EFFECTS OF PASTURE BASED DAIRY FARMING ON GRASSLAND BIRD SPECIES IN SOUTHWEST MICHIGAN

By

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ABSTRACT

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Changes in land use, agricultural practices, and the subsequent reduction of mosaic grasslands, which vary spatially and temporally in structure, have resulted in dramatic and range wide population declines of grassland birds. These grassland species have exhibited more substantial and continuous population declines than any other behavioral or ecological guild. To understand the impact of agricultural practices, we investigated if grassland bird communities differed on dairy pastures and grassland fragments and if vegetation structure and composition contributed to bird community differences in southwest Michigan, United States. Rather than relying on bird counts, we created utilization distributions to analyze these bird communities. Correspondence analysis indicated that pasture and grassland bird communities differed. Based on this analysis, specific species showed a stronger association with dairy pastures or grassland fragments. Canonical correlation analysis confirmed that vegetation structure and composition contributed to variation in species distributions, suggesting that species-specific associations found in the correspondence analysis were, at least partially, due to the vegetation structure of the dairy pastures and grassland fragment. Species-specific models indicated that some grassland birds were associated with unique vegetation characteristic. We concluded that species-specific habitat requirements are generally fulfilled through mosaic grasslands and that both grasslands and agriculture fields should be managed to maintain mosaic vegetation structure, that varies spatially and temporally in order to maintain a diverse community of grassland bird species.

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INTRODUCTION

Across North America, grassland birds have experienced dramatic and continuous population declines throughout the 20th century (Askins et al. 2007). Over the last 25 years, these species have shown a "steeper, more consistent, and more geographically widespread decline than any other behavioral or ecological guild" (Askins et al. 2007; 2). Of 57 grassland animal species presently at risk, 28 are birds (Reynolds and Symes, 2013). Population declines, some range wide, have been documented annually by the Breeding Bird Survey (BBS) of North America. From 1966 to 2002, only three of 28 grassland bird species have shown a significant increase, while 17 have significantly decreased (Askins et al. 2007). Some species, including the Eastern Meadowlark (*Sturnella magna*), have experienced a 3 % annual population decline in population estimates (Macias-Duarte et al. 2009).

Askins et al. (2007) suggested the major factors influencing population declines of grassland birds include: habitat fragmentation, degradation, or loss (ie. from woody encroachment); nest parasitism; and use of pesticides (depleting food sources). Worldwide, there has been a dramatic decrease in grassland habitats (Reynolds and Symes, 2013); roughly 41% of temperate grasslands have been lost globally (Henderson and Davis, 2014). In North America, at least 79% of native grassland habitat has been lost (Henderson and Davis, 2014). The tall-grass prairies of the Midwest United States, have experienced dramatic changes in land-use and grazing management, 80% of pre-settlement prairies have been converted to agriculture (Askins et al. 2007). Currently grassland birds in this region depend predominantly on land used for agronomic crop production, particularly during the breeding season (Askins et al, 2007).

Historically, Midwestern prairies were maintained by drought, fire, and grazing (Askins et al. 2007). The frequency and intensity of these disturbances not only prevented woody encroachment but also provided highly heterogeneous vegetation structure (Renne and Tracy, 2007), referred to here as a mosaic of grassland structure.

Through modernization and increased agriculture, disturbances that allowed grasslands to persist have been either eliminated (fire and drought) or altered significantly (grazing), substantially transforming their vegetation structure and composition (Hovick et al. 2012). Intensification of agriculture and agricultural practices in the Midwest has resulted in a shift from vegetatively diverse pastures and hay fields to crop monocultures, increased use of non-native forage species (Askins et al. 2007), and increased frequency and earlier initial harvests (as early as late-May; Perlut et al. 2006). Increasing agriculture is problematic for breeding success of grassland birds because harvesting and mowing destroy nests and limit the ability of females to re-nest successfully (Perlut et al. 2006), and it has been suggested that agriculture fields can become ecological traps for grassland birds (Ribic et al. 2009). In addition, intense agriculture decreases the potential of grasslands to sustain mosaic vegetation structure (Hovick et al. 2012).

Grassland birds evolved in mosaic grasslands once maintained by natural disturbances (Reynolds and Symes, 2013). While modernized agriculture may directly have strong negative effects on grassland birds (Perlut et al. 2006), grazing systems have the potential, if managed to include ecological benefits, to create vegetation structure and composition that varies spatially and temporally, potentially supporting a variety of bird species (Henderson and Davis, 2014, Willcox et al. 2010). Theoretically, a larger variety of grassland birds can be supported by creating small niches for each species through spatial and temporal variation of the grasslands structure. Increasing the heterogeneity of vegetation structure results in less competition for resources among birds, thus creating micro-habitats for species requiring different habitat characteristics. Understanding species-specific micro-habitats is useful for future conservation and management of grassland birds, especially if agriculture fields are incorporated in these conservation plans (Ribic et al., 2009).

