list of bird species observed at each site is listed in the appendices.

In 2015 and 2016, total obligate grassland breeding bird abundance was significantly lower at Galop Island than at the Green LIP site and Ogden Island (Table 1, Figure 2). There were no significant differences in obligate grassland breeding bird abundance between Whitehouse Point and the other three sites in either year (Figure 2). In 2015 and 2016, Savannah Sparrow abundance was similar across all four sites (Table 1, Figure 2). In 2015, Bobolink abundance was lower at Galop Island than at the Green LIP site and Ogden Island (Figure 2). However, Bobolink abundance at Whitehouse Point was not different from the other three sites (Figure 2). In 2016, Bobolink abundance was lower at Galop Island than that at the three other sites (Figure 2). Bobolink abundance was also higher at the Green LIP site than at Ogden Island, but Bobolink abundance at Whitehouse Point was not different from that at the Green LIP site or Ogden Island (Figure 2). Abundance data for other obligate grassland breeding bird species were not robust enough for statistical analysis.

In summary, my data suggest that Ogden Island supported an obligate grassland breeding bird community with high total abundance in 2015 and 2016—one that was similar to those at the Green LIP and Whitehouse Point mainland sites (Figure 2). Ogden Island supported a high Savannah Sparrow abundance, which was similar to that at the mainland sites in both years (Figure 2). While Ogden Island supported Bobolink abundance in 2015 similar to that of mainland sites, it supported a lower abundance of Bobolink in 2016. In contrast, Galop Island supported a lower abundance of both total obligate grassland breeding birds and Bobolink in both 2015 and 2016, in comparison to mainland sites. However, Savannah Sparrow abundance at Galop Island was similar to that of the mainland sites in both years.

Grassland bird habitat relationships

I used two principle components from my PCA for 2015 and 2016 in my analyses of grassland bird-habitat relations. For 2015 data, the first principle component axis (PC1) explained 36.8 percent of the variance, and the second principle component axis (PC2) explained 21.4 percent of the variance (Table 2). Positive loadings associated with PC1 represented increased percent graminoid cover, while negative loadings represented increased percent forb and woody vegetation cover, as well as tallest vegetation (Table 2). Positive loadings associated with PC2 represented increased percent legume cover, and negative loadings represented increased litter depth (Table 2). For 2016 data, PC1 explained 36.1 percent of the variance and PC2 explained 23.0 percent of the variance (Table 3). I eliminated percent bare ground cover as a variable because of high correlation with percent woody vegetation (r=0.879). Positive loadings associated with PC1 represented increased percent grass and legume cover, and negative loadings represented increased percent standing dead vegetation and woody vegetation cover (Table 3). Positive loadings associated with PC2 represented increased percent forb cover, Robel Pole score, and tallest vegetation height (Table 3).

In 2015, the best model for total obligate grassland breeding bird abundance showed a strong positive relationship with PC1 (Table 4), which was characterized by positive values for points with high percent graminoid cover and negative values for points with high woody vegetation and forb cover as well as tall vegetation (Table 2). In 2016, the best model for total obligate grassland breeding bird abundance showed a strong positive relationship with PC1 (Table 5), which was characterized by positive values for those points with increased percent graminoid cover, and negative values for increased woody cover (Table 3). The second-best model for total obligate grassland breeding bird abundance in 2016 included both PC1 and PC2 (Table 5); in this case the negative relationship with PC2 indicated that grassland birds tended to be more abundant at points with lower forb cover, lower Robel pole scores, and shorter vegetation (Table 3).

In 2015 and 2016, the best models for Savannah Sparrow abundance (Table 6 and 7) showed similar relationships to vegetation variables as did total obligate grassland breeding bird abundance models, with more Savannah Sparrows tending to occur at points with increased graminoid cover and lower woody vegetation cover (Table 2 and 3). In 2015 and 2016, the best models for Bobolink abundance also showed similar relationships to vegetation variables as did total obligate grassland breeding bird and Savannah Sparrow abundance, with more Bobolinks tending to occur at points with increased graminoid cover and less woody vegetation (Table 2, 3, 8, and 9). In 2016, the second-best model for Bobolink abundance also included PC2 (Table 9), which indicated that more Bobolinks generally were found at points with lower forb cover and shorter vegetation (Table 3).

The strong positive relationship between graminoid cover and obligate grassland breeding bird abundance, as suggested by results of my generalized linear models, can be represented by univariate linear regression plots of total obligate grassland breeding bird abundance against percent graminoid cover, across all point count stations at the four sites (Figure 3). In 2015 and 2016, these plots showed significant positive relationships (2015: $r^2 = 0.262$, $P = 0.005$; 2016: $r^2 = 0.481$, $P < 0.001$) between total obligate grassland breeding bird abundance and percent graminoid cover (Figure 3). Although from a statistical standpoint these analyses violate the principle of pseudoreplication (Hurlbert 1984) because I used data from each point count station regardless of sites, they still provide a valuable picture of the general relationship between obligate grassland breeding bird abundance and percent graminoid cover.

Arthropod biomass and grassland bird abundance

In 2015, arthropod biomass from pitfall traps at Ogden Island and Whitehouse Point did not differ significantly ($t = 1.252$, $df = 7$, $P = 0.225$), but arthropod biomass collected with sweep nets was significantly higher at Ogden Island than at Whitehouse Point ($t = 2.866$, $df = 7$, $P = 0.024$; Figure 4). In 2016, the difference between arthropod biomass from pitfall traps at Ogden Island and Whitehouse Point approached significance ($t = 2.215$, $df = 7$, $P = 0.055$), suggesting greater arthropod abundance at plots on Ogden Island (Figure 4). However, arthropod biomass from sweep nets at Galop Island, Ogden Island, and Whitehouse Point did not differ significantly ($F= 1.424$, $df = 2, 11$, $P = 0.282$; Figure 4). While violating the principle of pseudoreplication, neither pitfall trap or sweep net arthropod biomass showed a significant relationship with obligate grassland breeding bird abundance in either 2015 or 2016 (Figures 5 and 6).

Trail camera results

While I was not able to place trail cameras during 2016, in 2015 trail cameras recorded the presence of mesopredators on Galop and Ogden Islands, including multiple sightings of coyote (*Canis latrans*), though the sighting rate was low. They also captured other animals such as white-tailed deer (*Odocoileus virginianus*), and wild turkey (*Melagris gallopavo*) in addition to the large number of cows at the grazed sites. Although I observed raccoons (*Procyon lotor*) and mink (*Neovison vison*) while conducting field work at both islands, I did not record their presence on trail cameras.

Grassland breeding bird productivity

Due to time constraints, I found it difficult to access the four sites—particularly Ogden and Galop islands—frequently enough to conduct point counts, analyze vegetation, and intensively search for nests. Thus, I was not able to find and monitor nests frequently enough to calculate

MAYFIELD nest survival probabilities in either 2015 or 2016. However, I found enough Savannah Sparrow nests to compare clutch sizes at island and mainland sites. Average clutch size at island sites was 4.2 in 2015 (n = 10) and 4.4 in 2016 (n = 8), and 4.1 in 2015 (n = 9) and 4.0 in 2016 at mainland sites (n = 6). Differences in mean clutch size between island nests ($\bar{x} \pm 1$ SE = 4.31 ± 0.13, n = 19) and mainland nests ($\bar{x} \pm 1$ SE = 4.07 ± 0.16, n =14) were not significant (t = 1.163, df = 31, P = 0.254).

