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The Influence of Spatial Scale on Landcover and Avian Community Relationships within the Upper Green River Watershed, KY

Cabrina L. Hamilton
Western Kentucky University

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THE INFLUENCE OF SPATIAL SCALE ON LANDCOVER AND AVIAN
COMMUNITY RELATIONSHIPS WITHIN THE UPPER GREEN RIVER WATERSHEAD

by

Cabrina L. Hamilton

A Capstone Experience/Thesis

submitted in partial fulfillment of the requirements of

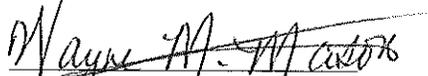
University Honors College at

Western Kentucky University

Approved by:


Albert J. Meier


Ouida W. Meier


Wayne M. Mason

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by

CABRINA L. HAMILTON

Under the Direction of Dr. Albert J. Meier

ABSTRACT

Landscape ecology studies are needed to aid land managers and conservationist in developing management plans that will effectively improve avian population trends. This study uses riparian avian point count survey data and landcover data to examine the possible relationships between riparian avian communities and landcover within the Upper Green River watershed. How avian-landcover relationships change with increasing spatial scale is also examined. Results showed unexpected avian-landcover relationships for specific species. A landcover gradient from open and successional habitat to closed, forest habitat was most prevalent in the study area and explained most of the variation within the avian datasets. Riparian avian communities within the watershed responded more to landcover at a broader spatial scale than at a finer spatial scale.

INDEX WORDS: Landscape ecology, Spatial scale, Birds, Riparian

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CABRINA HAMILTON

Committee Chair: Dr. Albert J. Meier

Committee: Ouida W. Meier
Wayne M. Mason

Electronic Version Approved:

Honors College
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INTRODUCTION

Avian monitoring efforts during the past five decades have demonstrated that numerous avian species have undergone dramatic population declines throughout the United States (Rich *et al.* 2004, Robbins *et al.* 1989). Many of these species require management plans in hopes of slowing or reversing these population trends (Rich *et al.* 2004). Increased knowledge of the ecological factors influencing avian populations will better aid wildlife managers in conservation efforts directed at stabilizing or improving particular avian species' population fluctuations and community dynamics. Ecological studies need to be coupled with avian monitoring at local and regional scales to better plan for local and regional management.

Landscape studies have been incorporated in avian population studies to provide more complete understanding of the environmental factors affecting avian population fluctuations. Turner (2005) reviewed landscape ecology literature and comprised a concise and general definition of a landscape: "an area that is spatially heterogeneous in at least one factor of interest." This general definition allows for flexibility in the landscape characteristics used within avian studies and the spatial scales at which those studies can take place (Turner 2005). Variables studied within landscapes are often quantitative (an area measurement of landscape characteristics) or describe the configuration of landscape characteristics.

Landscape heterogeneity uses a quantitative landcover, topography, climate, or other landscape characteristic measurement to describe the landscape's diversity of habitat. Landscape heterogeneity may not show linear relationships when tested against multiple species due to differences in habitat needs, life history characteristics, and dispersal strategies

(Wagner and Fortin 1978). Different avian guilds require a heterogeneous landscape in which to carry out life history traits: i.e., resource allocation, breeding, rearing of young, and migration. These needs vary temporally and among species. Flather and Sauer (1996) found that different migratory avian species and guilds had varying responses to landscape heterogeneity variables: edge effects, habitat diversity, habitat fragmentation, and habitat dispersion. They suggested that patterns in landscape may not be the same regionally, and conservation planning should consider that associations with landscape structure differ between avian species (Flather and Sauer 1996).

MacArthur determined that vegetation height diversity within a habitat determines bird species diversity found in that habitat (MacArthur and MacArthur 1961). MacArthur's finding has been supported by more recent studies (Roth 1976, Willson 1974, Cody 1968). Likewise, increased heterogeneity within landscapes is generally considered to raise species diversity, because heterogeneity increases the number of niches and habitats available (Turner *et al.* 2001). Habitats within a heterogeneous landscape may only promote species diversity if the habitat is suitable for species, and habitat suitability may be limited by habitat area, shape, structure, edge amount, and other characteristics (Graham and Blake 2001, Vance *et al.* 2003, Herkert 1994, Sisk *et al.* 1997, Askins 2000).

Quantifying landscape heterogeneity within a landscape analysis may provide a measure of habitat fragmentation and loss, if anthropogenic alterations of the landscape increase heterogeneity. For example, the amount of farmland within a landscape represents native habitat loss and fragmentation. Landscape studies that focus on habitat fragmentation have generally yielded negative relationships between biodiversity and increased fragmentation (Fahrig 2003). Landscape studies suggest that habitat fragmentation and loss

from agricultural practices and other human activities has decreased grassland bird populations and species richness (Herkert 1994, Jones–Farrand 2007, Fletcher and Koford 2003, Coppedge *et al.* 2001, Murphy 2003) and forest associated species (Rodewald and Yahner 2001, Boulinier *et al.* 2001). Donovan and Flather (2002) tested whether regional population change for species whose reproduction success is negatively affected by habitat fragmentation depended on the proportion of the population occupying the fragmented landscape. They concluded that fragmentation could greatly affect regional populations. Variables other than fragmentation could affect regional populations as well, and more studies examining the effects of life history traits as well as other possibly influential variables are needed (Donovan and Flather 2002).

General landscape variables, such as the amount and proportion of different land cover types and the spatial arrangement of land cover, have been shown to explain avian populations fluctuations, species richness, and community characteristics. Landscape characteristic models were able to predict the distribution of forest birds showing the best fit for migrant species and habitat specialist and a poorer fit for resident species and generalist (Mitchell *et al.* 2001). Mitchell *et al.* (2001) concluded that coarse landscape characteristic models best predict migrant species limited by the breeding habitat available. Similarly, Lichstein *et al.* (2002) also found that Neotropical migrants within a forest landscape were significantly correlated to landscape variables. Saab (1999) found that the landscape most frequently predicted species occurrence in riparian forests. In grasslands, higher avian densities were associated with landscapes of lower cover type diversity (Ribic and Sample 2001). Differences in survey methodology and landscape makeup may present different

results. For example, a landscape that contains an array of distinct habitat types may show different influences on avian populations than landscapes that are uniform in habitat.

Landscape ecology is flexible in that it allows research to focus on the spatial scale that pertains specifically to the organism of interest (Turner 2005). Turner (2005) states that finding the spatial scale that best explains organism response to habitat heterogeneity “remains a key goal in landscape ecology.” Spatial scales fall under general categories: local scale reflects vegetation species richness, the landscape scale reflects different vegetation communities, and the regional scale reflects different landscapes (Whittaker 2001). Landscape spatial scales have been defined at different extents; Bohning-Gaese (1997) defines local scales as generally 0.0025 to 0.4 km² and regional scales as generally 400 – 50,000 km². Many studies create their own definition for local, intermediate, and regional scales while complying to general standards.

Measures of diversity are influenced by the scale at which they are studied (Bohning-Gaese 1997). Increasing the spatial scale of a landscape study increases the possibly influential variables present; therefore, a broader scale may provide a greater explanation of variation, but deciphering the actual influential variables may become more difficult. Autocorrelation between landscape variables also poses a threat to independent sampling, and measures should be taken within experiment design and analysis to reduce the effects of possible autocorrelation (Wagner and Fortin 2005).

Literature presents varying conclusions regarding the following questions: 1) Do landscape scales provide greater explanatory power for avian associations than local scales, and 2) How do different landscape spatial scales affect the associations between landscape variables and birds? In some contexts, broader scales yield little additional information when

compared to local habitat scales (Lichstein *et al.* 2002). Lichstein *et al.* (2002) found that although all the forest birds he studied showed a significant correlation to at least one landscape variable, landscape factors provided only a small increase in the variation explained by local habitat variables. This suggests that forest bird species are more affected by habitat amount than by habitat configuration, but studies that examine more landscape variables are suggested (Lichstein *et al.* 2002). In contrast, landscape variables were more important to avian densities and/ or species richness than local habitat characteristics for either all species studied or a number of the species studied in a grassland landscape (Ribic and Sample 2001), a riparian landscape (Saab 1999), a forest landscape (Rodewald and Yahner 2001), and a matrix landscape (Pearson 1993).

Mitchell *et al.* (2001) concluded that “no single scale is appropriate” when correlating several avian species or guilds with landscape variables. Bohning-Gaese (1997) suggests a need for studies that examine landscape influences on an “intermediate” scale. Landscape variables have shown avian associations at finer (Pearson 1993, Ribic and Sample 2001) and broader (Bohning-Gaese 1997) intermediate scales. Multiscale analysis is necessary to discover landscape influences that are occurring over several spatial scales. If any element of the landscape is heterogeneous, then a single scale analysis cannot be scaled up or down to explain influences on finer or broader scales (Turner *et al.* 2001).

Pearson (1993) studied how landscape characteristics at different spatial scales and microhabitat vegetation influenced avian communities; his study methodology is unique in that the bird surveys were done within the same habitat and landscape characteristics were analyzed surrounding the study plots at constant spatial intervals and in equal size. Holding the bird survey habitat constant reduced the influence of variables outside the scope of the

study, allowing for stronger conclusions regarding the influence of the landcover variables studied on bird communities. Specifically Pearson studied avian communities within electrical powerline and natural gas pipeline right-of-ways which contained successional vegetation. He studied the influences of microhabitat vegetation and the influence of landcover within five 100 m wide concentric bands, all within 500 m radiating out from the right-of-ways on wintering bird populations. Pearson found that the surrounding landscape characteristics accounted for thirty to ninety percent of the variation within the bird abundance. Landscape characteristics also completely explained the variation in bird species richness and bird species diversity. While some species were most strongly influenced by landscape characteristics, other species were more strongly related to within patch vegetation (Pearson 1993). Pearson's study provides a strong experimental methodology to examine the influences of landscape variables within different spatial scales on bird communities.

Riparian zone avian communities provide an interesting ecological background for studies of landscape effects on bird communities and landscape effects at different spatial scales. Riparian zones consist of vegetation and abiotic characteristics that undergo constant spatial and temporal change through disturbance, creating variable habitat that is utilized by many avian guilds for different life history uses (Naiman and Decamps 1997). Because riparian zones offer a heterogeneous habitat, they are thought to generally hold more avian species than surrounding habitat (Naiman and Decamps 1997, Naiman and Decamps 1993). Naiman and Decamps (1993) state that riparian biodiversity should be considered at a landscape perspective. Saab (1999) studied habitat use by riparian breeding birds in the western United States at different spatial scales. Saab found that the landscape scale was the most frequent significant predictor of species occurrence (Saab 1999).