The consequences of agricultural practices, including the effects of grazing, on grassland birds is inadequately understood. Agricultural fields are often incorporated in management plans for grassland birds, therefore determining if agricultural fields support different bird communities than are found in grassland fragments is the first step to understanding specifically how agriculture effects grassland birds. In this study, we compare bird species composition and fine-scale vegetation structure in an unmanaged grassland fragment to dairy farm pastures that experienced different management intensities. The objectives of this study were to: 1) identify grassland bird species in both dairy pastures and natural grasslands; 2) determine potential differences in bird species composition between natural grasslands and dairy pastures; and 3) determine fine-scale relationships between vegetation structure and grassland bird habitat selection during the breeding season.

METHODS

Study areas

Our study sites were located in southwest Michigan within 3 km of each other. Sites were located in a highly-fragmented landscape, dominated by agriculture. Two sites were part of a large dairy farm and have undergone extensive anthropogenic changes. The main dairy site comprises the main pastures for the milk producing herd of an active dairy farm, the alternative dairy site is a small pasture area used to graze young non milk producing cows. The third site has been a Michigan Department of Natural Resources (MDNR) hunting field since 1988.

Main Dairy Pastures

The largest site (65 ha), consisted of intensively managed dairy pastures, of the Dairy Farms main facility at Kellogg Biological Station (KBS; Fig. 1a). The main dairy pastures were grazed by 135 milk-producing cows; 8 paddocks surrounded a central milking barn. Six paddocks were surveyed in this study. Five were sub-divided into eight smaller pastures, while one was sub-divided into four pastures (Fig. 1a). Sixteen pastures were planted with two-species (white clover (*Trifolium repens*) and rye (*Secale cereale*)) and 28 were planted with five-species (red (*Trifolium pretense*) and white clover, alfalfa (*Medicago sativa*), orchard grass (*D. glomerata*), and tall fescue (*Festuca arundinacea*)). All pastures were roughly 161 m long, ranging from 100-135m in width (Fig. 1a). Only the four-pasture paddock had pastures wider than 100 m. Rotational grazing (one pasture on each side of the barn was grazed each day based on its total biomass) occurred on all pastures, and when necessary were mowed and irrigated.

Because of sustained high temperatures and dry conditions during the study period, we conducted at least half of our bird surveys during rotational irrigation (where sprinklers were moved across the pastures every 24hrs).

Alternative Dairy Pastures

The alternative dairy site was smaller (16.18 ha), also located at the KBS dairy facility. These pastures were grazed by heifers. This site had two large paddocks, one was sub-divided into seven pastures; the other was sub-divided into nine (Fig. 1b). These pastures were similar in size to those at the main dairy pastures. Ten pastures were used concurrently in a grazing intensity study. The grazing intensity pastures were divided into half, each around 0.40 ha, resulting in 20 smaller pastures, and had five different heifer stocking rates (0, 3, 6, 9, and 13) each had f our replicates. All pastures were planted with the same five-species of vegetation as the main dairy and were never irrigated. Only three pastures, that were not part of the grazing intensity study, were mowed once at the beginning of the study period.

MDNR Field

The MDNR field was planted once with native grassland species and not managed on a 10 year burn rotation, now representing a grassland fragment. The vegetation at this site included 45 plant species including those planted by the DNR and unplanted species. This sites vegetation was dominated by Canada goldenrod (*Solidago canadensis*), timothy grass (*Phleum pratense*), and big bluestem (*Andropogon gerardii*). A layer (of varying thickness) of plant litter from previous growing seasons occurred across this field. To mimic the organization of the dairy sites, 10 contiguous plots were created (Fig. 1c). These plots were 161m in length and were 131m wide. Unlike the other two sites, no wires or fence posts separated these plots. We flagged the beginning and end of each plot.

Bird Surveys

We placed one bird survey transect down the center and parallel to the long side of each pasture, and were the length of the pasture (dairy pastures) and plots (MDNR field) (Fig. 2). We surveyed 70 transects in this study (44 main dairy, 16 alternative dairy, 10 MDNR; Fig. 1). We conducted surveys during the bird breeding season, starting in late-May and extending through mid-to-late July of 2012. Surveys began at dawn and ended by 10:30 am. We surveyed 6-10 transects each day, and we surveyed each transect six or seven times. Surveys of all transects were completed before any transect was re-surveyed. We designed a stratified random sampling protocol to determine the order pastures were surveyed each day. We selected one site at random each day. Within that site we randomly assigned each transect an order and observer. At the main dairy site the order of paddocks was randomly chosen and within each paddock the pastures were randomly assigned an order and observer, adding an additional stratum. Our sampling protocol ensured that each transect had the same likelihood of being surveyed at any time during the survey day by either observer.

Surveys were conducted by slowly walking along each transect using binoculars to observe birds and their activities within 50m of the survey transect. We recorded species, life stage, along with any activity such as calling, feeding, or nest-building. For each sighting, the location was recorded using a Garmin eTrex 20 GPS (Global Positioning System) unit. At the beginning of each survey day the temperature, cloud cover, and wind speed were recorded. Surveys were not performed during continuous precipitation or when wind speeds were >39 kph.

