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Effects of Surrounding Landscape Features on Avian Populations

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Abstract

Habitat structure has been shown to have a strong influence on the bird communities living within it. This study looked at the effects of nearby landscape features on bird populations in a variety of habitats. The study measured habitat composition and nearby features at a 500-ha site in Noble County, IN, USA to determine which landscape features most significantly affect diversity and density. Canonical Correspondence Analysis (CCA) was used to show correlations between bird species and habitat types and the Shannon diversity index was used to calculate diversity levels for each site. Proximity to landscape features such as roads and agricultural fields were shown to affect bird community composition, as did the proximity to other habitat types. The area of surrounding landscape with appropriate habitat also affects community composition. However, using only habitat areas was shown to be less accurate than considering both total available habitat and proximity of landscape features.

Introduction

With increasing urbanization and agriculture, habitat conversion and destruction has become a major problem for many species of birds. The increasing desire for bigger houses with larger plots of land has led to the development of previously isolated areas and the fragmentation of larger forests. Habitat fragmentation is the process of a habitat being partially removed, altering its original configuration. Fahrig (1997) defines fragmentation as the separation of formerly continuous habitat into several pieces representing the same overall amount of habitat. The fragmentation of forest and its effects on bird diversity and density has been a major topic for research. Research on habitat size has shown that bird community diversity in rural landscapes was primarily related to the amount of landscape in deciduous forest, native grassland, and roads (Boren et al. 1999). Some breeding birds, particularly the Ovenbird have been shown to be affected by distance to big woods (>5000 ha) (Mancke and Gavin 2000). The effect of other habitats nearby has not been researched as thoroughly.

In this study we examined how bird community composition was affected by the surrounding landscape. Individual species are also examined because each species responds differently to the different habitat variables. We also examined which habitat variables most influenced bird community composition. We expected that some species would increase in density closer to human dominated habitats because they are generalists and thrive with the increase of edge and ornamental vegetation as shown by Boren et al. (1999). I also expected species that nest in forest interiors would decrease in density close to human dominated landscapes as shown in the research by Beissinger and Osbourne (1982).

The objectives of this study are to determine: (1) if the distance to different habitats has an effect on an area's bird diversity and community composition, (2) which landscape features most affect bird community composition, (3) what nearby landscape features most affect forest bird communities, and (4) which species are sensitive to the presence of certain nearby habitat types.

Methods

An area in northern Indiana was selected that is composed of several prominent habitat types. Merry Lea Environmental Center is a managed area consisting of wooded areas, open wetlands (marshes), forested wetlands (swamps), restored and periodically burned prairies, and several small lakes. There are several trails that wind through the property but these are not high traffic and most likely have small influence the bird communities. The area surrounding Merry Lea is primarily human dominated landscapes (residential areas and agricultural fields). Sites were selected throughout the Merry Lea property, spaced in a grid 340 meters apart. Every intersection in the grid falling inside the Merry Lea property lines was selected as a sample point. This left a total of 32 accessible sample points.

The point was classified into wooded, grassland, residential, agriculture, swamp, and marshland habitats based on the dominant vegetation at the point. Each point was visited twice between June 10 and July 22 between dawn and 10 am on fair weather days. Mac Nally (1997) showed that two or more sampling times per season was effective to distinguish resident birds from visitors. The June start date roughly coincided with the end of spring migration to avoid counting non-resident birds. At each site, habitat and weather data were taken while the birds adjusted to the new human presence. All birds seen and heard were recorded along with an estimation of their distance from the observer. Time was limited to 6 minutes as this is the estimated amount of time necessary to count every individual species in the hearable range.

Since it is possible to detect some birds at a much larger distance than others, a variable circular-plot method was used based on the methods of Reynolds et al. (1980). With this technique, the radius within which birds could be identified was determined by looking a histogram of birds versus distance to the observer. The histogram plotted number of birds detected in increasing 20-m radii. When a 50% decrease in detection rate was observed, it was assumed to be due to the inability to detect all of the birds of the species beyond that distance. This is done individually for each species. All birds falling outside of that detectable range were removed from the data and the densities for the species were then calculated based on the birds sighted within this radius.