This study uses the Upper Green River watershed (UGRW) riparian zone of Kentucky to study the effects of landscape at different spatial scales on breeding bird communities. A large scale conservation program, the Conservation Reserve Enhancement Program (CREP), is designed to within the Upper Green River to both improve water quality and enhance wildlife habitat (The Commonwealth of Kentucky 2000). A prior study has shown that certain avian species are significantly more abundant within UGRW CREP tallgrass plantings than within agricultural pastures/ hayfields (Hulsey *et al.* 2008). The Conservation Reserve Program (CRP), from which CREP stems, has been shown to provide habitat for several avian species during the breeding season (Patterson and Best 1996, Klute *et al.* 1997, Johnson and Schartz 1993, Deslisle and Savidge 1997, McCoy *et al.* 2001) and for winter residents (McCoy *et al.* 2001, Deslisle and Savidge 1997, Best *et al.* 1998). CREP has been found to contain higher total bird density and species richness during summer when compared to row crop fields (Blank and Gill 2006). These results indicate that CRP is a viable avian conservation and population restoration program. This conservation program is changing the landcover within the watershed, but it is unknown if small scale (within agricultural fields) bird abundance increases are also occurring at broader landscape scales within the watershed. This study will not directly evaluate the effects of the UGRW CREP, but it can provide better understanding of avian community and abundance trends during this time of CREP landscape alteration within the UGRW.

The objective of this study is to determine which landcover types most influence riparian bird community composition, how spatial scale changes these influences, and at which spatial scale the influences are the greatest. This study also aims to determine if bird population increases that are occurring within CREP tallgrass plantings compared to pasture

fields will be shown at broader scales. Are these particular species also responding to landcover at a landscape level? The following hypotheses were made:

1) Avian community composition will change with change in landcover type, showing distinct groupings of species that utilize forested and non-forested habitats. Bird species will be grouped into guilds based on the landcover that matches birds' habitat preference for breeding and foraging.

2) Spatial scale will change the species grouped within guilds, because species may have different territory size or mobility.

3) Avian communities, individual avian species, and species richness will be more strongly correlated to landcover at finer scales than within broader scales during the breeding season. The species present will be restricted to breeding territories that are probably concentrated within the area they were sited.

4) Species richness will be correlated to landcover heterogeneity. The increase in landcover types will offer a greater variety of habitats or niches for a greater number of species to occupy; although, landcover types, such as row-cropped fields, that cannot be utilized by the birds and that create the loss of useable habitats will decrease species richness.

5) The particular avian species that were significantly more abundant in CREP tallgrass plantings will respond to landcover scales that contain the habitat resources they require. These species will be positively correlated to non-forested landcover types since they represent successional grassland and generalist guilds. These species have been found to be significantly more abundant in CREP tallgrass plantings (Hulsey *et al.* 2008), and likewise, will have increased in the Upper Green River watershed. This increase will appear within the

study area, because CREP plantings are implemented near the riparian zone, within the spatial scales studied.

The results of this study will provide better understanding of the effects of landscape characteristics on avian communities which will aid land managers and conservationist in making more effective land management decisions.

METHODS

Study Site

This study took place in the Upper Green River watershed (UGRW) in Kentucky, USA. The Green River is a sixth order river of high biodiversity. The highest biodiversity and endemism is found in the Upper Green River section which includes the river stem running from the Green River Dam to the confluence with the Barren River (The Commonwealth of Kentucky 2000). Seven federally endangered mussel species, one federally endangered cave shrimp, and two federally endangered bat species are found in the watershed along with several federal and state threatened species and species of concern (The Commonwealth of Kentucky 2000). The UGRW is located in an agricultural region. The UGRW was enrolled in the Conservation Reserve Enhancement Program (CREP) in 2000 in efforts to reduce and control non-point source pollution, mainly from agriculture. The program pays private landowners to take land out of agricultural production and plant tallgrass or bottomland hardwood tree buffers (The Commonwealth of Kentucky 2000). In 2007 the UGRW CREP was expanded to include the watershed area to the confluence of the Green River and the Barren River, adding 382793 eligible hectares (Kentucky Division of Conservation 2007). 33404 ha of the 753890 ha eligible are currently enrolled in CREP

contracts, buffering approximately 1990 km of the Upper Green River and its tributaries (Kentucky Division of Conservation 2007). The goals of the program are to reduce non-point source pollution in the Upper Green River and its tributaries and to improve wildlife habitat (The Commonwealth of Kentucky 2000).

The implementation of the CREP and the biological uniqueness of the UGRW have designated the area as a region of interest for ecological landscape studies. Although this particular project does not directly include CREP as a landuse variable and does not directly study any impacts of the CREP, current avian and landscape studies may yield insightful information for the future conservation in this area. Survey canoe routes in five areas of the UGRW were chosen to achieve a representative sample of watershed riparian areas. Three of the five routes are located on the main stem of the Green River and two of the five routes are located along major tributaries of the Green River: the Little Barren River and Russel Creek. For each route a point count was conducted every 731 m as measured by GPS units. If bank conditions or a high amount of noise prevented a point count from being conducted every 731 m, that particular site was skipped, and the point count was taken at the next 731 m site available downstream. The point count center was within twenty-five m of the river bank, within the riparian zone. Forty-four points total were surveyed. Routes did not contain an equal number of points due to access limitations. Sixteen points were conducted in Mammoth Cave National Park and twenty-eight points were conducted outside the park in four different counties.

For this study the riparian zone is considered the area immediately adjacent to the river. The forested riparian corridors have been dramatically reduced by agricultural practices in many areas of the Upper Green River watershed. An estimated eighty percent of

the bottomland hardwood forest within the Green River watershed has been cleared for agricultural use (The Commonwealth of Kentucky 2000). The second growth forest of the area is about seventy-five years old (The Commonwealth of Kentucky 2000). Point counts were taken within twenty-five meters of the river so that the sampled habitat type (bottomland riparian forest) was held as constant as possible sensu (Pearson 1993).

Bird Surveys

Ten minute circular point count surveys were conducted by Kentucky Fish and Wildlife Resources personnel with minor alterations sensu (Hamel *et al.* 1996). Modifications were made based on suggestions by Farnsworth *et al.* (2002) and Rosenstock *et al.* (2002) in order to preserve sample size and better estimate detection probabilities. Point counts were modified to have a duration of ten minutes with birds recorded separately for three distinct time intervals (zero to three min, four to five min, six to ten min), and modified distance bands included areas zero m to twenty-five m, twenty-five m to fifty m, fifty m to one hundred m, greater than one hundred and flyovers. Birds within each band were included in analysis, but flyovers were not included following the protocol of Nur *et al.* (1999). Surveys were conducted from the last week in May (one survey began in the second week of May) to the third week in June from 2004 through 2007. Surveys were not conducted in rain or high winds. Permission to use any data presented in this paper is required and can be gained by contacting the Nongame Branch of the Kentucky Fish and Wildlife Resources.

Landscape Analysis

Landscape analysis was taken from the Kentucky Land Cover Data Set 2001 and all analyses were performed with ESRI ArcGIS 9.3. Landcover was analyzed at a thirty m² grain

size. To study landscape effects at different spatial scales, three concentric circles were drawn around the center of each survey point with 100m, 300m, and 500m radii from the point center. The square footage of each landcover type was then tabulated within each of the three different circular areas. Square footage was converted to square meters.

Certain landcover area measurements were aggregated to create landcover variables with broader descriptions to prevent autocorrelation and decrease landcover identification error. Table 1 gives the aggregated landcover types used for multivariate analysis. Table 2 provides a slightly modified landcover aggregation that was used for regression analysis. A different landcover aggregation strategy was used for regression analysis, because small variance values for some landcover variables decreased statistical power more so in the regression analysis than within the multivariate analysis. The proportion of each landcover variable (x) within its respective circle was calculated and arcsine \sqrt{x} transformed.

A landscape diversity measure, shown in Figure 2 (Turner *et al.* 2001), was used to calculate the landcover heterogeneity for each sample site at each spatial scale. The landcover heterogeneity measure was calculated using the twenty four original, un-aggregated landcover types as described by the Kentucky Land Cover Data Set 2001. Within the landscape diversity measure equation, H = landcover heterogeneity, p_i = the proportion of the landscape occupied by landcover type i , and s = the number of landcover types present. This measure ranges from values of zero to one, with one representing low heterogeneity and zero representing high heterogeneity.

Statistical Analysis

Avian point count data was rarified at the twenty percent abundance level. Bird species matrices for 2004 and 2007 were $\log(x+1)$ transformed. Canonical Correspondence Analysis (CCA) was performed to determine the influence of seventeen landcover variables (Table 1) at three different spatial scales on the variation of the riparian avian species for each year (twenty four species in 2004 and twenty three species in 2007) using CANOCO. Also using CANOCO, Principle Components Analysis (PCA) was performed with the $\log(x+1)$ transformed and rarified bird species matrices of 2004 and 2007 to summarize variation in the bird communities.

The particular species that were found to be significantly more abundant in CREP fields than pastures (Hulsey *et al.* 2008) and that were present in the 2004 and 2007 bird species matrices after rarefaction were used for individual species analysis. For the 2004 bird data, the individual species chosen for analysis were the American goldfinch, brown-headed cowbird, common yellowthroat, indigo bunting, and northern cardinal. For the 2007 bird data, the individual species chosen for analysis were the common yellowthroat, indigo bunting, and northern cardinal. The relationship between these individual bird species and the landcover variables and between species richness and the landcover variables (Table 2) at the three different spatial scales was determined using a stepwise multiple linear regression with a backward strategy using the $\log(x+1)$ transformed and rarified bird species data of 2004 and 2007. Species richness data were not transformed and were calculated before rarefaction. Landcover variables with a significance level of 0.05 were retained. The relationship between species richness and landcover diversity was determined using simple linear regression. Species richness was calculated separately for 2004 and 2007 using raw bird data. The

individual bird species included in the multiple regression analysis and that were also found in both the 2004 bird dataset and the 2007 bird dataset were used to examine abundance changes of individual bird species. These species were common yellowthroat, indigo bunting, and American goldfinch. A Kruskal-Wallis test was performed using 2004, 2005, 2006, and 2007 raw point count data with year as the grouping variable to determine abundance trends. All regression analysis and the Kruskal-Wallis tests were performed in SYSTAT 11.0.

RESULTS

Canonical Correspondence Analysis (CCA)

The CCA model produced by the 2004 bird data and the 100 m spatial scale landcover data showed that canonical axis one explained 11.6 % (eigenvalue 0.116) of the variation within the bird dataset, but axis one was not significant. Axis one showed an unclear landcover gradient that may represent a moisture gradient. Deciduous Forest and Early Successional were positively loaded on axis one. Riparian Forest, Barren, Water, and Woodland Wetland were negatively loaded on axis one. Canonical axis two explained 8.7 % (eigenvalue 0.087) of the variation within the bird dataset. Axis two shows a gradient that may range from a more open habitat to a moister and more closed habitat. Pasture and Deciduous Woodland were positively loaded on axis two. Woodland Wetland and Deciduous Forest were negatively loaded on axis two.