Vegetation Sampling

Vertical and horizontal vegetation cover were measured in each pasture. We recorded species composition, percent cover per species, and height of vegetation in each pasture the second week in July. Sampling occurred at three locations per transect (¼, ½, ¾ along the transect length) using a 1 m by 1 m Daubenmire frame (Daubenmire 1959). To determine percent cover, the percentage of the frame (10% increments) covered by each species, bare ground, or leaf litter was visually estimated. The total percent cover for vegetation, bare ground, and leaf litter could be more than 100% if overlap occurred. Height was measured, using a graduated pole (a vertical pole with height marks for every cm), at five points evenly distributed throughout the Daubenmire frame. At each of these points the height and species was recorded (cm) of the highest plant touching the pole.

Statistical Analyses

Thirteen bird species occurred frequently (when addition of a bird location did not increase the size of the 90% likelihood contour of a KDE) enough to be used in our analysis. To understand the spatial distribution of each species at each location, utilization distributions (UD) were calculated based on bird locations. A UD represents the interpolated frequencies of animal locations for a specified period of time, given the observed locations (Keating and Cherry, 2009), and are used primarily in landscape ecology studies (Kernohan et al. 2001). An individual's home-range is often estimated with UD's using telemetry techniques. In our study, the UDs represent the likelihood of a bird using a particular location within a site. We chose this approach over the more typical point-count method because UDs give a weighted probability distribution of each species across the whole site as opposed to bird observations at a specific point, or the abundance of each species of birds.

We estimated UDs using the kernel density estimator method (Kernohan et al, 2001). Kernel Density Estimator (KDE) methods are generally preferred over other methods because they have the fewest limiting assumptions and tend to be more accurate (Kernohan et al. 2001). The UD is calculated with a KDE using this equation:

$$\hat{f}(x) = \frac{1}{nh^2}\sum_{i=1}^{n} K\left[\frac{x - X_i}{h}\right]$$

where $\hat{f}(x)$ is the estimated probability density function (EPDF) for a location, *n* is the number of locations, *h* is the user determined bandwidth or smoothing parameter, *X* signifies all the x, y coordinates for the *n* observed locations, *x* is the coordinates where the kernel estimate is calculated, and *K* is the kernel function (Kernohan et al. 2001).

For each of our 13 bird species, a UD was estimated using a fixed KDE method. Fixed KDEs use a consistent bandwidth for each observation, while an adaptive KDE uses different bandwidths for every observation (Kernohan et al. 2001). ArcGIS software (ArcMap 9.3 & 10.1, ESRI, Redlands, California) was used to create each species UD using the Hawth's Tools extension (Beyer, 2004). Hawth's Tools creates a raster output containing the kernel estimates for all location at each of the sites. We used $\hat{f}(x)$ as the response variable for subsequent analyses of bird species composition among sites and to evaluate bird-vegetation structure relationships.

We used a correspondence analysis (CA), to determine bird species composition among the sites. Correspondence analysis is a dual ordination where samples (i.e. bird KDEs) and variables (i.e. vegetation measures) are ordinated concurrently; it attempts to describe the relationship between samples and variables (McGarigal et al. 2000). For each of the 210 vegetation sampling points (3 per transect), we extracted the KDE value from the calculated EPDF raster for each of the bird species, which was the basis for the CA.

We subsequently paired the vegetation characteristics with the species-specific UD data and performed a Canonical Correlation Analysis (CCA). A CCA allows two different sets of variables (i.e. bird KDE and vegetation), which have been measured on the same object (i.e. vegetation sampling location), to be compared. A CCA derives linear functions that explain the largest correlation between the two sets of variables attempting to reduce the dimensionality of multivariate data (McGarigal et al. 2000). Here, the CCA was used to evaluate the role of vegetation in shaping spatial variation of bird habitat used. A Bartlett's chi-squared test was performed on the reduced canonical correlations to determine which sets of correlates were statistically significant. The sets of correlates significantly different from zero are retained for further ecological interpretation (Mcgarigal et al. 2000).

Finally, we tested whether specific vegetation characteristics (structure or species composition) were related to bird species occurrence. We created, species-specific regression models based on bird KDE values and vegetation characteristics at each vegetation sampling points. Prior to the creation of their species-specific models, we performed principal component analyses (PCA). Because each species was distributed across our study areas in different ways, for a given species, we selected only those sites where a species was observed. We identified four groups of bird species that had similar distribution patterns: (1) species found on all three sites; (2) species found on both dairy sites (3) species found only on the main dairy site; and (4) species found only on the MDNR site. One PCA was created from the vegetation data for each of the four distribution groups.

We used PCAs to create linearly uncorrelated variables from our potentially correlated vegetation variables (McGarigal et al. 2000). The resulting principal components (PC) contain the maximum variation among the uncorrelated original variables (McGarigal et al. 2000). Each PC can be thought of as a gradient of the maximized variation from the original dataset and is a weighted linear combination of the original variables, representing an explanatory ecological or environmental gradient found in the data, thereby retaining any explanatory information which may have been lost by separating correlated variables into separate models (McGarigal et al. 2000).

A scree plot was used to determine the number of PCs that should be retained for analysis (McGarigal et al. 2000). Up to 6 PCs were retained for each bird distribution group, explaining ≥ 65% of the variation. Before using each retained PCs in our species-specific models, an ecological interpretation of each PC was conducted (Table 3). We used Tabachnik and Fidell's (1989) rule for interpreting important component loadings to portray ecological meaning (McGarigal et al. 2000).