To study the area at each point a GIS map was created of the Merry Lea property and the surrounding area with each habitat occupying a different layer. The habitat data was obtained by using a 1.0-m resolution digital orthophoto quadrangle provided by the USGS as well as visual landscape observations. At all the points 300-m radii circles were laid over the map and the habitat falling inside of these circles was analyzed for percent habitat composition. This datum was also analyzed to determine distance from each point to each of the other habitat types as well as the distance to the nearest road. The 300-m diameter was the area assumed to be most directly influencing the bird community at each point. Proximity to habitat was calculated as the inverse of the distance as shown in equation (1).

$$\text{Proximity} = 1/\text{distance} \tag{1}$$

Both the species abundance and all environmental data were analyzed using canonical correspondence analysis (CCA) with the program CANOCO (ter Braak 1992) in order to determine the influence of environmental variables on bird abundance and composition. CCA is a constrained ordination technique that relates species composition to measured environmental variables (Palmer 1993). CCA models a unimodal response of the species to the environmental variables along a gradient (ter Braak 1986). This technique explains variation in the bird community by detecting the patterns of variation in the species data that can best be predicted by the measured environmental variables (ter Braak 1986, Boren et al. 1999).

To look at the bird communities' response to their surroundings, bird point densities were related to point habitat data with a CCA ordination. Points recognized by CANOCO to be greatly affecting the data were removed. The computer program CANOCO selected the most significant variables. Using an unrestricted Monte Carlo permutation, I tested the first two axes for significance ($P<0.05$). Initially, a CCA ordination was run with all sites data and then run with each habitat type individually to look for significant results. Significant data was obtained using the grassland sites and the forested sites.

Diversity was measured using the Shannon index for each point and averaged for each habitat type. Birds were also divided into three migration guilds (permanent, temperate, neo-tropical) and the diversity was calculated for each guild at each site.

Results

A total of 70 species of birds were found at the 32 sites during the summer. One species, Carolina Wren, was only heard on one occasion and from a great distance, not giving enough data to calculate density and was therefore deleted, leaving a total of 69 species. A total of 1178 individuals were recorded. After the variable circular-plot method was applied, 991 individuals remained. Species richness ranged from 6 to 20 species per point and Shannon species diversity ranged from 1.22 to 2.64 per point. Seven species (COYE, INBU, AMGO, AMRO, SOSP, NOCA, GRCA) were seen at over 50% of the points and two of these (NOCA, GRCA) were seen at 75% of the points.

Habitats ranged from entirely forested to 67% agriculture and only 16% forest. Most sites contained two or more habitat types. Overall, total sites consisted of 49% forest, 19% grassland, 18% agriculture, 6% wetlands, 5% water, and 3% residential.

The most important variables in the overall CCA (Figure 1) were proximity to agriculture, wooded, wetlands, grassland, proximity to grassland, and proximity to water. The eigenvalues for the first and second axes are fairly good (.554 and .440). The total species variation that was explained by this model is significant, with 26.9% explained by the first axis, 48.2% explained by the second axis, and 83.5% explained by the whole model. A Monte Carlo test of significance using 199 permutations showed that the data were significant (P=0.0050).

The most important variables in the CCA analyzing the eleven forested sites were agriculture, grassland, water, and proximity to road. The first axis makes the separation between Agriculture and all other habitats showing the importance of this habitat on bird communities. The second axis separates human variables from the natural habitats, stressing the influence of human interference. The CCA biplot (Figure 2) shows a strong negative correlation between diversity and human dominated areas (roads, agriculture). The biplot also shows the bird species clustered around 3 major vectors. The eigenvalues for the first and second axes were .809 and .551, respectively. The total species variation explained by this model is significant, with 44.7% explained by the first axis, 75.1% explained by the second axis, and 100% explained by the whole model. A Monte Carlo test of significance using 199 permutations showed that the data were significant (P=0.0100).