To better understand the relationships between the bird community and landcover variables I consider the bird species within the context of life-history guilds, although the species were not grouped into guilds prior to analysis. Guild classification is based on life-history and is strongly influenced by environment. Guild classification can provide useful

insight for understanding how birds should respond to environmental variables, and in this case, landcover variables (Hansen and Urban 1993). Table 3 provides a list of the habitat guilds and the species placed in them.

The CCA model produced by the 2004 bird data and the 100 m spatial scale landcover data showed that generalist species, northern cardinal, brown-headed cowbird, American goldfinch, and American crow, were positively loaded on axis one, placing them in forest and successional habitat. Successional grassland species, indigo bunting, and common yellowthroat, did not have strong loadings on either axis. Some forest species were positively loaded on axis one and axis two, and other forest species were negatively loaded on axis one as well as axis two. The forest species that showed a strong positive loading on axis one were Louisiana waterthrush, downy woodpecker, and red-bellied woodpecker. The forest species that showed a strong negative loading on axis one were Kentucky warbler, Carolina chickadee, and white-breasted nuthatch. The forest species that showed a strong positive loading on axis two was tufted titmouse. The forest species that showed a strong negative loading on axis two were Louisiana waterthrush and northern parula.

The CCA model produced by the 2007 bird data and the 100 m spatial scale landcover data showed that canonical axis one explained 11 % (eigenvalue 0.11) of the variation within the bird data, and axis one was significant ($p = 0.006$). Cropland and Pasture were negatively loaded on axis one. Riparian Forest was positively loaded on axis one. The axis one landcover gradient ranged from forested landcover to open landcover. Canonical axis two explained 8 % (eigenvalue 0.08) of the bird dataset variation. Coniferous Forest, Oak Pine Forest, Early Successional, Developed Open Space, and Other Mixed Forest were positively loaded on axis two. Deciduous Woodland and Woodland Wetland were

negatively loaded on axis two. The axis two landcover gradient ranged from successional habitat, including herbaceous cover and coniferous forest, to more mature deciduous forest habitat. Indigo bunting, song sparrow, and common yellowthroat are the three successional grassland species within the 2007 bird dataset. These species were separated on the open habitat to forest gradient of axis one. Indigo bunting and song sparrow were found in more open habitats while common yellowthroat was found in a more closed habitat. On axis two, the gradient moving from successional to mature forest, common yellowthroat was found in more successional habitat and indigo bunting and song sparrow were placed in a more mature woodland habitat. The two generalist species, northern cardinal and American crow, were placed in open habitat on axis one. Northern cardinal and American crow did not load heavily on axis two. The only forest riparian species, prothonotary warbler, showed a heavy negative loading on axis one, placing it in open habitat, and loaded slightly positive on axis two, placing it in successional habitat. The remaining species were all forest species and were distributed across both axes. More forest species were positively loaded on axis one, placing them in forest habitat. The forest species most positively loaded on axis one were Kentucky warbler, Louisiana waterthrush, wood thrush, and northern parula. Figure 3 shows a bi-plot containing the bird species and important landcover variables.

The CCA model produced by the 2004 bird dataset and the 300 m spatial scale landcover data showed that canonical axis one explained 14 % (eigenvalue 0.14) of the variation within the bird species data, but axis one was not significant. Axis one showed a landcover gradient that ranged from open and successional habitat to a more closed, forest habitat. Coniferous Forest and Riparian Forest were negatively loaded on axis one. Early Successional, Pasture, Cropland, Developed Open Space, and Deciduous Woodland were

positively loaded on axis one. Canonical axis two explained 8 % (eigenvalue 0.08) of the bird dataset variation. Axis two showed a gradient that ranged from open and wet habitat to a more closed, mixed forest habitat. Pasture/ Hay, Water, and Barren were positively loaded on axis two. Oak Pine Forest was negatively loaded on axis two. Successional grassland species, indigo bunting and common yellowthroat were not strongly loaded on axis one, and common yellowthroat was negatively loaded on axis two which placed it in a more forested habitat. The generalist species, northern cardinal, brown-headed cowbird, American goldfinch, and American crow were positively loaded on axis one, placing them in more open habitats. American goldfinch and American crow were positively loaded on axis two, placing them in open habitat. Northern cardinal and brown-headed cowbird were not heavily loaded on axis two. The remaining species were forest species, and these were distributed across each axis. Of the forest species, Kentucky warbler showed the strongest loading, which was negative on axis one. This placed Kentucky warbler in wet, forested habitat.

The CCA model produced by the 2007 bird data and the 300 m spatial scale landcover data showed that canonical axis one explained 15 % (eigenvalue 0.15) of the variation within the bird dataset, and axis one was significant ($p = 0.004$). The axis one landcover gradient again ranged from open landcover to forested landcover. For this spatial scale, open habitats were positively loaded and closed habitats were negatively loaded, which shows the opposite loadings from the 2007 data 100 m spatial scale. Pasture/ Hay, Cropland, and Developed Open Space were positively loaded on axis one. Riparian Forest, Coniferous Forest, Oak Mixed Forest, and Oak Pine Forest were negatively loaded on axis one. Coniferous forest landcover was grouped with more mature forest types in this model. Canonical axis two explained 6 % (eigenvalue 0.06) of the bird dataset variation. Water,

Deciduous Forest, Early Successional, and Riparian Forest were positively loaded on axis two. Deciduous Woodland, Woodland Wetland, and Barren were negatively loaded on axis two. The axis two gradient ranged from woodland landcover to both forest and successional landcover. Similar to the 2007 data at the 100 m spatial scale, indigo bunting and song sparrow were separated from common yellowthroat on the first axis of the 2007 data 300 m spatial scale. Indigo bunting, song sparrow, and common yellowthroat were not heavily loaded on axis two. The generalist species, American crow and northern cardinal, showed a slight positive loading on axis one and were not heavily loaded on axis two. The only riparian forest species, prothonotary warbler, was positively loaded on axis one, placing it in open habitats, and negatively loaded on axis two, placing it in wet woodland habitat. Some forest species were negatively loaded on axis one and axis two, and other forest species were positively loaded on axis one and axis two. Of the forest species, Kentucky warbler again showed the strongest loading, which was negative on axis one. Figure 4 shows a bi-plot containing the bird species and important landcover variables.

The CCA model produced by the 2004 bird data and the 500 m spatial scale landcover data showed that canonical axis one explained 14 % (eigenvalue 0.14) of the variation within the bird dataset, and axis one was significant ($p = 0.042$). Similar to the other models, the first axis showed a gradient that ranged from open landcover to forested landcover. Developed Open Space, Early Successional, Coniferous Woodland, Cropland, Pasture/ Hay, and Deciduous Woodland were positively loaded on axis one. Riparian Forest, Deciduous Forest, Barren, Coniferous Forest, and Woodland Wetland were negatively loaded on axis one. Canonical axis two explained 11 % (eigenvalue 0.11) of the 2004 bird dataset variation. Hemlock Forest and Deciduous Woodland were positively loaded on axis two.

Woodland Wetland, Coniferous Woodland, and Oak Pine Forest were negatively loaded on axis two. Axis two showed a gradient that ranged from hemlock forest and deciduous woodland to coniferous forest and woodland wetland. These two landcover groupings seem to be highly similar, in that both are comprised of wet/ moist habitats and woodland. The gradient may be representing a more subtle moisture gradient or forest maturity gradient. The generalist species, northern cardinal, brown-headed cowbird, American goldfinch, and American crow, were again placed in open and successional habitat. Successional grassland species, indigo bunting and common yellowthroat were not strongly loaded on either axis. Most forest species were negatively loaded on axis one and negatively loaded on axis two, placing them in forested or successional forested habitat. The forest species with the strongest negative loading on axis one and axis two was Kentucky warbler. Louisiana waterthrush and red-bellied woodpecker showed the strongest positive loading on axis one. Figure 5 shows a bi-plot containing the bird species and important landcover variables.

The CCA model produced by the 2007 bird data and the 500 m spatial scale landcover data showed that canonical axis one explained 15 % (eigenvalue 0.15) of the variation within the bird dataset, and axis one was significant ($p = 0.004$). The first axis also showed a gradient that ranged from open landcover to forested landcover. Pasture/ Hay, Deciduous Woodland, Developed Open Space, and Cropland were positively loaded on axis one. Deciduous Forest, Oak Mixed Forest, Riparian Forest, Oak Pine Forest, Coniferous Forest were negatively loaded on axis one. Canonical axis two explained 7 % (eigenvalue 0.7) of the bird dataset variation. Axis two showed a gradient that ranged from wet woodland and forest to coniferous forest. This gradient may be similar to the 2004 data secondary gradient in that it depicts a moisture gradient and possibly a forest maturity gradient.

Woodland Wetland and Oak Mixed Forest were positively loaded on axis two. Coniferous Forest was negatively loaded on axis two. The bird species were plotted on axis one and axis two as they were at the 100 m and 300 m spatial scales. Figure 6 shows a bi-plot containing the bird species and important landcover variables.

Principle Components Analysis (PCA)

Principal components axis one explain 12 % (eigenvalue 0.12) of the total variation within the 2004 bird dataset. Principal components axis two explained 10 % (eigenvalue 0.10) of the total variation within the 2004 bird dataset. Together these axes explained 23 % of the total variation within the 2004 bird dataset. The PCA did not explain a large amount of variation within the data set, and bird groupings are not easily distinguished in the plot. Generalist, including northern cardinal, American crow, American goldfinch, and brown-headed cowbird, tend to be negatively loaded on the first and second axes. Most of the species within the data set are forest species. These species are well distributed throughout the plot. A plot of the PCA scores for the 2004 data set is shown in Figure 7.

Principle components axis one of the 2007 bird dataset explained 16 % (eigenvalue 0.16) of the total variation within the 2007 bird dataset and PCII explained 13 % (eigenvalue 0.13) of the total bird dataset variation. Together these two axes explained 30 % of the total bird dataset variation for 2007. Again, the PCA failed to clearly distinguish groups of birds and explained little variation within the dataset. Indigo bunting and song sparrow are both successional grassland species and are negatively loaded on axis one. Figure 8 shows a plot of the PCA scores for the 2007 data set.

Multiple Regression Analysis

The individual species studied within the regression analysis were species that were found to be significantly more abundant in Upper Green River watershed Conservation Reserve Enhancement Program tallgrass plantings (Hulsey *et al.* 2008) and were still present in the dataset after twenty percent rarefaction. The following are results from multiple regression analysis with a backwards stepwise procedure and are summarized in Table 4: At the 100m spatial scale for the 2004 individual species American goldfinch (adjusted $r^2 = 0.088$; $p = 0.028$) and indigo bunting (adjusted $r^2 = 0.112$; $p = 0.015$) each showed a significant positive relationship with Early Successional landcover. Brown-headed cowbird showed a significant positive relationship with Early Successional and Deciduous Forest (adjusted $r^2 = 0.207$; $p = 0.003$). Northern cardinal showed a significant positive relationship with Floodplain Forest (adjusted $r^2 = 0.239$; $p < 0.000$). Common yellowthroat and Species Richness were not significantly correlated to any landcover variables.