Discussion

The primary objective of my study was to evaluate the quality of two large islands in the St. Lawrence River as obligate grassland breeding bird habitat, by comparing their grassland bird communities to those present at two mainland sites. Ogden Island supported an obligate grassland breeding bird community characterized by high overall abundance, similar to high-quality mainland sites for grassland birds such as the Green LIP site and Whitehouse Point (Figure 2). The site provided high-quality habitat for obligate grassland breeding birds, especially Savannah Sparrow and Bobolink, whose abundance was like that at mainland sites (Figure 2). Bélanger and Picard (1999) also found that Savannah Sparrows and Bobolinks were the most common obligate grassland breeding birds in grassland habitat on large islands in the lower St. Lawrence River in Quebec. However, Galop Island supported an obligate grassland breeding bird community characterized by low overall abundance in comparison to the mainland sites, as well as to Ogden Island (Figure 2). Thus, Ogden Island exemplifies the viability of large islands in the St. Lawrence River as high quality grassland habitat (Bélanger and Picard 1999), while in its current state Galop Island does not provide high-quality habitat for obligate grassland breeding birds. Focused habitat management based on important habitat factors at the other three sites could likely transform Galop Island into a site with high-quality grassland habitat.

My best models for total obligate grassland breeding bird abundance in 2015 and 2016 showed that increased percent graminoid cover was the most important predictor variable (Table 4, Table 7). Percent legume cover (and decreased litter depth) was also an important factor in the best models for total obligate grassland breeding bird abundance in 2016. This is consistent with other studies that have identified increased graminoid cover an important factor positively affecting grassland bird abundance (Wiens 1974, Patterson and Best 1996, Cunningham 2005, Lazazzero 2006, Fisher and Davis 2010).

The results of my habitat modelling help put the differences in abundance across the four sites into perspective. Galop Island had the most variable vegetation among the four study sites. While higher percent graminoid cover characterized the other three sites, high percent woody vegetation, bare ground, and forb cover characterized Galop Island. Galop Island was characterized by high horizontal heterogeneity, which is associated with lower obligate grassland breeding bird abundance (Wiens 1974, Norment *et al.* 1999), due to widespread patches of shrubs and trees, which were lacking at the other three sites. Galop Island also had the lowest obligate grassland breeding bird abundance of the four sites in both 2015 and 2016 (Figure 2), likely due to low percent graminoid cover and high percent woody vegetation and forb cover. Total obligate grassland breeding bird abundance was higher at the Green LIP site, Ogden Island, and Whitehouse Point. These sites were characterized by high percent graminoid cover and had lower forb and woody vegetation cover.

The effects of increased vegetation height, and percent woody vegetation and forb cover, at Galop Island are most evident in the low Bobolink abundance in both 2015 and 2016. In 2015, I found an inverse relationship between Bobolink abundance and percent forb and woody vegetation cover and average tallest vegetation. Similarly, other studies have found that Bobolink abundance increases with higher graminoid cover and lower forb cover (Skinner 1975, Bollinger and Gavin 1992, Patterson and Best 1996, Winter *et al.* 2005).

Models in 2015 and 2016 generally showed weaker relationships between habitat data and Savannah Sparrow abundance, in comparison to models for total obligate grassland breeding bird abundance and Bobolink abundance. While I found that increased graminoid cover and decreased woody vegetation cover yielded higher Savannah Sparrow abundance, other studies have suggested that decreased litter depth also positively affects Savannah Sparrow abundance (Davis 2005, Winter *et al.* 2005). In PCA results from 2015, negative eigenvalues in PC2 represented increased litter depth, but this variable did not enter the model for Savannah Sparrow abundance. In both years I found relatively similar Savannah Sparrow abundance across all four sites, despite clear differences in grassland habitat among the sites. This suggests Savannah Sparrow is more of a generalist than other obligate grassland breeding birds, such as Bobolink. Similarly, past studies have suggested Savannah Sparrows are grassland generalists and are less affected by among-site differences in grassland vegetation than many other obligate grassland breeding birds (Baird 1968, Norment *et al.* 1999, Winter *et al.* 2005). A more focused study is needed to evaluate the importance of litter depth on Savannah Sparrow abundance, and studies like Vickery *et al.* (1992), Norment *et al.* (1999), and Shustack *et al.* (2010) could help identify regional differences in factors affecting Savannah Sparrow abundance.

Increased arthropod abundance positively influences territory selection and size in some tundra- and woodland- nesting passerines (Seastedt and MacLean 1979, Burke and Nol 1998), and a number of European studies have demonstrated a causal link between increased pesticide use, declines in arthropod populations, and loss of farmland birds (Newton 2004, Hallman *et al* .2014). Although obligate grassland breeding birds are primarily insectivorous during the breeding season

(Martin *et al.* 1951, Wiens and Rotenberry 1979), I found no significant relationships between arthropod biomass estimated from sweep net and pitfall trap captures, and obligate grassland breeding bird abundance (Figure 4). Most likely, the prey base is not a limiting factor of obligate grassland breeding bird abundance at these sites. However, I still found differences in arthropod biomass across sites, including higher sweep net arthropod biomass at Ogden Island than at Whitehouse Point in 2015 (Figure 4). There was no difference in arthropod biomass from pitfall traps at Ogden Island and Whitehouse Point in 2015, but pitfall trap arthropod biomass approached significance in 2016, with a trend toward higher biomass on Ogden Island (Figure 4). While other comparisons showed no significant differences in arthropod abundance across sites and sampling techniques, my data suggest that an island with extensive grassland habitat, such as Ogden Island, can support a prey base for obligate grassland breeding birds that equals or exceeds that found at "mainland" grassland sites. In the Midwest, McIntyre and Thompson (2003) found that arthropod abundance was higher in native grassland patches than in private CRP grasslands. A similar comparison between LIP and CRP grasslands such as the Green LIP site, and public managed grasslands in New York would help evaluate the quality of grasslands on private lands in terms of prey abundance for grassland birds.

Management Implications

My results suggest that Ogden Island and Whitehouse Point, currently managed by the NYSDEC, provide high-quality habitat for obligate grassland breeding birds. Both sites had high obligate grassland breeding bird abundance, particularly Bobolinks and Savannah Sparrows. Along with Ogden Island, the Green LIP site had the highest abundance of obligate grassland breeding birds among the four sites in both 2015 and 2016. The Green LIP site also had a similarly high Bobolink abundance in 2015 and the highest Bobolink abundance among the four sites in 2016.

