INFLUENCE OF VEGETATION STRUCTURE AND LANDSCAPE CONTEXT ON THE OCCUPANCY OF SHRUBLAND BIRDS

BY

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THESIS

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ABSTRACT

Across the guild of shrubland birds, some species have been experiencing long-term population declines while other have been increasing. One potential reason for these differences is that various shrubland bird species prefer different types of shrubland habitat and some habitats are more common than others. However, we lack a clear understanding of the attributes of shrublands that shrubland birds prefer. Specifically, we lack information on how the percent shrub cover, the proportion of shrubs comprised of non-native shrubs, the patchiness of shrubs, and the surrounding landscape context influence occupancy (the probability that a given species will be at a site) of shrubland birds. To better understand these relationships I used bird survey and vegetation data from a long-term monitoring program that randomly monitored shrublands across the state of Illinois. I examined the influence of landscape and site-level variables on the occupancy of 22 shrubland bird species. Generally, the proportion of non-native shrubs at a site had little influence on shrubland bird occupancy. Shrubland birds responded positively to both the percent shrub cover and to the patchiness of shrubs; however the strength of the relationship differed between species. Over half (6/10) of the species that are experiencing population declines in the region (as determined by Breeding Bird Survey data) responded strongly to the patchiness of the shrubs, whereas, only 3 of the 12 shrubland species whose populations were either stable or increased responded to the patchiness of shrubs. The difference in population trends across the suite of shrubland birds may be driven by preferences for patchy shrublands. When creating or managing shrubland habitat, it is important to consider that the presence of shrubs is not enough and that the patchiness of shrubs may be important for a subset of shrubland birds.

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CHAPTER 1: REVIEW OF STATUS OF SHRUBLANDS AND SHRUBLAND BIRDS

Over the past 50 years, there have been declines in populations of shrubland birds (Hunter et al. 2001, North American Bird Conservation Initiative 2016). The North American Breeding Bird Survey (BBS), a long-term, large-scale program spanning North America and conducted annually since 1966, has estimated negative trends for many shrubland birds at broad spatial scales. While certain shrubland birds have experience large declines, other have increased. From 1966-2015 in Illinois, species such as the Northern Bobwhite (*Colinus virginianus*) have declined 3.93% annually, Yellow-billed Cuckoo (*Coccyzus americanus*) have declined 2.19% annually, and Field Sparrows (*Spizella pusilla*) have declined 3.29% annually. Alternatively, Cedar Waxing (*Bombycilla cedrorum*), Chipping Sparrow (*Spizella passerina*), and Blue Grosbeaks (*Passerina caerulea*) have increased at annual rates of 6.27%, 5.12%, and 5.30%, respectively (Sauer et al. 2017).

Given the alarming declines of some shrubland species, the Illinois Department of Natural Resources has listed many shrubland species as species in greatest need of conservation in their state Wildlife Action Plan. The report lists shrubland birds such as Bell's Vireo (*Vireo bellii*), Brown Thrasher (*Toxostoma rufum*), Northern Bobwhite, Willow Flycatcher (*Epidonax traillii*), Yellow-billed Cuckoo, and Yellow-breasted Chat (*Icteria virens*) as state species of conservation concern. The Wildlife Action Plan lays out the goals of better understanding what is causing the population declines and seeking ways to reverse the negative trends. Many factors might be responsible for shrubland bird declines, but one of the main drivers is habitat loss (Askins 1993, Illinois Department of Natural Resources 2005).

Habitat loss occurs in many ways and for many reasons. Similar to grasslands and prairies, shrubland habitat is often lost to land development (Askins 1993). Generally, shrublands in the Midwest exist on soils that are more valuable if converted into row-crop agriculture (Warner 1994). Another important aspect to consider is that shrublands are often deemed an undesirable habitat (Walk et al. 2010). A shrubland's dense and impenetrable structure, including many thorny and undesirable plants, often results in little desire to implement conservation and management actions to create or maintain shrublands (Askins 2001). The fate of many shrublands has been that either the woody vegetation is removed and the shrubland is converted to grassland, or the shrubland is ignored and allow to succeed into what is often a low quality, second-growth forest.

Shrublands are a successional habitat, whereby the plant community changes in species composition and vegetation structure over time (Gleason 1926). Being often deemed undesirable, shrubland habitat is typically not maintained with the necessary disturbance regime (Brawn et al. 2001). Successional plant communities require disturbance (Gleason 1926) and there are two types of succession that can result in shrubland habitat (primary and secondary succession). Primary succession is the colonization of a habitat devoid of life. A good example is the change in plant community as a glacier recedes. Secondary succession is the reestablishment of a habitat after a disturbance. A good example of secondary succession is how a forest develops after logging. However, the successional process is dynamic and creates dissimilar habitats because of a variation in frequency and intensity of abiotic and biotic agents of change (Clements 1916).

While historically shrublands would have been dynamic habitats driven by disturbance regimes, with the reduction in disturbance and with the introduction of non-native species, the dynamics of shrublands have changed. Non-native plant species often aggressively invade habitats sending succession along another trajectory (Spyreas et al. 2012). Within shrublands some invasive plant species include Autumn Olive (*Elaeagnus umbellata*), Bush Honeysuckle (*Lonicera maackii*), and Common Buckthorn (*Rhamnus cathartica*). These non-native plants can have deleterious impacts on native plant diversity (Greene and Blossey 2012), soil communities (Kuebbing et al. 2014), and vegetation structure (Hejda, Pyšek et al. 2009). In some cases these non-native shrubland plants create unique habitats that have been coined "novel ecosystems" (Miller and Hobbs 2007, Suding 2011).

These novel ecosystems do not have a traditional response to disturbance. Historically, early-successional woody habitat in the Midwest was created either by a decrease in the frequency of prairie disturbance, or by the occasional high-intensity forest disturbance (Turner et al. 1998, Brawn et al. 2001). Grasslands were developed and maintained with frequent fire disturbance, and although the intensity of these fires varied, the frequency was great enough to halt the encroachment of most woody vegetation (Vale 2013). When the frequency of disturbance events decrease, the equilibrium of the habitat changes, and woody plant growth ensues (Sousa 1984). In the case of shrublands this can lead to near monocultures of certain non-native plant species that may provide little habitat for shrubland birds (Nelson et al. 2017).

In contrast to the relatively frequent and high-intensity disturbances historically experienced in grasslands, Midwestern forests were less-frequently subject to high intensity disturbances such as a "blow-down" events or tornados that uproot entire trees, major floods, or exceptionally intense wildfires. When disturbance events like these occur in forests a type of secondary succession called "young forest succession" begins (Lorimer 2001). The pace of young forest succession is much quicker than succession in grasslands because of an abundance of woody species represented in the soil seed bank. Once exposed to light, the young forests soil seed bank begins to germinate and grow. Additionally, some trees will quickly re-sprout from damaged stems, and the forest edge will expand into the newly available light (Martin and Hornbeck 1989, Stephens 1992, Thompson, Robinson et al. 1996).