At the 100m spatial scale for the 2007 individual species common yellowthroat showed a significant positive relationship with Coniferous Forest and Floodplain Forest (adjusted $r^2 = 0.287$; $p < 0.000$). Indigo bunting showed a significant positive relationship with Cropland (adjusted $r^2 = 0.127$; $p = 0.007$). Species Richness showed a significant negative relationship with Coniferous Forest (adjusted $r^2 = 0.117$; $p = 0.013$).

At the 300m spatial scale for the 2004 individual species brown-headed cowbird showed a significant positive relationship with Developed Open Space (adjusted $r^2 = 0.161$; $p = 0.004$). Common yellowthroat showed a significant negative relationship with Pasture/ Hay (adjusted $r^2 = 0.091$; $p = 0.026$). Northern cardinal showed a significant negative relationship with Developed Open Space, Deciduous Forest, and Coniferous Forest. The best landcover

influence model for northern cardinal also showed a significant positive relationship with Early Successional (adjusted $r^2 = 0.227$; $p = 0.007$). Species Richness showed a significant negative relationship with Woodland (adjusted $r^2 = 0.148$; $p = 0.006$).

At the 300m spatial scale for the 2007 individual species common yellowthroat showed a significant positive relationship with Deciduous Forest and Floodplain Forest (adjusted $r^2 = 0.212$; $p = 0.003$). Indigo bunting showed a significant negative relationship with Early Successional, Coniferous Forest, and Water (adjusted $r^2 = 0.127$; $p = 0.038$). Northern cardinal showed a significant positive relationship with Pasture/ Hay (adjusted $r^2 = 0.117$; $p = 0.013$). Species Richness was not significantly related to any landcover variables.

At the 500m spatial scale for the 2004 individual species brown-headed cowbird showed a significant negative relationship with Deciduous Forest, Woodland, and Water and a significant positive relationship with Early Successional (adjusted $r^2 = 0.506$; $p < 0.000$). Common yellowthroat showed a significant negative relationship with Cropland (adjusted $r^2 = 0.121$; $p = 0.012$). Northern cardinal showed a significant positive relationship with Pasture/ Hay (adjusted $r^2 = 0.185$; $p = 0.002$). Indigo bunting was not significantly related to any landcover variables. Species Richness showed a significant negative relationship with Developed Open Space, Deciduous Forest, Woodland, and Water (adjusted $r^2 = 0.238$; $p = 0.005$).

At the 500m spatial scales for the 2007 individual species common yellowthroat showed a significant negative relationship with Pasture/ Hay (adjusted $r^2 = 0.170$; $p = 0.003$). Indigo bunting showed a significant positive relationship with Cropland (adjusted $r^2 = 0.105$; $p = 0.018$). Northern cardinal showed a significant negative relationship with Pasture/ Hay (adjusted $r^2 = 0.113$; $p = 0.015$). Species Richness showed a significant negative relationship

with Developed Open Space, Deciduous Forest, Woodland, and Water (adjusted $r^2 = 0.189$; $p = 0.015$).

Linear Regression Analysis

Species Richness did not show a significant relationship with landscape heterogeneity at any of the three spatial scales studied.

Kruskal-Wallis Test

Kruskal-Wallis test results showed that indigo bunting had a significant negative trend in abundance from 2004 to 2007 ($p = 0.031$). The other individual species studied, common yellowthroat and northern cardinal, did not show significant abundance trends between 2004 and 2007.

Descriptive Statistics

Table 5 provides lists of bird species recorded after rarefaction in 2004 and 2007 and their relative abundances. Raw bird data was used to calculate species richness. Table 6 provides a list of all bird species recorded in 2004 and 2007. Using the raw bird data, the average site species richness in 2004 was twelve species/ site and the average site species richness in 2007 was fourteen species/ site. Figure 1 provides the raw abundance of all bird species sited.

DISCUSSION

The landcover variables did not explain a high amount of variation within the bird datasets. The highest amount of variation accounted for by landcover variables within the first two canonical axes of the six CCA models was 25.4 %. Landcover influence is weaker within the results of this study than results reported by other avian-landscape studies that used similar analysis methods (Pearson 1993 and Saab 1999). Although a high amount of variation was not explained by the landcover variables, one of the two 100 m spatial scale models, one of the two 300 m spatial scale models, and both 500 m spatial scale models were significant, indicating that the landcover variables within the spatial scales studied are influencing avian populations within the study sites. Significant relationships found between individual bird species and landcover variables at each spatial scale support the idea that landcover variables at different spatial scales are influencing avian populations.

Of the birds present in the CCA and PCA analysis, most are associated with forest guilds. The few successional grassland guild birds present were highly separated on the open habitat to forest habitat gradient. Common yellowthroat was separated from indigo bunting and song sparrow at each spatial scale; common yellowthroat was placed in closed, forested habitat, and indigo bunting and song sparrow were placed in open and successional habitat. The regression results related the successional species to the habitats they were placed in by the CCA. The placement of the successional grassland species in forest habitat does not match the habitat guild requirements of the successional grassland guild. The successional grassland species included in the analysis remained in the dataset after a twenty percent rarefaction process, suggesting that a low sample size within these three species did not contribute to the gradient separations that occurred. Considering that the floodplain and

riparian zone is often anthroprogenically modified within the Upper Green River watershed (UGRW), indigo bunting and song sparrow may have been sited directly in open and/or successional habitat. Common yellowthroat may have been sighted in more closed riparian habitat; although, we would still expect a certain amount of open and successional habitat near the common yellowthroat. The placement of common yellowthroat, a successional grassland species, in closed, forested riparian habitat suggests bird species within habitat guilds other than forest are utilizing the riparian zone of the UGRW. This result supports literature that claims riparian zones offer resources for multiple avian guilds (Naiman and Decamps 1997).

Generalist species were loosely grouped together by the CCA and the PCA. The CCA placed generalists in open and successional habitats for all spatial scales and the regression results supported these habitat placements. Northern cardinals are generally associated with more closed habitats, but since they are generalist, the placement of northern cardinal in open habitat is acceptable.

The one bird species within the datasets that belonged to a habitat guild specific to riparian forest, prothonotary warbler, was placed in open and successional habitats by the CCA at the three different spatial scales. This one species may show a relationship to open and successional landcover unique from other riparian forest species, but since it was the only riparian forest species in the dataset we cannot draw any conclusions as to which landcover variables the entire riparian forest guild would respond. The results for prothonotary warbler are unexpected. The relationship may be, again, due to anthropogenic disturbance thinning the forest habitat the prothonotary warbler uses. Also, the prothonotary warbler is a Neotropical migrant species. This species may be traveling through the area and

may not have established breeding territories at the time it was recorded in the point count surveys.

The majority of the species studied are placed in the forest habitat guild, see Table 3. Most of these species did not show strong correlations to the landcover data at the different spatial scales. A few forest species did, including the Kentucky warbler and the Louisiana waterthrush. These forest species were surprisingly separated on the closed to open habitat gradient. The Kentucky warbler was placed in forested habitat, which complements its guild habitat requirements, but the Louisiana waterthrush was placed in open and successional habitats, not meeting the forest guild habitat requirements. Louisiana waterthrush, also a Neotropical migrant, may not have established breeding territories at the time of the study. While the other forest guild species did not show strong relationships with forested landcover variables, they did show the strongest correlation with forested habitats at the 500 m spatial scale.

The common yellowthroat, prothonotary warbler, and Louisiana waterthrush were all correlated to landcover types that do not represent the habitat requirements of the guilds these species are placed in: successional grassland, riparian forest, and forest respectively. These species may be using marginal habitats (habitats that do not offer the best resources) for breeding. If this is occurring, these species may experience the negative effects of breeding in marginal habitats, including increased possibility of abundance declines or population extinction within the area (Kawecki 2008). Also, marginal habitat populations are often sink populations, where high amounts of immigration from source habitats (habitats with better resources) occur, making the population dependent on source habitats (Kawecki 2008). Identifying marginal habitats is important for conservation practices, and the results of this

study indicate that further study of possible marginal habitat use within the watershed is needed.

The insignificance of one 100 m spatial scale CCA model and one 300 m spatial scale model and the significance of both 500 m spatial scale CCA models indicates that finer spatial scale landcover is not influencing bird communities as much as landcover within broader spatial scales. Increased influence of landcover at broad scales on bird communities compared to finer scales has been supported by landscape ecology literature within different physical landscapes (Pearson 1993, Saab 1999, Ribic and Sample 2001, Rodewald and Yahner 2001). Having established territories does not seem to be inhibiting birds from responding to broader spatial scales.

Landcover heterogeneity did not show the significant relationship with species richness that was expected. This result contradicts the idea that landscape heterogeneity influences species richness (Turner *et al.* 2001). The landscape heterogeneity within the study area, including each spatial scale, may not have contained enough variance to produce a strong relationship between landcover heterogeneity and avian species richness. If this is true, then the study area may not suffer from high levels of habitat fragmentation (habitat fragmentation resulting in habitat loss) which has been shown to decrease avian populations (Fahrig 2003). If the habitats available within the landscape are not suitable for avian use, then an increase in landcover heterogeneity from an increase in unsuitable habitat may not produce a significant result. An example of unsuitable habitat associated with increased landscape heterogeneity includes increase edge effects, which has been shown to increase brood-nest parasitism (Gustafson *et al.* 2002). The measure of landcover heterogeneity used

in this study (Turner *et al.* 2001) may not be an appropriate measure of the landcover heterogeneity or the habitat fragmentation in the study area, leading to insignificant results.

In addition to lacking a significant relationship with landcover heterogeneity, species richness was significantly and negatively related to Developed Open Space, Deciduous Forest, Woodland, and Water at the 500 m spatial scale for the 2004 and 2007 data. Generally, riparian zones are considered to have greater species richness (Naiman and Decamps 1997). The result that species richness is not positively related to water (which would indicate the riparian zone area as well) contradicts past studies (Naiman and Decamps 1997).

The UGRW is an especially interesting region to perform landscape analysis within, because the Conservation Reserve Enhancement Program (CREP) is altering landcover on a large scale. A majority of the species found to be more abundant in the URGW CREP tallgrass plantings were successional species (Hulsey *et al.* 2008). CREP tallgrass plantings are implemented within 305 m of the Upper Green River and the major tributaries studied within this project (Johnson and Hill 2006.), which is with the 100 m and 300 m spatial scales studied. Considering that the 100 m and 300 m spatial scale CCA models were not significant, there is evidence that the landcover variables associated with CREP plantings, such as early successional, also show insignificant relationships with bird communities at finer scales. This decreases the possible effects CREP might have on bird communities within the watershed.

