THESIS DEFENSE

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ABSTRACT:

Over the course of the last century, shrubland habitat in the northeastern United States has declined due to farmland abandonment, deforestation, reforestation, human population growth and increased anthropogenic efforts to limit natural disturbances. In turn, these landscape alterations have caused a decline in the shrubland guild of birds in the northeastern United States, specifically the Great Lakes Plain Region. Declines have been so significant that wildlife managers must actively conserve existing shrublands and create new habitat to support shrubland birds. Thus, to offer suggestions for conservation and management of shrubland habitats and the birds that rely on them, I studied shrubland birds and their associated habitats in the Great Lakes Plains Region over two breeding periods in 2006 and 2007. My results revealed few consistent patterns in the bird habitat models developed from my data. This was not surprising, as most areas studied drastically varied in both vegetation community structure and composition. In addition, shrubland birds are often characterized by broad habitat preferences. Thus, the majority of the results can best be examined on a site-specific and species-specific basis. Some habitat variables did stand out in the models. Shrub hit diversity seemed to be an important predictor of shrubland bird abundance. Shrubland area also came up as a significant variable in a number of bird-habitat models. Even with the lack of consistency among my models, my data, along with other research, yielded management recommendations that should increase shrubland habitat, which should benefit shrubland birds. There are four main characteristics of shrubland habitat that need to be considered in order to increase and sustain declining species of shrubland birds: (1) shrublands should be

relatively large (>0.6 ha) in area, regardless of area-sensitivity (or lack-there-of) of shrubland birds; (2) shrublands should be adjacent or near other shrubland sites in order to avoid displacement of shrubland and forest birds; (3) shrublands need to be reasonably accessible to brush hogs and tractors so that they can be maintained without issue; and (4) shrublands should be created and/or maintained from existing shrublands, grasslands, or old fields, as shrublands converted from forest habitats are often of poor quality. When looking at the "big picture" of shrubland management, there is no one management practice that is best. Thus, management should be adaptive so that practices can be changed when new data becomes available, without compromising explicit management and conservation goals.

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INTRODUCTION:

LANDSCAPE CHANGE DYANAMICS AND THE DECLINE OF EARLY SUCCESIONAL HABITATS IN THE GREAT LAKES PLAINS REGION OF NEW YORK STATE

Degradation and loss of suitable habitat have negatively affected biodiversity, including shrubland birds, in the northeastern United States. Traditionally, early successional habitats required by shrubland birds were maintained by natural disturbances such as fires, beavers, floods, windstorms, and Native American agriculture and burning (Askins 2001, Lorimer 2001, DeGraaf and Yamasaki 2003). Upon European settlement, structure of the natural landscape was transformed due to extensive clearing of fire-prone forests and conversion of land into pasture and cropland (DeGraaf and Miller 1996, Trani *et al.* 2001, DeGraaf and Yamasaki 2003). Westward movement of Europeans, and changing economic conditions during the late 1800s and 1900s, caused agricultural and cropland to revert to a variety of early successional habitats (Litvaitis 1993). These changes have led to the development of complex mosaic of vegetation and the coexistence of a variety of successional habitats (Hunter *et al.* 2001, Sirami *et al.* 2007).

Over the last century many different processes have led to landscape change. Farmland abandonment, deforestation, reforestation, human population growth and increased efforts to limit natural disturbances, such as fire suppression, have resulted in increased forest habitat, which in turn has caused a significant decline in early successional habitats that support shrubland birds (Trani *et al.* 2001, Foster *et al.* 2002, Sirami *et al.* 2007). These dynamic landscape changes have caused natural shrubland habitats to be among the most endangered ecosystems in the United States (Noss *et al.* 1995, Foster *et al.* 2002). Of the forested land that exists in the northeastern United States, only 15% exhibits early successional characteristics, although historically approximately 33% of forests were considered early successional (Trani *et* *al*. 2001). Thus conservation, research, and active management efforts need to focus on the restoration of these ecosystems to the point of sustainability (Trani *et al*. 2001, Brooks 2003).

IMPACTS ON SHRUBLAND AVIFAUNA

The decline of shrubland habitats in the Northeast has caused a number of shrubland birds to decline steeply, including the Golden-winged Warbler (*Vermivora chrysoptera*) and Spruce Grouse (*Falcipennis canadensis*; Noss *et al*. 1995, Thompson and DeGraaf 2001, Dettmers 2003). These species, as well as many others, are listed as either endangered or threatened in many northeastern states. According to the Breeding Bird Survey (BBS), a continental avian monitoring program initiated in 1966, 37% of the species in the shrubland guild of birds in New York State declined significantly through 2006, with the majority of these declines being greater than 50% (Dettmers 2003, Sauer *et al*. 2007). However, the proportion of declining avifauna within shrublands may actually be greater, if we include species of grassland and forest birds that depend on shrubland habitats at some time during the yearly cycle (ex. foraging, mate attraction, nesting; Brawn *et al*. 2001). Some shrubland bird species with drastic declines include the Eastern Towhee (*Pipilo erythrophthalmus*; Figure 1), Brown Thrasher (*Toxostoma rufum*; Figure 2), Field Sparrow (*Spizella pusilla*), Golden-winged Warbler, Song Sparrow (*Melospiza melodia*), and Chestnut-sided Warbler (*Dendroica pensylvanica*). Comparative data from the Breeding Bird Atlas (BBA) of New York State for 1980-1985 and 2000-2005 provide further evidence of declines in shrubland bird species, including the Golden-winged Warbler, American Woodcock (*Scolopax minor*) and the Black-billed Cuckoo (*Coccyzus virginianus*; New York State Department of Environmental Conservation [NYSDEC] 2006).

IMPORTANCE OF SHRUBLAND HABITAT IN THE GREAT LAKES PLAINS REGION

Protection of source breeding populations is critically important in terms of shrubland bird conservation (Dettmers 2003). According to BBS data, in North America more than 20% of the global populations of ten continental shrubland bird breeding species occur in the northeastern United States (Sauer *et al.* 2007). Northwestern New York, specifically the Great Lakes Plains Region, which extends from low-lying areas to the south of Lake Ontario in New York and to the north of Lake Erie in southernmost Ontario in Canada, contains relatively high proportions of many populations of these shrubland breeding bird species (Andrle and Carrol 1988, Dettmers 2003, Partners In Flight [PIF] 2008). Thus, it is imperative that we actively manage for shrubland species of management concern that breed in the region.

The North American Bird Conservation Initiative (NABCI 2008) has developed bird conservation plans to classify and determine high priority species in high need of active management. Bird Conservation Plans are used to actively manage for priority species of concern in each physiographic area, such as the Lower Great Lakes and St. Lawrence Plain Regions (Bird Conservation Region 13). Currently, approximately 74% of the land area in this region is used for agricultural purposes, while approximately 7% is urbanized (PIF 2008). Historically, this area contained a mixture of oak-hickory, northern hardwood, and mixed-coniferous forests. NABCI's main focus in this region is on wetlands and Great Lakes lakeshore habitats, which are of high concern due to its use as a migratory stopover for many bird species (NABCI 2008). However, the region also contains many other habitats in need of attention, such as shrublands. Many of these areas occur on land owned and managed by the New York State Department of Environmental Conservation (NYSDEC), The Nature Conservancy, and the US

Fish and Wildlife Service, which makes them ideal for management action. In addition, a vast amount of habitat with early-successional potential occurs on privately owned land.

The Audubon Society of New York State (2007) has compiled a list of red-listed and yellow-listed species. According to Audubon (2007) species that are red-listed are "declining rapidly and/or have very small populations or limited ranges, face major conservation threats, and are typically of global conservation concern." Yellow-listed species include "species that are either declining or rare, often on a national level." Shrubland birds, and other bird species that depend on shrubland habitat at some point in their lifecycle, in New York State that are red-listed include Bicknell's Thrush (*Catharus bicknelli*), Golden-winged Warbler, and Henslow's Sparrow (*Ammodramus henslowii*). Yellow-listed species in New York State include the Olive-sided Flycatcher (*Contopus cooperi*), Willow Flycatcher (*Empidonax traillii*), Wood Thrush (*Hylocichla mustelina*), Blue-winged Warbler (*Vermivora pinus*), Prairie Warbler (*Dendroica discolor*), Bay-breasted Warbler (*Dendroica castanea*), Cerulean Warbler (*Dendroica cerulea*), Prothonotary Warbler (*Protonotaria citrea*), Canada Warbler (*Wilsonia canadensis*), Nelson's Sharp-tailed Sparrow (*Ammodramus nelsoni*), and Rusty Blackbird (*Euphagus carolinus*).

CONSERVATION OF SHRUBLAND BIRDS

Unlike other bird assemblages, such as grassland and forest birds, relatively few shrubland birds exhibit area sensitivity in habitat patches 0.8 ha or greater (Rudnicky and Hunter 1993, Krementz and Christie 2000, DeGraaf and Yamasaki 2003, Dettmers 2003, Askins 2007). However, there are exceptions such as the Golden-winged Warbler, which requires patches of habitat exceeding 10 ha (Dettmers 2003, Confer and Pascoe 2003). Therefore, area is not so much of an issue as is the structure of habitat for most shrubland birds. However, increased patch size of shrubland habitat may still be highly desirable from a management perspective, as increased area creates more shrubland habitat, thereby increasing absolute shrubland bird abundance. Present research should focus on how current land use practices can be altered to increase habitat suitable for shrubland birds, because impacts of natural disturbances that once maintained shrubland habitat have sharply declined due to anthropogenic effects (Trani *et al.* 2001, Sirami *et al.* 2007). In order to increase populations of shrubland birds, it is crucial to preserve and maintain natural shrubland habitats that still exist. In addition, there needs to increased research and focus on ways to create new shrubland habitat from existing woodlands through active forest management focused on maintaining or creating early-successional shrub and forest stands.

Forest management consists of a variety of cutting methods such as clear, group, and selective-cuts, all of which will have an impact on the type of shrubland habitat that may result after the cut. Some research suggests that clear-cuts are most suitable for creating desirable habitat for most shrubland birds, while group selection cuts (<0.6 ha) should be avoided, as they provide habitat more suited to mature forest and canopy-gap specialists (Costello *et al.*, 2000, Krementz and Christie 2000, Yahner 2003, Askins *et al.* 2007). However, clear-cuts tend to be less favored as a management practice due to increased soil erosion and decreased aesthetics. Other research suggests that increased size of gap openings does not correlate with individual shrubland species abundance, but seems to be related to species richness (Rudnicky and Hunter 1993, Moorman and Guynn 2001) and thus group selection cuts should not be discounted. The research results tend to be contradictory, but this is to be expected as different species of shrubland birds require different types of habitats.

Shrubland birds occupy a wide range of habitats, from relatively open and low shrublands (such as the Field Sparrow and Song Sparrow), to thicker and more dense shrubs [such as the

Gray Catbird (*Dumetella carolinensis*) and Yellow Warbler (*Dendroica petechia*)], to areas with low trees (such as the Chestnut-sided Warbler and Blue-winged Warbler). Those species that occupy relatively thick and dense shrublands tend to respond to vegetation structure more than increased area. Thus, for these species it is best to assess habitat structure and determine best management practices using local levels of analysis (Askins *et al.* 2007). In contrast, shrubland bird species that are found in relatively open and low shrublands tend to be at least somewhat influenced by size of habitat and surrounding land use (Askins *et al.* 2007). With theses species, it appears that a broader analysis, such as landscape level-remote sensing, may be a helpful technique for assessing management practices. Due to the differences in habitat preference among shrubland birds, it is important to look at both local and landscape levels of analysis when deriving management techniques for the conservation of shrubland birds.

SHRUBLAND HABITATS: ANTHROPOGENIC vs. "NATURALLY" MAINTAINED

Shrubland habitats are created and maintained through disturbance. There are two broad categories of shrubland habitat: (1) those that are maintained by "natural" processes and (2) those that are maintained by anthropogenic disturbance.

Naturally occurring shrublands, such as swampy areas, oak openings, and alvar grasslands and shrublands are maintained on a site without human disturbance. These natural shrublands are rare in the United States, primarily due to changes in disturbance history and land use over time (Noss *et al.* 1995, Trani *et al.* 2001, Foster *et al.* 2002, Sirami *et al.* 2007). Natural ecological disturbances, such as floods and fires, are often cyclic, large-scale, and involve factors such as climate, weather, and location, and result in a mosaic of habitats (Brawn *et al.* 2001). At a regional level, naturally occurring shrublands are patchy, often more heterogeneous, and relatively larger than those that are created, or maintained, by anthropogenic disturbances.

However, at a local level, naturally maintained shrublands tend to look more homogenous and appear relatively similar to those that are anthropogenically maintained (Brawn *et al.* 2001).