The lack of natural disturbance regimes and the introduction of non-native plant species have brought shrubland conservation and management to the forefront. One of the primary means by which we monitor the health of habitat is via changes in the bird community within these habitats. Some shrubland bird species appear to respond to unique habitat requirements (Askins 1993, Schlossberg et al. 2010). Past research has shown vegetation structure and plant community composition influences shrubland bird habitat use (MacArthur and MacArthur 1961, 1962; Rotenberry and Wiens 1980a), and provided evidence about bird-habitat relationships within forests and grasslands (Karr and Roth 1971). For example, research has identified that Field Sparrows are associated with sparse shrub cover (Scott and Lima 2004, Schlossberg et al. 2010), while large dense shrub patches are likely habitat for Gray Catbirds (Thompson et al. 1995, Schlossberg et al. 2010). Fortunately, some progress has been made in understanding the response of shrubland birds to "young forest succession" in eastern deciduous forests (Johnston and Odum 1956, Askins 2001, Thompson and DeGraaf 2001, DeGraaf and Yamasaki 2003, King and Schlossberg 2014). In summary, not all shrubland birds prefer the same type of shrublands, to this end, it is imperative to understand what factors of shrublands are positively and negatively associated with the presence of different bird species.

In a meta-analysis, Schlossberg and King (2009) found that the abundance of 14 of 28 shrubland bird species varied among different successional stages over 20 years in recently logged eastern delicious forests. Interestingly, seven of these 14 species varied in a unimodal fashion; abundance started low, peaked after ten years, and then decreased. Curiously, some species, including Yellow-breasted Chat (*Icteria virens*) and Field Sparrow, did not vary over time, and other shrubland species such as Brown Thrasher, Gray Catbird (*Dumetella carolinensis*), American Goldfinch (*Spinus tristis*), and Northern Cardinal (*Cardinalis cardinalis*) showed no response to successional changes in the vegetation composition. However, the Brown Thrasher results are contradicted in another study where populations did decrease when shrub cover was greater than fifty percent (Mabry 2013).

Offering additional complications to understanding this dynamic system is the role non-native shrubs play in changing habitat structure for shrubland birds (Nelson et al. 2017). Non-natives usually leaf-out earlier, and keep their leaves longer. They also tend to have architecturally unique stem and branch construction. Bird species which respond positively to invasive shrubs could be displaying such a relationship because any shrub cover, whether native or not, provides the appropriate structure (McCusker et al. 2010). This might be the case during the early stages of shrubland development as non-native species quickly colonize a grassland and provide new layers of vegetation structure (Gosper et al. 2005). This responses might also be an ecological trap (Rodewald et al. 2010). Distinguishing what factors of vegetation structure are important will inform habitat creation choices and understanding the mechanistic role of non-natives plants in the distribution of birds.

An additional factor that warrants concern is the spatial heterogeneity or arrangement of the shrubs (identified as “patchiness” hereafter). The patchiness of vegetation has been shown to influence occupancy and distribution of grassland birds, and it might also play a role in creating unique shrubland habitats (MacArthur and MacArthur 1962, Rotenberry and Wiens 1980b, Hovick et al. 2015). As mentioned earlier, Field Sparrows have shown a preference to space between shrubs, while Gray Catbirds prefer shrubs to be clumped closer together. These spaces between shrubs are often dominated by grasses, but in some cases are also barren soil. An example of vegetation spatial arrangement influencing habitat quality has been identified in the response of wetland birds to wetland hemi-marsh conditions (Murkin et al. 1997). While several studies have suggested that the distribution of shrubs may be important for certain species of birds, to my knowledge there are no studies that have explicitly determined how different species of shrubland birds respond to the distribution of shrubland woody plants.

Compared to studies of grassland and forest birds, shrubland birds have received relatively little attention. This may be due to the relatively little attention paid to the management and conservation of shrubland habitat, or it may be due to the fact that some traditionally shrubland species (e.g. Chipping Sparrow, Cedar Waxwing) have been experiencing large population increases. Regardless of the reason for the lack of attention, the advice to simply provide more shrubland habitat, while it may not hurt a population, may not be attaining the desired results. For example, the Illinois Wildlife Action plan calls for creating shrubland habitat to address shrubland bird population declines. Unfortunately, if particular species of shrubland birds requires specific structure or arrangement, then creating random shrublands might not solve the problem. A better understanding of how the amount of shrub cover, the influence of non-native plant species, and how the patchiness of the shrubs influences shrubland bird could help inform land managers and potential provide management recommendations to more effectively manage and conserve shrublands and species that use this habitat.

CHAPTER 2: HOW VEGETATION STRUCTURE AND LANDSCAPE CONTEXT INFLUENCE SHRUBLAND BIRD OCCUPANCY

Introduction

Declines of bird populations in North America have been well documented (Robbins et al. 1989, Askins 1993, North American Bird Conservation Initiative 2016) with much of the emphasis focused on the decline of grassland and forest birds (Vickery and Herkert 1999, Fisher and Davis 2010, Reidy et al. 2014). Another group with species exhibiting sharp population declines is shrubland birds (Askins 1993, Walk et al. 2010). One potential reason for shrubland bird declines is simply that the habitat they require is no longer present (Askins 1993). This potential lack of habitat is confounded by the lack of information on the preferred habitat by many shrubland birds (Askins et al. 2007, Schlossberg and King 2008, Schlossberg et al. 2010).

While there is a considerable amount of information about habitat needs and management approaches for grassland birds (Wiens 1974; Herkert 1994a; Fisher and Davis 2010; Hovick et al. 2014); there are not even widely accepted definitions for shrubland habitat. Shrublands are generally a neglected transitional habitat (Askins 2001), with most management oriented toward either climax forest communities or disturbance-mediated grassland communities. Management for shrubland birds is guided by research on how vegetation structure and composition influence bird species presence or abundance in forested environments (MacArthur and MacArthur 1961; MacArthur and MacArthur 1962; Karr and Roth 1971). This approach to creating shrubland habitat overly simplifies habitat creation to a simple equation of shrubs equals' habitat. Due to this approach, there is a lack of specific information on how the percent shrub cover, patchiness of shrubs, and the proportion of shrubs comprised of non-native shrubs influences conservation priority birds in shrublands.

The percent shrub cover has long been indicative of shrubland bird habitat. However, all shrubland birds are not found in the same habitat, instead some shrubland birds exhibit unique habitat requirements (Askins 1993, Schlossberg et al. 2010). For example, Field Sparrows are associated with sparse shrub cover (Scott and Lima 2004, Schlossberg et al. 2010), and large dense shrub patches are likely habitat for Gray Catbirds (Thompson et al. 1995, Schlossberg et al. 2010). However, the patchiness of shrubs might play a role in creating these unique habitats (Figure 1). An example of vegetation spatial arrangement influencing habitat quality has been identified in the response of waterfowl to wetland hemi-marsh conditions (Murkin et al. 1997).