On the other hand, the regression models found that the individual species more abundant in CREP plantings (Hulsey *et al.* 2008), common yellowthroat, indigo bunting, northern cardinal, brown-headed cowbird, and American goldfinch, were significantly related

to landuse variables at the 100 m spatial scales. The individual species studied with regression analysis are only a small proportion of the bird species within the avian datasets for 2004 and 2007. If all species in the data have significant relationships with landcover variables at the 100 m and 300 m spatial scales, we would expect the CCA models for the 100 m and 300 m spatial scales to be significant as well. Those models were not all significant (one of the two 100 m spatial scale models was not significant and one of the two 300 m spatial scale models was not significant), suggesting that not all species within the dataset have significant relationships with the landcover variables at the 100 m and 300 m spatial scale.

When the abundance of common yellowthroat, indigo bunting, and northern cardinal (the three species found to be significantly more abundant in CREP tallgrass plantings and that were in both the 2004 and 2007 bird datasets after rarefaction) was analyzed to determine if their abundance had increased over the study period, these species did not show significant population increases from 2004 to 2007. Indigo bunting was particularly interesting in that the species' abundance showed a positive relationship with early successional landcover in 2004 at the 100 m spatial scale, yet indigo bunting also showed a positive relationship with cropland landcover in 2007 at the 100 m spatial scales. From 2004 to 2007 indigo bunting showed a significant population decline in the study area. There is little evidence to believe that either early successional or cropland landcover has declined in the study area between 2004 and 2007. It is hard to determine the effects that landcover change from cropland to early successional habitats, an outcome of the CREP, may have on indigo bunting abundance because indigo bunting had a significant positive relationship to both landcover types.

The significant indigo bunting abundance decrease from 2004 to 2007 combined with the insignificant abundance trends for common yellowthroat and northern cardinal suggest that CREP is not positively influencing avian population within the riparian zone of the UGRW. The individual species studied did show significant relationships with landcover variables at each spatial scale. These significant relationships show that these particular species are responding to landcover at different spatial scales. The landcover variables the species are significantly responding to may not actually be effected by current CREP plantings, and thus the abundance trends from 2004 to 2007 also may not be influenced by CREP. We must consider, though, that there were few CREP plantings found within even the broadest spatial scale of the study sites; thus, any conclusion made regarding the influences of CREP are only speculative and have not been statistically tested.

Studies that examine the effects of the CREP on a landscape scale are lacking in the current literature, although projections have been made regarding the possible landscape scale impact of the CREP (Dunn *et al.* 1993). Past studies of the CREP in other states and within the UGRW, have only compared CREP plantings to agricultural plantings (Hulsey *et al.* 2008, Patterson and Best 1996, Klute *et al.* 1997, Johnson and Schartz 1993, Deslisle and Savidge 1997, McCoy *et al.* 2001, Best *et al.* 1998, Blank and Gill 2006). The UGRW CREP's influence on a landscape scale is considered in this study. The increase of certain bird species in CREP tallgrass plantings (Hulsey *et al.* 2008) leads to the expectation that CREP will increase the abundance of the bird species found more abundant in CREP plantings on a landscape scale as well. The lack of increased avian abundance from 2004 to 2007 does not support the expectation of increased avian abundance on a landscape scale, but results may have several explanations. The UGRW CREP is still a young conservation

program. Many contracts are still in the process of being implemented and numerous contracts have not had enough time to become fully established (herbaceous habitat for successional/ scrub species and bottomland hardwood trees for forest species). Also, because the CREP is young and plantings may not be fully established, avian populations may not have had enough time to respond or respond at significant numbers. If the results presented in this paper do provide an accurate account of which spatial scales avian communities are responding to landcover variables, then the CREP program may need to expand the contract eligibility area further from the riparian zone to influence avian communities. Specifically, contracts may need to be established within the broad scale range (at least within 500 m², CREP contracts are currently established within 305 m of the river) in order to improve wildlife habitat in a way that will increase avian abundance.

This study examines avian-landcover relationships within an entire watershed. The sample size of the study may not have been large enough to fully produce a representative sample of the landcover and avian community conditions within the watershed. Also, study sites were not randomly chosen, but relied on canoe river access points. These areas may have contained greater amounts of anthropogenic disturbance in the riparian zone than areas that are more secluded, decreasing the forest landcover and increasing open landcover. Also, observer bias or non-proficiency may have skewed or affected the avian point count data in other ways, again affecting the analysis results.

Landscape variables, including landcover, tend to be autocorrelated when used in statistical analysis (Wagner and Fortin 2005). Landcover variables may seem explicit, but actually provide similar habitats for avian species. Pearson (1993) pointed out that large tracts of one landcover type encompassed more than one of the spatial scales that he studied.

Unlike Pearson's study, bands at different spatial scales were not used in this study, but the entire area leading up to each spatial scale measurement (100 m, 300m, and 500 m radiating out from point count sites) was included. This resulted in the entirety of the 100 m spatial scale being included in the 300 m spatial scale, and the entirety of the 100 m and 300 m spatial scales were included in the 500 m spatial scale. To avoid the autocorrelation that Pearson encountered, the spatial scale data of this study was not analyzed within the same test.

Conclusion

As expected, the landcover gradients found at each spatial scale by CCA were similar to each other, with the most prevalent being a gradient ranging from closed, forested landcover to open and successional landcover. Contrary to the hypothesis stated, the avian community did not show a clear change across the landcover gradients present, and the placements of certain bird species on the gradient did not match the species' habitat requirements. This lack of specific habitat association may indicate the species are using marginal habitat for breeding, that the UGRW riparian zone offers unique resources that birds of different guilds are utilizing, and/ or that some Neotropical migrant birds had not set up breeding territories when they were sited during the survey. Also contrary to the hypothesis stated, the overall relationships between bird species and landcover variables did not change as spatial scale changed.

Although at least one spatial scale model was significant for each spatial scale, the landcover matrix did not explain a large amount of variation in the avian species data for any spatial scale. Considering that both 500 m spatial scale models were significant compared to

one 100 m spatial scale model and one 300 m spatial scale model, it appears that the bird community within the UGRW responds more to landcover at the 500 m spatial scale during the breeding season. This result is also contrary to the hypothesis stated. The individual species studied showed significant relationships with landcover variables for all spatial scales studied. The change in the relationship between species richness and landcover between spatial scales was unclear. The establishment of breeding territories does not seem to inhibit the spatial scale at which the avian communities respond. Species richness was not significantly related to landcover heterogeneity, possibly due to low landcover heterogeneity within the spatial scales, increased presence of habitats unsuitable for avian use, or due to an inaccurate measure of spatial heterogeneity.

As stated before, not all individual bird species studied were significantly related to or responded to landcover that meets the habitat needs required by the guild with which they are associated. The guild requirements of the species may not be clear and guilds may not be useful for predicting the habitat requirements or usage for all species. The individual species studied did not show significant positive abundance trends between 2004 and 2007. This indicates that CREP plantings are not producing increased landscape population increases as was predicted. Avian species may not be responding to CREP related landcover variables at the spatial scales studied. Since no direct measure of CREP landcover was included in the analysis, all CREP related inferences are subjective. Studies that directly study CREP variables are needed for monitoring efforts.

This study has shown that expected avian-landscape relationships may not be accurate and that studies should be conducted that considered avian-landscape relationship on a landscape by landscape process. This study also suggests that avian communities are

more responsive to landcover contained by broader spatial scales than landcover contained by finer spatial scales within a landscape. Conservation programs should consider the landscape on a broad scale when designing habitat and species management plans and goals.

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APPENDIX 1: Tables and Figures

Permission to use any data presented in this paper is required and can be gained by contacting the Nongame Branch of the Kentucky Fish and Wildlife Resources.

Table 1. Bird species placed in habitat guilds.

Successional grassland	Species Code
indigo bunting	INBU
common yellowthroat	COYE
song sparrow	SOSP
Generalist	
northern cardinal	NOCA
brown-headed cowbird	BHCO
American crow	AMCR
American goldfinch	AMGO
Riparian forest	
prothonotary warbler	PROW
Forest	
Kentucky warbler	KEWA
white-breasted nuthatch	WBNU
tufted titmouse	TUTI
Carolina chickadee	CACH
pileated woodpecker	PIWO
blue-gray gnatcatcher	BGGN
yellow-billed cuckoo	YBCU
great-crested flycatcher	GCFL
northern parula	NOPA
red-eyed vireo	REVI
blue jay	BLJA
wood thrush	WOTH
downy woodpecker	DOWO
Acadian flycatcher	ACFL
Louisiana waterthrush	LOWA
Eastern wood pewee	EWPE
red-bellied woodpecker	RBWO

Table 2. Landcover aggregation for multivariate analysis.

Variable Name	Landcover	Aggregation
Open_110	Developed Open Space	Developed Open Space
ImpeDeve	Developed Impervious	Developed Low Intensity + Developed Medium Intensity
Crop_210	Cropland	Cropland
Past_222	Pasture/ Hay	Pasture/ Hay
EarlySucc	Early Successional	Herbaceous + Shrub
DeciFore	Deciduous Forest	Oak Forest + Yellow Poplar Forest + Mixed Deciduous Forest
ConiFore	Coniferous Forest	Pine Forest + Red Cedar Forest
HemF_432	Hemlock Forest	Hemlock Forest
OPF_431	Oak – Pine Forest	Oak – Pine Forest
OMF_433	Other Mixed Forest	Other Mixed Forest
DecW_441	Deciduous Woodland	Deciduous Woodland
ConW_442	Coniferous Woodland	Coniferous Woodland
MixW_443	Mixed Woodland	Mixed Woodland
Wat_510	Water	Water
RipaFore	Floodplain Forest	Riparian Forest + Floodplain Forest
WoWe_615	Woodland Wetland	Woodland Wetland
Barr_710	Barren	Barren

Table 3. Landcover aggregation for regression analysis.

Landcover	Aggregation
1. Developed Open Space	Developed Open Space
2. Developed Impervious	Developed Low Intensity + Developed Medium Intensity
3. Cropland	Cropland
4. Pasture/ Hay	Pasture/ Hay
5. Early Successional	Herbaceous + Shrub
6. Deciduous Forest	Oak Forest + Yellow Poplar Forest + Mixed Deciduous Forest + Oak – Pine Mixed Forest + Other Mixed Forest
7. Coniferous Forest	Pine Forest + Red Cedar Forest + Hemlock Forest
8. Woodland	Deciduous Woodland + Coniferous Woodland + Mixed Woodland
9. Water	Water
10. Floodplain Forest	Riparian Forest + Floodplain Forest + Woodland Wetland
11. Barren	Barren

Table 4. Multiple regression analysis with a backwards stepwise procedure significant ($p < 0.05$) results for 2004 analysis (top) and 2007 analysis (bottom) at 100 m, 300 m and 500 m spatial scales.