Shrublands that occur in anthropogenically maintained habitats are disturbed periodically using methods such as burning, flooding, logging, and mowing (Askins *et al.* 2001). Wildlife managers may use disturbance regimes to create and maintain shrubland habitats that are critical to the survival and maintenance of declining species (Brawn *et al.* 2001, Thompson and DeGraaf 2001, Degraaf and Yamasaki 2003, Oehler 2003, Vickery *et al.* 2005). However, while grasslands and forests exposed to anthropogenic disturbances are often relatively easy to maintain, shrublands tend to pose somewhat of a problem. The practice of burning and mowing of grasslands is often done at frequent intervals to achieve suitable habitats for grassland birds (Vickery *et al.* 2005). Forests are relatively easy to maintain, as often they are simply left to grow and eventually become a climax community. However, shrublands are in successional transition, and thus pose quite an issue for maintenance by wildlife managers (Zuckerberg and Vickery 2006). Shrublands cannot simply be burned, or they may revert to earlier successional grasslands. On the other hand, if they are allowed to grow in an uncontrolled manner, they will inevitably succeed to a closed-canopy forest. To add to the complexity, the type and frequency of disturbance regimes affect the resulting growth of both vegetation and the structure of the resulting vegetation and avian communities. What is done by nature is not easily duplicated by man.

The current lack of natural disturbances has resulted in the need for habitat manipulation to create and maintain habitat for shrubland birds. Obviously, there does not seem to be one management practice currently in place that is best for creating habitat suitable for all shrubland bird species (Rudnicky and Hunter 1993, Costello *et al.* 2000, Morman and Guynn 2001, Askins *et al.* 2007). Also, there are always limitations when dealing with the economic and ecological goals of wildlife management. Increased understanding of shrubland bird habitat requirements and shrubland maintenance is required in order to sustain viable populations of declining shrubland birds.

OBJECTIVES:

Given the lack of understanding in shrubland habitat selection and the importance of this declining habitat in Western New York I focused on two main objectives for my study: (1) to examine habitat selection of shrubland birds present in the Great Lakes Plains region at both local and landscape levels; and (2) to suggest management recommendations for shrubland bird conservation. These objectives were approached by using data on abundance and habitat characteristics to model shrubland bird habitat selection in both managed and naturally maintained shrubland habitats within the Great Lakes Plains Region.

I focused on all shrubland birds encountered during the study, and report results based on both abundance of most common species and the presence and absence of all species encountered. Ultimately, I hope the findings of my research will aide wildlife managers in their efforts to sustain shrubland birds in the Northeast.

METHODS:

STUDY SITES

The majority of the study sites occurred in anthropogenic, early successional habitats at Iroquois National Wildlife Refuge in Genesee and Orleans Counties. In addition, I studied naturally occurring shrubland habitats in both mesic areas (Bergen Swamp Preserve, Genesee County; Cicero Swamp, Onondaga County) and xeric areas (Chaumont Barrens Preserve, Jefferson County; Three Mile Creek, Jefferson County). Also, I studied one additional area in 2006, Quinn Oak Openings (Monroe County). This area was not included in most analyses due to the disruption of the shrublands through mowing and burning just prior to the first field season. Three Mile Creek Barrens was studied only during the 2007 season, as it replaced the previous area at Quinn Oak Openings.

The Bergen Swamp is located in the town of Bergen, Genesee County. It contains approximately 800 ha of wetlands surrounded by a relatively high diversity of community types, including naturally occurring shrublands (Johnson 1994). The shrubland community, which is surrounded by pine forests and numerous wetlands, consists primarily of American larch (*Larix laricina*), black huckleberry (*Gaylussacia baccata*), blueberry (*Vaccinium* spp.), juniper (*Juniperus* spp.), Labrador tea (*Ledum groenlandicum*), northern white cedar (*Thuja occidentalis*), and shruby cinquefoil (*Potentilla fruticosa*). The diversity of vegetation in the Bergen Swamp creates ideal habitats for many species of breeding birds (Johnson 1994).

Cicero Swamp, located in Onondaga County, 18 km north of Syracuse, contains approximately 1500 ha of wetland and upland habitats (NYSDEC 2006). Somewhat similar to Bergen Swamp, the upland habitats are diverse and consist of naturally maintained shrublands that include American larch, black chokeberry (*Pyrus melanocarpa*) black huckleberry, Labrador tea, leatherleaf (*Chamaedaphne calyculata*), and mountain holly (*Nemopanthus mucronata*).

Although some experiments have been conducted to determine the results of different disturbance regimes on vegetation, Cicero Swamp is not actively managed (LeBlanc and Leopold 1992, Johnson and Leopold 1998).

Iroquois National Wildlife Refuge (INWR) is located in Genesee and Orleans Counties in the town of Alabama, between Buffalo and Rochester, New York. It consists of approximately 4400 ha of freshwater marshes, hardwood swamps, forests, woods, pastures, meadows and shrublands (USFWS 2006). Shrubland habitats within INWR are quite diverse and include both native and introduced species. Sparse shrubland fields contain mostly young ash (*Fraxinus* spp.) and dogwood (*Cornus* spp.). Plant species such as ash, dogwood, buckthorn (*Rhamnus* spp.), hawthorn (*Crataegus* spp.), and honeysuckle (*Lonicera* spp.) are found in diverse and patchy shrublands. Dense shrub fields consist primarily of invasive honeysuckle. The refuge maintains habitats that sustain numerous species of concern in the area, such as the American Woodcock and the Golden-winged Warbler, and also manages some habitat for recreational purposes. In recent years the refuge has worked to preserve large grassland habitats due to the steep decline of grassland bird species in New York State and the Northeast (USFWS 2006). Currently, the refuge is trying to actively manage for shrublands due to new studies which show significant declines of shrubland birds in Northeastern United States (Paul Hess 2007, personal communication).

Chaumont and Three Mile Creek Barrens Preserves, both located in Jefferson County, are part of The Nature Conservancy's (TNC) Central and Western New York Alvar Barrens and Grasslands (TNC 2006). The alvar barrens and grasslands owned by TNC include almost 4000 ha of habitat. Chaumount Barrens contains approximately 2100 ha of open grasslands, shrub savannas, woods, and moss gardens. Three Mile Creek Barrens, which is located approximately

3 km northwest of Chamount, includes 97 ha of similar habitat. Both areas consist of similar shrubland habitats with species such as common juniper (*Juniperus communis*), ash, buckthorn, honeysuckle, fragrant sumac (*Rhus aromatica*), arrowwood (*Viburnum* spp.), dogwood, choke-cherry (*Prunus virginiana*), hop hornbeam (*Ostrya virginiana*), pale swallow-wort (*Cynanchum rossicum*) and bur oak (*Quercus macrocarpa*). The Nature Conservancy actively manages this land to protect the variety of habitats suitable for sustaining numerous wildlife species. It is known for its alvar grasslands and prairie smoke (*Geum triflorum*). TNC works to increase its land coverage by acquiring high-priority tracts of land adjacent to the established preserves.

FIELD METHODS

My assistants and I performed point counts for shrubland birds at five study areas within the Great Lakes Plains region during three time intervals from 15 May through 30 June in 2006 and 2007: (1) 15-31 May; (2) 1-15 June; and (3) 16-30 June. Point counts were done between 0600 and 1000 on fair days with light wind and no rain. The five areas and locations within these sites represent gradients in a number of characteristics, including vegetation height and density, frequency and type of disturbance, and soil moisture

I established 60 bird and vegetation study plots: 31 in INRW, 12 in Chamount Barrens Preserve, seven in Three Mile Creek Barrens Preserve, five in Cicero Swamp, and five in Bergen Swamp. In each study plot I surveyed shrubland bird abundance and species richness during the breeding season using a circular plot count (CPC) sampling method (Fancy 1997, Rosenstock *et al.* 2002, Thompson 2002). The CPC method was chosen due to its increased ability to determine detectability of inconspicuous, hard to see birds that are located in difficult terrain and dense, patchy vegetation, such as shrublands. This method takes into account the probability of detecting species within different distances from a center observation point. The CPC has three critical assumptions: (1) birds at or near the point of sampling will always be detected as long as the sampling period lasts between 5-8 min; (2) birds are detected prior to fleeing caused from disturbance by observer; and (3) estimated distances of birds are recorded accurately (Rosenstock *et al.* 2002).

Each CPC had a 50 m radius. The center of each CPC was placed within the core of the shrubland using HawtV's Analysis Extension Tools in ArcMap (James Zollweg 2005, personal communication). The edges of each CPC were at least 150 m apart from each other and 50 m away from natural and anthropogenic edges. The number of CPCs in each study area was determined by how many could fit according to the method rules described above. Bird surveys were done using a single observer method. Following a 2-min. waiting period at the center of the CPC, my field assistants or I counted birds for 5-min periods. For each detection, we recorded the species, number of individuals, and distance from the center of the plot (Fancy 1997; Rosenstock *et al.* 2002, Thompson 2002). In both 2006 and 2007, the week prior to the census start date was dedicated to training assistants in both species identification and distance estimation. In order to increase consistency and accuracy among observations, distances were broken up into four intervals during the 2006 season (0 to 10 m, 10 to 20 m, 20 to 35 m, and 35 to 50 m; Rosenstock *et al.* 2002). However, in 2007 distances were recorded to 1 m accuracy to reduce observer bias (Wilson and Doherty 2007, personal communication).

I examined vegetation at both local and landscape levels. At the local level, both quantitative and qualitative vegetation data were collected from 1 June to 15 July in both 2006 and 2007. Data variables labeled as "quantitative" were relatively time consuming to collect (> 1 hr/plot). These variables involved careful repeated measurements and the identification of shrubland species. Quantitative variables included shrub height, shrub density, shrub cover, ground cover, and shrub composition. Quantitative vegetation measurements were taken within the 50 m radius of each CPC at ten random points, determined from a random number table. Each of the ten vegetation points consisted of five 1-m^2 sampling areas, one in the center and four more 2 m away from the center in each cardinal direction. This provided a total of 50, 1-m^2 vegetation sampling plots per CPC. The vegetation sampling points selected in 2006 were sampled again in 2007. At each vegetation sampling point, height of tallest shrub and shrub species present were recorded to the nearest cm. Average height of shrubs was determined by measuring the tallest and smallest shrubs, noting the number of each, and then calculating a midpoint value. Shrub foliage density was estimated as the number of hits of foliage on a 12 mm diameter, 3-m tall telescoping rod, which was placed in the center of each vegetation plot. Shrub and ground cover were estimated using seven Daubenmire cover classes (0-5%, >5 to 15%, >15 to 25%, >25 to 50%, >50 to 75%, >75 to 95% and >95 to 100%; Daubenmire 1959).

Qualitative data collection involved a "quick-and-dirty" method, in which I spent no more than 2 min/plot assessing the characteristics of the habitat in order to obtain a general idea of its composition. Because managers often do not have the time and resources necessary to gather detailed habitat data, I wanted to determine if a wildlife manager could accurately describe shrubland habitat with minimal effort. Qualitative data were based on visual estimates made from the center of each CPC and included total percent shrub cover, average shrub height, total percent ground cover, and number of tree stems per plot.

On a landscape level, I analyzed aerial photographs to estimate the proportional area of grasslands, wetlands, and forests contained within a 250 m radius of each survey point located in the shrubland study sites (Table 1).

ANALYSIS

Estimation of Detection Probabilities – I analyzed bird survey data using the free online statistical program DISTANCE to estimate probability of detection, which varies with observer and species (Buckland *et al.* 1993, Rosenstock *et al.* 2002). Detection coefficients were calculated for birds encountered in the study areas within the Great Lakes Plains Region of New York State; all sites excluding those in INWR; and sites only within INWR (Table 2). Due to sample size issues, only species that were found in at least 10 separate survey plots were used in DISTANCE. The half-normal cosine model was chosen based on its low AIC*c* value. Akaike's Information Criterion (AIC) is a goodness-of-fit measure used in statistical tests (Akaike 1973). The AIC*c* is a corrected unbiased estimator AIC, which is commonly used in model selection based on small sample sizes (Sugiura 1978, Hurvich and Tsai 1989).

Detection probabilities were similar for the three trials (Table 2), thus I used detection probabilities based on all study areas to increase the sample size, thereby increasing confidence in the detection coefficient. For each species, I then divided the average number of individuals detected / count / point by the detection probability, to obtain an estimate of the actual number of individuals / count / point. These corrected abundance estimates were then used as response variables in my statistical models.

Bird Habitat Models – To develop bird habitat models, I used a combination of best subsets and stepwise multiple regression techniques to analyze the relationship between bird count results and predictor variables (Minitab 2007; Norment 2008, personal communication). These analyses were done independently for all areas combined, Jefferson County sites, and sites in Iroquois National Wildlife Refuge. Data from 2006 produced relatively few, weak models, thus the main focus for analyses of bird habitat models was on data gathered in 2007. Due to small sample sizes, best subsets and stepwise multiple regressions could not be used to independently analyze data from the Bergen and Cicero swamps, thus correlation matrices were used as an exploratory tool to examine bird-habitat relations at these sites.

Predictor variables that were highly correlated ($r > 0.8$) were omitted from the final data set used for analysis. Landscape variables used included log of field area (Area; note that area data were not normally distributed even after log transformation) and perimeter to area ratio (P/A). Local vegetation variables included vegetation hit diversity (V'; calculated using the Shannon Weiner Index based on # hits/1-m height intervals: 0-1, 1-2, 2-3 m), density (Total Hits), height, shrub cover, ground cover, and number of plant species (NumberPS).