Further complicating our understanding of shrubland habitat is that shrublands are often dominated by non-native plant species. Many of these non-native shrub species are invasive and outcompete native species to become dominant (Pimentel et al. 2005), often resulting in structurally homogenous plant communities (Medley and Krisko 2007). For shrubland birds, non-native species may provide the appropriate structure to encourage habitat use (McCusker et al. 2010), but dominance of non-native species can result in decreased food resources (Reif et al. 2016), decreased plant diversity (Greene and Blossey 2012), altered insect communities and lower insect biomass; (Tallamy 2004, Fickenscher et al. 2014), and changes to soil nutrient cycling (Kuebbing et al. 2014). While non-native shrubs can be an important food source for frugivorous species (McCusker et al. 2010, Gleditsch and Carlo 2011), non-native shrubs can also act as an ecological trap, where nest-predation rates are greater than in native shrubs

(Rodewald et al. 2010). Overall, the impacts of non-native shrubs on birds are complicated, with research often producing conflicting or ambiguous results (Nelson et al. 2017).

While percent shrub cover, patchiness of shrubs, and proportion of shrubs comprised of non-native shrubs may be important, the surrounding landscape may also impact bird populations (Miguet et al. 2015). Landscape context has been found to influence the abundance and nest success of forest birds (Mitchell et al. 2001, Lichstein et al. 2002, Chapa-Vargas and Robinson 2013, Labbe and King 2014), and grassland bird occupancy and abundance (Herkert 1994b, Shahan et al. 2017). The influence of landscape context on shrubland birds has been studied in the northeastern United States (DeGraaf and Yamasaki 2003, Askins et al. 2007, Schlossberg and King 2008, Schlossberg et al. 2010, Labbe and King 2014), but because northeastern landscapes are mostly forested the focus has been on size of shrubland patches and how disturbance factors influence vegetation succession. Similar investigations of how landscape context influences shrubland birds in the agriculturally dominated Midwest are rare (but see; Mabry et al. 2010; Chapa-Vargas and Robinson 2013).

The goal of this study was to understand the relationship between woody vegetation (percent shrub cover, patchiness of shrubs, and the proportion of shrubs comprised of non-native shrubs), landscape context, and the occurrence of bird species. I focused on 22 shrubland bird species, including eight species of conservation concern in Illinois, the Midwest, and nationally (Illinois Department of Natural Resources 2005, U.S. Fish and Wildlife Service 2008). I had four objectives: (1) to understand how the percent of shrub cover influences the occupancy of bird species in shrublands; (2) to understand how the patchiness of shrub cover influences the occupancy of bird species in shrublands; (3) to understand how the proportion of shrubs comprised of non-native shrubs at a site influence the occupancy of bird species in shrubland habitat, and (4) to understand how the surrounding landscape influences the occupancy of bird species in shrublands.

Methods

Study sites

This study was conducted using vegetation and bird survey data collected by the Illinois Critical Trends Assessment Program (CTAP). CTAP began in 1997, and was designed to draw statistical inferences about the statewide status and trends of several taxa, including plants and birds, in randomly selected grasslands, forests, and wetlands throughout Illinois. Each year, 30 sites of each habitat type are sampled, and within a 5-year period, 150 unique sites are sampled. These sites are resampled every five years unless the land use of the site has changed, there is a drastic change in management (e.g., increase in grazing pressure), or, for grasslands and wetlands, the site becomes >50% covered by woody vegetation. Sites where sampling is discontinued are replaced by another suitable site that meets the CTAP habitat criteria within the township (Molano-Flores 2002).

This study was limited to CTAP grassland sites. Most sites (n=158) had data collected in recurring 5-year intervals (n=116), but some sites were only visited once (n=42). On average, sites used for this analysis were visited 2.3 times (range: 1 to 4), resulting in 369 visits from 1997-2014 when vegetation sampling and bird point counts were conducted in the same year.

Sites were excluded if they were heavily grazed, frequently mowed, fallow agricultural fields less than one year old, or manicured grasslands (Molano-Flores 2002).

Vegetation sampling

CTAP vegetation sampling was conducted by trained botanists sampling along a randomly placed 41-m transect at each site using twenty 0.25 m^2 quadrats. The cover of each species, including woody cover <1 m tall, was estimated in the 20 quadrats by assigning each species to one of seven cover classes (<1%; 1-5%; 6-25%; 26-50%; 51-75%; 76-95%; 96-100%). In addition, stems of woody vegetation <5 cm diameter at breast height (DBH), but >1 m tall and rooted within 2 m of the established transect were identified and counted (Molano-Flores 2002). The proportion of non-native shrub cover at a site was calculated by dividing the number of non-native shrub stems by the total number of stems counted during CTAP vegetation surveys. All the vegetation sampling was conducted during the growing season each year, typically in August.

Bird sampling

Bird sampling occurred within the same randomly selected area as the vegetation sampling. Surveys were conducted by trained and experienced personnel during the period of peak breeding activity, between May 15 and July 30. Sites were sampled once or twice per season, and surveys were point counts of a 10-minute duration conducted between sunrise and 11:00 am. Surveys were only conducted when wind speeds were below 19 km/h, and when it was not raining. Observers recorded the number of each species seen or heard within an unlimited radius of the point.

Site-level shrub cover and distribution

Although CTAP sampling included shrub cover (number of shrub stems along transect), the nature of this sampling was focused on relatively small spatial scales. The bird point counts cover a larger area and, functionally, I expected birds to respond to woody vegetation at larger scales. To quantify this larger scale, I used aerial imagery within Google Earth. The images were collected within 1 year of the bird sampling and offer a resolution clear enough to identify clumps of shrubs with a diameter ≥1.5m. Using these images I quantified both the percent of shrub cover and the number of discrete shrub patches >1.5 m in diameter within a 150-m radius circle of the sample point (Table 1), estimates of shrub cover and patches were made by a single observer. Estimates of shrub cover (percent of site with shrub cover) may include tree saplings and woody vines because bird species likely respond to all shrub-layer woody vegetation in similar ways. Patches were identified as single contiguous aggregations of woody vegetation within a site, and because of this definition a patch of shrubs could vary in size from site to site (average shrub-patch size = 0.05 ha, range 0 to 0.35). Shrub cover and the number of patches were highly correlated (r = 0.81); therefore, to understand the influence of the number of patches on species occupancy, I generated a patchiness index using the residuals of the relationship between number of patches and percent shrub cover. This index represents how many more or fewer patches were present at a site than expected based on shrub cover alone. Positive coefficients for the effect of patchiness on species occupancy indicate species that are more likely to be found when sites have relatively more patches, whereas negative coefficients represent an affinity for shrub cover that is more homogenous rather than distributed in patches.

Landscape variables

I quantified the landscape composition within a 1-km radius surrounding each sample point using data from the 2006 National Land Cover Database (Fry et al. 2011). The 1-km distance was selected because it is commonly used in landscape studies and has been show to capture the effect of surrounding landscape (Cunningham and Johnson 2006). The National Land Cover Database contained 16 different categories combined into four variables to facilitate analysis and eliminate three of the four developed classifications (Low intensity, Medium intensity, High intensity) because they were rare. I also combined the categories of developed open space, barren land, shrub/scrub, grassland/herbaceous, and pasture/hay into an "Open herbaceous" variable. The categories of deciduous forest, evergreen forest, mixed forest, and woody wetlands were combined into a single "forest" variable. Open water and emergent herbaceous wetland were combined into a "water" variable. Additionally included in the analysis are categories of cultivated crops, and latitude to account for differences in geographic range for some species (Table 1).