We used the refined PCs from each bird distribution group as independent variables in each of the species-specific regression models. Each regression model was based on a beta distribution. The beta distribution can accommodate a wide variety of data distributions, and are designed for rates, proportions, or dependent variables that range from 0 to 1 (Cribari-Neto and Zeileis 2010). The beta regression model for our study is defined as:

$$g(p_i) = \boldsymbol{x}_i^T \boldsymbol{\beta} = n_i,$$

Where p_i is the KDE for a species at location i, $\boldsymbol{\beta} = [\beta_1, \ldots \beta_k)]$ is a $k \times 1$ vector of unknown regression parameters $(k < n)$, n is the sample size, $\boldsymbol{x}_i = [(x_{i1}, \ldots x_{ik})]^T$ is a vector containing the k covariates and η_i is a linear predictor (i.e., $\eta_i = \beta_1 x_{i1} + \cdots + \beta_k x_{ik}$). Usually $x_1 = 1$ so that the model has an intercept. We used a logit link function, $\eta = log(\frac{p}{1-p})$, where p is the KDE value, to relate the KDE at each point to the PCs describing vegetation (Cribari-Neto and Zeileis 2010).

To obtain the most robust and complete parameter estimates for each model, we performed model averaging (Grueber et al. 2011). First, we ran the full model (which included all independent variables from the PCAs) for each species. We only included the top ranking models (i.e, Δ AIC < 2) in our model averaging. Model averaging resulted in one model that contained the weighted parameter estimates. These parameter estimates from the best models were then used to interpret the effects of each explanatory variable on the dependent variable (species KDE in this case).To assess goodness of fit for each averaged model, we used a pseudo-R^2 based on:

$$R^2 = 1 - \left(\frac{\sum_{i=1}^{n} (z_i - \hat{z}_i)^2}{\sum_{i=1}^{n} (z_i - \bar{z})^2} \right)$$

Where z_i is the observed dependent variable (KDE) for observation i, $\hat{z}_i$ is the predicted dependent value of the back transformed logits from the model, $\bar{z}$ is the mean of the dependent variable. In this case the r-squared of the back-transformed logits was used to illustrate how much better a predictor of occurance the model is than the mean.

RESULTS

We observed 33 species across all three sites, totaling 2,024 individual bird sightings throughout the breeding season (Table 1). The most abundant species across all sites were Savannah Sparrow (*Passerculus sandwichensis,* SAVS), Red Winged Blackbird (*Agelaius phoeniceus,* RWBL), Bobolink (*Dolichonyx oryzivorus*, BOBO), Barn Swallow (*Hirundo rustica*, BARS), and Common Yellowthroat (*Geothlypis trichas*, COYE); (Table 1). We observed 24, 23, and 13 species at the main dairy, alternative dairy, and MDNR sites, respectively (Table 2).

In the CA used to determine patterns of covariation among species across our three study sites, the first two eigenvalues account for 44% of the variability in the contingency table. There is separation of the MDNR site from the two dairy sites (Figure 3), with some separation of the two dairy sites. Field Sparrow (*Spizella pusilla*, FISP), American Goldfinch (*Spinus tristis*, AMGO), and Common Yellowthroat's spatial distributions, grouped together in the first dimension, are most closely associated with each other and are strongly associated with the MDNR site. Likewise, the spatial distributions of Grasshopper Sparrow (*Ammodramus savannarum*, GRSP), Eastern Meadowlark (*Sturnella magna*, EAML), American Robin (*Turdus migratorius*, AMRO), Bobolink, and Red-Wing Blackbird were more strongly associated with the dairy sites. The fist dimension shows Song Sparrows (*Melospiza melodia*, SOSP), and Chipping Sparrows could likely be found on any of the three sites (Fig. 3).

The second CA dimension indicated a small separation of the three sites (Figure 3). Here, the bird species associated with the alternative dairy site (have higher values) are the American

Tree Sparrow (*Spizella arborea*, ATSP), American Robin, and Red-Wing Blackbird. Again, Field Sparrow, Common Yellowthroat, and American Goldfinch are most strongly associated with the MDNR site. It should be noted here that while along the first dimension the Chipping Sparrow (*Spizella passerine*, CHSP) is more strongly associated with the MDNR site, it appears it is equally associated with either of the two dairy sites, when analyzing the second dimension. The other interesting species in Figure 3 is the American Tree Sparrow, which appears to be strongly associated to both the MDNR and the alternative dairy sites.