<u>2004 Specis</u>	<u>Spatial Scale</u>	<u>Variable(s)</u>	<u>adjusted r^2</u>	<u>p</u>
American goldfinch	100 m	+ Early Successional	0.088	0.028
brown-headed cowbird	100 m	+ Deciduous Forest, + Early Successional	0.207	0.003
	300 m	+ Open	0.161	0.004
	500 m	+ Early Successional, - Deciduous Forest, - Woodland, - Water	0.506	<
common yellowthroat	300 m	- Pasture/ Hay	0.091	0.026
	500 m	- Cropland	0.121	0.012
indigo bunting	100 m	+ Early Successional	0.112	0.015
				<
northern cardinal	100 m	+ Floodplain Forest	0.239	0.000
	300 m	- Open, + Early Successional, - Deciduous Forest, - Coniferous Forest	0.227	0.007
	500 m	+ Pasture/ Hay	0.185	0.002
Species Richness	300 m	- Woodland	0.148	0.006
	500 m	- Open, - Deciduous Forest, - Woodland, - Water	0.238	0.005
<u>2007 Specis</u>	<u>Spatial Scale</u>	<u>Variable(s)</u>	<u>adjusted r^2</u>	<u>p</u>
common yellowthroat	100 m	+ Coniferous Forest, + Floodplain Forest	0.287	<
	300 m	+ Deciduous Forest, + Floodplain Forest	0.212	0.003
	500 m	- Pasture	0.17	0.003
indigo bunting	100 m	+ Cropland	0.14	0.007
	300 m	- Early Successional, - Coniferous Forest, - Water	0.127	0.038
	500 m	+ Cropland	0.105	0.018
northern cardinal	300 m	+ Pasture	0.117	0.013
	500 m	- Deciduous Forest	0.113	0.015
Species Richness	100 m	- Coniferous Forest	0.117	0.013
	500 m	- Open, - Deciduous Forest, - Woodland, - Water	0.189	0.015

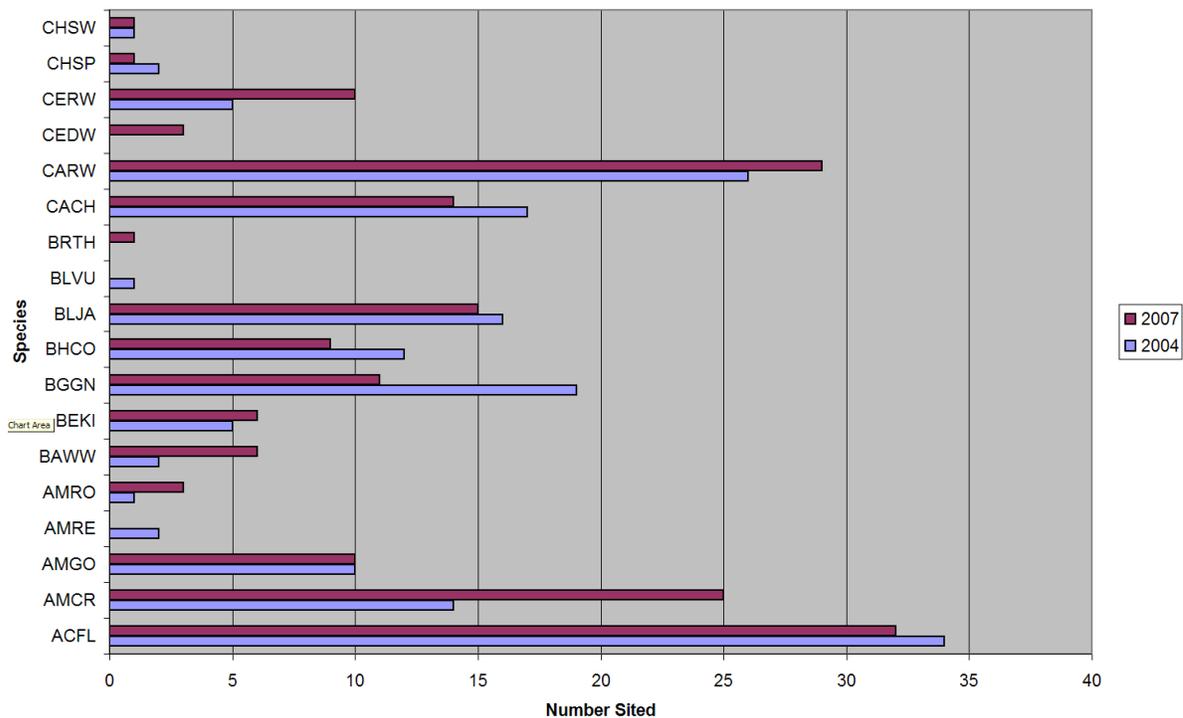
Table 5. Bird species recorded after rarefaction in 2004 and 2007 and their relative abundances.

2004	Abundance	2007	Abundance
acadian flycatcher	53	northern cardinal	55
American crow	18	Carolina wren	45
American goldfinch	14	indigo bunting	40
blue-gray gnatcatcher	24	acadian flycatcher	39
brown-headed cowbird	15	northern parula	35
blue jay	25	red-eyed vireo	35
Carolina chickadee	25	American crow	33
		red-bellied	
Carolina wren	33	woodpecker	33
common yellowthroat	24	tufted titmouse	32
downy woodpecker	13	Louisiana waterthrush	29
eastern wood pewee	27	eastern wood pewee	28
great-crested			
flycatcher	12	wood thrush	28
indigo bunting	48	yellow-billed cuckoo	26
Kentucky warbler	12	pileated woodpecker	24
Louisiana waterthrush	13	blue jay	21
northern cardinal	55	common yellowthroat	20
		white-breasted	
northern parula	19	nuthatch	20
		great-crested	
pileated woodpecker	15	flycatcher	18
red-bellied			
woodpecker	12	Kentucky warbler	16
red-eyed vireo	32	Carolina chickadee	15
tufted titmouse	16	prothonotary warbler	14
white-breasted			
nuthatch	22	song sparrow	14
wood thrush	24	blue-gray gnatcatcher	12
yellow-billed cuckoo	16		

Table 6. All bird species recorded in 2004 and 2007.

Common Name	Species Code	Common Name	Species Code
acadian flycatcher	ACFL	Kentucky warbler	KEWA
American crow	AMCR	killdeer	KILL
American goldfinch	AMGO	Louisiana waterthrush	LOWA
American redstart	AMRE	mourning dove	MODO
American robin	AMRO	northern bobwhite	NOBO
black-and-white warbler	BAWW	northern cardinal	NOCA
belted kingfisher	BEKI	northern parula	NOPA
blue-gray gnatcatcher	BGGN	northern rough-wing swallow	NRWS
brown-headed cowbird	BHCO	oven bird	OVEN
blue jay	BLJA	pileated woodpecker	PIWO
black vulture	BLVU	prothonotary warbler	PROW
brown thrasher	BRTH	rose-breasted grosbeak	RBGR
Carolina chickadee	CACH	red-bellied woodpecker	RBWO
Carolina wren	CARW	red-eyed vireo	REVI
cedar waxwing	CEDW	red-shouldered hawk	RSHA
cerulean warbler	CERW	red-tailed hawk	RTHA
chimney sweep	CHSP	ruby-throated hummingbird	RTHU
chimney swift	CHSW	scarlet tanager	SCTA
common grackle	COGR	song sparrow	SOSP
common yellowthroat	COYE	spotted sandpiper	SPSA
downy woodpecker	DOWO	summer tanager	SUTA
eastern meadowlark	EAME	tufted titmouse	TUTI
eastern phoebe	EAPH	turkey vulture	TUVU
eastern towhee	EATO	white-breasted nuthatch	WBNU
eastern wood-pewee	EAWP	white-eyed vireo	WEVI
field sparrow	FISP	worm-eating warbler	WEWA
great-blue heron	GBHE	wild turkey	WITU
great-crested flycatcher	GCFL	wood duck	WODU
gray catbird	GRCA	wood thrush	WOTH
green heron	GRHE	yellow-breasted chat	YBCH
hairy woodpecker	HAWO	yellow-billed cuckoo	YBCU
hooded warbler	HOWA	yellow-shafted flicker	YSFL
house wren	HOWR	yellow-throated vireo	YTVI
indigo bunting	INBU	yellow-throated warbler	YTWA
		yellow warbler	YWAR