Statistical analyses

I examined the effects of percent shrub cover, patchiness of shrubs, proportion of shrubs comprised of non-native shrubs, and landscape context on bird use of sites using single-season occupancy models (MacKenzie et al. 2002). Models were fit using the 'occu' function in the R software package 'unmarked' (Fiske et al. 2011). CTAP bird survey data were truncated to contain only observations that occurred within a 150-m radius. I focused on shrubland and grassland species, following Walk et al. (2010) and Vickery et al. (1999), that were recorded at ≥5% of sites, resulting in 22 shrubland and three grassland species with suitable sample sizes. In total, there were 11 species of conservation concern (8 shrubland and 3 grassland birds; Table 2). The grassland species were included in the analysis to examine the biological meaningfulness of the models, as past research provides clear expectations for responses of these species to the selected variables (Rotenberry and Wiens 1980a, Herkert 1994a, Coppedge et al. 2001).

Covariates on detection probability in all models included day of year and time of day; initially observer identity was included, but this variable received little support and was dropped from subsequent analyses. I also included all landscape variables (latitude, forest, open herbaceous, crops, and water) in subsequent habitat-based models to facilitate direct comparison of the influence of all land-cover types for all bird species of interest. I confirmed that landscape variables were not highly correlated with each other ($r < 0.50$) prior to fitting models. I used Akaike's Information Criterion (AIC) (Burnham and Anderson 2003) and model coefficients to evaluate the effect of habitat variables of interest on the occupancy of the selected bird species using a two-step process. The first step was to use AIC to compare two models; a linear shrub-cover model and a quadratic shrub-cover model, which allowed for peaked occupancy at intermediate values of shrub cover. Next, I fit the best-supported model (linear or quadratic) as determined by AIC weight, with the variables representing patchiness and percent non-native for the 25 bird species. This final model includes all of the variables of interest in one model. Each variable was scaled by subtracting the mean and dividing by the standard deviation prior to analyses. The scaling allows for comparison of variable strength between variables within the same model. Model convergence was successful, with the exception of Brown Thrasher *(Toxostoma rufum)* and Northern Mockingbird *(Mimus polyglottos)*, which needed to have landscape and habitat variables modeled independently. I base my interpretation of effects of individual variables on model coefficients and their associated precision. If the standard error of a variable's coefficient overlapped zero, then I assumed the variable was not meaningful.

Results

A total of 366 sites were sampled from 1997 to 2014 in which observations of 6,023 individual birds of the 22 focal species were recorded. The most commonly detected species was American Robin (*Turdus migratorius*; n=770), and the least commonly detected species was Blue Grosbeak (*Passerina caerulea*; n=33; Table 2). Detection probability was influenced more by day of year than by time of day, but the response to day of year was mixed, while time of day had a decidedly negative impact on detection probability.

Latitude and forest were the most common landscape factors influencing occupancy. The latitude variable was meaningful for 16 out of the 22 species, with 12 of those 16 species being more common to the south (Table 3). The amount of forest in the landscape was meaningful for 18 out of 22 species, with 12 of the 18 preferring forested landscapes. The amount of cultivated crops in the landscape affected 17 species, with eight being positively impacted and nine being negatively impacted. The amount of open herbaceous habitat in the landscape influenced 14 out of 22 species, including a positive response by half of the shrubland species. The amount of water in the surrounding landscape was largely unimportant (Table 3).

The most influential habitat variable for shrubland bird occupancy was shrub cover, with 20 out of the 22 species displaying a meaningful response. Only Northern Bobwhite and Northern Mockingbird showed no meaningful response, and American Robin exhibiting a negative response. A quadratic relationship to shrub cover was the most parsimonious model for seven species: Willow Flycatcher, Yellow-billed Cuckoo *(Coccyzus americanus)*, Eastern Kingbird *(Tyrannus tyrannus)*, Blue Grosbeak, Cedar Waxwing (*Bombycilla cedrorum*), Chipping Sparrow *(Spizella passerina)*, and Gray Catbird (*Dumetella carolinensis*) (Table 3), indicating that occupancy peaked at intermediate values of shrub cover. The proportion of non-native woody vegetation was important in understanding the occupancy of 11 of the 22 species. However, the response of the bird species was mixed. Yellow Warbler *(Setophaga petechia)*, Northern Cardinal (*Cardinalis cardinalis)*, Indigo Bunting *(Passerina cyanea)*, and American Robin all increased in occupancy as the proportion of non-natives increased (Table 3). The patchiness of shrubs (Patchiness index) helped explain occupancy for 15 of the 22 species. Only three of the 15 species were more common at sites with fewer patches (American Goldfinch *(Spinus tristis)*, Mourning Dove *(Zenaida macroura)*, and White-eyed Vireo *(Vireo griseus)*).

The Breeding Bird Survey (BBS) trends for Illinois from 1966 to 2015 estimate that five of the 22 species have had stable populations, seven species have increased, and 10 species have declined (Table 2). Over half (6/10) of the species that are experiencing population declines responded strongly to the patchiness of the shrubs (Figure 2), whereas, only 3 of the 12 shrubland species whose populations were either stable or increased responded positively to the patchiness of shrubs (Figure 3). All four species that responded positively to invasive species were either stable or increasing in population. Given nearly all species were positively associated with shrub cover there were mixed trends with shrub cover and population trend, and there were no obvious trends between population trends and landscape variables.

Discussion

Shrubland birds are positively associated with shrub cover. This was a rather obvious result of this study; however, it does not explain why nearly half of the shrubland species we were investigating had populations that were declining, while the other half were either increasing or stable. As has been found in other habitats (forests, grasslands, and wetlands), and in a few shrubland studies (Fink et al. 2001) not all habitat support the same suite of species. The species that prefer non-native species have robust populations, however this only accounts for four species. The patchiness of the shrubland appears to be the factor that differentiates the species whose populations are increasing from those that are decreasing. We suggest that as shrublands become invaded with non-native shrubs (e.g. honeysuckle, multi-flora rose, autumn olive) they lose their heterogeneous vegetation structure (Collier et al. 2002, Hartman and McCarthy 2008). This change does not greatly affect the use of these sites for roughly half of the 22 species we investigated. However, for the other half of the species they prefer patchiness and their occupancy declines with the loss of shrub patches.

The role non-native shrubs play in creating habitat for shrubland bird species is complicated (Nelson et al. 2017). Bird species that responded positively could be displaying that relationship because some shrub cover, whether native or not, provides the appropriate structure (McCusker et al. 2010). This might be the case during the early stages of shrubland development as non-native species quickly colonize a grassland and provide new layers of vegetation structure (Gosper et al. 2005). Of the 25 species included in the study, only Northern Cardinal, Indigo Bunting, and Yellow Warbler were species that respond positively to shrub cover and to an increase in the proportion of non-native shrubs. Of the remaining 20 species, seven species (Blue Grosbeak, Chipping Sparrow, Common Yellowthroat, Eastern Kingbird, Field Sparrow, Mourning Dove, and Yellow-billed Cuckoo) displayed a negative response to an increase in non-native shrub cover while displaying a positive response to shrub cover. Nine species (American Goldfinch, Bell's Vireo, Brown Thrasher, Cedar Waxwing, Eastern Towhee, Gray Catbird, White-eyed Vireo, Willow Flycatcher, and Yellow-breasted Chat) responded positively to shrub cover with no response to the proportion of non-natives.