Some of the species in this biplot that show up as positively correlated with grassland (COYE, GCFL) may not really be correlated with grassland. What is probably happening is their negative response to agriculture is stronger than any other association. One important thing to remember is that the biplot only takes into account the first two axes. The third and fourth axes are important for explaining all the relationships but cannot be displayed in two dimensions.

The biplot of forest sites show the species clustering around three major vectors. These can be classified as species associated with agriculture, species associated with residential areas, and species that are associated with bodies of water. The species that are furthest from the center of the biplot are those that are most associated with the environmental variables in that quadrant.

In the grassland CCA (Figure 3), the most important variables in the CCA were agriculture, grassland, water, proximity to woods, and proximity to water. The majority of the species were strongly associated with proximity to woods and agriculture. The eigenvalues for the first and second axes were .827 and .666, respectively. The total species variation explained by this model is significant, with 32.8% explained by the first axis, 59.2% explained by the second axis, and 92% explained by the whole model. A Monte Carlo test of significance using 199 permutations showed that the data were significant (P=0.0400).

Discussion

Bird communities are clearly influenced by their surroundings as expected. The CCA graphs show strong correlations between variables such as habitat size and proximity to other habitats with the diversity of the bird communities. Human dominated landscapes showed the strongest influence, especially on forest communities. These include residential areas, agricultural fields, and roads.

In forest communities (Figure 2) and in all the sites (Figure 1), the presence of agriculture had a negative effect on bird diversity, with only 5 species strongly correlated with agriculture at forested sites (Figure 2) and only 2 species in the overall CCA (Figure 1). The large monoculture of an agriculture area provides good habitat for very few species, mainly introduced species such as the House Sparrow and the European Starling as well as swallows, which are attracted to the insects in the fields. Forest area is important in explaining the bird-habitat interactions in the CCA including all sites (Figure 1). The Ovenbird is strongly associated with large forested areas, which is consistent with the research done by Mancke and Gavin (2000) when they studied the effects of depth on breeding bird density in forests. Proximity to forest is also important in describing the interactions occurring in grassland communities (Figure 3). This is most likely due to the edge effect present in the boundary between the grassland and forest.

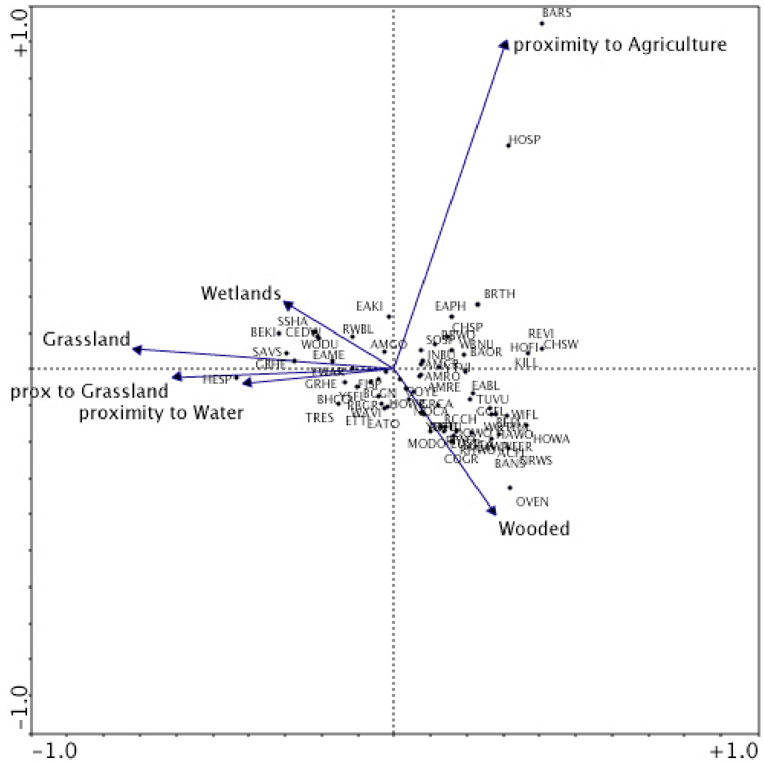

Figure 1. Canonical Correspondence Analysis (CCA). All bird species vs. habitat variables for each sample site.