I began my analysis by using best subsets regression and choosing the most parsimonious model, the one that explains the most variance with the least amount of variables (Anderson *et al.* 2000). This entailed choosing a model with a high adjusted r^2 value and a low Mallow's C*p* value. The adjusted r^2 value is a coefficient of determination, or the proportion of variability in a data set adjusted for the number of explanatory terms in the model (Zar 1999). Mallow's C*p* value is a measure of the difference between the fitted regression models from the true model, along with random error (MTSU 2004). Once the best model was selected, I entered the predictor variables included in the model into a stepwise multiple regression analysis in order to determine the strength and direction of the relationship. Only those models that contained some level of statistical significance ($P \leq 0.100$) were included in the results.

Qualitative vs. Quantitative Methods – I wanted to see how well qualitative estimates compared to quantitative vegetation measurements, thus two-sample paired T-tests were used to compare the qualitative and quantitative vegetation predictor variables for both 2006 and 2007 data. Also, I ran a linear regression analysis on qualitative versus quantitative vegetation variables for both 2006 and 2007 data to determine the strength of the relationships between qualitative and quantitative predictor variables. In addition, I wanted to examine how well qualitative variables did at predicting bird abundance, relative to models developed using quantitative data. Therefore, I used best subsets and stepwise multiple regression statistics with the 2007 qualitative vegetation variables (shrub cover, shrub height, and ground cover) and landscape variables (area and P/A) for INWR, developed bird-habitat models and then compared the best bird-habitat models to models developed from the 2007 quantitative data.

Community Similarity – I determined avian community similarity among study areas using the Bray-Curtis coefficient of community similarity for 2007 (Bray and Curtis 1957). The Bray-Curtis coefficient of community similarity (BC) was chosen due to its unbiased equation which includes rare species. The Bray Curtis coefficient formula is as follows: $BC = 2w/(a+b)$; where w = sum of the lower of two values for abundance of shared species, a = sum of all abundance values for community I, and b = sum of all abundance values for community II.

RESULTS:

Bird Habitat Models, All Areas. There were relatively few significant bird habitat models developed from the 2006 data (Table 3). Those models that were significant generally had relatively low r^2 values and varied drastically from the 2007 bird habitat models. Thus, throughout the results and discussion I refer to 2007 data, unless otherwise stated (Table 4).

In 2007, average shrubland bird abundance per plot increased significantly with increases in V' and ground cover (r^2 = 34.3). Species richness increased significantly with increased shrub cover and field area, and decreased shrub height (r^2 = 85.1). Among widely distributed (or common) early successional species, Eastern Towhee abundance increased significantly with increased shrub cover and field area, and decreased number of plant species (r^2 = 67.7). Prairie Warblers (*Dendroica discolor*) increased significantly with increases in field area and P/A (r^2 = 66.6). Field Sparrows increased significantly with increases in ground cover and field area, and decreases in V' (r^2 = 54.3). Black-and-white Warblers (*Mniotilta varia*) increased significantly with decreases in V', ground cover and P/A (r^2 = 50.1) (Table 4).

Field area appeared to be the most important predictor variable, as it was significant in eight of the 17 models (Table 4). Field area was significantly and positively correlated with four models (Species Richness, Eastern Towhee, Field Sparrow, and Prairie Warbler), while it was significantly negatively correlated with four models [Common Yellowthroat (*Geothlypis trichas*), Gray Catbird, Swamp Sparrow (*Melospiza georgiana*)], and Yellow Warbler]. V' also seemed to be important, as it entered significantly into six models. Shrub cover and ground cover each were significant in five out of the 20 models, and thus also seem to be relatively important. Shrub cover and ground cover generally were negatively related to one another because when shrub cover was significant in a particular model, ground cover often was not, and vice-versa.

Due to the mix of relatively xeric and mesic shrublands, and anthropogenic and natural habitats in my study, the five main study areas differed substantially in vegetation structure and composition. Because these differences may have at least partially masked site-specific responses of shrubland birds to habitat characteristics, I constructed separate bird-habitat models for INWR and the Jefferson County areas, the two areas with relatively large numbers of circular plots. Although I was unable to construct bird-habitat models for the two other areas in the study, Bergen Swamp and Cicero Swamp, due to relatively small sample sizes, I did use correlation matrixes to explore relationships between predictor and bird response variables. Few bird-habitat models for 2006 were significant (Table 5), and so I will focus on the analysis of data gathered in 2007.

Iroquois National Wildlife Refuge. During the 2006 field season we observed 27 species of birds within the CPCs (Appendix I). Few bird-habitat models for 2006 were significant (Table 5), and so I will focus on the analysis of data gathered in 2007. In 2007 we observed 32 species of shrubland birds in INWR CPCs (Appendix II). Of all study areas, INWR contained the greatest habitat diversity, likely due to active habitat management. The most abundant species observed in sparse shrubland fields, such as those containing young ash trees, included the Yellow Warbler, Common Yellowthroat, and Song Sparrow (Table 6). Within the heterogeneous, diverse, and patchy shrublands, common bird species included Yellow Warbler, Song Sparrow, and Gray Catbird. In dense fields, such as those with invasive honeysuckle, common species encountered included the Gray Catbird, Yellow Warbler, and Song Sparrow.

Increased shrubland bird abundance at INWR was significantly related to increases in both V' and shrub height ($r^2 = 46.4$; Table 7). Species richness increased significantly with increases in shrub cover, ground cover, and area and decreased shrub height and number of plant species ($r^2 = 55.3$). Gray Catbirds increased significantly with increases in shrub height ($r^2 = 60.4$). They also were positively associated with increased number of plant species and decreased area. No significant relationships were observed between Yellow Warblers and vegetation variables. Song Sparrows were significantly related only to decreased P/A ($r^2 = 37.5$), although, in the best model, decreased V' and increased ground cover and height were also important. Field Sparrows increased significantly with decreases in V' and increases in number of plant species; in the best model decreased shrub cover and increased ground cover were also related to increases in Field Sparrow abundance ($r^2 = 58.1$). Common Yellowthroats increased significantly with increased number of plant species and decreased shrub cover ($r^2 = 22.7$).

Jefferson County. In 2007, a total of 32 shrubland bird species were observed in the more xeric study areas in Jefferson County CPCs (Appendix II). Due to the similarity between the two study areas in Jefferson County, many bird species were found in both Chaumont and Three Mile Creek. However, Willow Flycatchers (*Empidonax traillii*) were only found within Chaumont Barrens, while both Yellow Warblers and Alder Flycatchers (*Empidonax alnorum*) were only observed in Three Mile Creek Barrens. The four most abundant species observed in Chaumont were the Eastern Towhee, Common Yellowthroat, Song Sparrow and Gray Catbird, respectively. In Three Mile Creek Barrens, the most abundant species, starting with the greatest, were the Gray Catbird, Yellow Warbler, and Savannah Sparrow (*Passerculus sandwichensis*).

Abundance and species richness of shrubland birds increased significantly with an increase in V' and a decrease in height (abundance, r^2 = 19.4; species richness, r^2 = 20.7; Table 8). Gray Catbirds increased significantly with increased V', ground cover, and shrub cover (r^2 = 67.1). Prairie Warblers increased significantly with increased V' and shrub cover, and decreased ground cover and shrub height (r^2 = 55.8). Yellow Warbler abundance increased significantly with decreased shrub cover, although increased V' and shrub height were also important in the best model (r^2 = 43.1). In all models where V' was significant, an increase in V' was positively correlated with the bird response variable.

Bergen Swamp. Vegetation structure at Bergen Swamp varied among the 5 CPCs. A total of 16 species of birds was observed at Bergen Swamp in 2007 (Appendix II), with the majority occurring in habitats with low shrub cover, shrub height, and density. The most common bird species that I encountered included the Common Yellowthroat, Swamp Sparrow, Black-capped Chickadee (*Poecile atricapilla*), and Cedar Waxwing (*Bombycilla cedrorum*).

The correlation matrix for bird response and predictor variables showed some interesting relationships (Table 9). Abundance was correlated with increased ground cover (r = 0.827, P = 0.084) and decreased shrub height (r = -0.723, P = 0.167). Surprisingly, species richness was significantly and negatively related to shrub height (r = -0.945, P = 0.015), shrub cover (r = -0.842, P = 0.073), and positively related to increased ground cover (r = 0.845, P = 0.071). The only species specific correlation of significance was that Cedar Waxwings showed a significant relationship with decreased shrub height (r = -0.961, P = 0.009) and increased ground cover (r = 0.944, P = 0.016).

Cicero Swamp. The vegetation structure of Cicero swamp was generally homogeneous among the five CPCs. In terms of the bird community, the most abundant species observed included the Gray Catbird, Eastern Towhee, Cedar Waxwing, and Yellow Warbler.

The correlation matrix did not show any strong relationships between vegetation predictor variables and species abundance or richness (Table 10). There was no strong correlation between dependent variables and Gray Catbirds. Eastern Towhee abundance significantly increased with an increase in ground cover ($r = 0.909$, $P = 0.032$) and decreased number of plant species ($r = -0.837$, $P = 0.077$). Decreases in shrub density also had a positive, although non-significant effect on Eastern Towhees ($r = -0.744$, $P = 0.149$). Increases in Cedar Waxwing abundance were significantly related to decreased shrub height ($r = -0.952$, $P = 0.013$). Cedar Waxwings were also related positively with increased density ($r = 0.803$, $P = 0.102$). Yellow Warbler abundance had a strong positive correlation with decreased shrub cover ($r = -0.779$, $P = 0.121$).

Qualitative vs. Quantitative Vegetation Methods. Due to sample size constraints and the need to present comparisons clearly, only data from INWR were used to compare qualitative and quantitative methods of data collection. Qualitative and quantitative estimates of shrub height did not differ significantly in 2006 (Table 11), however in 2007 qualitative shrub height was significantly higher than quantitative shrub height. Qualitative and quantitative estimates of shrub cover showed no significant difference in either 2006 or 2007. In both 2006 and 2007, qualitative ground cover estimates were significantly higher than quantitative ground cover measurements. In all cases, qualitative values tended to be greater than quantitative measurements.

For both 2006 and 2007 data, regression analyses based on data in each INWR field suggested that qualitative estimates and quantitative measurements were most highly correlated for shrub height; there also was a significant positive relationship between the two shrub cover variables (Figures 3 and 4). However, in both 2006 and 2007 there was no significant relationship between the two ground cover variables (Figures 3 and 4).

For INWR shrublands, bird abundance models based on quantitative data produced a stronger relationship (2007 $r^2 = 46.4$, 2006 $r^2 = 46.4$), compared to those based on qualitative data ($r^2 = 26.7$; Tables 7, 12, and 13). Coefficients of determination for regression models for species richness were similar (Tables 7, 12, and 13). Models based on quantitative vegetation data were better predictors for the Black-capped Chickadee ($r^2 = 35.3$), Field Sparrow ($r^2 = 58.1$), and Gray Catbird ($r^2 = 60.4$) compared to models based on qualitative predictors for these species (Tables 7, 12, and 13). However, qualitative predictors from 2006 produced stronger models for the Common Yellowthroat ($r^2 = 41.2$) and the Cedar Waxwing ($r^2 = 61.3$) compared to both qualitative and quantitative models from 2007 (Tables 7, 12, and 13). All qualitative bird-habitat models from 2007 were weak compared to the best bird-habitat models using 2007 quantitative data, and 2006 qualitative data (Tables 7, 12, and 13).

Qualitative and quantitative vegetation collection methods produced vastly different, "best" bird-habitat models. Depending on the type of vegetation collection method used, predictor variables often differed for the same species. Overall, bird habitat models were stronger when based on quantitative vegetation measurements, rather than those models developed using qualitative vegetation estimates. In my study, rapid visual estimates of characteristics (qualitative vegetation collection) generally produced poorer models with greater variability than did vegetation data obtained using standardized, quantitative methods; perhaps because qualitative estimates were based entirely on the data collector's ability to estimate vegetation characteristics correctly.

Invasives. Invasive plant species were found throughout the five study areas, especially in INWR (Table 14). I ran regressions of species richness and shrubland bird abundance on number of invasive species for INWR and the GLPR as a whole. Only one significant relationship arose; in the GLPR, the average number of shrubland birds significantly increased with increases in invasive plant species ($r^2 = 0.26$, $P = 0.015$; Figure 5). Although the other three regressions were not significant, there seemed to be an overall trend of increased shrubland bird abundance and species richness with increased invasive plant species.

Community Similarity. Using the Bray-Curtis coefficient of community similarity, I found that Chamount and Three Mile Creek Barrens, the two xeric areas located in Jefferson County, were most similar in bird community composition and structure in 2007 ($BC = 0.53$; Table 15). Three Mile Creek Barrens and INWR also were relatively similar ($BC = 0.52$). In 2007, Bergen Swamp and INWR had the least similar avian communities ($BC = 0.24$).