Beyond site-level factors, we found that the surrounding landscape influenced occupancy of most shrubland bird species. Forest cover is the most predictive variable for shrubland species occupancy with 10 species that respond positively to shrub cover also responding positively to forest cover (Blue Grosbeak, Brown Thrasher, Common Yellowthroat, Eastern Kingbird, Eastern Towhee, Field Sparrow, Indigo Bunting, Northern Cardinal, Yellow-breasted Chat, and Yellow-billed Cuckoo; Table 3). In many ways, shrublands are extensions of forest (Gleason 1913; Bond, Woodward, and Midgley 2005; Matlack 2013), providing a source of woody plant seeds that ultimately creates shrublands (Bond and Midgley 2001, Anderson et al. 2007). Additionally, nesting near forests might provide safe dispersal habitat for fledglings (Rodewald and Vitz 2005; Streby et al. 2015). Also, it might be beneficial to take advantage of the additional food sources along forest edges (Suarez et al. 1997, McCollin 1998). However, four species (American Goldfinch, Bell's Vireo, Mourning Dove, and Willow Flycatcher) displayed a positive response to shrub cover and a negative response to forest in the landscape.

Although most shrubland species were associated with forested landscapes, the amount of crops and open herbaceous area in the landscape also contribute to bird occupancy. Of the species that respond positively to shrub cover, American Goldfinch, Cedar Waxwing, Chipping Sparrow, Gray Catbird, Mourning Dove, Northern Cardinal, White-eye Vireo, and Yellow Warbler all responded negatively to the amount of crops in the landscape. However, there were species that increased in occupancy as the amount of crops increased, including Blue Grosbeak, Brown Thrasher, Common Yellowthroat, Eastern Kingbird, Eastern Towhee, and Yellow-breasted Chat.

Management Implications

In summary, shrublands are not all the same and the disparity across the population trends of shrubland birds might be due to the patchiness of shrublands. More research is needed to understand how these different factors influence nesting success (Woodward et al. 2001), but this study is the first step in understanding the habitat that needs to be created and managed for in order to conserve shrubland bird species (Thompson III and DeGraaf 2001). In general, the creation of shrublands in forested landscapes would benefit most shrubland species with the exception of Bell’s Vireo and Willow Flycatcher. Within any landscape in Midwestern United States, it is likely that non-native species will quickly colonize shrublands and studies have found that without management within five years shrublands can succeed in second-growth forest (Thompson and DeGraaf 2001). Given the issue of non-native species, the lack of disturbance regimes (Brawn et al 2001), and the potential rapid succession, active management will be needed to maintain patchy shrublands that are needed by several shrubland species.

CHAPTER 3: CONCLUSION

There are several threats to shrubland habitats, including non-native plant species and the lack of disturbance regimes. While there are several threats to shrublands, and some researchers have suggested that shrubland birds are declining due to the lack of habitat, across shrubland birds there is great variation in the trajectory of their populations. Several species of birds have been experienced large population declines while other are experiencing population increases. The overall goal of my research was to understand how features of shrubland habitat influence the occupancy of 22 shrubland birds and while the results provide some potential for conservation actions, they highlight the effort needed to improve shrublands for birds.

I found that the proportion of non-native plant species in a shrubland did not have a large impact on the overall shrubland bird community. There were species that were more or less likely to occur in shrublands with high amounts of non-native plant species, however overall the impact were small. This result could be because non-native plant species are very common in the shrublands used in the study. Another potential confounding factor is that the variable was the proportion of non-native species and I did not break this down by species. However, my interpretation of the non-native plant species data is that if desired vegetation structure is present the vast majority of shrubland bird species will be present. In addition, the species that are experiencing large populations increases (e.g., American Robin, Cedar Waxwing) are likely benefiting from the fruit on several of the non-native plant species (e.g. autumn olive, honeysuckle). From a management point-of-view, the removal of non-native plant species will likely only be beneficial for shrubland birds if the requisite native shrubs are restored.

In general, shrubland birds did not have a large response to the matrix in which a shrubland was embedded. There were a couple species (e.g., Bell's Vireo) that preferred a specific landscape; however, it appears that regardless of the matrix the creation or restoration of a shrubland will be beneficial for shrubland birds as a whole.

The overwhelming more important factor in the present of shrubland birds is the presence of shrublands. At first glance, this is an obvious result, however in the context of the patchiness of shrubs within a shrubland a clearer picture of the type of shrubland needed by birds, appears. The bird species that have been experiencing population increases do not appear to be very sensitive to the patchiness of shrublands, while the species that are declining prefer shrublands with more patchiness. In general, the bird species that are increasing also are not affected by non-native species and thus the situation in which shrublands become dominated by non-native plant species and have little patchiness are likely becoming more common allowing these birds species to increase in abundance. Conversely, the species that are declining prefer "patchy" shrublands. The invasive non-native plant species can create dense, homogenous shrublands. I would suggest that managers create more patchiness within shrublands. While more research is needed, the creation of more patchiness within shrublands might be attained by fire or mechanical removal of shrubs. It might be as simple as randomly removing vegetation for a shrubland to create the desired shrubland patchiness. In summary, there appears to be two groups of shrubland birds; one that can use dense homogenous patches of shrubs, and another that prefers a patchy composition of shrubs and open grassy areas. I suggest that managers begin to actively manager shrublands and while this study was not designed to determine the effectiveness of management approaches a first step would be to simply remove shrubs and manage for patchiness and record how these changes impact the shrubland bird community.

TABLES AND FIGURES

Table 1. Summary statistics for habitat and landscape variables used to estimate occupancy. Habitat variables are estimated for a 7-ha area (i.e., 150-m radius). Landscape variables, with the exception of latitude, are the proportion of area within a 1-km radius circle centered on the corresponding point count location (n=369).

		Mean	**SD**	**Median**	**Min.**	**Max.**
Habitat variables	Percent shrub cover	17.57	20.69	10	0	100
	Patchiness index	0	21.67	-0.66	-83.23	206.16
	Proportion Non-native shrubs	0.11	0.25	0	0	1
Landscape variables	Latitude	39.89	1.25	39.91	37.16	42.47
	Proportion Crops	0.48	0.27	0.5	0	0.96
	Proportion Water	0.01	0.04	0.001	0	0.47
	Proportion Forest	0.23	0.19	0.18	0	0.87
	Proportion Open herbaceous	0.20	0.14	0.18	0.01	0.75

Table 2. The 22 shrubland bird species used in the analysis, n is the number of detection of a given species. The trend is the percent yearly change between for Illinois from 1966 to 215 as estimated by the Breeding Bird Survey. A “stable” overall trend is when the 95% confidence interval overlapped zero. An “increasing” trend is where a species’ trend was greater than zero and did not overlap zero. A “decreasing” trend was when the estimate was less than zero and did not overlap zero. We considered Willow Flycatcher to have a declining trend even though its confidence interval barely overlapped zero because its trend was greatly declining.