The ability of the Green LIP site to support healthy populations of grassland birds is consistent with the results of an analysis comparing grassland bird abundance in 33 NYSDEC managed grasslands and 34 LIP sites in upstate New York, which showed that obligate grassland breeding bird abundance was significantly greater in the LIP site than in the NYSDEC-managed grasslands (Norment 2016). While currently managed by the NYSDEC under BMPs, the discontinuation of the LIP program will put grassland habitat and obligate grassland breeding birds on properties such as the Green LIP site in peril. While grasslands on NYSDEC managed state land will continue to be protected and managed under BMPs, grasslands on private land in New York State will be lost without the support of LIP by state agencies. Without LIP, the only practical ways to protect and manage grassland and private lands include direct purchase of land, or expansion of CRP through the United States Department of Agriculture (USDA). While the CRP program has wide-ranging ecological benefits (Dunn *et al.* 1993), studies have suggested a notable positive impact on grassland bird populations. Patterson and Best (1996) showed that CRP fields provide better habitat than row-crops for grassland birds and have helped increase grassland bird abundance. Similarly, Cunningham (2005) found that CRP fields in Minnesota had greater grassland bird abundance and diversity than grasslands on public lands. Further, Cunningham (2005) also argued that CRP fields were larger, provided better habitat, and were closer together than fields on public lands. In New York, efforts to protect private lands that provide quality grassland bird habitat, such as the Green LIP site, should include use of the CRP to protect large patches of grassland habitat that are in close proximity to large grasslands already managed under BMPs and those within a landscape mosaic with extensive open area and grassland. With discontinuation of the LIP, the CRP in New York needs expansion, since only 13931 ha in the state are enrolled as of October 2016 out of approximately 9510113 ha nationwide (USDA 2016).

Winter *et al.* (2006) argued for the importance of understanding the effects of local factors on obligate grassland breeding bird communities. I found that the Green LIP site, Ogden Island, and Whitehouse Point all provide quality grassland bird habitat and will likely continue to do so, as long as management practices prevent or retard successional change, and favor grassland habitat with increased graminoid cover, reduced forb cover, and minimal woody vegetation cover. While Galop Island does not currently provide quality grassland bird habitat due to substantial development of shrubby and early successional forest habitat on some parts of the island, intensive management under a Habitat Improvement Plan could transform Galop Island into a high-quality site for obligate grassland breeding birds. Due to the rocky substrate and poorly drained soils, the site already has a varied vegetation community with patches of taller, dense vegetation mixed with patches of shorter, sparse vegetation. This likely explains why Galop Island was the only site during my study to support Grasshopper Sparrows, a New York State threatened species that prefers less dense vegetation and more bare ground cover (Whitmore 1981), although in 2014 the species also occurred in relatively sparse grassland vegetation at Whitehouse Point (C. Norment, personal communication). Further, Galop Island already supports a Savannah Sparrow population with similar abundance to that at the Green LIP site, Ogden Island, and Whitehouse Point. Removal of the large patches of trees and shrubs at this site, along with the establishment of a mowing regime, will reduce forb cover, woody vegetation cover, and horizontal heterogeneity, improving site quality for grassland birds. Management activities aimed at creating high-quality grassland habitat on Galop Island would be a crucial addition to the New York Power Authority-funded Grassland Habitat Improvement Project outlined in NYSDEC's (2015) report. Addition of 170 ha of high-quality grassland habitat to the Habitat Improvement Project would make the landscape a more effective area for grassland bird conservation and could facilitate its inclusion as a grassland bird conservation center in the next NYSDEC grassland management plan.

It should be recognized that increasing the amount of grassland habitat on Galop Island would come at the cost of losing shrubland and early successional forest habitat and their associated bird species, such as Field Sparrow and Brown Thrasher, which have significant negative populations trends in the lower Great Lakes/St. Lawrence Plain region, according to Breeding Bird Survey data (Sauer *et al.* 2017). However, while 36 percent of shrubland/early successional bird species have declined in the lower Great Lakes/St. Lawrence Plain region since 1966 according to Breeding Bird Survey data, 92 percent of grassland breeding bird species have declined in the same time frame (Sauer *et al.* 2017). While the site cannot be managed for all species in all habitats, management focused on obligate grassland breeding birds would be most beneficial, considering the amount of habitat loss and population declines throughout the region (Norment 2002). Knowing that obligate grassland breeding bird species are area-sensitive, and that their populations and distribution are declining in New York State (McGowan and Corwin 2008, Sauer *et al.* 2017) it is important that we take every available opportunity to protect and manage large patches of grassland habitat, such as those on Galop Island and Ogden Island.

Lastly, I recommend managing the habitat at the study sites for the entire suite of grassland birds, rather than focusing on Grasshopper Sparrows. Since I observed singing male Grasshopper Sparrows at Ogden Island in 2015 and 2016, Whitehouse Point in 2016, and Galop Island in 2015 and 2016, managers may be inclined to manage the sites for the species, since it is listed as threatened in New York State and is a primary target species for the St. Lawrence Grassland Bird Habitat Improvement Project (NYSDEC 2015). However, managing for Grasshopper Sparrows would likely produce limited and inconsistent results because of the lack of a nearby source population. Grasshopper Sparrows were detected in few nearby blocks in the 2000-2005 New York State Breeding Bird Atlas (McGowan and Corwin 2008), and the 2001-2005 Ontario Breeding Bird Atlas (Cadman *et al.* 2007). Further, there have been relatively few eBird records of Grasshopper

Sparrows in the surrounding landscape during the breeding season (Jun-Jul) since 2010 (eBird 2018). With the entire suite of grassland birds declining in New York State and the Lower Great Lakes/St. Lawrence Valley region (Sauer *et al*. 2017), it is important that managers use BMPs to maintain and grow populations of more common obligate grassland breeding birds such as Savannah Sparrows, Bobolinks, and Eastern Meadowlarks. With limited resources available, it is prudent to focus conservation efforts at these sites on the entire suite of obligate grassland breeding birds rather than on a single species.

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Tables

Table 1. Kruskal-Wallis Test results for comparisons of 2015 and 2016 grassland bird abundance across sites; significant differences are in boldface.

	Year	test statistic (χ^2)	*P*	df
Total OGBB	2015	8.396	**0.038**	3
	2016	13.174	**0.004**	3
Savannah Sparrow	2015	5.011	0.171	3
	2016	5.23	0.156	3
Bobolink	2015	20.714	**0.000**	3
	2016	22.19	**0.000**	3

Table 2. Habitat factors and factor loadings from principal components analysis for obligate grassland breeding birds in 2015

	Habitat factors	
	PC1	PC2
Eigenvalue	3.308	1.925
Percent of total variance explained	36.760	21.386
Cumulative proportion of variance explained	36.760	58.147
Variable		
Percent graminoid cover	0.755	0.129
Percent forb cover	-0.797	0.142
Percent legume cover	0.598	0.645
Percent standing dead vegetation cover	-0.412	-0.433
Percent woody vegetation cover	-0.815	0.199
Percent bare ground cover	0.057	0.558
Litter depth	0.084	-0.868
Tallest vegetation height	-0.844	0.223
Robel Pole score	-0.433	0.361

Table 3. Habitat factors and factor loadings from principal components analysis for obligate grassland breeding birds in 2016

	Habitat factors	
	PC1	PC2
Eigenvalue	2.885	1.842
Proportion of total variance explained	36.067	23.026
Cumulative proportion of variance explained	36.067	59.093
Variable		
Percent graminoid cover	0.909	-0.188
Percent forb cover	-0.384	0.772
Percent legume cover	0.755	0.148
Percent standing dead vegetation cover	-0.735	-0.183
Percent woody vegetation cover	-0.793	0.204
Litter depth	0.146	-0.155
Tallest vegetation height	0.265	0.759
Robel Pole score	0.285	0.717

Table 4. Best models for obligate grassland breeding bird abundance in 2015. AIC_c refers to the second order Akaike's Information Criteria, B refers to the slope of the effect (logistic coefficient), and w_i is the weight of each individual variable in the model.