Bartlett's test (from the CCA) resulted in five statistically significant canonical correlations; however, only the first two canonical correlates appear to be biologically relevant. The reason for the three additional significant correlations is most likely the power of this test based on the data used. The results of the CCA suggested that differences in vegetation across fields affected bird habitat use. The first set of canonical correlations (Figure 4) groups the MDNR site separately from the dairy sites. The structural aspects of the vegetation with the largest negative loadings were Alfalfa (*Medicago sativa*, Alf), Orchard Grass (*Dactylis glomerata*, Orch), and bare ground (BaGr), which are associated with Red-Wing Blackbirds, Savannah Sparrows, and Chipping Sparrows. The MDNR site contained positive loadings for Kentucky Bluegrass (*Poa pratensis*, KBG), Hawkweed (*Hieracium spp*, HaWe), Fleabane (*Erigeron spp*, Flea) and American Goldfinch, American Tree Sparrow, and Common Yellowthroat respectively. The second set of canonical correlations grouped the dairy sites separately (Figure 5). The dairy sites were separated by positive loadings of Alf and negative loadings of Orch and Rye. The smallest of the three negative loadings correspond to the separation of the main dairy and the MDNR sites by Big Bluestem (*Andropogon gerardii*, BiBl). The two smaller of the three largest vegetation loadings, Narrow Goldenrod (*Solidago* *spathulata*, NaGo) and Flea, separate the secondary dairy from the MDNR site. The CCA results indicate that the separation of bird species across the three sites as seen in the CA is at least partially resulting from the vegetation characteristics of each site.

The MDNR only distributional group included: American Goldfinch, American Tree Sparrow, Common Yellowthroat, and Field Sparrow (Table 4). For this analysis Goldenrod species were only identified to the genus (*Solidago Spp*.). The PCA executed for this distributional group resulted in the retention of six PCs (Table 4), which is higher than recommended, and probably due to the high degree of vegetation heterogeneity and diversity in the MDNR site. Of these six retained PCs only 3 were statistically significant in a model (PC1, 3, and 5), the other three PC's were present in at least one model but were never significant (PC 2, 4, and 6) (Refer to Table 3 for a description of the PC gradients). The final American Goldfinch model shows that the occurance of American Goldfinch increases as the amount of patchy vegetation decreases (PC5, Table 3 and 4), conversely, American Tree Sparrow and Field Sparrow have increasing occurrence as patchy vegetation increases (PC3, Table 3 and 4). The Field Sparrow's final model shows that the occurrence of Field Sparrows increases as wildflowers do (PC3, Table 3 and 4) and decreases as both vegetation height decreases and vegetation become less attractive to insects (PC1, Table 3 and 4). The Common Yellowthroat's model has no statistically significant relationships with any of the vegetation gradients, however, it does have a poor R^2.

The main dairy only distributional group's species, (Eastern Meadowlark, Grasshopper Sparrow, and Song Sparrow (Table 5)) models retained only 3 PC's (Table 5), however, for both Grasshopper Sparrow and Song Sparrow all three PCs were included but none were statistically significant (Table 5). Eastern Meadowlark's model indicates that as vegetation height increases occurrence decreases (PC 2, Table 3 and 5). Although Eastern Meadowlark did have one statistically significant relationship, none of these final species models predicted occurrence significantly better than the mean. One vegetation gradient (PC1: High species richness to low species richness) was not represented in the Eastern Meadowlark model, which indicates that this gradient does not contribute significantly to the variation of the observed distribution.

American Robin, Bobolink, European Starling, Red-Winged Blackbird, and Savannah Sparrow, were all part of the distributional group with diary sites included, which retained 4 PCs (Table 6). The final model for the European Starling suggests that their occurrence increases with an increase of species richness (PC1) and vegetation height (PC3, Table 3 and 6). While American Robin and Bobolink's final models reported all PCs, only one was significant for each. Bobolink had a significantly positive relationship with the gradient showing low species richness to high species richness (PC1, Table 3 and 6). American Robin also had a significantly positive relationship with decreasing cover (PC2, Table 3 and 6). In both the Red-Winged Blackbird and Savannah Sparrow models all PCs were present and all but one was significant. The final model for Red-Winged Blackbird indicates that as vegetation richness (PC1), height (PC3) and percent red clover increases (PC3) so does the likelihood of its occurrence. Savannah Sparrow also had a positive relationship with decreasing vegetation cover (PC2, Table 3 and 6), but had a positive relationship with height (PC3, Table 3 and 6)), and a negative relationship with Red Clover (PC4, Table 3 and 6). This model indicates that the rate of occurrence for Savannah Sparrow increases as both vegetation height and bare ground increases and decreases with more red clover. The r-squared values of these models, however, do not indicate they are better predictors of occurrence than the mean, except for Red Winged Blackbird.

Chipping Sparrow was in its own distributional group because it was observed on all three sites. This model included six PC's (Table 7), only two PC's were excluded from the final model (Table 7). Although this model had a low R2 it did show a statistically significant positive relationship with increased wildflowers (PC5, Table 3), showing that as wildflowers increase so does the occurrence of Chipping Sparrows.

DISCUSSION

One objective of this study was to determine which species of grassland birds were located on dairy fields and grassland fragments. We observed a total of 33 species across all three sites with a total of 2024 individual observations of bird species. We were interested in examining if there was a difference in the bird species observed at the two types of fields. We observed a difference in the species found on each of the site, some species were observed only on one site and not the other two. Some species were seen on both dairy sites and only one species was observed on all sites. More specifically we wanted to determine if vegetation structure and composition contributed to the observed distributions of bird species observed distributions. Lastly we attempted to determine what vegetation characteristics were significant to the distributions of each species individually, since we determined previously that vegetation played a role in the site where a species was observed. Our results showed a few common bird species and many rare bird species. Interestingly, we found there were different bird species observed at each location with little species overlap between the three. This is important when evaluating current management plans for grassland species. If it is believed that species are using agricultural fields as a substitute for the loss of grasslands, and therefore are assumed to be using both pasture and grassland fragments for nesting purposes, managers are currently over estimating the available nesting habitat for many grassland species.