Common Names	Scientific Names	n	Trend Estimate	Overall Trend
American Goldfinch (AMGO)	*Spinus tristis*	625	0.51	Stable
American Robin (AMRO)	*Turdus migratorius*	770	1.84	Increasing
Bell's Vireo (BEVI)	*Vireo bellii*	40	-0.53	Stable
Blue Grosbeak (BLGR)	*Passerina caerulea*	33	4.30	Increasing
Brown Thrasher (BRTH)	*Toxostoma rufum*	94	-1.49	Declining
Cedar Waxwing (CEWX)	*Bombycilla cedrorum*	162	6.27	Increasing
Chipping Sparrow (CHSP)	*Spizella passerina*	115	5.12	Increasing
Common Yellowthroat (COYE)	*Geothlypis trichas*	558	-1.24	Declining
Eastern Kingbird (EAKI)	*Tyrannus tyrannus*	202	-0.99	Declining
Eastern Towhee (EATO)	*Pipilo erythrophthalmus*	175	-0.73	Declining
Field Sparrow (FISP)	*Spizella pusilla*	588	-3.29	Declining
Gray Catbird (GRCA)	*Dumetella carolinensis*	170	0.52	Increasing
Indigo Bunting (INBU)	*Passerina cyanea*	746	-0.35	Stable
Mourning Dove (MODO)	*Zenaida macroura*	543	0.54	Increasing
Northern Bobwhite (NOBO)	*Colinus virginianus*	301	-3.93	Decreasing
Northern Cardinal (NOCA)	*Cardinalis cardinalis*	485	0.26	Increasing
Northern Mockingbird	*Mimus polyglottos*	66	-1.83	Declining
White-eyed Vireo (WEVI)	*Vireo griseus*	35	0.38	Stable
Willow Flycatcher (WIFL)	*Empidonax traillii*	69	-1.05	Declining
Yellow-breasted Chat (YBCH)	*Icteria virens*	85	-1.19	Declining
Yellow-billed Cuckoo (YBCU)	*Coccyzus americanus*	81	-2.19	Declining
Yellow Warbler (YWAR)	*Setophaga petechia*	80	1.09	Stable

Table 3. Parameter estimates (SE) for land-cover and habitat variables from models of the occupancy of grassland and shrubland birds. All variables were scaled prior to analysis. Bold parameter estimate values are deemed meaningful. Int. (p or psi) = Intercept value for the detection probability or occupancy portion of the model, respectively; Shrub cover^2 = represents quadratic relationship with shrub cover; all other variables are described in the methods section. Species marked with asterisk denote that modeling for landscape variables and habitat variables were completed with detection variables in two separate models because of convergence issues.

	Detection probability			**Occupancy: Landscape variables**							**Habitat variables**		
Species	**Int. (p)**	**Day**	**Time**	**Int. (psi)**	**Latitude**	**Forest**	**Crops**	**Water**	**Open herba-ceous**	**Non-native**	**Patch-iness index**	**Shrub cover**	**Shrub cover^2**
AMGO	0.87 (0.21)	0.34 (0.16)	0.51 (0.18)	1.87 (0.56)	0.03 (0.30)	**-2.21 (1.56)**	**-3.72 (2.25)**	-0.21 (0.60)	**-2.28 (1.29)**	0.16 (0.34)	**-0.39 (0.29)**	**0.76 (0.39)**	--
AMRO	0.98 (0.12)	0.10 (0.12)	0.10 (0.12)	32.02 (15.17)	**2.86 (1.27)**	**-53.26 (28.96)**	**-66.89 (37.57)**	0.73 (4.62)	**-41.16 (22.00)**	**1.92 (1.03)**	**1.11 (0.84)**	**-0.86 (0.62)**	--
BEVI	0.86 (1.18)	0.15 (1.01)	0.13 (0.50)	-3.69 (0.59)	**-1.46 (0.51)**	**-1.07 (0.51)**	-0.47 (0.57)	0.09 (0.19)	-0.21 (0.42)	-0.16 (0.30)	**0.36 (0.28)**	**1.11 (0.31)**	--
BLGR	-0.29 (0.53)	-0.27 (0.32)	-0.29 (0.33)	-4.23 (0.89)	**-1.81 (0.70)**	**2.77 (1.40)**	**2.40 (1.81)**	**1.19 (0.75)**	**1.93 (1.09)**	**-0.68 (0.53)**	**0.85 (0.40)**	**3.28 (1.19)**	**-3.70 (1.42)**
BRTH*	-0.41 (0.44)	-0.48 (0.23)	-0.14 (0.20)	3.72 (1.97)	0.65 (0.65)	**5.39 (2.50)**	**0.97 (0.96)**	**-2.61 (1.25)**	0.79 (1.00)	-0.22 (0.23)	**0.83 (0.76)**	**1.00 (0.50)**	--
CEWA	0.31 (0.43)	-0.59 (0.27)	-0.03 (0.27)	-1.39 (0.30)	**0.63 (0.24)**	-0.21 (0.28)	**-0.38 (0.33)**	**0.30 (0.22)**	-0.19 (0.30)	-0.03 (0.19)	0.14 (0.22)	**2.07 (0.60)**	**-1.74 (0.64)**
CHSP	0.17 (0.62)	0.20 (0.37)	-0.33 (0.29)	-1.41 (0.38)	0.03 (0.24)	0.03 (0.29)	**-0.44 (0.37)**	-0.08 (0.20)	-0.14 (0.31)	**-0.28 (0.23)**	0.01 (0.27)	**1.39 (0.67)**	**-1.59 (0.83)**
COYE	1.54 (0.31)	0.02 (0.23)	-0.16 (0.20)	1.29 (0.27)	-0.04 (0.21)	**0.44 (0.25)**	**0.41 (0.30)**	0.09 (0.16)	0.18 (0.25)	**-0.21 (0.18)**	0.05 (0.21)	**0.38 (0.23)**	--
DICK	1.61 (0.35)	-0.38 (0.31)	-0.39 (0.24)	-0.02 (0.19)	**-0.22 (0.18)**	-0.07 (0.29)	**1.21 (0.39)**	**0.23 (0.19)**	**0.75 (0.27)**	**-0.32 (0.16)**	-0.15 (0.16)	**-0.87 (0.43)**	**0.76 (0.42)**

Table 3. Cont.