Total obligate grassland breeding bird abundance

Rank	AIC_c	ΔAIC_c	w_i	Variable	B
1	128.382	0	0.78	PC1	1.226
2	130.912	2.53	0.22	PC1	1.226
				PC2	0.156

Table 5. Best models for total obligate grassland breeding bird abundance in 2016. AIC_c refers to the second order Akaike's Information Criteria, B refers to the slope of the effect (logistic coefficient), and w_i is the weight of each individual variable in the model.

Total obligate grassland breeding bird abundance

Rank	AIC_c	ΔAIC_c	w_i	Variable	B
1	123.074	0	0.55	PC1	1.874
2	123.506	0.432	0.45	PC1	1.874
				PC2	-0.501

Table 6. Best models for Savannah Sparrow abundance in 2015. AIC_c refers to the second order Akaike's Information Criteria, B refers to the slope of the effect (logistic coefficient), and w_i is the weight of each individual variable in the model.

Savannah Sparrow abundance

Rank	AIC_c	ΔAIC_c	w_i	Variable	B
1	118.915	0	0.72	PC1	-0.327
2	120.812	1.897	0.28	PC1	-0.327
				PC2	-0.282

Table 7. Best models for Savannah Sparrow abundance in 2016. AIC_c refers to the second order Akaike's Information Criteria, B refers to the slope of the effect (logistic coefficient), and w_i is the weight of each individual variable in the model.

Savannah Sparrow abundance

Rank	AIC_c	ΔAIC_c	w_i	Variable	B
1	119.129	0	0.79	PC1	0.263
2	121.815	2.686	0.21	PC1	0.263
				PC2	-0.045

Table 8. Best models for Bobolink abundance in 2015. AIC_c refers to the second order Akaike's Information Criteria, B refers to the slope of the effect (logistic coefficient), and w_i is the weight of each individual variable in the model.

Bobolink abundance

Rank	AIC_c	ΔAIC_c	w_i	Variable	B
1	115.08	0	0.64	PC1	-0.873
2	116.261	1.181	0.36	PC1	-0.873
				PC2	0.360

Table 9. Best models for Bobolink abundance in 2016. AIC_c refers to the second order Akaike's Information Criteria, B refers to the slope of the effect (logistic coefficient), and w_i is the weight of each individual variable in the model.

Bobolink abundance

Rank	AIC_c	ΔAIC_c	w_i	Variable	B
1	110.859	0	0.56	PC1	1.495
2	111.354	0.495	0.44	PC1	1.495
				PC2	-0.400

Figures

Figure 1. Study area in the St. Lawrence River Corridor showing locations of the four study sites

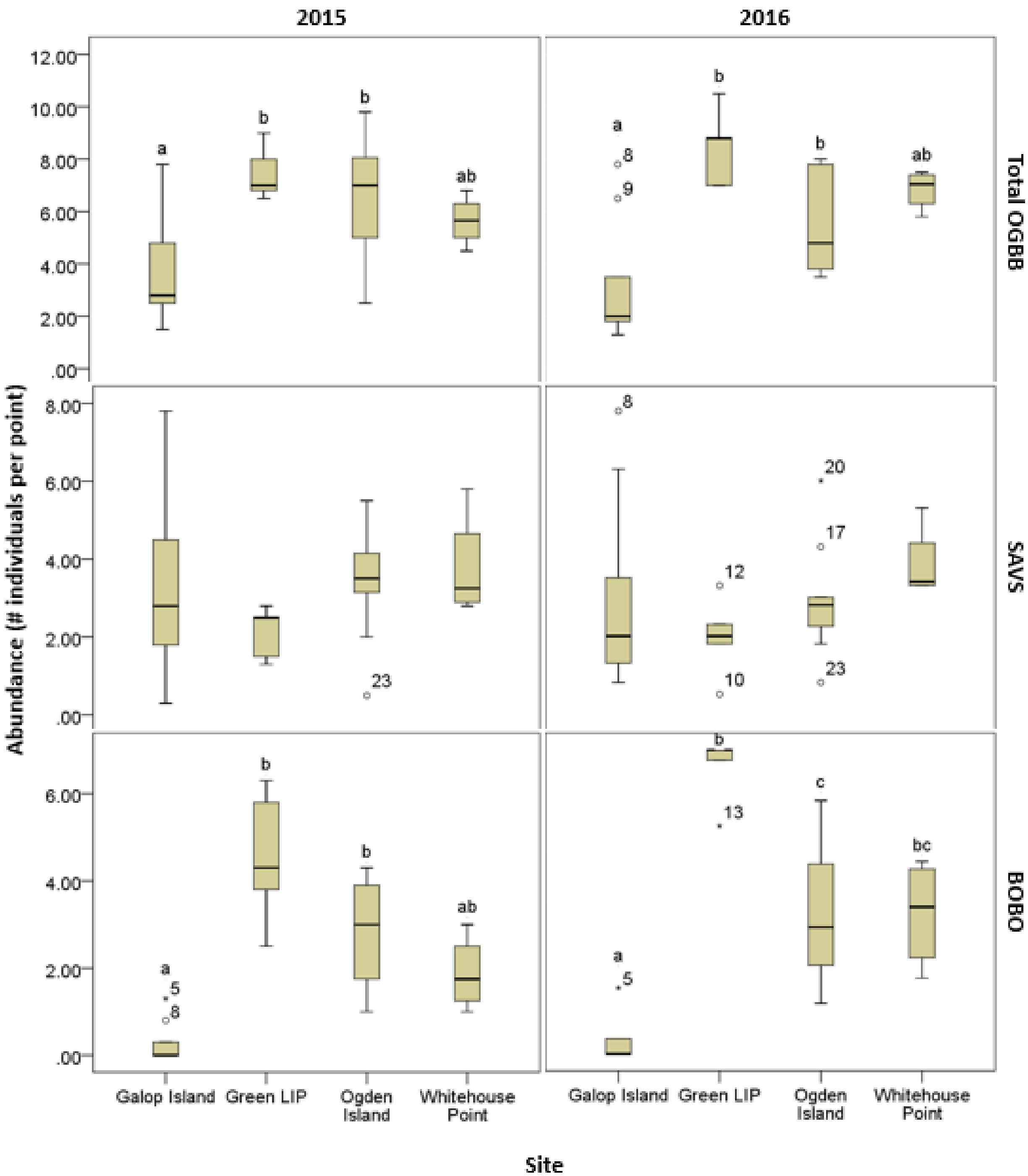

Figure 2. Abundance of total obligate grassland breeding birds (OGBB), Savannah Sparrow (SAVS), and Bobolink (BOBO) across all four sites in 2015 and 2016. Letters a, b, ab etc. denote significant differences between sites. Boxes and error bars represent the range of the data.