Summary of Bird Habitat Relations - The five study areas differed vastly in vegetation structure and composition. The best species-specific bird-habitat models differed substantially between the INWR and the xeric areas in Jefferson County. The only predictor variable that was consistent among models for these two study areas was increased shrubland bird abundance per plot with increased V'. Because the mesic areas (Bergen and Cicero Swamps) also varied in terms of vegetation variables and habitat structure, it was no surprise that correlation matrices for species found in both areas suggested different habitat preferences.

Many shrubland bird species found in my study areas are experiencing significant declines throughout New York State, including the Field Sparrow, Eastern Towhee, and Song Sparrow (BBS 2007). Thus, I think it is important to give a general overview of the best bird habitat models for each species, and the predictor variables that influence increased abundance. In general, my models suggest that Field Sparrow abundance tends to increase with increased ground cover and decreased V'. Although not significant, there was also a trend of increased Field Sparrow abundance with increased area and decreased shrub cover. Overall, Eastern Towhee abundance increased with increases in shrub cover, V', and area, and decreased ground cover and number of plant species. Generally, abundance of Song Sparrows increased with increased ground cover and decreased P/A. In addition, there seemed to be a trend of increased Song Sparrow abundance with decreased number of plant species, V', and shrub height.

Common Yellowthroats, Yellow Warblers, and Blue-winged Warblers are also declining throughout New York State (BBS 2007). Although these species' declines are not significant, they should still viewed by managers as species of concern when maintaining and creating shrubland habitat. Data from my study suggested that Common Yellowthroat abundance increased with increased number of plant species and decreased shrub cover. Some of the models also suggest that increased ground cover and decreased height, P/A, and area, are important to increased Common Yellowthroat abundance. In general, Yellow Warbler abundance increased with increased V', number of plant species, and height, and decreased area and shrub cover. Overall, Blue-winged Warbler abundance increased with increased V' and shrub cover and decreased height, although increased area and decreased number of plant species also seemed to be important.

Area effects differed vastly among best bird habitat models (Tables 4, 7, and 8). In terms of species richness, my data suggests that increased area results in a greater number of shrubland bird species. However, in the majority of models, area did not seem to affect shrubland bird abundance (avg. # individuals/count). However, for declining shrubland species found in my study areas, increased area had a positive significant relationship with abundance of the Field Sparrow, Eastern Towhee, and Blue-winged Warbler. Although not declining, the Prairie Warbler also showed a significant positive relationship with area. Common Yellowthroat and Yellow Warbler abundances increased with decreased area. Other species that showed a significant negative relationship with area included the Gray Catbird, Swamp Sparrow, and Brown-headed Cowbird (*Molothrus ater*). There seemed to be no relationship between area and Song Sparrow abundance.

DISCUSSION:

Overall Trends – According to BBS data, 53% of shrubland birds in New York State have declined significantly over the last 20 years, along with 28% in the Great Lakes Plains Region (GLPR) (Sauer *et al.* 2007). Many of these declining species occurred in my study areas, including the Northern Flicker (*Colaptes auratus*), Alder Flycatcher, Willow Flycatcher, Song Sparrow, Brown-headed Cowbird, Savannah Sparrow, Common Grackle (*Quiscalus quiscula*), Field Sparrow, Brown Thrasher, Eastern Kingbird (*Tyrannus tyrannus*), Golden-winged Warbler, and Nashville Warbler (*Vermivora ruficapilla*). This emphasizes the need for increased efforts to conserve shrubland birds, through habitat maintenance and creation. However, my study found few consistent patterns in habitat preference among the suite of shrubland birds encountered. This is not surprising, given the documented differences in habitat preference among many shrubland birds in the Northeast (Birds of North America (BONA) 2008). In addition, the Bray-Curtis coefficients of community similarity suggested that none of the five study areas were highly similar in term of their bird communities. Thus, results of this study are best understood in terms of site-specific and species-specific responses to habitat characteristics.

I found that increased area, along with increased shrub cover, is important for increased shrubland bird species richness throughout the Great Lakes Plains Region of New York State. However, when study areas were analyzed independently of one another, area did not show up as an important predictor variable for species richness. Many studies have found that most shrubland birds are not area sensitive (Rudnicky and Hunter 1993, Krementz and Christie 2000, DeGraaf and Yamasaki 2003, Dettmers 2003, Rodewald and Vitz 2005, Askins 2007), which correlates with my findings when study areas were analyzed independently, although other studies suggest that area effects do exist for some shrubland avifauna (Rudnicky and Hunter 1993, Rodewald and Vitz 2005).

BBS data suggest that 39% of the common shrubland birds at INWR have declined in New York State over the last 10 years (Sauer *et al.* 2007). The most frequent species encountered varied with shrubland characteristics, although Yellow Warblers and Song Sparrows were encountered consistently across all habitats, even while experiencing significant declines in New York State (Sauer *et al.* 2007; Table 6). Only one Golden-winged Warbler was found in INWR during the two-year study period. Thus, I could not develop a bird-habitat model for this species of concern. Overall, at INWR increased shrubland bird abundance increased with increased vegetation hit diversity and increased shrub height. Species richness increased with increases in shrub cover, ground cover area, and decreases in shrub height and number of plant species.

Over the past ten years, 50% of the shrubland birds in Jefferson County declined significantly in New York State (Sauer *et al.* 2007). The four most abundant species observed in Chaumont were the Eastern Towhee, Common Yellowthroat, Song Sparrow and Gray Catbird. Of these species, the Eastern Towhee and Song Sparrow are experiencing significant declines (Sauer *et al.* 2007). Within Three Mile Creek the Gray Catbird, Yellow Warbler, Savanna Sparrow, and American Goldfinch (*Carduelis tristis*) were most common. With the exception of the Gray Catbird, all of these species are significantly declining. Although no Golden-winged Warblers were found during the survey periods, I did observe two individuals during the 2007 field season.

Specific Shrubland Species Trends – Blue-winged Warblers are yellow-listed in New York State by the Audubon Society (2007). In my study, I found that Blue-winged Warblers prefer habitats with increased shrub cover, increased area, and decreased shrub height. Confer and Knapp (1981) found similar habitat requirements, as their study suggested that Blue-winged Warblers prefer dense patches of herbaceous vegetation and shrubs, with some woody tree stems. Research by Rodewald and Vitz (2005) suggest that Blue-winged Warblers avoid edges, thus they would most likely be found in large areas of continuous habitat. However, other research suggests that Blue-winged Warblers are not area-sensitive and are often found around utility-rights-of-way (ROWS) and roadside shrubland patches, regardless of habitat patch size (Confer and Knapp 1981, Confer and Pascoe 2003, Askins *et al.* 2007).

Over the last 40 years, Alder Flycatchers have declined drastically in New York State and the Great Lakes Plains region (Sauer *et al.* 2007). In INWR I found that increased abundance of Alder Flycatchers was significantly related to increased shrub cover, although increased ground cover and decreased shrub height were also important in the best bird-habitat model. In Jefferson County, my results suggested that increased Alder Flycatcher abundance was significantly related to decreased numbers of plant species. Previous studies have found that Alder Flycatchers are often found in around edges of dense brush and shrubby wetlands, and in early successional stands of 3-8 years after burning or clear-cutting (Morgan and Freedman 1986, Lowther 1999). Alder Flycatchers in New York often occur in habitats consisting of dogwood, choke-cherry, red raspberry (*Rubus idaeus*), arrowwood, speckled alder (*Alnus incana*), apple (*Malus* spp.), and beaked willow (*Salix bebbiana*; Lowther 1999). Many of these plants are abundant throughout INWR, thus it is no surprise that Alder Flycatchers were seen fairly often. In contrast, Jefferson County had few patches of dogwood, choke-cherry, red raspberry, and arrowwood, with other species such as juniper and fragrant sumac, appearing as the dominant vegetation type. In addition, Jefferson County had relatively few edges compared to INWR. Together, the different landscape characteristics help explain my findings that Alder Flycatchers in Jefferson County had decreased abundance, compared to INWR.

Willow Flycatchers are yellow-listed by New York State Audubon society, and have declined significantly throughout the Great Lakes Plain Region since 1966 (Audubon 2007, Sauer *et al.* 2007). In INWR Willow Flycatchers significantly increased with increased ground cover, although in the best bird-habitat model, increased P/A ratio was also important. According to BONA, the Willow Flycatcher is an edge specialist and prefers habitat of moist shrublands with standing or running water (Sedgwick 2000). Increased perimeter/area ratio creates a greater amount of edge habitat, and edges are found abundantly throughout INWR due primarily to active management of plots of land. Thus, my best bird-habitat model, including increased abundance of Willow Flycatchers with increased P/A, seems to agree with the habitat preference suggested by Sedgwick (2000).

Although Chipping Sparrows do not show significant declines in the Great Lakes Plains Region, they have declined significantly in New York State since 1966 (Sauer *et al.* 2007). My study found that in INWR, Chipping Sparrow abundance increased with increased ground cover and decreases in the number of plant species and V'. In contrast, Chipping Sparrows in Jefferson County increased significantly only with increased hit diversity. Breeding habitat for the Chipping Sparrow is quite diverse, as they can be found anywhere from open fields, to shrublands, to coniferous forests (Middleton 1998). Thus, habitat preference of Chipping Sparrows seems to be site-specific in the Great Lakes Plain Region.

As with Chipping Sparrows, Eastern Towhees also show a significant negative trend in abundance in New York State (Sauer *et al.* 2007). In INWR, Eastern Towhees increased in abundance with increased hit diversity and decreased shrub height and number of plant species. The best bird-habitat model showed that increased shrub cover and area were also important in increased Eastern Towhee abundance. Again, relationships were slightly different in Jefferson County, where Eastern Towhee abundance increased significantly with decreased ground cover and increased shrub cover. The difference in the best bird-habitat models between INWR and Jefferson County may be related to the observation that Eastern Towhees are habitat generalists, and occur in both mesic and xeric habitats (Greenlaw 1996). Eastern Towhees are edge-associated species which prefer dense shrubs, low trees, and plenty of ground cover (Greenlaw 1996). Thus, increased habitat patches may be beneficial to this species, as increased area results in an increase of absolute amount of edge.

Field Sparrows have declined significantly in both New York State and the Great Lakes Plains Region over the past 40 years (Sauer *et al.* 2007). Results from INWR suggest that Field Sparrows prefer areas with relatively open habitat, as indicated by the best-fit model, which included decreased hit diversity and increased numbers of plant species; increased ground cover and decreased shrub cover were also important. Confer and Pascoe (2003) also found that abundance of Field Sparrows increased with increases in herbaceous cover. Area did not appear in the best bird-habitat model for INWR, although Confer and Pascoe (2003) found that Field Sparrows increased proportionally with increased habitat patch size. However, Confer and Pascoe's (2003) findings do support the area-sensitivity I observed for Field Sparrows when all areas were analyzed as a whole (Table 4). According to Carey *et al.* (1994), Field Sparrows prefer woodland edges and openings, and old fields, including those by roadsides or railroads.

Song Sparrows have declined significantly throughout New York State and the Great Lakes Plains Region (Sauer *et al.* 2007). In INWR, increased Song Sparrow abundance was significantly related to decreased P/A ratio. Increased ground cover and shrub height and decreased V' were also important in terms of Song Sparrow abundance in INWR. Song Sparrows in Jefferson County showed significant increases in abundance with decreased shrub height, although increased ground cover was also important. According to Arcese *et al.* (2002), Song Sparrows range across a variety of habitats, including grasslands, forest edges, oak savannas, and eastern deciduous forests with dense undergrowth. Song sparrows were relatively abundant in all study areas, ranging across numerous shrub habitat types. This may be the reason for the relatively weak and contradictory best bird-habitat models.

The majority of shrubland avifauna encountered during my study appeared to be habitat generalists and occurred throughout a variety of open and closed shrubland habitats. This may be the reason why the best bird-habitat models varied for species at different study areas. More detailed studies should be done to increase our understanding of shrubland bird habitat preference.

MANAGEMENT RECOMMENDATIONS:

Actively Managed Anthropogenic Shrublands – In my study, area did not seem to have a major effect on the abundance of most shrubland species, although some species did respond favorably to increased shrub patch size, including the Blue-winged Warbler, Eastern Towhee, Field Sparrow, and Prairie Warbler. Research has suggested that some shrubland bird species are edge- and area-sensitive (Rudnicky and Hunter 1993, Rodewald and Vitz 2005). For example, the Eastern Towhee, Alder Flycatcher, Song Sparrow and Prairie Warbler are often found in patches >8 ha, but never in patches smaller than 0.6 ha (Annand and Thompson 1997, Robinson and Robinson 1999, Costello *et al.* 2000). These data suggest that shrubland bird management may be more effective if patches greater than approximately 0.6 ha are maintained as shrublands – a threshold size much smaller than for grassland birds at INWR and in the surrounding region (Norment et al. 1999), and in the Great Lakes Plain region of Jefferson County (Lazazzero 2006). Thus, in protected, actively managed areas such as INWR, smaller parcels of land that are ineffective for supporting species with increased area sensitivity, such as grassland birds, could be converted and managed as shrubland habitat. However, although many shrubland species may do well in relatively small habitat patches, or may not be area-sensitive, in that an increase in the size of the shrubland patch results in an increase in the number of individuals per unit area, focusing on patches of shrub habitat larger than 0.6 ha still may be of value to shrubland birds because this will increase the amount of available habitat, and thus the absolute number of shrubland birds, and also may be easier to manage efficiently. In INWR, this should not pose too many issues, as the majority of the habitat patches potentially or currently managed as shrublands are of adequate size. This recommendation is supported by Askins (2001) and

Dettmers (2003), who determined that area sensitivity is generally unimportant for shrubland bird conservation.