	Detection probability				Occupancy: Landscape variables						Habitat variables		
Species	**Int. (p)**	**Day**	**Time**	**Int. (psi)**	**Latitude**	**Forest**	**Crops**	**Water**	**Open herba-ceous**	**Non-native**	**Patch-iness index**	**Shrub cover**	**Shrub cover^2**
EAKI	0.73 (0.37)	0.62 (0.28)	-0.58 (0.24)	-0.28 (0.23)	0.14 (0.19)	**0.32 (0.29)**	**0.77 (0.38)**	0.14 (0.15)	**0.69 (0.29)**	**-0.70 (0.16)**	**0.28 (0.21)**	**1.54 (0.51)**	**-1.42 (0.59)**
EAME	1.17 (0.30)	-0.29 (0.19)	-0.22 (0.20)	0.37 (0.27)	**-0.37 (0.23)**	**-0.99 (0.28)**	0.19 (0.31)	**-0.21 (0.16)**	**0.42 (0.25)**	**-0.69 (0.19)**	-0.10 (0.17)	**-0.30 (0.18)**	--
EATO	0.36 (0.31)	-0.31 (0.20)	-0.19 (0.21)	-0.89 (0.30)	-0.11 (0.25)	**2.18 (0.59)**	**1.32 (0.75)**	0.14 (0.24)	**0.40 (0.16)**	-0.12 (0.23)	**0.42 (0.33)**	**1.08 (0.33)**	--
FISP	2.37 (0.53)	0.46 (0.36)	0.19 (0.32)	0.69 (0.25)	**-0.27 (0.20)**	**1.36 (0.30)**	0.21 (0.29)	**-0.31 (0.20)**	**0.29 (0.26)**	**-0.27 (0.17)**	0.10 (0.24)	**0.99 (0.23)**	--
GRCA	1.01 (0.54)	0.02 (0.27)	0.21 (0.40)	-0.97 (0.27)	**-0.97 (0.27)**	-0.09 (0.25)	**-0.52 (0.32)**	**0.25 (0.15)**	-0.23 (0.27)	-0.14 (0.21)	**0.45 (0.17)**	**3.00 (0.60)**	**-2.53 (0.60)**
GRSP	0.19 (0.84)	0.40 (0.42)	-0.28 (0.32)	-3.10 (0.66)	**0.51 (0.34)**	**5.82 (2.34)**	**9.43 (3.50)**	**1.40 (0.64)**	**5.48 (1.95)**	**-0.43 (0.31)**	**-0.38 (0.36)**	-0.22 (0.29)	--
INBU	2.30 (0.30)	0.21 (0.27)	-0.04 (0.22)	2.37 (0.46)	**-0.46 (0.21)**	**1.77 (0.44)**	0.32 (0.35)	0.18 (0.24)	**-0.52 (0.28)**	**0.51 (0.27)**	**0.90 (0.47)**	**1.15 (0.43)**	--
MODO	0.34 (0.12)	0.18 (0.12)	-0.13 (0.11)	7.83 (2.25)	**-2.26 (0.70)**	**-10.34 (4.28)**	**-13.47 (6.03)**	-1.15 (1.36)	**-7.62 (3.40)**	**-0.78 (0.65)**	**-2.37 (1.11)**	**5.61 (1.88)**	--

Table 3. Cont.

	Detection probability			Occupancy: Landscape variables							Habitat variables		
Species	**Int. (p)**	**Day**	**Time**	**Int. (psi)**	**Latitude**	**Forest**	**Crops**	**Water**	**Open herba-ceous**	**Non-native**	**Patch-iness index**	**Shrub cover**	**Shrub cover^2**
NOBO	0.18 (0.28)	-0.19 (0.17)	-0.30 (0.17)	-0.32 (0.35)	**-1.59** **(0.41)**	**1.52** **(0.67)**	**3.38** **(1.09)**	0.07 (0.31)	**1.96** **(0.75)**	0.02 (0.27)	0.22 (0.28)	0.22 (0.28)	--
NOCA	1.80 (0.31)	0.38 (0.23)	-0.09 (0.19)	1.74 (0.38)	**-0.55** **(0.22)**	**0.56** **(0.37)**	**-0.55** **(0.41)**	-0.14 (0.15)	**-0.45** **(0.34)**	**0.71** **(0.46)**	-0.27 (0.28)	**0.64** **(0.29)**	--
NOMO*	-1.47 (0.27)	-0.05 (0.19)	-0.19 (0.14)	-0.35 (0.75)	**-3.26** **(1.56)**	**3.15** **(1.92)**	**5.56** **(3.14)**	-1.27 (1.33)	**2.25** **(1.52)**	0.19 (0.30)	**0.96** **(0.73)**	0.30 (0.97)	--
WEVI	-0.67 (0.41)	0.24 (0.30)	-0.87 (0.35)	-4.73 (1.18)	**-2.95** **(1.30)**	-0.07 (0.60)	**-3.19** **(1.24)**	**-0.49** **(0.46)**	**-1.81** **(1.00)**	0.27 (0.45)	**-1.29** **(0.68)**	**1.59** **(0.61)**	--
WIFL	-0.63 (0.73)	-0.50 (0.35)	-0.22 (0.34)	-2.04 (0.54)	**0.45** **(0.39)**	**-1.52** **(1.14)**	-0.93 (1.10)	0.37 (0.40)	-0.91 (1.02)	-0.01 (0.33)	**0.36** **(0.32)**	**2.31** **(1.18)**	**-1.88** **(1.11)**
YBCH	0.63 (0.56)	0.14 (0.48)	-0.20 (0.34)	-2.15 (0.36)	**-0.78** **(0.30)**	**1.45** **(0.69)**	**1.15** **(0.99)**	**0.35** **(0.25)**	**1.08** **(0.57)**	-0.23 (0.25)	**0.45** **(0.29)**	**0.81** **(0.27)**	--
YBCU	-0.67 (0.35)	0.35 (0.20)	-0.12 (0.18)	-0.54 (0.50)	**-1.14** **(0.44)**	**0.48** **(0.47)**	-0.46 (0.62)	-0.03 (0.25)	-0.14 (0.51)	**-0.44** **(0.33)**	0.35 (0.49)	**1.43** **(0.94)**	**-0.74** **(1.06)**
YWAR	0.22 (0.50)	-2.04 (0.61)	0.73 (0.55)	-2.93 (0.43)	**0.99** **(0.38)**	**-0.72** **(0.46)**	**-1.60** **(0.55)**	-0.03 (0.25)	**-1.82** **(0.63)**	**0.53** **(0.27)**	**0.48** **(0.24)**	**0.35** **(0.28)**	--