It was surprising to find Red-winged Blackbirds and Song Sparrows on our sites, as they are traditionally considered wetland or marshy species (Yasukawa and Searcy 1995). Many observations of species together on a site were consistent with previous research, such as

Savannah Sparrows and Grasshopper Sparrows which often inhabit the same areas (Wheelwright and Rising 2008). It is also common for American Goldfinches and American Tree Sparrows to feed together in the same habitat (McGraw and Middleton, 2009 and Naugler, 2014).

As seen in Figure 4 there is distinct separation between the vegetation and bird species at the MDNR site (vegetation and bird species) from the dairy sites (vegetation and bird species), which is somewhat unsurprising based on minimal management and disturbance of the vegetation at the MDNR field, allowing more natural vegetation species with a heterogeneous structure to persist. In contrast, vegetation at the dairy sites is strictly managed, planted with specific species, grazed, irrigated, and mowed to maintain a homogenous and simplified structure and to increase the energetic potential when grazed, therefore increasing milk production and farm profitability.

There is an observable difference between the vegetation and bird species that are found on the two dairy sites. As seen in Figure 1, the alternative and main dairy have different species that were more likely to be found on each. While an affinity towards either the main dairy or alternative dairy by individual species can be seen (Fig. 3), the separation of species between these sites becomes more evident through the addition of vegetation characteristics to the analysis. The observed separation is most likely explained by the differing degree of management at these sites. While the main dairy has higher plant species diversity, it is managed for increased milk production by cows, increased management also increases disturbances on nesting birds for the entire breeding season. In contrast to the alternative dairy site, which, due to its involvement in the grazing intensity study was only grazed. Although there were few vegetation species planted in the alternative dairy site (than the MDNR field), it had a more complex and heterogeneous structure; Thus creating a more ideal environment for specific bird species, such as the Savannah Sparrow and Red-winged Blackbird which benefit from a more heterogeneous complex structure than vegetation species richness alone may be.

Our species specific models along with previous research help to explain the observed species distribution, supporting the idea that one technique implemented to manage all grassland species is likely ineffective at maintaining or increasing all grassland bird populations. Instead management needs to address the specific habitat characteristics that influence individual species' habitat and nesting needs. This study supports earlier conclusions, that while there is overlap of important vegetation characteristics between species, no two species analyzed had the same relationships with the measured vegetation structure and composition characteristics. This means if an area is managed for one specific species it may also be deterring others. For instance looking at the MDNR field, there is overlap in our species specific models, however, if you only managed for vegetation with single stalks which American Goldfinches like, it would likely exclude or decrease important habitat characteristics for the American Tree Sparrow and Field Sparrows, which prefer patchy vegetation. It is important to note our model also showed that Field Sparrows are attracted to areas with increased wildflowers and vegetation attractive to insects, these characteristics would also need to be included in management plans aimed to conserve Field Sparrow populations (Carey et al. 2008).

Although our study does support previous research on the need for diverse and heterogeneous mosaic vegetation structure and composition in order to support a variety of grassland bird species, we did have a few interesting species specific divergences from that research. Bobolinks appear attracted to pastures with high species richness, probably largely due to foraging needs, unlike previous research which suggests Bobolink prefer fields with low alfalfa levels. We found Bobolinks more likely to be observed in fields with alfalfa than without.

This however, may be due less to preference and more to the high interactions of Bobolinks and Red-winged Blackbirds. It has been documented that while Bobolinks are aggressive towards males of other species, they are almost always submissive to Red-winged Blackbirds (Martin and Gavin, 1995). In our study Red-winged Blackbird's territorial aggression towards Bobolinks may have resulted in Bobolink observations in fields with high alfalfa, which is not thought to be their preferred habitat. The Chipping Sparrow was observed on all three sites. Literature has documented that the presence of Chipping Sparrow in pastures has increased in frequency (Middleton, 1998). Our study alternatively suggests that they prefer uncultivated, naturally occurring grasses and wildflowers as opposed to traditionally planted forage found in the pastures.

Our two most observed species models also had interesting results. The Savannah Sparrow's model reported contradictory relationships with vegetation structure, depicting an attraction to no vegetation cover but also to taller vegetation. This may be because they prefer to forage in low vegetation or bare ground but build their nests near high vegetation with protection from predators (Wheelwright and Rising, 2008). Red-winged Blackbirds were the second most common species we observed, while they were most commonly considered wetland birds using cattails for nest building support (Yasukawa and Searcy, 1995). It is apparent from our research, that while grasslands are not their traditional habitat, their habitat requirements are met through the pasture vegetation. Our model concluded that in grassland habitats Red-winged Blackbirds prefer areas with high species richness and taller vegetation. A taller vegetation preference here is likely for nest building. In our fields, orchard grass is a tall plant with a sturdy stem, which may mimic cattails. The attraction to fields with higher species richness may be due to their tendency to have increased alfalfa, which Red-winged Blackbirds have previously been observed in as opposed to wetlands.