Raw Abundance of All Species Sited: 2004, 2007



Raw Abundance of All Species Sited: 2004, 2007

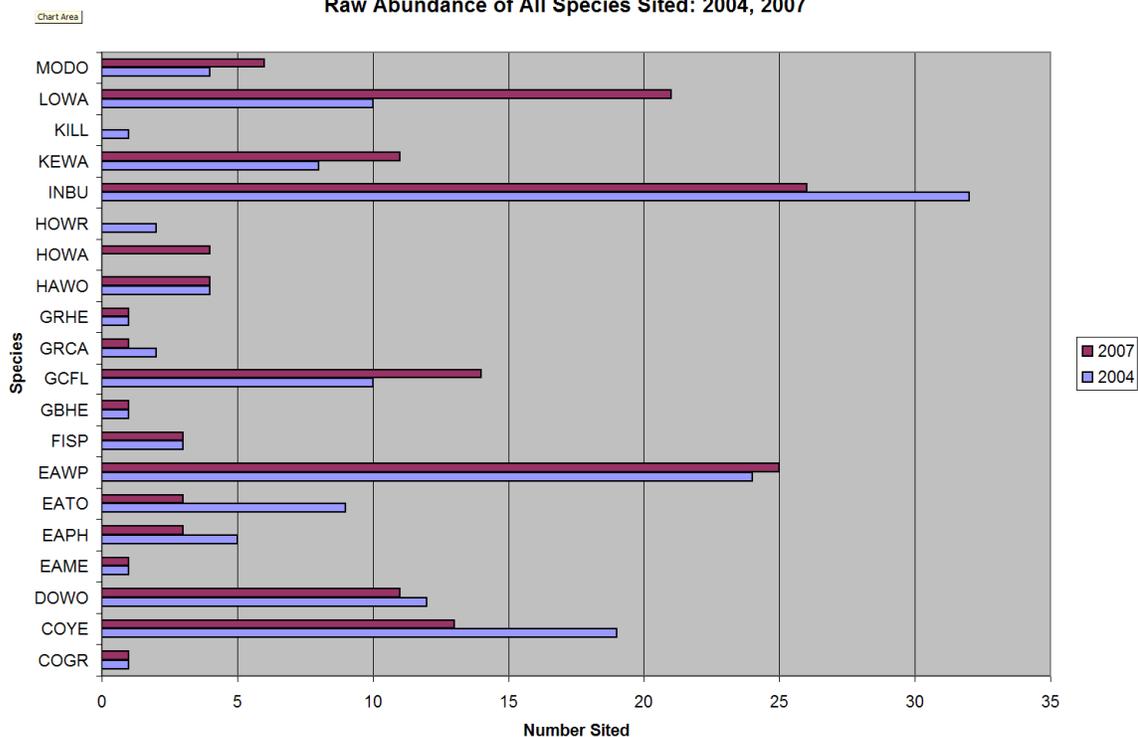
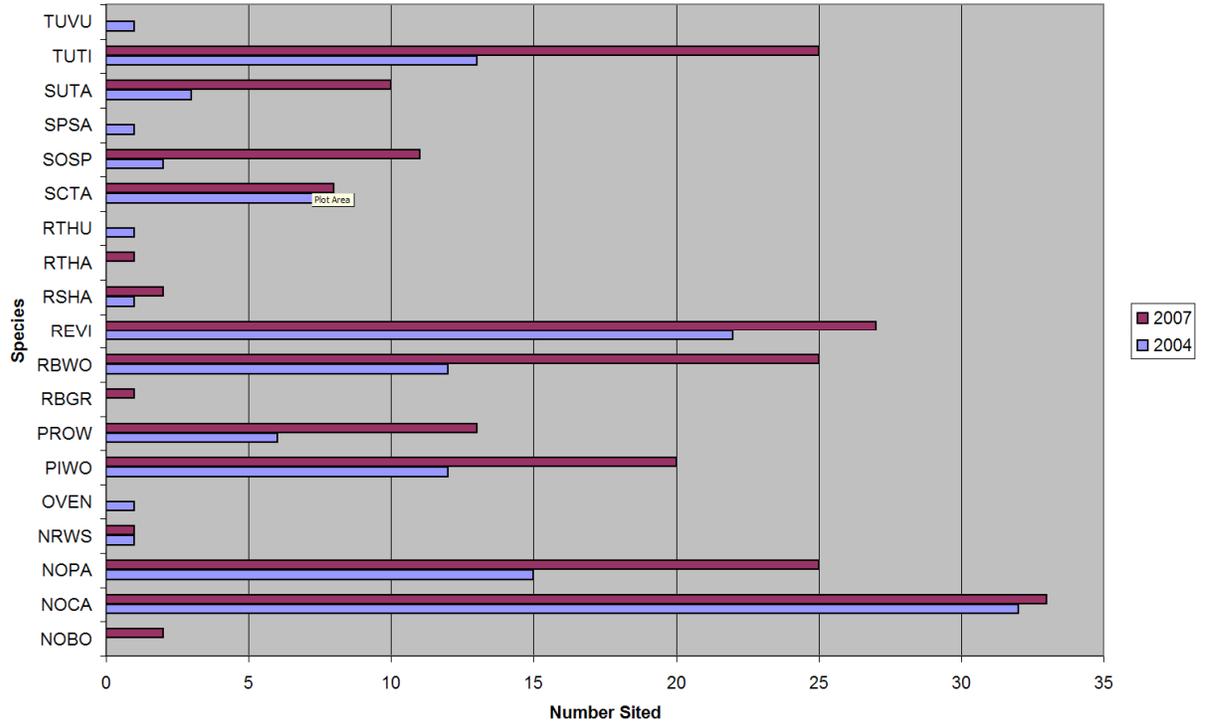


Figure 1. Raw abundance of all bird species sited in 2004 and 2007 and shown in four charts. Reference Table 6 for species code information. Continued on page 46.

Raw Abundance of All Species Sited: 2004, 2007



Raw Abundance of All Species Sited: 2004, 2007

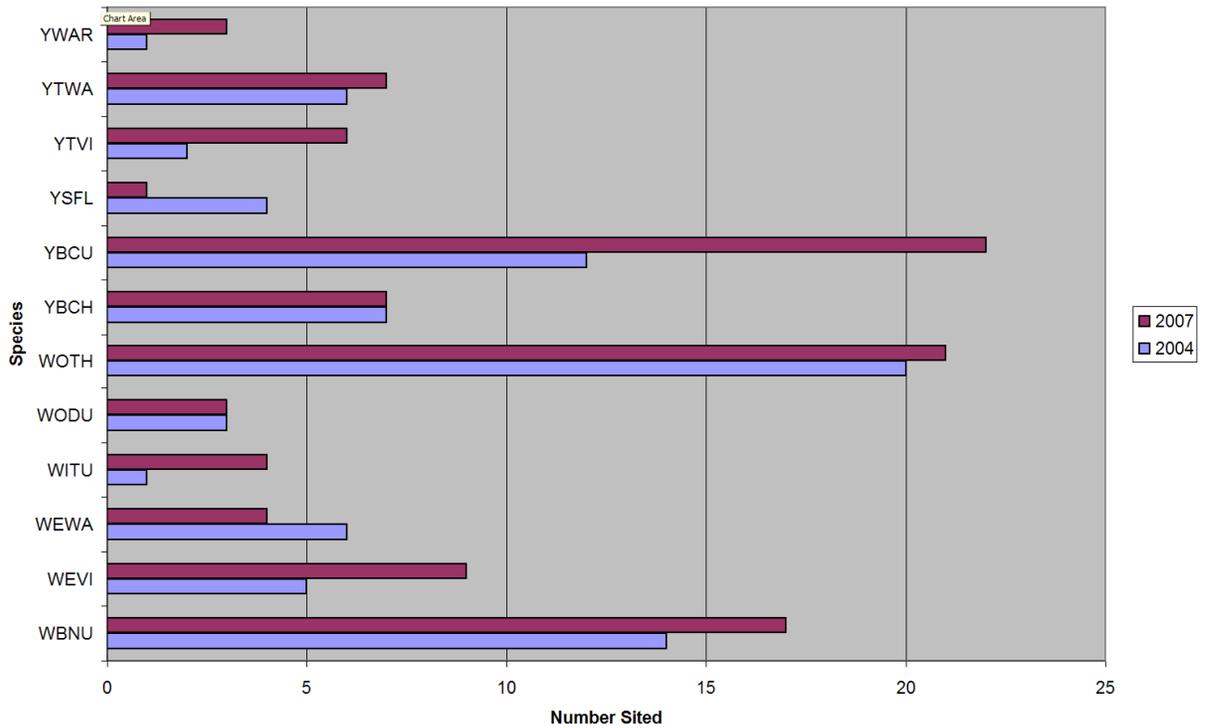


Figure 1 continued.

$$H = -\sum \frac{p_i \times \ln(p_i)}{\ln(s)}$$

Figure 2. Landscape diversity measure (Turner *et al.* 2001) used to calculate landcover heterogeneity, where H = landcover heterogeneity, p_i = the proportion of the landscape occupied by landcover type i , and s = the number of landcover types present.

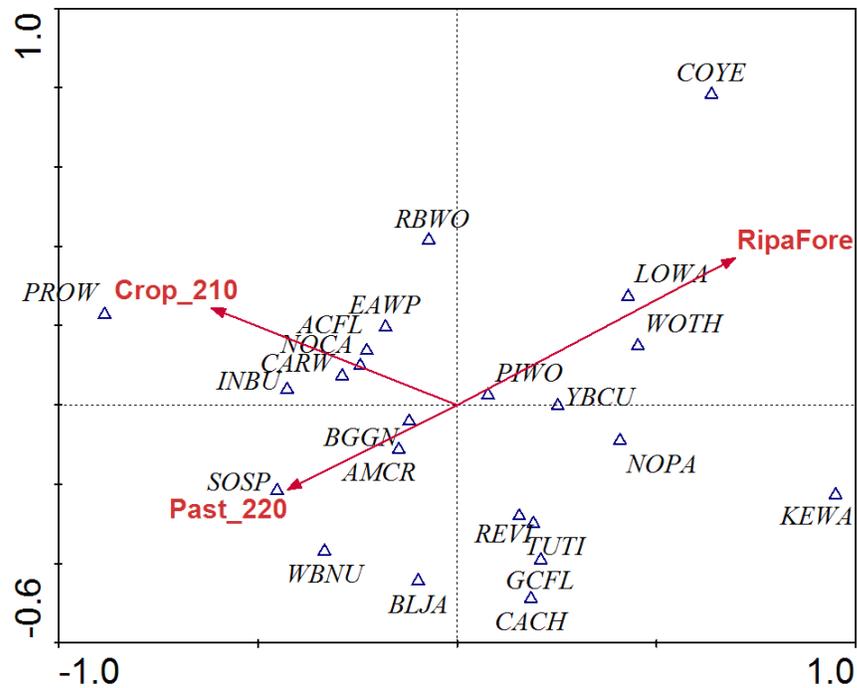


Figure 3. A bi-plot of the CCA comparing the 2007 bird species matrix to the 100 m spatial scale landcover variables. Canonical axis one explained 11 % (eigenvalue 0.11) of the variation within the bird dataset, and axis one was significant ($p = 0.006$). Axis two did not contain high explanatory power.

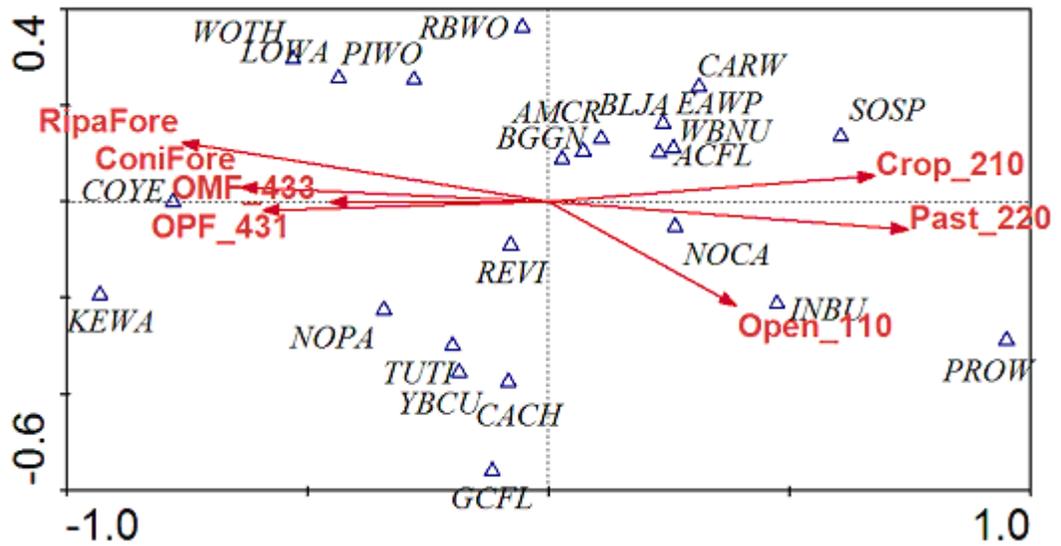


Figure 4. A bi-plot of the CCA comparing the 2007 bird species matrix to the 300 m spatial scale landcover variables. Canonical axis one explained 15 % (eigenvalue 0.15) of the variation within the bird dataset, and axis one was significant ($p = 0.004$). Axis two did not contain high explanatory power.