In terms of conserving slow-growing persistent shrublands, the maintenance of old fields is preferred over conversion of forest stands. Degraaf and Yamasaki (2003) found that vegetative characteristics of early-successional habitats in the northeastern United States varied among different shrubland habitats, and with different disturbance regimes such as burns, old fields, and hardwoods regenerating from logging. In regenerating forest habitats, early-successional stages are relatively short-lived, as the tree canopy develops rather quickly, blocking sunlight from the shrubland undergrowth. In contrast, old fields and burned areas allow for shrublands to exist for longer intervals (Latham 2003), as it takes longer for an old field to become occupied by trees than it does for a forest to regenerate. In addition, patches of shrublands should be located close to one another. Succession of shrublands into forests, especially in wildlife refuges with numerous habitat types existing close in proximity, is inevitable. Once an early successional habitat reverts to a mature forest, shrubland birds are often displaced and have difficulty finding new suitable habitat (Dettmers 20003). If shrubland patches are placed next to each other, birds in this guild will have an easier time transferring to a new shrubland, once the current one is no longer suitable for their needs. Also, shrublands that located within close proximity to each other are often easier to maintain while using similar disturbance regimes.

Naturally Maintained Shrublands – In terms of naturally occurring xeric and mesic shrubland habitats, not much effort may be needed to maintain existing vegetation in an early-successional stage (Degraaf and Yamasaki 2003). The edaphic factors of the barren sites are characterized by shallow soil over limestone bedrock, which results in a low water holding capacity within the substratum (Shanks 1966)). Together, the dry air and substratum are consequently favorable to fire and allow for little colonization. Thus, xeric areas, such as the barren areas in Jefferson County, are maintained by naturally occurring fires, edaphic factors, and management removal of invasive species including European buckthorn, honeysuckle, and pale swallow-wort (Shanks 1966, Chris Lajewski, personal communication). Mesic areas in the Northeast, such as Bergen and Cicero Swamps, are also maintained for long periods of time without anthropogenic disturbance, due to the limited number of colonizers that can persist in such environments (Degraff and Yamasaki 2003, Mike Putnam personal communication). However, experimental studies have been conducted in shrub-swamp areas, such as these, to see the impact that particular disturbance regimes would have on the regenerating shrubland (LeBlanc and Leopold 1992, Johnson and Leopold 1998).

Thus, within naturally occurring shrublands, no interference should be made to suppress fires, or reduce effects of ice storms and blow-downs. These natural disturbances, along with the unique edaphic characteristics of each area, are needed to maintain the persistence of these shrubland communities. However, I do think that continued management action is needed to avoid colonization of invasive species into these areas, such as the common reed (*Phragmites australis*), common barberry, European buckthorn, honeysuckle and pale swallow-wort, as they often out-compete native species and result in undesirable habitat.

Forest Management – In situations in which forest management is necessary, it should be done in such a way that early successional habitat and logging can coexist. Rotation time, size of regeneration cut, and silvicultural system all influence the growth and habitat characteristics of shrubland habitat (DeGraaf and Yamasaki 2003). In terms of managing for shrubland birds, the choice between clear-cuts and group-cuts is unclear. One study suggested that forest management should consist of increased group-cuts, which would result in increased early successional habitat suitable for shrubland birds (King *et al.* 2001). However, there are important issues that need to be addressed when practicing group cuts. Although group-cuts are good for creating early successional habitat, they can fragment mature forests used by forest birds such as the Ovenbird (*Seiurus aurocapillus*) and Wood Thrush (*Hylocichla mustelina*; Rudnicky and Hunter 1993, Annand and Thompson 1997, Costello *et al.* 2000, King *et al.* 2001), resulting in forest bird displacement. In addition, nest predation increases along forest edges, which would increase with increased group-cuts (Thompson 1993). Due to these issues, the positive impact on shrubland bird abundance from group-cuts might not outweigh the costs of increased predation and declines of mature forest birds. In contrast, clear-cuts may provide increased shrubland area for those shrubland birds that are area-sensitive, such as Golden-winged Warblers and Field Sparrows (King *et al.* 2001, Confer and Pascoe 2003); however, the resulting early successional habitat in clear-cuts is limited in variety, managed specifically for trees (shrubs actively removed), and often cut again before dense shrublands can be established, usually within 20 years (DeGraaf and Yamasaki 2003). Silviculture practices need to be varied and should be chosen based on site-specific conservation needs.

A model needs to be designed to provide both economic benefits to foresters, as well as conservation for indigenous and declining species. There is often conflict between foresters and the ecological (environmental) community. This can be avoided if both ecological and economical goals are clearly defined. The Manomet Bird Observatory developed the Forest Conservation and Management Program (2008) and the Shifting Mosaic Model to avoid such conflict. The Shifting Mosaic Model is a form of adaptive management and has two specific goals. The first is an economic goal that states, "forestry operations in the model area can proceed at a level that meets the economic expectations of the land owner, so long as a sustained flow of wood can be maintained for the long-term (century-scale)." The second goal is ecological: "self-sustaining populations of all plant and animal species indigenous to the area must be maintained indefinitely." In order to achieve these two very specific goals, foresters and ecologists need to work together in communication, execution, and public distribution of management decisions. Although no long-term success can be demonstrated yet, as the implementation of this model is relatively new, it seems to be working thus far. The reason for the success, up to this point, may be due to the fact that this model is goal-oriented, not method-oriented, and recognizes that there are many possible solutions to specific management problems. In some cases group-cuts might be favored, whereas in other situations clear-cuts might be more beneficial. In fact, it may not be the harvest method that is most important to the model, rather it may be the harvest rate.

Disturbance Frequency –In the Northeast, continuous naturally occurring shrub habitats in rural areas, such as barrens and swamps, may be maintained by natural disturbance regimes and edaphic factors (Shanks 1966, Litvaitis 2003, Lorimer and White 2003). In anthropogenic shrublands, such as INWR, managers may have to rely on prescribed burns, clear-cuts, group-cuts, and other disturbance regimes (brush-hogging, prescribed burns and hydro-axing). In terms of maintaining fragments of shrubland habitat, disturbance frequency will be varied, dependent upon site conditions and type of bird species of management concern. In order to create desirable habitat, shrublands should be monitored at frequent intervals to determine the length of time needed between each disturbance. In addition the intensity of the disturbance should be relatively high (Brawn *et al.* 2001).

Disturbance frequency must be examined when forest management is practiced with shrubland conservation in mind. Different species of birds will occupy a clear-cut forest within different time periods, and in the same way, decline at different time intervals through forest maturation (DeGraaf and Yamasaki 2003). For example, Willow Flycatchers become relatively abundant about two years after a clear-cut, but start to decline when the forest becomes about five to seven years old, while Common Yellowthroats are commonly seen in clear-cuts that are six years of age, and declining after about 10 years of forest growth (Degraaf and Yamasaki 2003). Other species, such as the Black-and-white Warbler and White-throated Sparrow (*Zonotrichia albicollis*), inhabit clear-cuts even later and are commonly seen after 20 years of growth. For most shrubland species of concern in the Great Lakes Plains Region, if clear-cutting is desired, then disturbance between cutting should occur every 10-20 years.

In addition to different silviculture approaches, prescribed burns are also used to maintain existing, relatively young, shrubland patches (Oehler 2003, Paul Hess, personal communication). Prescribed burns are often more cost-effective and efficient to use than other techniques, such as brush-hogging and hydro-axing. However, prescribed burns are not easy to implement as expertise and permits (air quality) to carry them out properly are often hard to acquire (Oehler 2003). In the Northeast, timing of fire is also an important management consideration, as early season burns may encourage increased shrub growth, while mid-season burns may discourage such growth (Mitchell 2000).

Again, there is not one simple solution for creation and maintenance of shrubland habitat, as practices with benefits to one species will ultimately be a high cost for another. In addition, different disturbance methods result in different habitat characteristics and span over a range of economic costs. Local surveys should be conducted to determine what species of concern are found in or close to an area of interest, and then management should be focused on practices that will benefit those species of concern, while keeping limited resources in mind.

Devising a Reasonable Shrubland Management Plan:

A sane management plan for shrubland habitats must be approached with adaptive management in mind. Personally, I tend to favor the Strategic Habitat Conservation (SHC) plan approach developed by the United States Fish and Wildlife Service due to its wide range of use (USFWS 2008). Adaptive management plans such as the SHC are cyclical and allow for changes to be made when new information is obtained. The SHC involves continuous relationships between biological planning, conservation design, delivery of conservation actions, and monitoring and research. The use of SHC, or a similar adaptive approach to management, would be beneficial to the maintenance and conservation of shrubland habitat, especially in a fragmented landscape such as INWR.

Biological Planning – In terms of planning, shrubland habitat patches that are currently or potentially important to shrubland birds must be identified. Before this can occur, an overall management goal should be clearly laid out to avoid ambiguity. Two general goals for shrubland management are: 1) identify shrubland habitat critical for maintaining species of management concern, such as the Golden-winged Warbler, and 2) identify, conserve, and maintain shrubland habitat for those species that are locally abundant. Because no natural area can be all things to all species (Hendricks 1997, Norment 2002), and resources, both natural and economic, are limited, it might not be possible, or a good idea, to create or maintain habitat for one or two declining shrubland habitat specialists if the probability of attracting large numbers of these species is small. On the other hand, it may actually be better to conserve and maintain shrubland habitat for those species that are locally abundant, if they are of regional management concern. The habitat plan that is put into action will ultimately depend on the overall management goals, which in turn are influenced by the available resources.

For example, if INWR would like to increase shrubland habitat, the refuge first needs to devise a set of management goals, which should explicitly state the outcome the refuge wishes to achieve through maintenance of existing, and creation of additional shrubland habitats. INWR supports numerous shrubland bird species that are declining at the regional level, and the refuge could potentially manage for many of these species. The trick to the management plan is to figure out what type of management will result in the greatest benefits to the largest number of species, given the reality of limited resources, and conflicting habitat requirements for the different suites of wildlife it is charged with managing.

Data on temporal population trends and regional abundance patterns of shrubland birds can be used to decide which species are best targeted for conservation and management efforts at INWR or other natural areas. All other things being equal, conservation efforts might best be directed towards species that are declining, but which also are relatively abundant in the region (Dettmers 2003). For example, the Song Sparrow has declined significantly in New York State and the Great Lakes Plain (BBA 2006, BBS 2007), yet the species, which prefers early successional shrublands with few trees, remains common at INWR and in the surrounding region (BBA 2006). These traits make the Song Sparrow an ideal target species for conservation efforts at INWR, because habitat management efforts will be relatively easy to undertake (see "Actively

Managed Shrublands," above), and appropriate habitat should attract large numbers of breeding individuals. Other species experiencing declines, but with similar habitat preferences and distributional patterns include the Chipping Sparrow, Eastern Towhee, Brown Thrasher, American Goldfinch, and Field Sparrow.

In contrast, other shrubland bird species that are declining have different distributions and habitat preferences throughout New York State and might not be suitable for conservation in INWR. For example the Chestnut-sided Warbler is declining in New York State and the Great Lakes Plain (BBA 2006, BBS 2007). This species prefers "deciduous second growth of large forest clearings" (Richardson and Brauning 1995), and has a very spotty breeding distribution in the area surrounding INWR (BBA 2006). Thus, habitat management for this species would be resource-intensive (see "Actively Managed Shrublands," above), and might not attract many breeding individuals, given its relatively uncommon status in the region. Golden-winged warblers also have a spotty distributions and strict habitat requirements that would involve extensive resources for INWR to conserve.

In the case of species that were encountered relatively frequently in INWR, I can suggest some basic vegetation management that might help to maintain favorable habitat for these species. Chipping Sparrows preferred habitats with 50-60% ground cover and 20-80% shrub cover. In addition, Chipping Sparrows also seemed to inhabit fields where shrub height was between 100-150 cm, and never greater than 175 cm. Field Sparrows were commonly found in habitats with 50-90% ground cover, 30-60% shrub cover, and an average shrub height of 125 cm. Although Song Sparrows occurred in fields with 40-80% ground cover and 25-85% shrub cover, preferred ground cover seemed to fluctuate around 60%, while preferred shrub cover was between 40-50%. Song Sparrows were encountered frequently in fields where shrub height was between 100-175 cm, yet they seemed to have a preference for shrub height around 125 cm. In addition to the recommendations above, it seems that few, if any, trees were found in favorable shrubland habitat. Generally, my data suggest that an equal distribution of shrub cover and ground cover (around 50% for each), shrub height around 125 cm, and few trees seem to appeal to these declining species of regional concern.