It is evident that some of our final models fit our data poorly, this is especially true with Grasshopper Sparrow, Common Yellowthroat, and Song Sparrow models which have no significant findings. These three species do not appear, based on our models, to have any relationship with the vegetation characteristics measured in our study. It is possible that while the models explain the variation in distribution that is due to vegetation, there are other factors that are also affecting species distributions, such as interactions with other species, size of grassland/pastures, or even proximity to human habitation, which have a larger effect on the species distributions than vegetation alone. Therefore, the vegetation data alone may not explain all of the spatial variation observed by the species. This may also be true for the remaining species with significant findings but low r-squared values. Illustrated by the Eastern Meadowlark, where previous research shows an affinity for large pastures with good grasses and tall vegetation (Jaster et al. 2012). Interestingly, our model with a low r-squared, had relationships consistent with previous research and described the vegetation of the main dairy. Another explanation, especially for the Song Sparrow, may be that while these species were observed on a site, it was not suitable breeding habitat, and therefore, no characteristics significantly explained their spatial distributions.

Management Implications

The combination of all three analyses brought us to the same conclusions as previous research, that in order to maintain a high diversity of grassland bird species, pasture land and grasslands should not be managed for just one vegetation or structure type. Instead, management needs to aim toward maintaining a mosaic grassland that is patchy in structure and composition in order to provide the necessary resources for a variety of different species. The characteristics of pasture land as well as those in grassland fragments must be included in this management style. Therefore, management on a landscape scale should include both agriculture (pasture and crop) fields and grassland fragments. Our remaining grasslands and even agricultural fields, especially pasture, need to be managed carefully for this patchiness during the breeding season to ensure the presence of varied composition and structure of vegetation. There are a few ideas of ways to accomplish this, farmers could create set aside fields or parts of fields during the breeding season, which is shorter than the growing or grazing season. Another solution is delaying initial harvest date or altering harvest schedule to accommodate at least one nesting attempt; many grassland species attempt to nest twice. It is especially important for agricultural fields including dairy pastures to incorporate considerations for the breeding season and grassland bird nesting to their field management plans, because pastures attract unique species that don't use grassland fragments during their breeding season, and if nesting is not successful due to disturbances by mowing, grazing, or irrigation these fields have a potential to become population traps for these species further declining their populations. This study highlights areas of concern for future research, an evaluation of how management techniques other than just grazing, affects nesting success rates in agriculture fields, and how the magnitude of different management techniques such as irrigation and mowing effect grassland bird nest success.

APPENDIX

APPENDIX

Figure 1: Site Maps. Aerial views of grassland bird and vegetation survey sites and associated plot boundaries (red lines) at Kellogg Biological Station, Kalamazoo, MI. Including A. the main dairy site, B. the alternative dairy site, C. Michigan Department of Natural Resources (MDNR site).

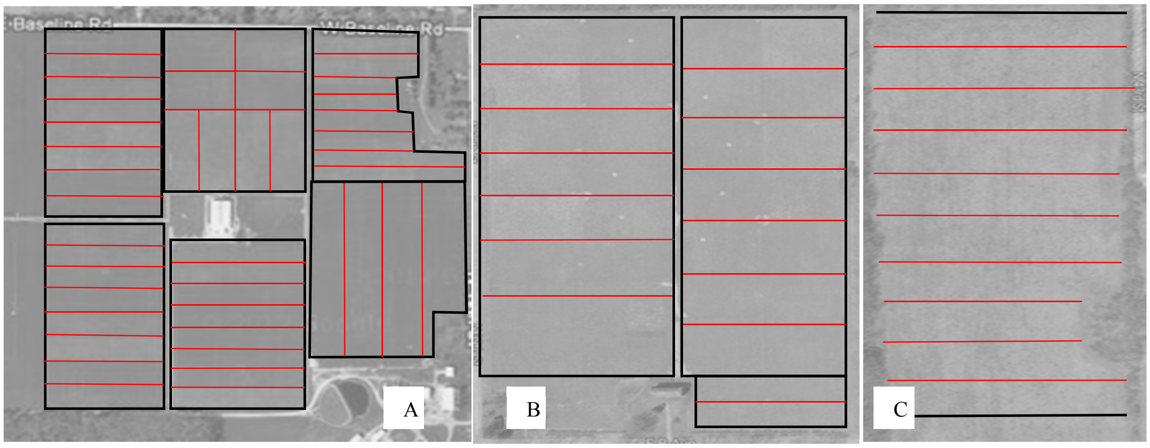

Figure 2: Sampling Maps. Example of the bird survey and vegetation sampling locations, Kellogg Biological Station, Kalamazoo, MI. A. the transect placement within a pasture. B. the placement of the three vegetation sampling locations.