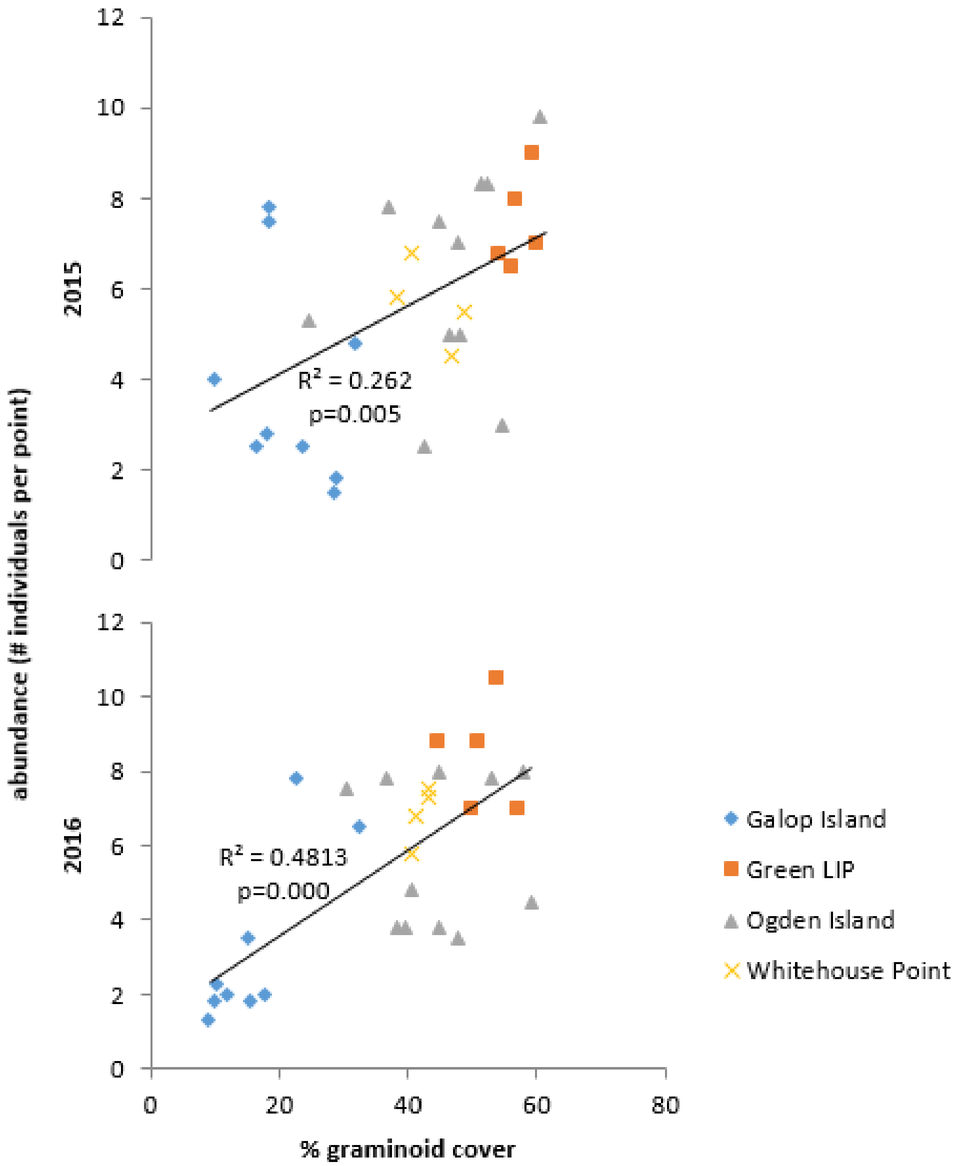

Figure 3. Regression analysis of total obligate grassland breeding bird abundance and percent graminoid cover across all four sites in 2015 and 2016.

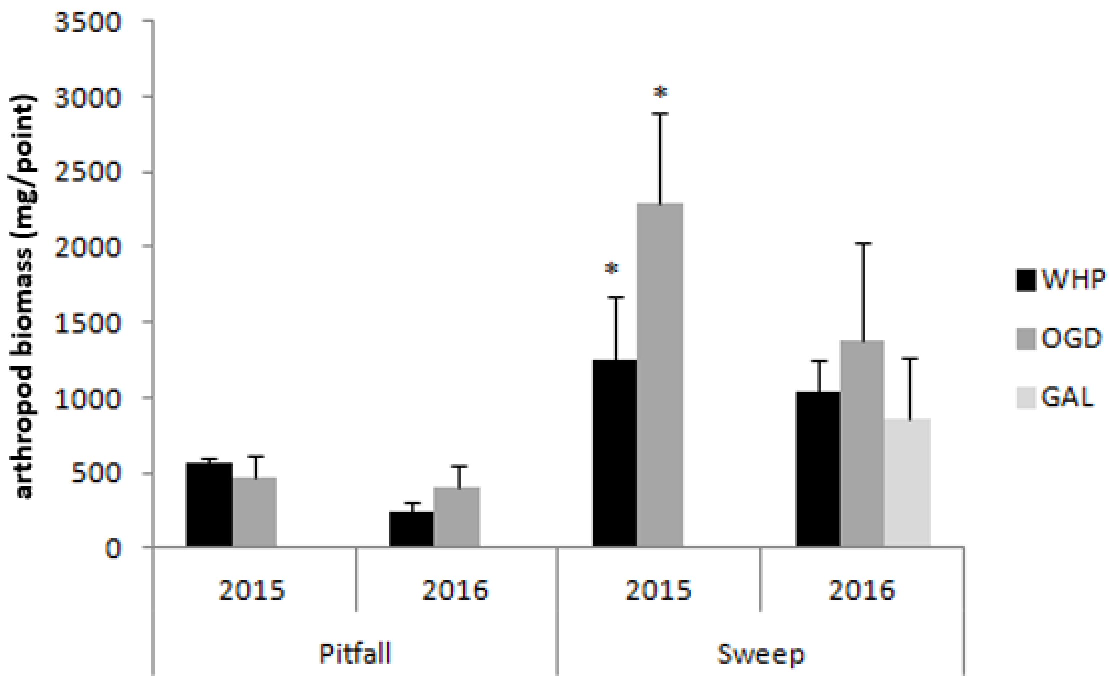

Figure 4. Arthropod biomass from pitfall traps and sweep nets in 2015 and 2016. An asterisk (*) denotes a significant difference between sites ($p<0.05$). Error bars represent +1 standard deviation.