Location and Maintenance of Shrublands – Locating shrubland sites suitable for management is just as important as deciding which species of birds to manage for. There are numerous characteristics of habitat structure that should be considered when locating shrublands. First, shrublands should be relatively large. As mentioned earlier, increased habitat patch size will increase the absolute number of shrubland birds able to be supported, regardless of area-sensitivity. Second, shrublands should be located near or adjacent to one another to avoid displacement of birds and perhaps for ease of management activities, such as disturbance. Third, shrublands need to be reasonably accessible to management tools such as brush hogs and tractors. Finally, current and past land use needs to be considered, as shrublands that arise from old growth fields are far easier and usually more economical to maintain, than those that are created from mature forests. Although habitat structure is important for breeding birds, managers must also consider species composition, as this may be more important to fall migrants. For example, young ash fields that provide favorable habitat for breeding birds may be poor for fall migrants. Fields containing *Cornus* spp. and *Lonicera* spp. may be better as they provide more sustenance for migrant birds.

In terms of maintenance, tractors and brush hogs can be used in shrublands that arise from old growth fields, as long as they contain a low density of shrubs with a diameter less than

7.5 cm (Paul Hess, personal communication). Once a shrubland becomes more established and is dominated by mature shrubs and trees around 15-25 cm in diameter, a Hydro-ax must be used to create or maintain the early successional field (Paul Hess, personal communication). In terms of economics, tractors and brush hogs are a relatively cheap disturbance regime, as they can be operated for approximately $90/ha, including fuel, maintenance, and operator expenses. Hydro-axing is much more costly and time consuming. A Hydro-ax is able to cut approximately 1 ha in 7 hours, compared to about 1 ha/hour when using a tractor or brush hog. In addition, the cost of running the Hydro-ax is much greater at over $1000/ha (Paul Hess, personal communication). Thus, in terms of limited time and resources, it seems that maintaining shrublands that can be managed with tractors and brush hogs would be more beneficial than the conversion of a forest to a shrubland.

Vegetation Collection Methods – Once a management conservation plan is put into place, continued observations must be conducted to determine the success of the plan, as well as to implement changes as needed. This will involve both bird monitoring and assessment of vegetation. In terms of vegetation techniques, it appears that quantitative vegetation data are generally better at predicting bird response variables, in part due to reduction of interobserver reliability. In both years of my field study, the qualitative vegetation methods always overestimated predictor variables, when compared to quantitative methods. In addition, the use of quantitative data resulted in better bird-habitat models, as they explained a greater amount of variance in bird-response variables in almost all cases. Although relatively time consuming, I found that quantitative estimates of shrub height, shrub cover, and ground cover seemed to give a decent representation of habitat characteristics. However, with limited amounts or resources, qualitative assessments do provide valuable information to wildlife managers and may be more beneficial in terms of limited resources, including time. Once disturbance regimes and rotation times are established, qualitative visual assessments of habitat may be sufficient to describe and assess shrubland fields.

GIS Integration – I believe that a landscape-level analysis would be useful for each of the study areas, as well as all the study areas together as a whole. Maps for each of the study areas have been constructed and each contains shapefiles of the CPCs as well as bird species presence/absence. With increased clarity of aerial photography and technology for geographical analysis, there is an array of new tools available to help develop bird-habitat models through geographical analysis. I encourage new research in this direction, as I plan on running this analysis myself in the near future.

Conclusion – There seemed to be a great variety of factors influencing different species of shrubland birds. It is difficult to identify any specific management action that will conserve shrubland birds in general, as a benefit for one species could be detrimental to others. In addition, the types of shrubland communities used by birds encountered during this study exhibit great variety. Shrubland birds inhabit areas from old fields to second growth understories of deciduous forests, from fields with few shrubs to those with dense thickets of honeysuckle. The amount of variety in habitat types among the shrubland guild of birds is quite extensive. This can also be seen in other studies (King and DeGraaf 2000, Thompson and DeGraaf 2001, Confer and Pascoe 2003). In other words, habitat preference among shrublands is variable between species. Thus, management efforts for the conservation of shrubland birds should be looked at with creativity and innovation.

New Direction – This project was broad in scope, thus I do not believe enough time was spent on quantifying habitat for shrubland species of concern in New York State and the Great Lakes Plains Region. Should a study similar to this be done again, I think that a preliminary period should be conducted to locate species of management concern prior to the start of counts. After sites are found, I think that they should be surveyed much more intensely and at more frequent intervals. This would allow for a larger sample size, a much stronger statistical analysis, and hopefully stronger best-bird habitat models.

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Table 1. Estimation of proportion of wetland, forest and grassland habitat within 250 m of each study field, USGS Ariel Photography 2006; INWR 2006-2007.

Site	Proportion Shrubland	Proportion Grassland	Proportion Forest	Proportion Wetland
A1	0.14	0.52	0.24	0.10
A2	0.35	0.10	0.52	0.03
A3	0.40	0.37	0.23	0.00
A5	0.36	0.32	0.26	0.06
A6	0.47	0.06	0.43	0.04
A7	0.68	0.08	0.24	0.00
A8	0.49	0.24	0.27	0.00
A10	0.35	0.10	0.52	0.03
A11	0.27	0.00	0.66	0.07
A12	0.32	0.05	0.55	0.08
A13	0.27	0.08	0.65	0.00
A14	0.64	0.09	0.11	0.16
A15	0.55	0.05	0.27	0.13
A16	0.61	0.13	0.20	0.06
A17	0.60	0.02	0.38	0.00
A17v	0.43	0.00	0.57	0.00
A18	0.41	0.15	0.44	0.00
A19	0.26	0.10	0.64	0.00
Bergen	0.85	0	0.15	0
Cicero	0.45	0	0.54	0
Chamount	0.52	0.04	0.43	0
Three Mile	0.54	0.11	0.20	0

Table 2. DISTANCE results of independent analysis of detection probability coefficients for study sites in the Great Lakes Plains Region of New York, 2007.[1]

Species	All Sites Combined	All Sites minus INWR	Only INWR sites
ALFL	0.56	0.55	0.56
AMGO	0.35	0.34	
AMRO	0.45	1.00	
BAWW	1.00	1.00	
BCCH	0.46	0.50	
BHCO	0.62	1.00	
BWWA	1.00		1.00
CEWA	0.25	0.37	
CHSP	0.55	1.00	
COYE	0.43	0.67	0.35
EATO	0.42	0.41	
FISP	1.00	1.00	
GRCA	0.18	0.26	0.187
PRWA	1.00	1.00	
RWBL	0.43		0.43
SASP	0.28		
SOSP	0.34	1.00	0.31
SWSP	0.55		
WIFL	1.00		0.62
YEWA	0.30	1.00	0.27

Table 3. Best stepwise multiple regression models for shrubland bird-habitat relationships in the Great Lakes Plains Region of New York State, 2006. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird Response Variable	Habitat variables entered into model[2]	Mallow's C-P	r^2 (adj)
Abundance	[NumberPS]**,[Area], V'*	1.5	37.9
Species Richness	[P/A]**, [ShrubCover]*, V'	0.3	52.8
Alder Flycatcher	[NumberPS]**, [P/A]*, [Area]*, ShrubCover**, [Height]*, [V']**	6.0	29.5
American Goldfinch	[P/A]***, [GroundCover]***, [Height]*	0.6	69.5
Chipping Sparrow	[P/A]*, GroundCover, [ShrubCover], [Height]	0.6	35.1
Gray Catbird	P/A, [ShrubCover], V'**	-1.2	20.7
Red-winged Blackbird	P/A, [ShrubCover]**, V'**		

[1] Key for four-letter alpha codes given in Appendix III.
[2] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 4. Best stepwise multiple regression models for shrubland bird-habitat relationships in the Great Lakes Plains Region of New York State, 2007. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird Response Variable	Habitat variables entered into model[3]	Mallow's C-P	r^2 (adj)
Abundance	V'**, GroundCover	-0.9	34.3
Species Richness	ShrubCover*, [Height], Area***	1.9	85.1
Alder Flycatcher	ShrubCover**, [NumberPS]	0.3	22.0
Black-and-white Warbler	[V']**, [GroundCover]**, [P/A]**	1.1	50.1
Blue-winged Warbler	V'**, ShrubCover, [Height]**	1.5	25.7
Cedar Waxwing	[GroundCover], [P/A]**, [NumberPS]	1.1	20.9
Chipping Sparrow	[V']**, [NumberPS]**, Area	1.8	34.2
Common Yellowthroat	[ShrubCover]**, [P/A]*, NumberPS*, [Area]**	2.8	31.3
Eastern Towhee	ShrubCover*, [GroundCover], [NumberPS]*, Area***	2.7	67.7
Field Sparrow	[V']**, GroundCover**, Area**	1.4	54.3
Gray Catbird	Height**, NumberPS**, [Area]**	2.1	40.6
Prairie Warbler	P/A**, Area***	-0.5	66.6
Red-winged Blackbird	[ShrubCover], GroundCover*, Height	0.5	31.6
Song Sparrow	GroundCover*, [P/A], [Number PS]*	1.1	25.8
Swamp Sparrow	[ShrubCover]**, [GroundCover], [P/A], NumberPS, [Area]**	4.1	15.6
Willow Flycatcher	GroundCover*, P/A*	-0.3	23.1
Yellow Warbler	V'*, NumberPS, [Area]*	0.1	29.4

[3] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 5. Best stepwise multiple regression models for shrubland bird-habitat relationships in Iroquois National Wildlife Refuge (Genesee/Orleans Counties), 2006. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird ResponseVariable	Habitat variables entered into model[4]	Mallow's C-P	r^2 (adj)
Abundance	[NumberPS]**, [P/A], [Area]*	2.3	46.4
Species Richness	[P/A]**, [ShrubCover]*, V'	0.3	52.8
Alder Flycatcher	[NumberPS], [P/A]*, [Area]*, ShrubCover**, [Height]*, [V']**	6.0	29.5
American Goldfinch	[P/A]***, [GroundCover]***, [Height]*	0.6	69.5
Chipping Sparrow	[P/A]*, GroundCover, [ShrubCover], [Height]	5.0	23.6
Gray Catbird	[ShrubCover], V'**	-1.2	20.7
Red-winged Blackbird	P/A, [ShrubCover]**, V'**	0.3	36.5

Table 6. Summary bird response data on habitat type for INWR, 2007. [a]Species experiencing significant declines in New York State over the past 10 years(1996 to 2006; BBS 2007); [b]Species experiencing significant declines in New York State over past 40 years (1966 to 2006).

Bird Response Variables	Sparse (young ash field)	Heterogeneous (patchy; diverse)	Dense (honeysuckle)
Shrub Cover (%)	24.4	67.9	88.6
Height (cm)	110.5	129.9	230.0
Average # individuals per 50 m radius point count	8.5	8.0	10.4
Total # species	17	10	17
Three most abundant species	Yellow Warbler[a] Common Yellowthroat Song Sparrow[b]	Yellow Warbler[a] Song Sparrow[b] Gray Catbird	Gray Catbird Yellow Warbler[a] Song Sparrow[b]

[4] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 7. Best stepwise multiple regression models for shrubland bird-habitat relationships in Iroquois National Wildlife Refuge (Genesee/Orleans Counties), 2007. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird ResponseVariable	Habitat variables entered into model[5]	Mallow's C-P	r^2 (adj)
Abundance	V'**, Height*	-0.6	46.4
Species Richness	ShrubCover**, GroundCover**, [Height]**, [NumberPS], Area**	5.2	55.3
Alder Flycatcher	ShrubCover**, GroundCover, [Height]	0.6	12.0
Black-capped Chickadee	ShrubCover**, GroundCover**	-0.4	35.3
Brown-headed Cowbird	NumberPS*, [Area]*	-1.0	15.6
Blue-winged Warbler	V'**, ShrubCover*, [Height]**, [NumberPS], Area*, P/A	6.3	25.9
Cedar Waxwing	V'*, ShrubCover, [Height]**, [NumberPS]*, Area	4.9	28.1
Chipping Sparrow	[V']*, ShrubCover, GroundCover*, [NumberPS]**	2.0	40.2
Common Yellowthroat	V', [ShrubCover]**, NumberPS**	0.5	22.7
Eastern Towhee	V'*, ShrubCover, [Height]**, [NumberPS]*, Area	4.9	28.1
Field Sparrow	[V']**, [ShrubCover], GroundCover, NumberPS**	3.1	58.1
Gray Catbird	Height***, NumberPS, [Area]	0.3	60.4
Song Sparrow	[V'], GroundCover, Height, [P/A]*	2.5	37.5
Willow Flycatcher	GroundCover*, P/A	-0.7	13.2

[5] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 8. Best stepwise multiple regression models for shrubland bird-habitat relationships in Jefferson County, 2007. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird Response Variable	Habitat variables entered into model[6]	Mallow's C-P	r^2 (adj)
Abundance	V'**, [Height]**	0.2	19.4
Species Richness	V'**, [Height]**	0.5	20.7
Alder Flycatcher	[NumberPS]*	-0.5	11.8
American Robin	V'**, [ShrubCover]**, NumberPS	2.5	43.3
Black-and-white Warbler	ShrubCover, [GroundCover]**	3.5	26.5
Brown-headed Cowbird	[GroundCover]**, Height, [NumberPS]**	3.7	21.0
Cedar Waxwing	[ShrubCover]*, NumberPS*	1.0	10.8
Chipping Sparrow	V'**	-0.1	16.2
Common Yellowthroat	GroundCover**, [Height]**	1.5	37.5
Eastern Towhee	ShrubCover, [GroundCover]**	1.3	36.6
Gray Catbird	V'**, ShrubCover, GroundCover***	2.5	67.1
Prairie Warbler	V'*, ShrubCover, [GroundCover]**, [Height]**	4.0	55.8
Savanna Sparrow	V', GroundCover**	0.6	31.4
Song Sparrow	GroundCover, [Height]**	0.9	20.8
Yellow Warbler	V', [ShrubCover]**, Height	3.3	43.1

[6] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 9. Correlation matrix models of shrubland bird-habitat relationships in Bergen Swamp (Genesee County), 2007. Only models that have relatively high correlation ($r^2 > 0.700$) are included; r values are based on Pearson correlation; $P \leq 0.10$ in bold.