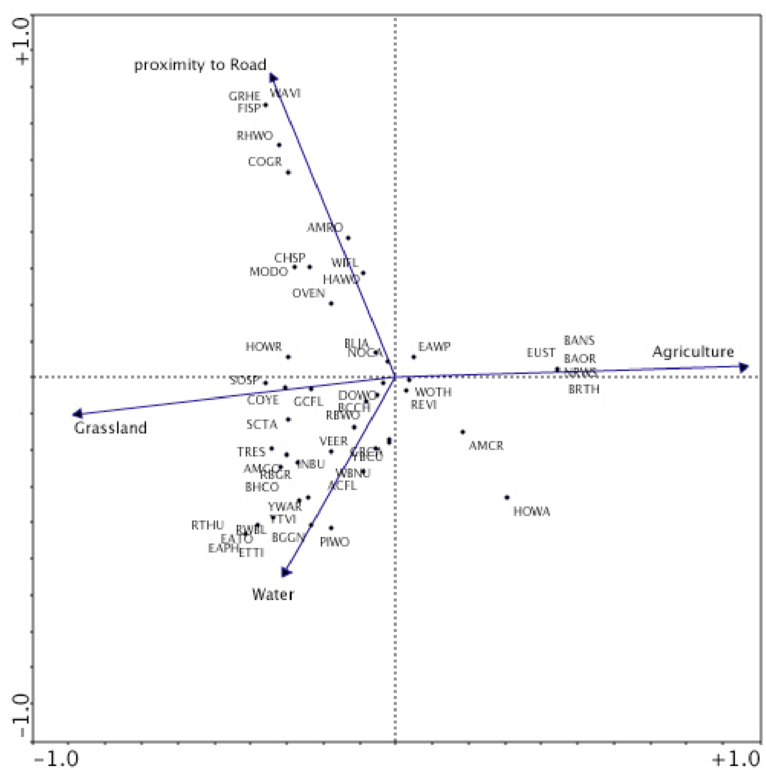

Figure 2. Canonical Correspondence Analysis (CCA). Bird species found in forested sites vs. habitat variables from forested sites.

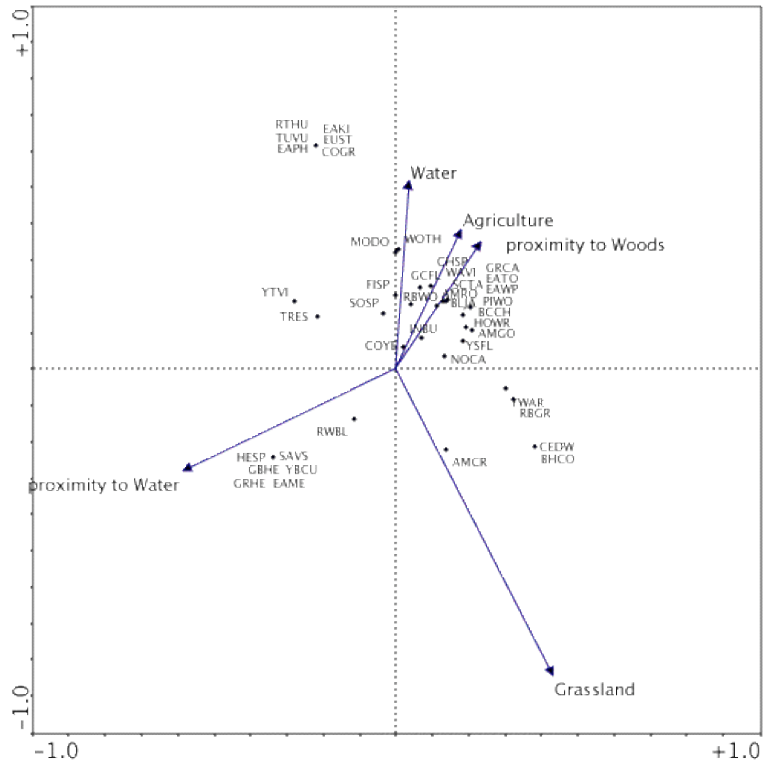

Figure 3. Canonical Correspondence Analysis (CCA). Bird species found in grassland sites vs. habitat variables from grassland sites.