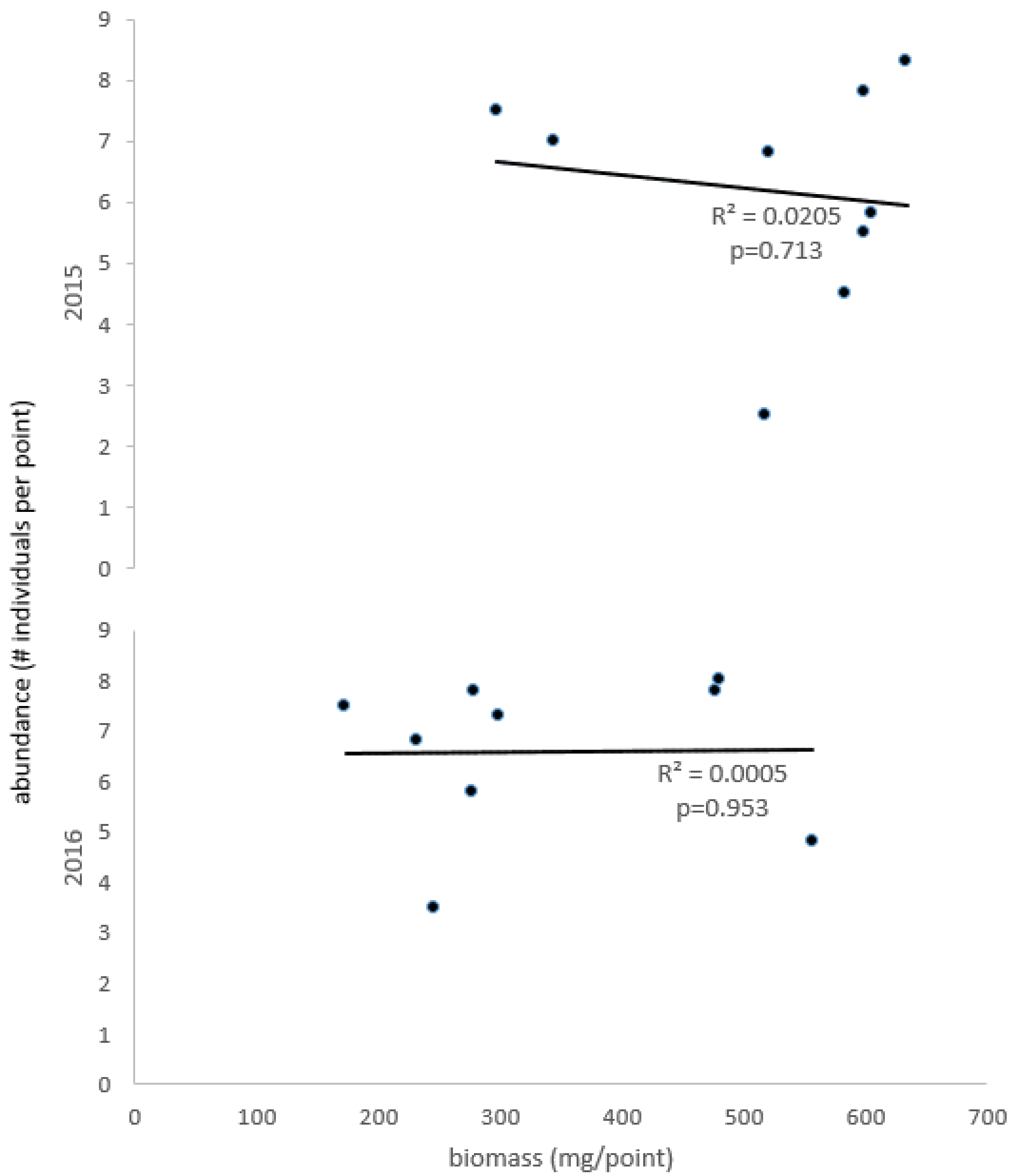

Figure 5. Regression analysis of arthropod biomass from pitfall traps in 2015 and 2016 plotted against total obligate grassland breeding bird abundance (OGBB).

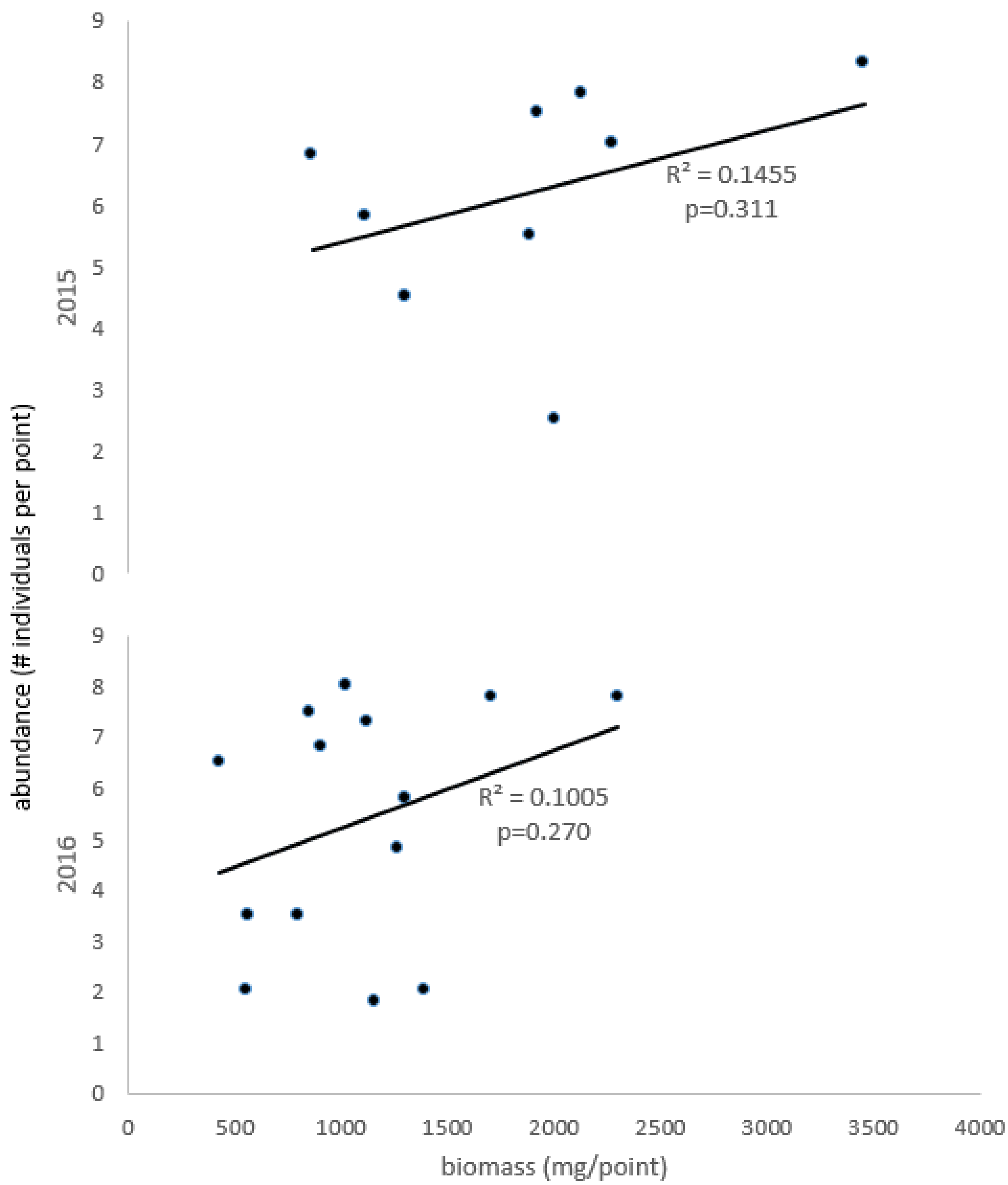

Figure 6. Regression analysis of arthropod biomass from sweep nets in 2015 and 2016 plotted against total obligate grassland breeding bird abundance (OGBB).

Appendices

Appendix 1. List of birds observed at Galop Island during field work in 2015 and 2016.