Bird Response Variable	Value	V'	Total Hits	Height	Shrub Cover	Ground Cover	Number Plant Species
Abundance	r^2			-0.724		**0.827**	
	P			0.167		**0.084**	
Species Richness	r^2			**-0.945**	**-0.842**	**0.845**	-0.735
	P			**0.015**	**0.073**	**0.071**	0.157
Alder Flycatcher	r^2			-0.735	-0.733		-0.756
	P			0.157	0.158		0.140
Black-capped Chickadee	r^2						0.801
	P						0.104
Brown-headed Cowbird	r^2			**-0.961**	-0.735	**0.944**	-0.706
	P			**0.009**	0.157	**0.016**	0.183
Cedar Waxwing	r^2			**-0.961**	-0.735	**0.944**	-0.706
	P			**0.009**	0.157	**0.016**	0.183
Chipping Sparrow	r^2			**-0.850**		0.788	
	P			**0.068**		0.113	
Common Yellowthroat	r^2			0.706			
	P			0.183			
Song Sparrow	r^2			**-0.961**	-0.735	**0.944**	-0.706
	P			**0.009**	0.157	**0.016**	0.183
Swamp Sparrow	r^2						-0.801
	P						0.104
Yellow Warbler	r^2	1.000	**0.989**		0.754		
	P	n/a	**0.001**		0.141		

Table 10. Correlation matrix models of shrubland bird-habitat relationships in Cicero Swamp (Onondaga County), 2007. Only models that have relatively high correlation ($r^2 > 0.700$) are included; r values are based on Pearson correlation; $P \leq 0.10$ in bold.

Bird Response Variable	Value	V'	Total Hits	Height	Shrub Cover	Ground Cover	Number Plant Species
Alder Flycatcher	r^2			-0.765	0.715		
	P			0.132	0.174		
American Robin	r^2	-0.801	0.720			-0.781	**0.884**
	P	0.104	0.170			0.119	**0.047**
Cedar Waxwing	r^2		0.803	**-0.952**			
	P		0.102	**0.013**			
Chipping Sparrow	r^2			0.756	**-0.930**		
	P			0.139	**0.022**		
Eastern Towhee	r^2		-0.744			**0.909**	**-0.837**
	P		0.149			**0.032**	**0.077**
Yellow Warbler	r^2				-0.779		
	P				0.121		

Table 11. Two-sample paired T-tests comparing qualitative vs. quantitative vegetation data for INWR, 2006-2007; values are means (x) ± 1 SD.

Predictor Variable	Qualitative	Quantitative	*T*-statistic	*P*-value
Average Shrub Height (cm)				
2006	155.6 ± 48.5	139.6 + 62.6	0.85	0.399
2007	191.4 + 36.0	141.2 + 31.5	4.45	0.000
Average Shrub Cover (%)				
2006	67.1 ± 26.9	53.6 + 25.2	1.56	0.129
2007	66.1 ± 21.7	55.0 + 18.4	1.66	0.106
Average Ground Cover (%)				
2006	78.0 + 16.3	62.5 + 16.6	2.84	0.008
2007	81.6 ± 10.3	55.8 + 11.9	6.93	0.000

Table 12. Best stepwise multiple regression models based on qualitative predictor variables for shrubland bird-habitat relationships in Iroquois National Wildlife Refuge, (Genesee/Orleans Counties), 2006. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird Response Variable	Habitat variables entered into model[7]	Mallow's C-P	r^2 (adj)
Abundance	[ShrubCover], [GroundCover], [Area]*, [P/A]	2.6	6.7
Species Richness	[ShrubCover]**, GroundCover, NumberTrees, [TreeHeight], [P/A]**	4.4	57.9
American Golfinch	[NumberTrees], TreeHeight, [P/A]**	0.6	41.6
American Robin	Height, [ShrubCover]**, [TreeHeight], [Area]	2.3	26.9
Black-capped Chickadee	[Height]**, [Area]	-0.0	29.8
Cedar Waxwing	Height**, ShrubCover**, [GroundCover], [NumberTrees]*, Area**	5.6	61.3
Chipping Sparrow	[ShrubCover], GroundCover, [P/A]**	1.3	37.1
Common Yellowthroat	[ShrubCover], [NumberTrees]**, TreeHeight**, P/A**	2.8	41.2
Field Sparrow	GroundCover**, [NumberTrees]	-0.8	30.9
Gray Catbird	[ShrubCover]*, [GroundCover]***, NumberTrees**, [TreeHeight]**	2.5	56.0
Northern Cardinal	[NumberTrees]**, TreeHeight**, [Area]*	2.2	37.6
Rose-breasted Grosbeak	GroundCover, NumberTrees**, [TreeHeight]	1.2	32.0
Red-winged Blackbird	[ShrubCover]*, [GroundCover]**, NumberTrees, [TreeHeight]	2.9	25.3
Swamp Sparrow	[ShrubCover]*, [GroundCover]**, [TreeHeight]**, [Area]	2.6	35.7
Yellow Warbler	Height*, [Area]	-1.1	27.0

[7] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 13. Best stepwise multiple regression models based on qualitative predictor variables for shrubland bird-habitat relationships in Iroquois National Wildlife Refuge, (Genesee/Orleans Counties), 2007. Square brackets indicate a negative relationship; variables are listed in the order in which they entered into the model; only models with at least one parameter $P \leq 0.10$ are included.

Bird Response Variable	Habitat variables entered into model[8]	Mallow's C-P	r^2 (adj)
Abundance	[ShrubCover], [GroundCover]**, Area**	0.5	26.7
Species Richness	Height**, [GroundCover], [P/A]	1.1	56.5
Black-capped Chickadee	NumberTrees**, [TreeHeight], Area, P/A	3.1	15.7
Brown-headed Cowbird	Height, ShrubCover, [NumberTrees]**, [Area]**	2.1	22.9
Common Yellowthroat	ShrubCover*, GroundCover**, Area**	1.0	38.7
Field Sparrow	[Height]*, Area, P/A	1.3	26.5
Gray Catbird	Height**, [GroundCover], TreeHeight	0.0	24.4
Red-winged Blackbird	[Height]*, NumberTrees, [TreeHeight], Area**	2.4	21.4
Savanna Sparrow	Height, [ShrubCover]**, [GroundCover], [NumberTrees]**, TreeHeight**	4.1	43.1
Song Sparrow	[Height]*, TreeHeight, [P/A]**	0.6	26.9

[8] *** $P \leq 0.001$, ** $P \leq 0.05$, * $P \leq 0.10$, no asterisk $P > 0.10$

Table 14. Invasive shrub species encountered in the shrubland study sites. No invasive shrub species were found in Cicero Swamp. Great Lakes Plains Region of New York State 2006-2007.

INWR	Bergen	Chamount	Three Miles
common buckthorn (*Rhamnus cathartica*)	common barberry (*Berberis vulgaris*)	common buckthorn (*Rhamnus cathartica*)	common buckthorn (*Rhamnus cathartica*)
multifloral rose (*Rosa multiflora*)	Russian olive (*Elaeagnus commutata*)	honeysuckle (*Lonicera* spp.)	honeysuckle (*Lonicera* spp.)
honeysuckle (*Lonicera* spp.)		pale swallow-wort (*Cynanchum rossicum*)	pale swallow-wort (*Cynanchum rossicum*)
Russian olive (*Elaeagnus commutata*)			
scotch pine (*Pinus sylvestris*)			
common buckthorn (*Rhamnus cathartica*)			

Table 15. Bray-Curtis coefficients of community similarity for study sites in 2007. Coefficients represent raw data normalized by number of census points for each study site.

	INWR	Chamount	Three Mile	Bergen	Cicero
INWR	n/a	0.36	0.52	0.24	0.25
Chamount	0.36	n/a	0.53	0.34	0.42
Three Mile	0.52	0.53	n/a	0.29	0.45
Bergen	0.24	0.34	0.29	n/a	0.40
Cicero	0.25	0.42	0.45	0.40	n/a

Figure 1. Abundance trends for Eastern Towhee (*Pipilo erythrophthalmus*) in New York State (BBS 2006)

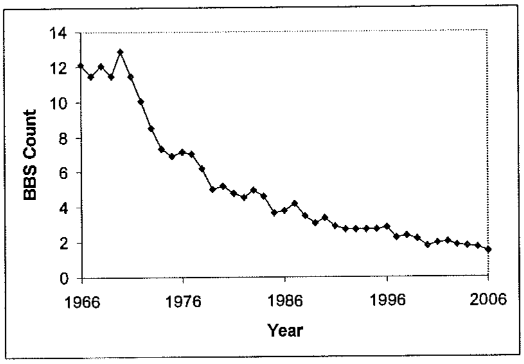


Figure 2. Abundance trends for Brown Thrasher (*Toxostoma rufum*) in New York State (BBS 2006)

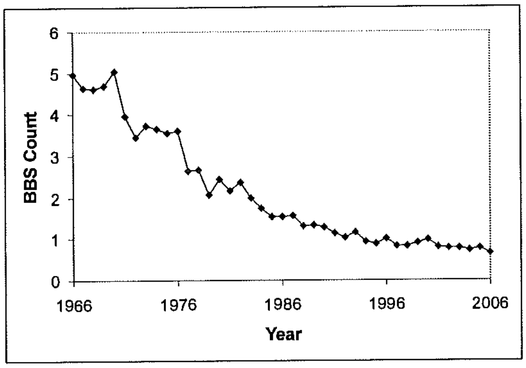


Figure 3. Regression analysis of qualitative vs. quantitative vegetation data in INWR, 2006.

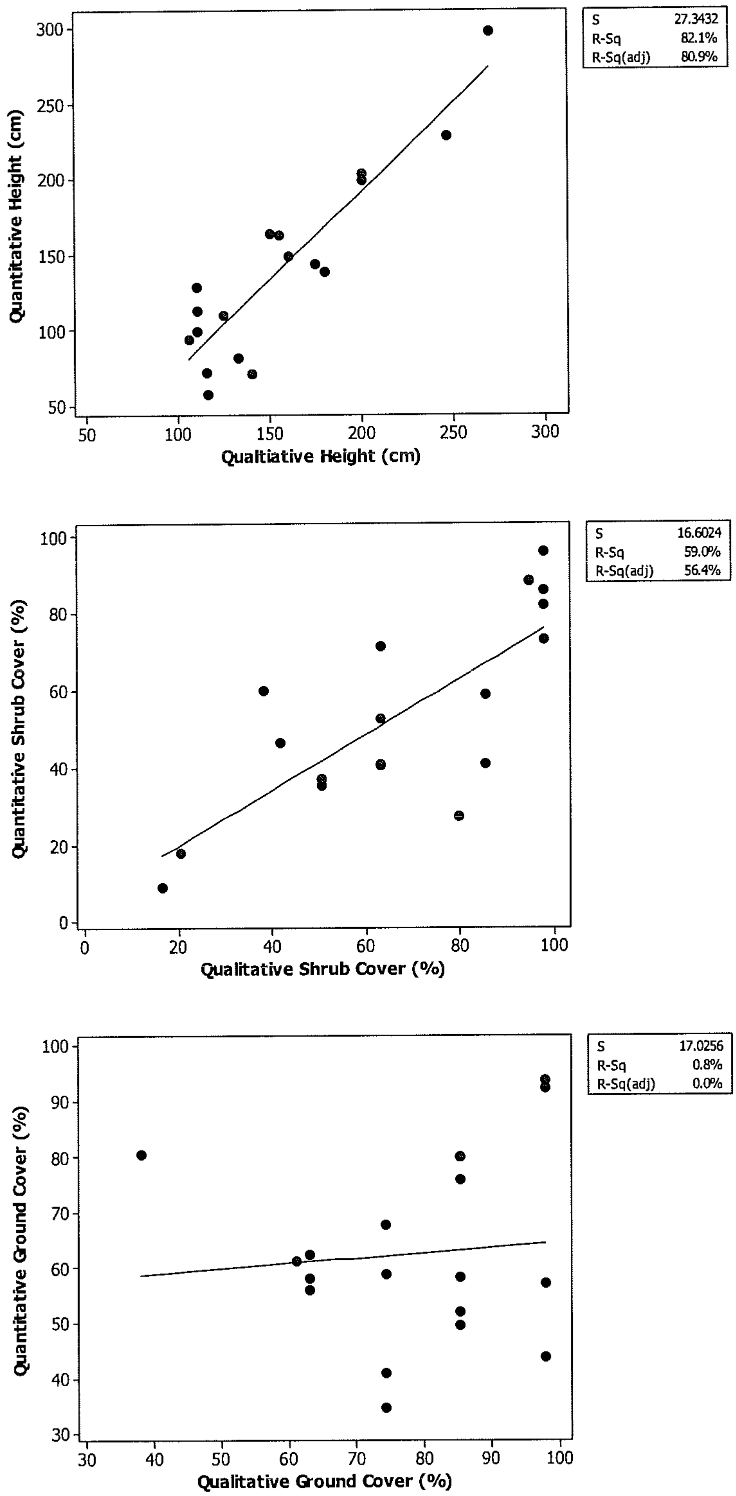


Figure 4. Regression analysis of qualitative vs. quantitative vegetation data in INWR, 2007.