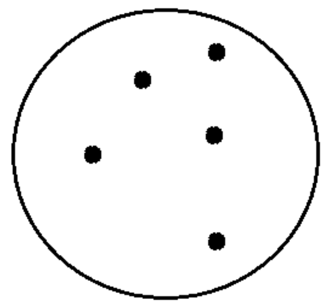
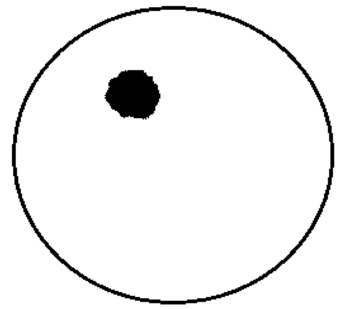
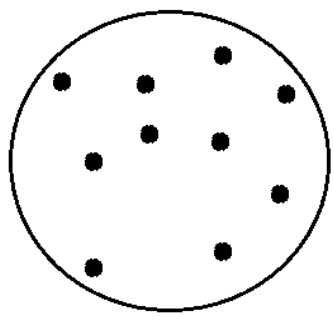
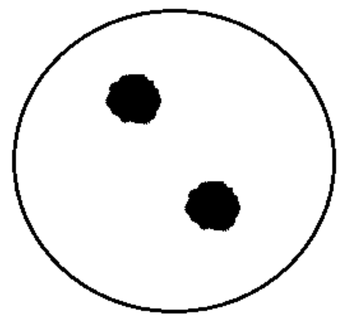
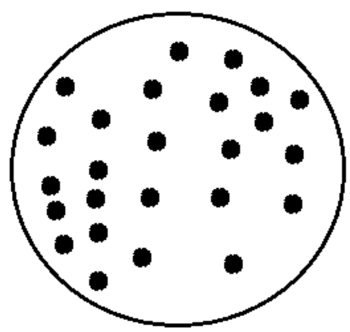
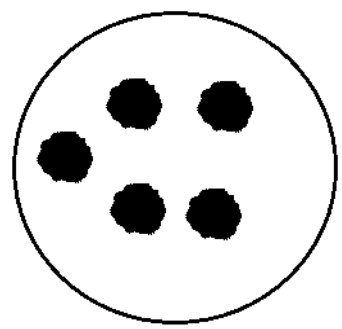
Example of percent shrub cover and number of shrub patches		
5% shrub cover represented as 5 clumps and 1 clump		
10% shrub cover represented as 10 clumps and 2 clumps		
25% shrub cover represented as 25 clumps and 5 clumps		

Figure 1. Examples of different estimates of percent shrub cover, and the number of shrub patches within a 150-m radius point count area.

Figure 2. Predictions from a single season occupancy model of species that the breeding bird survey estimates for Illinois suggest have been increasing.

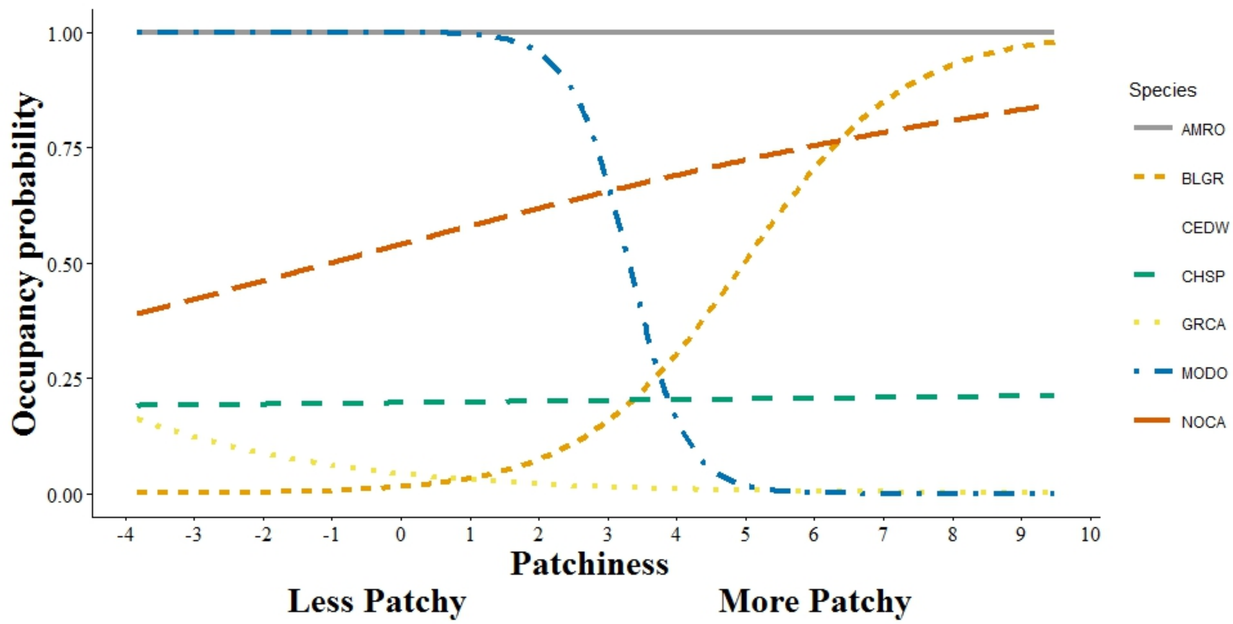
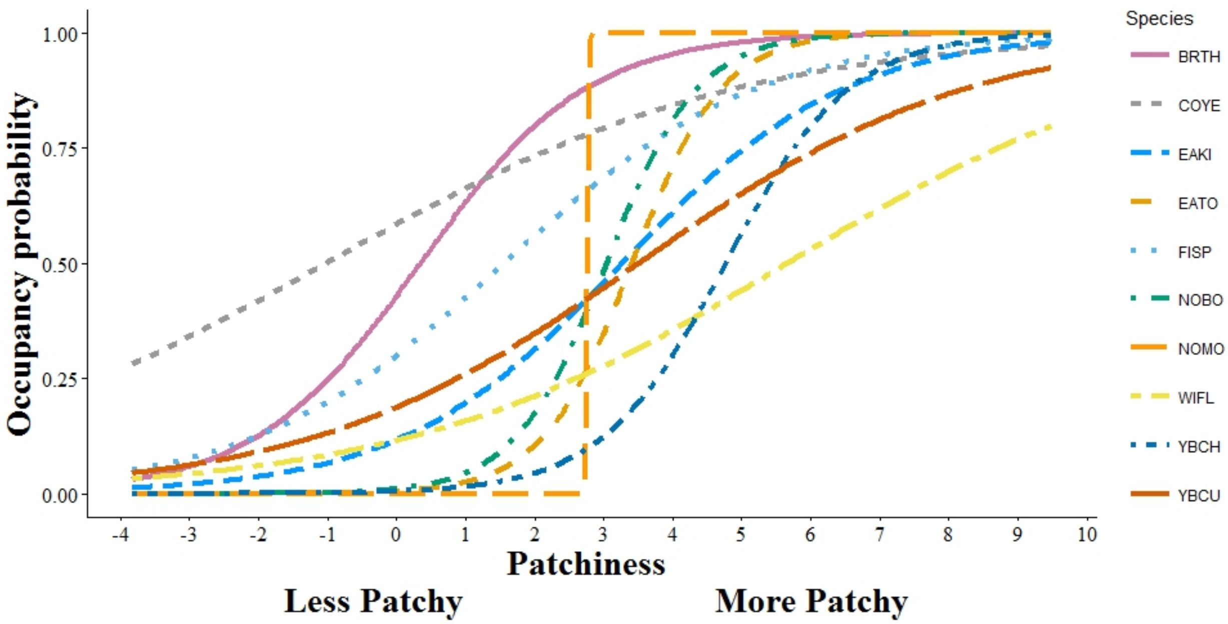


Figure 3. Predictions from a single season occupancy model of species that the breeding bird survey estimates for Illinois suggest have been decreasing.



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