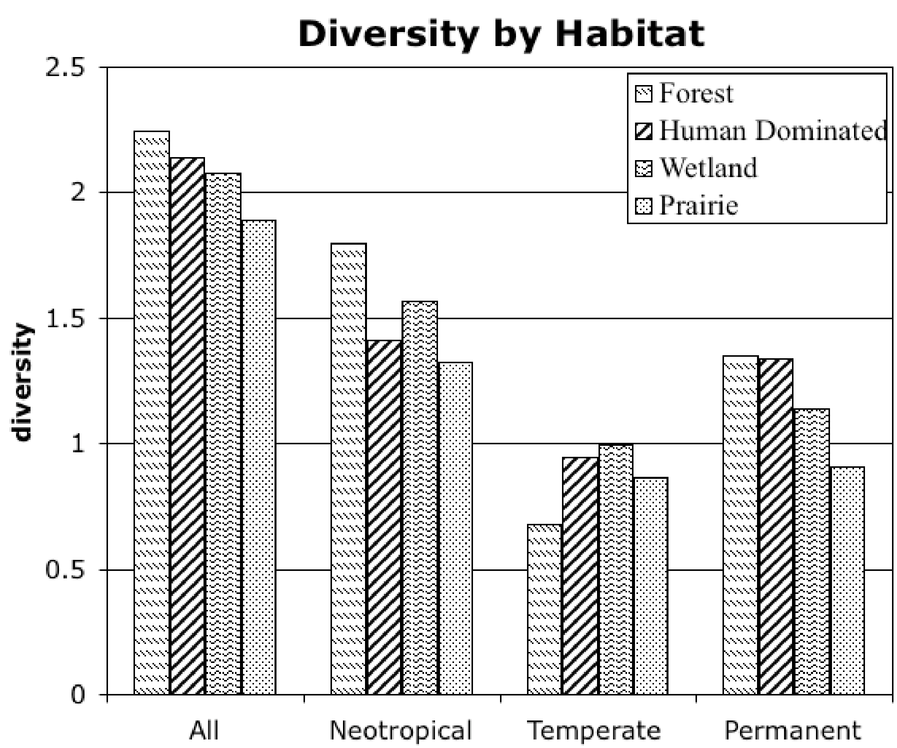

Figure 4. Diversity by habitat for entire site and each migration guild

For forest sites (Figure 2), the proximity to roads was also important for explaining many interactions. The Hooded Warbler shows a strong negative correlation with proximity to roads, which is expected as it is a forest-interior bird, while some birds such as Common Grackle and the Field Sparrow are positively influenced by proximity to roads. In a study looking at the effects of urbanization on riparian bird communities, Rottenborn (1999) looked at the richness and density along riparian corridors and found that species richness and diversity were negatively related to the abundance and proximity of bridges. Rottenborn found that sites located closer to developed areas had lower species richness, and the densities of several species increased as proximity to roads and buildings decreased. Another study by McDonnell et al. (1993) predicted that species richness should peak at intermediate levels of development because biotic limitations are high at the rural end and physical limitations are high at the urban end of an urban-to-rural gradient. These results are similar to the findings in this study.

The three most influential habitat features were proximity to agriculture, area of agriculture, and proximity to road. It is obvious from these results that human dominated areas have a great influence on the composition of surrounding bird communities.

There are several bird species that are highly correlated with forested areas and negatively correlated with proximity to woods. These birds such as the Hooded Warbler, Ovenbird, Wood thrush and Veery are all forest interior birds and tend to avoid any interaction with human dominated areas. Any further fragmentation and these birds would likely not return to nest because they are presently only occurring at the sites with the largest areas of forest.

One interesting thing that shows up in this data is the importance of proximity to other habitats. Half of the variables selected as most significant by the CANOCO program are proximities, emphasizing their importance. This data suggests that habitat area is not the only variable that needs to be looked at.