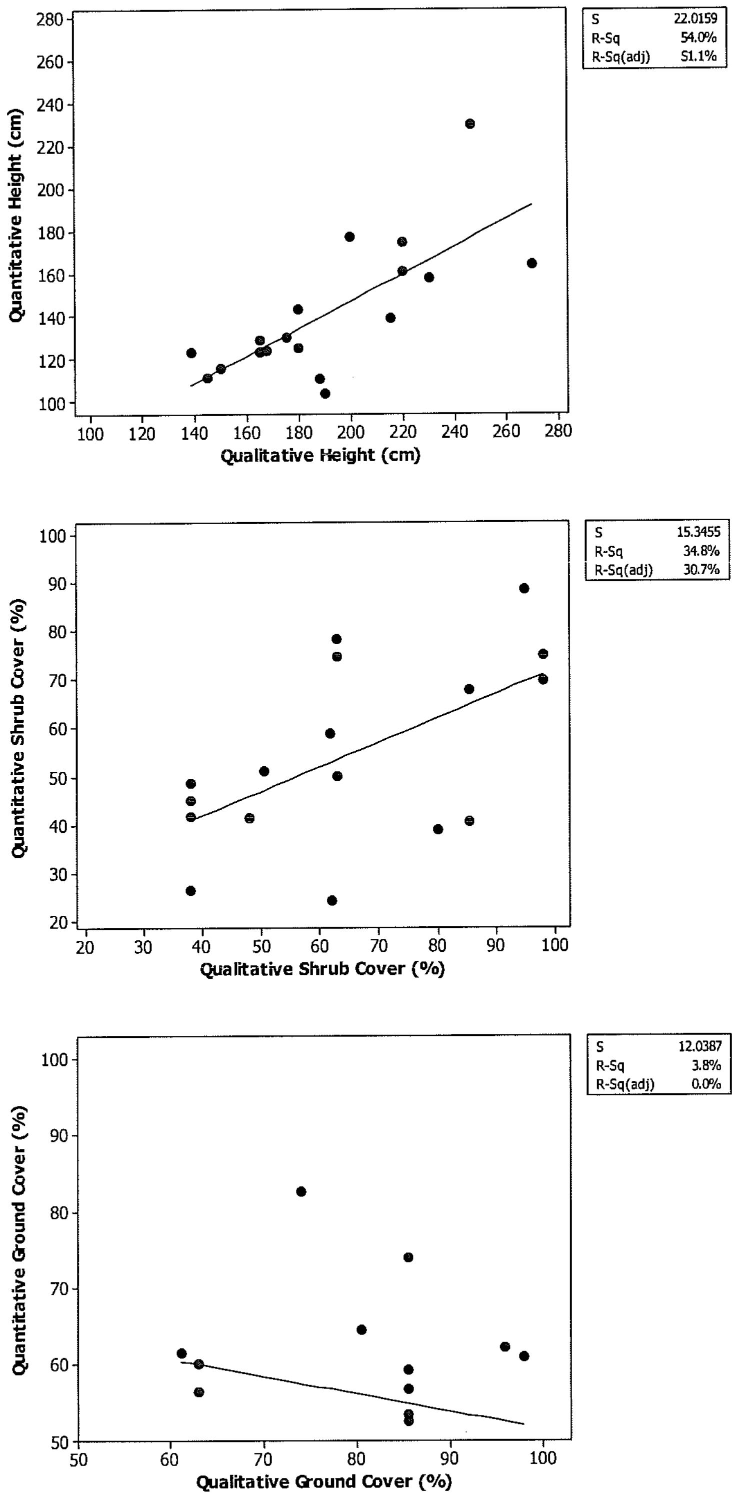
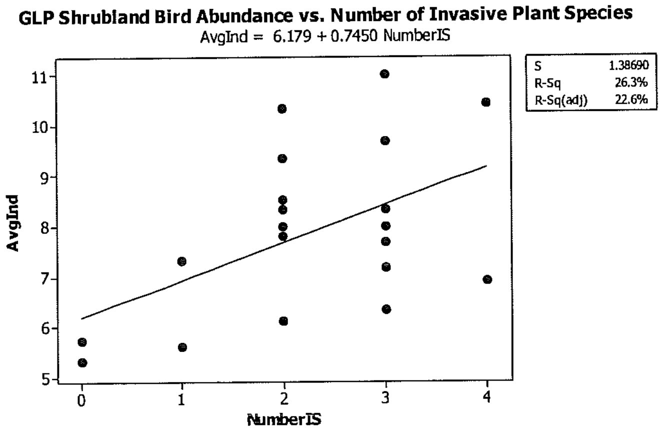


Figure 5. Regression of average individual shrubland birds on number of invasive shrub species. GLP 2006-2007 ($p = 0.015$).



Appendix I. Species present during the 2006 field season, 15 May 2006 – 8 July 2006.[9]

Species	INWR	Bergen Swamp	Quinn Oak Openings	Chaumont Barrens	Cicero Swamp
ALFL	x	x			x
AMCR	x	x	x		
AMGO	x	x	x	x	x
AMRO	x	x	x	x	x
BAOR	x		x	x	
BASW	x				
BCCH	x	x	x	x	x
BHCO	x		x	x	x
BLJA	x	x		x	x
BAWW		x		x	
BRTH			x	x	
BWGW				x	
BWWA	x	x	x	x	
CEWA	x		x	x	
CHSP	x		x	x	
COYE	x	x	x	x	x
CSWA	x			x	x
EABL			x		
EATO			x	x	x
EWPE				x	
FISP	x		x	x	
GRCA	x		x	x	x
HOWR	x			x	
INBU			x		
MAWR		x			x
MODO				x	
NOCA	x		x		x
NOHA				x	
OVBI				x	
PIWA	x				
PRWA				x	
RBGB	x			x	
RWBL	x	x			
SCTA				x	
SOSP	x		x	x	
SWSP	x	x			x
TRSW	x				
TUTI			x		
VEER	x	x		x	x
WBNU				x	
WIFL	x		x		
WOTH			x		
WTSP		x			
YEWA	x	x	x	x	x

9 Key for four-letter alpha codes given in Appendix III

Appendix II. Species present during the 2007 field season, 14 May 2007 – 7 July 2007.[10]

Species	INWR	Bergen Swamp	Three Mile Creek	Chaumont Barrens	Cicero Swamp
ALFL	x	x	x		x
AMCR	x				
AMGO	x		x	x	
AMRO	x		x	x	x
BAWW		x	x	x	x
BCCH	x	x	x	x	x
BHCO	x	x	x	x	x
BLJA				x	
BRTH	x		x	x	
BTGW			x		
BWGW	x		x		
BWWA	x		x	x	
CEWA	x	x	x	x	x
CHSP	x	x	x	x	x
COGR	x				
COYE	x	x	x	x	x
CSWA	x			x	
EABL	x				
EAKI				x	
EATO	x		x	x	x
EWPE				x	
FISP	x		x	x	
GCFL		x			
GRCA	x		x	x	x
GRSP			x		
GWWA			x		
HOFI	x				
HOWR			x	x	x
INBU	x				
MAWR		x			
MODO		x			
MOWA					x
NAWA	x	x			x
NOCA	x	x		x	x
NOFL			x	x	
OVBI	x			x	
PRWA			x	x	
RBGB	x				
RTHB	x				
RWBL	x				
SASP	x		x	x	
SCTA				x	
SOSP	x	x	x	x	
SUTA					x
SWSP	x	x			x
VEER		x	x	x	x
WBNU	x				
WIFL	x			x	
WTSP				x	
YEWA	x	x	x		x

[10] Key for four-letter alpha codes given in Appendix III

Appendix III. Key for four-letter alpha codes.

Species Abbreviation	Scientific Name	Common Name
ALFL	*Empidonax alnorum*	Alder Flycatcher
AMCR	*Corvus brachyrhynchos*	American Crow
AMGO	*Carduelis tristis*	American Goldfinch
AMRO	*Turdus migratorius*	American Robin
ATSP	*Spizella arborea*	American Tree Sparrow
BAWW	*Mniotilta varia*	Black-and-white Warbler
BAOR	*Icterus galbula*	Baltimore Oriole
BASW	*Hirundo rustica*	Barn Swallow
BCCH	*Poecile atricapilla*	Black-capped Chickadee
BHCO	*Molothrus ater*	Brown-headed Cowbird
BLJA	*Cyanocitta cristata*	Blue Jay
BRTH	*Toxostoma rufum*	Brown Thrasher
BTGW	*Dendroica virens*	Black-throated Green Warbler
BWGW		Blue-winged x Golden-winged Hybrid
BWWA	*Vermivora pinus*	Blue-winged Warbler
CEWA	*Bombycilla cedrorum*	Cedar Waxwing
CHSP	*Spizella passerine*	Chipping Sparrow
COGR	*Quiscalus quiscula*	Common Grackle
COYE	*Geothlypis trichas*	Common Yellowthroat
CSWA	*Dendroica pensylvanica*	Chestnut-sided Warbler
EABL	*Sialia sialis*	Eastern Bluebird
EAKI	*Tyrannus tyrannus*	Eastern Kingbird
EATO	*Pipilo erythrophthalmus*	Eastern Towhee
EWPE	*Contopus virens*	Eastern Wood-Pewee
FISP	*Spizella pusilla*	Field Sparrow
GCFL	*Myiarchus crinitus*	Great Crested Flycatcher
GRCA	*Dumetella carolinensis*	Gray Catbird
GRSP	*Ammodramus savannarum*	Grasshopper Sparrow
GWWA	*Vermivora chrysoptera*	Golden-winged Warbler
HOFI	*Carpodacus mexicanus*	House Finch
HOWR	*Troglodytes aedon*	House Wren
INBU	*Passerina cyanea*	Indigo Bunting
MAWR	*Cistothorus palustris*	Marsh Wren
MODO	*Zenaida macroura*	Mourning Dove
MOWA	*Oporornis philadelphia*	Mourning Warbler
NAWA	*Vermivora ruficapilla*	Nashville Warbler
NOCA	*Cardinalis cardinalis*	Northern Cardinal
NOFL	*Colaptes auratus*	Northern Flicker
NOHA	*Circus cyaneus*	Northern Harrier
OVBI	*Seiurus aurocapillus*	Ovenbird

Appendix III. Key for four-letter alpha codes (continued).

PIWA	*Dendroica pinus*	Pine Warbler
PRWA	*Dendroica discolor*	Prairie Warbler
RBGB	*Pheucticus ludovicianus*	Rose-breasted Grosbeak
RTHB	*Archilochus colubris*	Ruby-throated Hummingbird
RWBL	*Agelaius phoeniceus*	Red-winged Blackbird
SASP	*Passerculus sandwichensis*	Savannah Sparrow
SCTA	*Piranga olivacea*	Scarlet Tanager
SOSP	*Melospiza melodia*	Song Sparrow
SUTA	*Piranga rubra*	Summer Tanager
SWSP	*Melospiza georgiana*	Swamp Sparrow
TRSW	*Tachycineta bicolor*	Tree Swallow
TUTI	*Baeolophus bicolor*	Tufted Titmouse
VEER	*Catharus fuscescens*	Verry
WBNU	*Sitta carolinensis*	White-breasted Nuthatch
WIFL	*Empidonax traillii*	Willow Flycatcher
WOTH	*Hylocichla mustelina*	Wood Thrush
WTSP	*Zonotrichia albicollis*	White-throated Sparrow
YEWA	*Dendroica petechia*	Yellow Warbler

Appendix IV. Study used to examine the habitat selection of shrubland birds present in the Great Lakes Plains region of New York State, 2006-2007. The five main study sites spanned four counties (Jefferson, Genesee, Orleans, Onondaga) and contained a total of 60 census points.