Canada Goose - *Branta canadensis*

Gadwall - *Mareca strepera*

Mallard - *Anas platyrhynchos*

Common Goldeneye - *Bucephala clangula*

Common Merganser - *Mergus merganser*

Wild Turkey - *Meleagris gallopavo*

Common Loon - *Gavia immer*

Horned Grebe - *Podiceps auritus*

Double-crested Cormorant - *Phalacrocorax auritus*

Great Blue Heron - *Ardea herodias*

Green Heron - *Butorides virescens*

Turkey Vulture - *Cathartes aura*

Osprey - *Pandion haliaetus*

Red-shouldered Hawk - *Buteo lineatus*

Red-tailed Hawk - *Buteo jamaicensis*

Sandhill Crane - *Antigone canadensis*

Killdeer - *Charadrius vociferus*

Spotted Sandpiper - *Actitis macularius*

Bonaparte's Gull - *Chroicocephalus philadelphia*

Ring-billed Gull - *Larus delawarensis*

Herring Gull - *Larus argentatus*

Common Tern - *Sterna hirundo*

Black-billed Cuckoo - *Coccyzus erythropthalmus*

Chimney Swift - *Chaetura pelagica*

Ruby-throated Hummingbird - *Archilochus colubris*

Belted Kingfisher - *Megaceryle alcyon*

American Crow - *Corvus brachyrhynchos*

Northern Rough-winged Swallow - *Stelgidopteryx serripennis*

Purple Martin - *Progne subis*

Tree Swallow - *Tachycineta bicolor*

Bank Swallow - *Riparia riparia*

Barn Swallow - *Hirundo rustica*

Black-capped Chickadee - *Poecile atricapillus*

House Wren - *Troglodytes aedon*

Veery - *Catharus fuscescens*

American Robin - *Turdus migratorius*

Gray Catbird - *Dumetella carolinensis*

Brown Thrasher - *Toxostoma rufum*

European Starling - *Sturnus vulgaris*

Cedar Waxwing - *Bombycilla cedrorum*

Tennessee Warbler - *Oreothlypis peregrina*

Common Yellowthroat - *Geothlypis trichas*

American Redstart - *Setophaga ruticilla*

Yellow Warbler - *Setophaga petechia*

Blackpoll Warbler - *Setophaga striata*

Yellow-rumped Warbler - *Setophaga coronata*

Grasshopper Sparrow - *Ammodramus savannarum*

Chipping Sparrow - *Spizella passerina*

Clay-colored Sparrow - *Spizella pallida*

Field Sparrow - *Spizella pusilla*

Savannah Sparrow - *Passerculus sandwichensis*

Song Sparrow - *Melospiza melodia*

Downy Woodpecker - *Picoides pubescens*

Northern Flicker - *Colaptes auratus*

American Kestrel - *Falco sparverius*

Alder Flycatcher - *Empidonax alnorum*

Willow Flycatcher - *Empidonax traillii*

Eastern Phoebe - *Sayornis phoebe*

Great Crested Flycatcher - *Myiarchus crinitus*

Eastern Kingbird - *Tyrannus tyrannus*

Warbling Vireo - *Vireo gilvus*

Red-eyed Vireo - *Vireo olivaceus*

Blue Jay - *Cyanocitta cristata*

Eastern Towhee - *Pipilo erythrophthalmus*

Scarlet Tanager - *Piranga olivacea*

Northern Cardinal - *Cardinalis cardinalis*

Bobolink - *Dolichonyx oryzivorus*

Orchard Oriole - *Icterus spurius*

Baltimore Oriole - *Icterus galbula*

Red-winged Blackbird - *Agelaius phoeniceus*

Brown-headed Cowbird - *Molothrus ater*

Common Grackle - *Quiscalus quiscula*

American Goldfinch - *Spinus tristis*

Appendix 2. List of birds observed at the Green LIP site during field work in 2015 and 2016.

Canada Goose - *Branta canadensis*

Turkey Vulture - *Cathartes aura*

Killdeer - *Charadrius vociferus*

Wilson's Snipe - *Gallinago delicata*

Mourning Dove - *Zenaida macroura*

Northern Flicker - *Colaptes auratus*

Eastern Wood-Pewee - *Contopus virens*

Willow Flycatcher - *Empidonax traillii*

Eastern Phoebe - *Sayornis phoebe*

Eastern Kingbird - *Tyrannus tyrannus*

Warbling Vireo - *Vireo gilvus*

Blue Jay - *Cyanocitta cristata*

American Crow - *Corvus brachyrhynchos*

Tree Swallow - *Tachycineta bicolor*

Barn Swallow - *Hirundo rustica*

White-breasted Nuthatch - *Sitta carolinensis*

House Wren - *Troglodytes aedon*

American Robin - *Turdus migratorius*

Gray Catbird - *Dumetella carolinensis*

Brown Thrasher - *Toxostoma rufum*

European Starling - *Sturnus vulgaris*

Cedar Waxwing - *Bombycilla cedrorum*

Common Yellowthroat - *Geothlypis trichas*

American Redstart - *Setophaga ruticilla*

Yellow Warbler - *Setophaga petechia*

Savannah Sparrow - *Passerculus sandwichensis*

Song Sparrow - *Melospiza melodia*

Bobolink - *Dolichonyx oryzivorus*

Eastern Meadowlark - *Sturnella magna*

Baltimore Oriole - *Icterus galbula*

Red-winged Blackbird - *Agelaius phoeniceus*

Brown-headed Cowbird - *Molothrus ater*

Common Grackle - *Quiscalus quiscula*

House Finch - *Haemorhous mexicanus*

American Goldfinch - *Spinus tristis*

House Sparrow - *Passer domesticus*

Appendix 3. List of birds observed at Ogden Island during field work in 2015 and 2016.