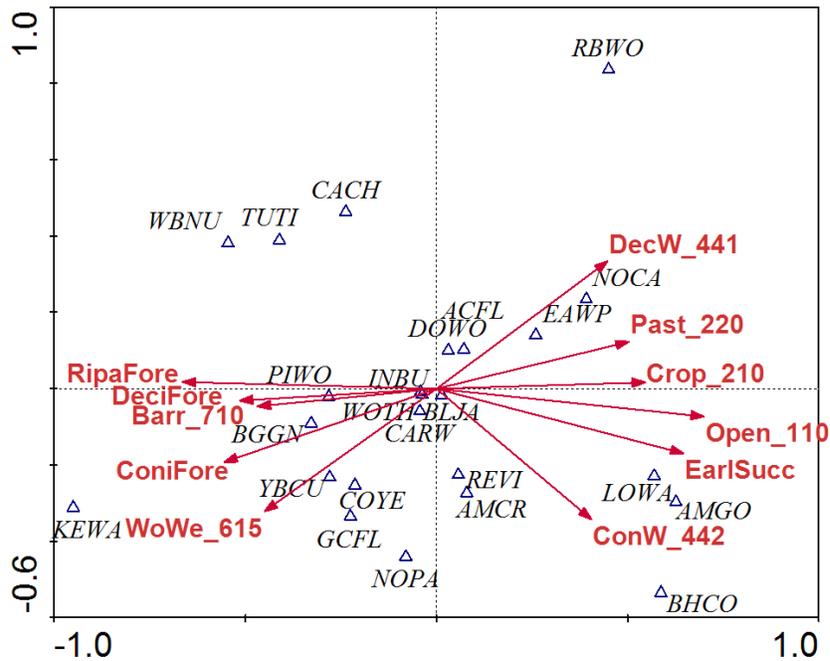


Figure 5. A bi-plot of the CCA comparing the 2004 bird species matrix to the 500 m spatial scale landcover variables. Canonical axis one explained 14 % (eigenvalue 0.14) of the variation within the bird dataset, and axis one was significant ($p = 0.042$). Axis two did not contain high explanatory power.

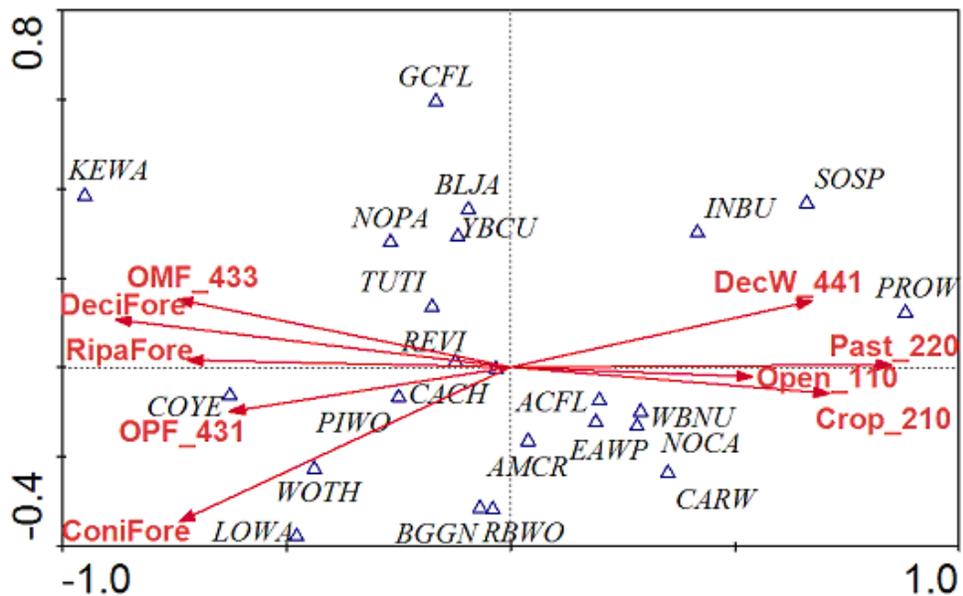


Figure 6. A bi-plot of the CCA comparing the 2007 bird species matrix to the 500 m spatial scale landcover variables. Canonical axis one explained 15 % (eigenvalue 0.15) of the variation within the bird dataset, and axis one was significant ($p = 0.004$). Axis two did not contain high explanatory power.

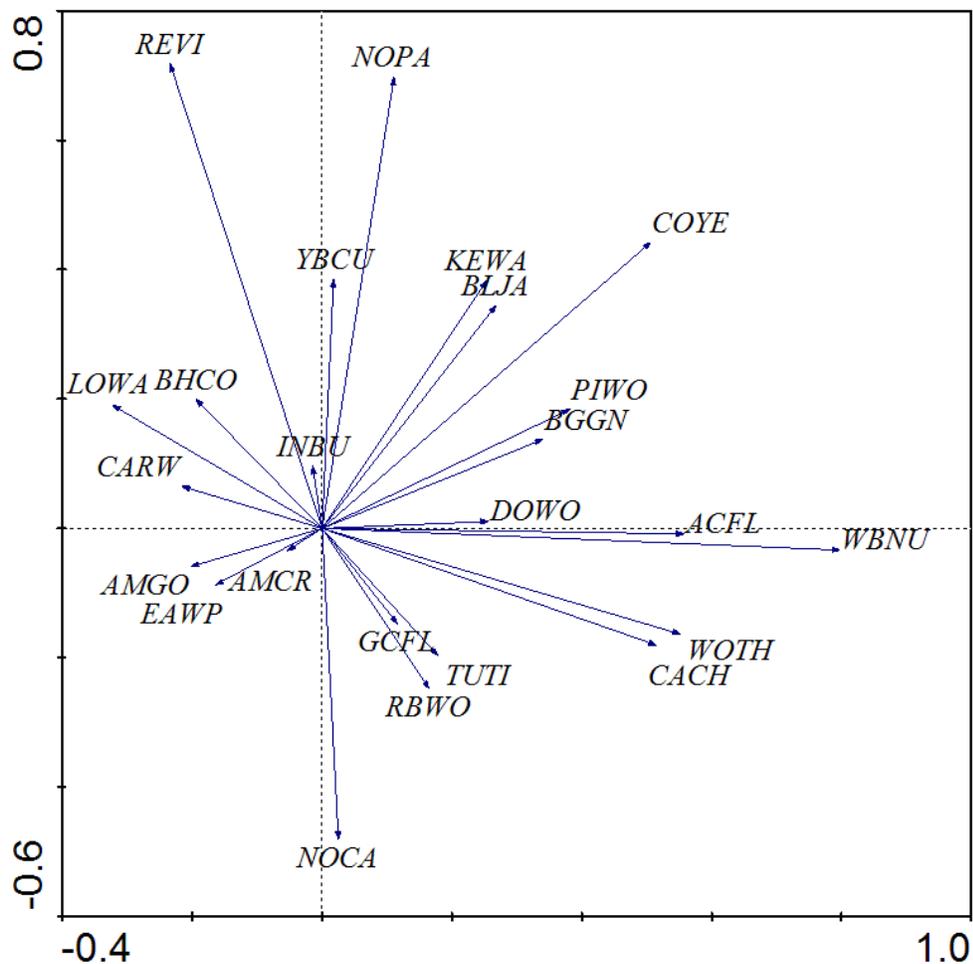


Figure 7. Plot of PCA scores of the 2004 bird species data. PCI (explained 12 % of the total bird dataset variation) and PCII (explained 10 % of the total bird dataset variation). Together these axes explained 22 % of the total variation within the 2004 bird dataset. Bird groups are not well distinguished except for northern cardinal, American crow, American goldfinch, and brown-headed cowbird. These individual species are considered generalist and are negatively loaded on PCI and PCII.

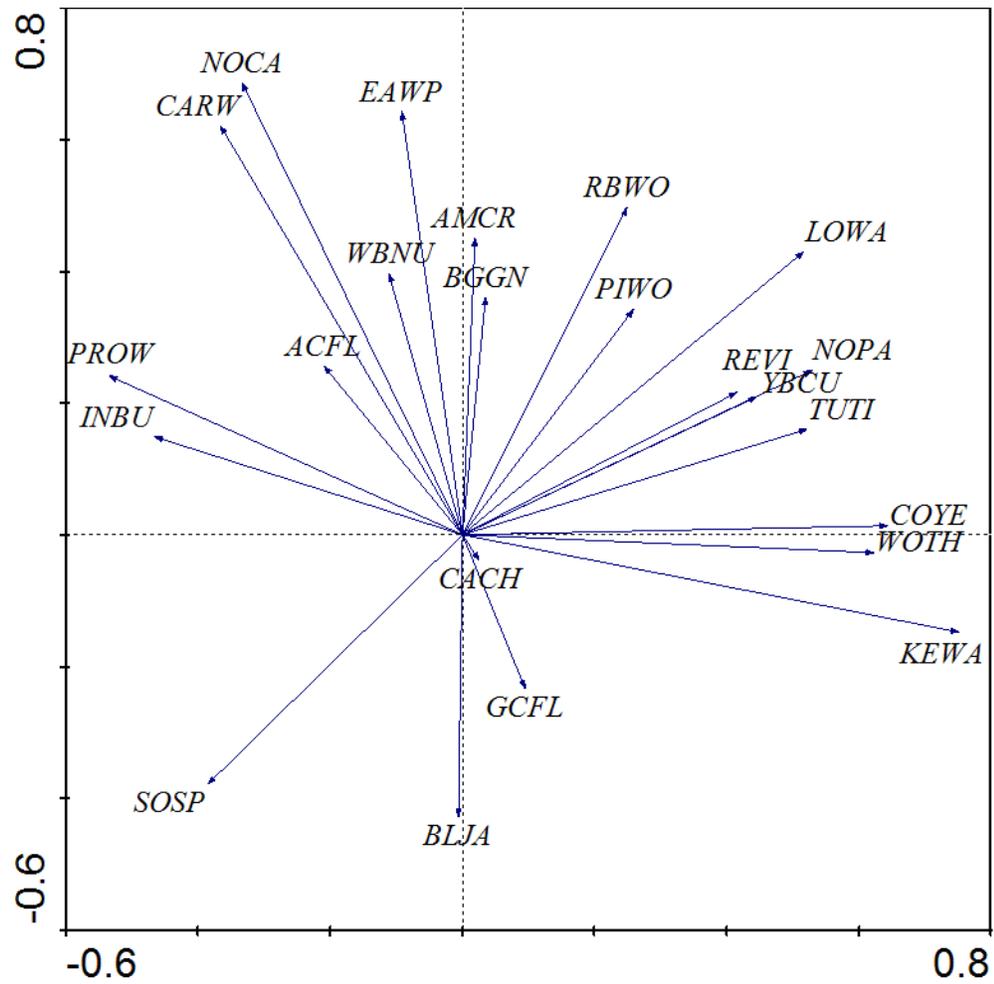


Figure 8. Plot of PCA scores of the 2007 bird species data. PCI (explained 17 % of the total bird dataset variation) and PCII (explained 14 % of the total bird dataset variation) together explained 31 % of the total variation in the 2007 bird dataset. Bird groups are not well distinguished.