Looking at the diversities obtained using a Shannon index (Figure 4), the average diversity for forest sites is higher than other habitat types for most migration guilds, which is expected. The only discrepancy is that with the temperate migrating guild, wetland habitats have the highest diversity. This can be explained by looking at the birds that belong to this guild, several sparrows and most of the water birds. Human dominated diversity is slightly lower but still fairly high, mainly due to the fact that most of these sites contained a large amount of edge. Prairie habitat diversity was relatively low across all migration guilds. One possible reason is that several bird species such as Red-winged Blackbirds are so abundant in the prairie areas that their presence lowers species diversity.

Conclusion

Proximity to landscape features and area of habitats have a significant impact on the composition of surrounding bird communities. There are many reasons for this impact including availability of roosting and nesting locations, food, and predators. Agriculture and proximity to roads were particularly influential on the composition of surrounding bird communities, especially affecting forest birds. Forest interior birds demonstrated a negative reaction to human dominated features, while the density of generalists such as House Sparrow increased in these areas. In a study looking at abundance of forest and the composition of bird communities (Askil et al.), it was shown that the amount of forest in the vicinity of a tract tends to be related to the density and species-richness of forest-interior birds. It was also shown by the same study that interior-edge birds are equally common in large and small forests, while both the density and species richness of forest-interior birds are higher in large forests. This study suggests that the forest-interior birds are influenced more by distance to roads and agriculture than by the size of forest. High abundance of forest-interior birds may depend on the absence of human dominated habitats.

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Appendix

Table 1. Four letter bird codes.

Acadian Flycatcher	ACFL	House Finch	HOFI
American Crow	AMCR	House Sparrow	HOSP
American Goldfinch	AMGO	Hooded Warbler	HOWA
American Redstart	AMRE	House Wren	HOWR
American Robin	AMRO	Indigo Bunting	INBU
Bank Swallow	BANS	Killdeer	KILL
Baltimore Oriole	BAOR	Mourning Dove	MODO
Barn Swallow	BARS	Northern Cardinal	NOCA
Black-capped Chickadee	BCCH	Northern Flicker	NOFL
Belted Kingfisher	BEKI	Northern Rough-winged Swallow	NRWS
Blue-gray Gnatcatcher	BGGN	Ovenbird	OVEN
Brown-headed Cowbird	BHCO	Pileated Woodpecker	PIWO
Blue Jay	BLJA	Rose-breasted Grosbeak	RBGR
Brown Thrasher	BRTH	Red-bellied Woodpecker	RBWO
Cedar Waxwing	CEDW	Red-eyed Vireo	REVI
Chipping Sparrow	CHSP	Red-headed Woodpecker	RHWO
Chimney Swift	CHSW	Red-tailed Hawk	RTHA
Common Grackle	COGR	Ruby-throated Hummingbird	RTHU
Common Yellowthroat	COYE	Red-winged Blackbird	RWBL
Downy Woodpecker	DOWO	Savannah Sparrow	SAVS
Eastern Bluebird	EABL	Scarlet Tanager	SCTA
Eastern Kingbird	EAKI	Song Sparrow	SOSP
Eastern Meadowlark	EAME	Sharp-shinned Hawk	SSHA
Eastern Phoebe	EAPH	Tree Swallow	TRES
Eastern Towhee	EATO	Turkey Vulture	TUVU
Eastern Wood-Pewee	EAWP	Veery	VEER
Tufted Titmouse	ETTI	Warbling Vireo	WAVI
European Starling	EUST	White-breasted Nuthatch	WBNU
Field Sparrow	FISP	Willow Flycatcher	WIFL
Great Blue Heron	GBHE	Wood Duck	WODU
Great Crested Flycatcher	GCFL	Wood Thrush	WOTH
Gray Catbird	GRCA	Yellow-billed Cuckoo	YBCU
Green Heron	GRHE	Yellow-throated Vireo	YTVI
Hairy Woodpecker	HAWO	Yellow Warbler	YWAR
Henslow's Sparrow	HESP		