Canada Goose - *Branta canadensis*

Wood Duck - *Aix sponsa*

Gadwall - *Mareca strepera*

Mallard - *Anas platyrhynchos*

Green-winged Teal - *Anas crecca*

Ring-necked Duck - *Aythya collaris*

Lesser Scaup - *Aythya affinis*

Hooded Merganser - *Lophodytes cucullatus*

Common Merganser - *Mergus merganser*

Red-breasted Merganser - *Mergus serrator*

Wild Turkey - *Meleagris gallopavo*

Common Loon - *Gavia immer*

Horned Grebe - *Podiceps auritus*

Red-necked Grebe - *Podiceps grisegena*

Double-crested Cormorant - *Phalacrocorax auritus*

Great Blue Heron - *Ardea herodias*

Turkey Vulture - *Cathartes aura*

Osprey - *Pandion haliaetus*

Northern Harrier - *Circus hudsonius*

Cooper's Hawk - *Accipiter cooperii*

Bald Eagle - *Haliaeetus leucocephalus*

Red-tailed Hawk - *Buteo jamaicensis*

Sora - *Porzana carolina*

Common Gallinule - *Gallinula galeata*

Killdeer - *Charadrius vociferus*

Dunlin - *Calidris alpina*

Least Sandpiper - *Calidris minutilla*

Eastern Wood-Pewee - *Contopus virens*

Willow Flycatcher - *Empidonax traillii*

Least Flycatcher - *Empidonax minimus*

Great Crested Flycatcher - *Myiarchus crinitus*

Eastern Kingbird - *Tyrannus tyrannus*

Warbling Vireo - *Vireo gilvus*

Red-eyed Vireo - *Vireo olivaceus*

Blue Jay - *Cyanocitta cristata*

American Crow - *Corvus brachyrhynchos*

Northern Rough-winged Swallow - *Stelgidopteryx serripennis*

Purple Martin - *Progne subis*

Tree Swallow - *Tachycineta bicolor*

Bank Swallow - *Riparia riparia*

Barn Swallow - *Hirundo rustica*

Cliff Swallow - *Petrochelidon pyrrhonota*

Black-capped Chickadee - *Poecile atricapillus*

House Wren - *Troglodytes aedon*

Veery - *Catharus fuscescens*

Wood Thrush - *Hylocichla mustelina*

American Robin - *Turdus migratorius*

Gray Catbird - *Dumetella carolinensis*

European Starling - *Sturnus vulgaris*

Cedar Waxwing - *Bombycilla cedrorum*

Ovenbird - *Seiurus aurocapilla*

Tennessee Warbler - *Oreothlypis peregrina*

Common Yellowthroat - *Geothlypis trichas*

American Redstart - *Setophaga ruticilla*

Wilson's Snipe - *Gallinago delicata*

Spotted Sandpiper - *Actitis macularius*

Solitary Sandpiper - *Tringa solitaria*

Greater Yellowlegs - *Tringa melanoleuca*

Ring-billed Gull - *Larus delawarensis*

Herring Gull - *Larus argentatus*

Caspian Tern - *Hydroprogne caspia*

Common Tern - *Sterna hirundo*

Rock Pigeon - *Columba livia*

Common Nighthawk - *Chordeiles minor*

Chimney Swift - *Chaetura pelagica*

Belted Kingfisher - *Megaceryle alcyon*

Yellow-bellied Sapsucker - *Sphyrapicus varius*

Downy Woodpecker - *Picoides pubescens*

Hairy Woodpecker - *Picoides villosus*

Northern Flicker - *Colaptes auratus*

Pileated Woodpecker - *Dryocopus pileatus*

Yellow Warbler - *Setophaga petechia*

Chestnut-sided Warbler - *Setophaga pensylvanica*

Blackpoll Warbler - *Setophaga striata*

Grasshopper Sparrow - *Ammodramus savannarum*

Field Sparrow - *Spizella pusilla*

White-crowned Sparrow - *Zonotrichia leucophrys*

Savannah Sparrow - *Passerculus sandwichensis*

Song Sparrow - *Melospiza melodia*

Swamp Sparrow - *Melospiza georgiana*

Northern Cardinal - *Cardinalis cardinalis*

Bobolink - *Dolichonyx oryzivorus*

Eastern Meadowlark - *Sturnella magna*

Baltimore Oriole - *Icterus galbula*

Red-winged Blackbird - *Agelaius phoeniceus*

Common Grackle - *Quiscalus quiscula*

American Goldfinch - *Spinus tristis*

Appendix 4. List of birds observed at Whitehouse Point during field work in 2015 and 2016.

Canada Goose - *Branta canadensis*

Gadwall - *Mareca strepera*

Mallard - *Anas platyrhynchos*

Ring-necked Duck - *Aythya collaris*

Common Merganser - *Mergus merganser*

Red-breasted Merganser - *Mergus serrator*

Wild Turkey - *Meleagris gallopavo*

Common Loon - *Gavia immer*

Double-crested Cormorant - *Phalacrocorax auritus*

Great Blue Heron - *Ardea herodias*

Turkey Vulture - *Cathartes aura*

Osprey - *Pandion haliaetus*

Northern Harrier - *Circus hudsonius*

Bald Eagle - *Haliaeetus leucocephalus*

Red-tailed Hawk - *Buteo jamaicensis*

Killdeer - *Charadrius vociferus*

Least Sandpiper - *Calidris minutilla*

Short-billed Dowitcher - *Limnodromus griseus*

Greater Yellowlegs - *Tringa melanoleuca*

Ring-billed Gull - *Larus delawarensis*

Herring Gull - *Larus argentatus*

Caspian Tern - *Hydroprogne caspia*

Common Tern - *Sterna hirundo*

Mourning Dove - *Zenaida macroura*

Black-billed Cuckoo - *Coccyzus erythropthalmus*

Belted Kingfisher - *Megaceryle alcyon*

Downy Woodpecker - *Picoides pubescens*

Black-capped Chickadee - *Poecile atricapillus*

White-breasted Nuthatch - *Sitta carolinensis*

House Wren - *Troglodytes aedon*

Veery - *Catharus fuscescens*

Wood Thrush - *Hylocichla mustelina*

American Robin - *Turdus migratorius*

Gray Catbird - *Dumetella carolinensis*

Brown Thrasher - *Toxostoma rufum*

European Starling - *Sturnus vulgaris*

American Pipit - *Anthus rubescens*

Cedar Waxwing - *Bombycilla cedrorum*

Black-and-white Warbler - *Mniotilta varia*

Tennessee Warbler - *Oreothlypis peregrina*

Nashville Warbler - *Oreothlypis ruficapilla*

Common Yellowthroat - *Geothlypis trichas*

American Redstart - *Setophaga ruticilla*

Cape May Warbler - *Setophaga tigrina*

Northern Parula - *Setophaga americana*

Bay-breasted Warbler - *Setophaga castanea*

Blackburnian Warbler - *Setophaga fusca*

Yellow Warbler - *Setophaga petechia*

Chestnut-sided Warbler - *Setophaga pensylvanica*

Blackpoll Warbler - *Setophaga striata*

Black-throated Blue Warbler - *Setophaga caerulescens*

Yellow-rumped Warbler - *Setophaga coronata*

Black-throated Green Warbler - *Setophaga virens*

White-throated Sparrow - *Zonotrichia albicollis*

Hairy Woodpecker - *Picoides villosus*

Northern Flicker - *Colaptes auratus*

Pileated Woodpecker - *Dryocopus pileatus*

American Kestrel - *Falco sparverius*

Alder Flycatcher - *Empidonax alnorum*

Willow Flycatcher - *Empidonax traillii*

Great Crested Flycatcher - *Myiarchus crinitus*

Eastern Kingbird - *Tyrannus tyrannus*

Warbling Vireo - *Vireo gilvus*

Red-eyed Vireo - *Vireo olivaceus*

Blue Jay - *Cyanocitta cristata*

American Crow - *Corvus brachyrhynchos*

Northern Rough-winged Swallow - *Stelgidopteryx serripennis*

Tree Swallow - *Tachycineta bicolor*

Bank Swallow - *Riparia riparia*

Barn Swallow - *Hirundo rustica*

Savannah Sparrow - *Passerculus sandwichensis*

Song Sparrow - *Melospiza melodia*

Swamp Sparrow - *Melospiza georgiana*

Eastern Towhee - *Pipilo erythrophthalmus*

Scarlet Tanager - *Piranga olivacea*

Northern Cardinal - *Cardinalis cardinalis*

Rose-breasted Grosbeak - *Pheucticus ludovicianus*

Indigo Bunting - *Passerina cyanea*

Bobolink - *Dolichonyx oryzivorus*

Eastern Meadowlark - *Sturnella magna*

Baltimore Oriole - *Icterus galbula*

Red-winged Blackbird - *Agelaius phoeniceus*

Brown-headed Cowbird - *Molothrus ater*

Common Grackle - *Quiscalus quiscula*

American Goldfinch - *Spinus tristis*