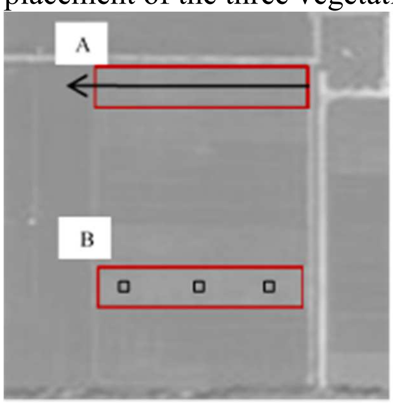

Figure 3: Correspondence Analysis. First two dimensions of a Correspondence Analysis (CA) of the spatial bird distributions at each site.

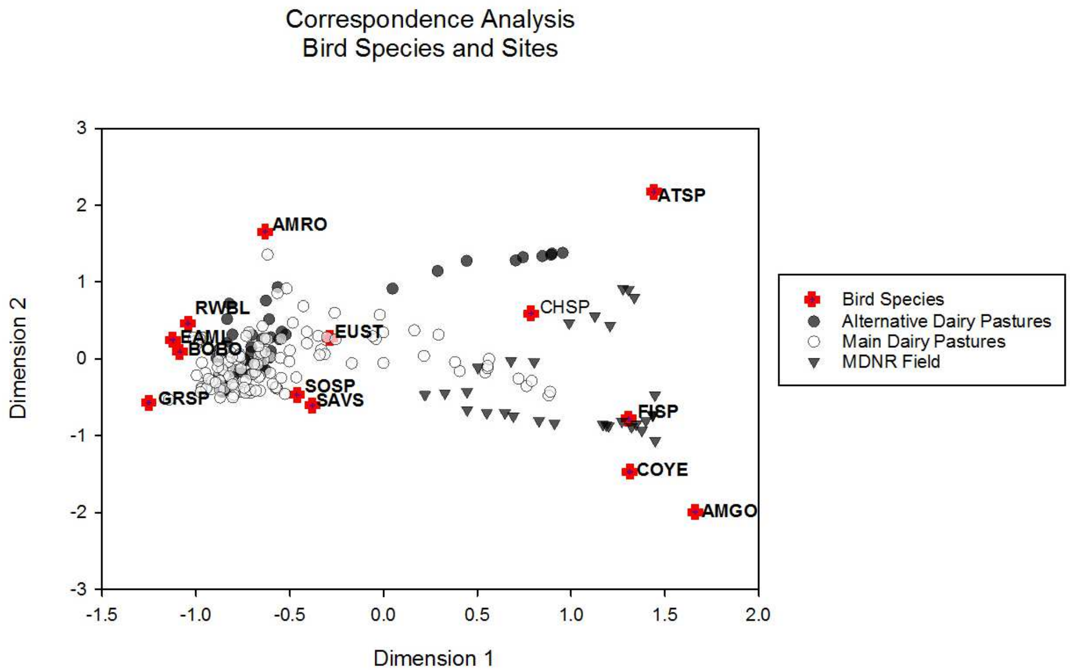

Figure 4: First set of Canonical Correlations. Plot of the first set of canonical correlations of both the spatial bird abundances (y) and the vegetation characteristics at each site (x). Open circles represent the main diary pasture, closed circles represent the secondary dairy pastures, and the triangles represent the MDNR sites.

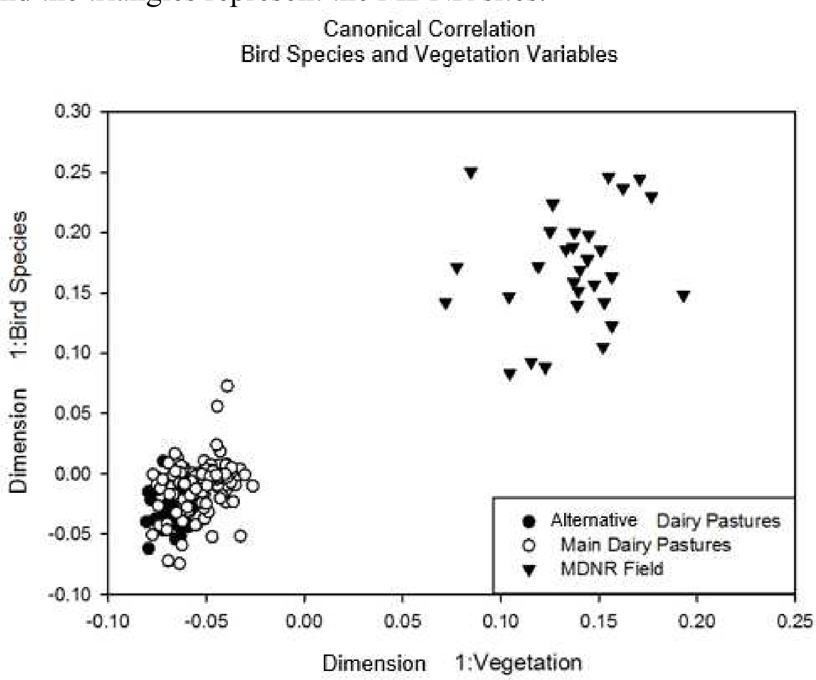

Figure 5: Second Set of Canonical Correlations. Plot of the second set of canonical correlations of both the spatial bird abundances (y) and the vegetation characteristics at each site (x). . Open circles represent the main diary pasture, closed circles represent the secondary dairy pastures, and the triangles represent the MDNR sites.

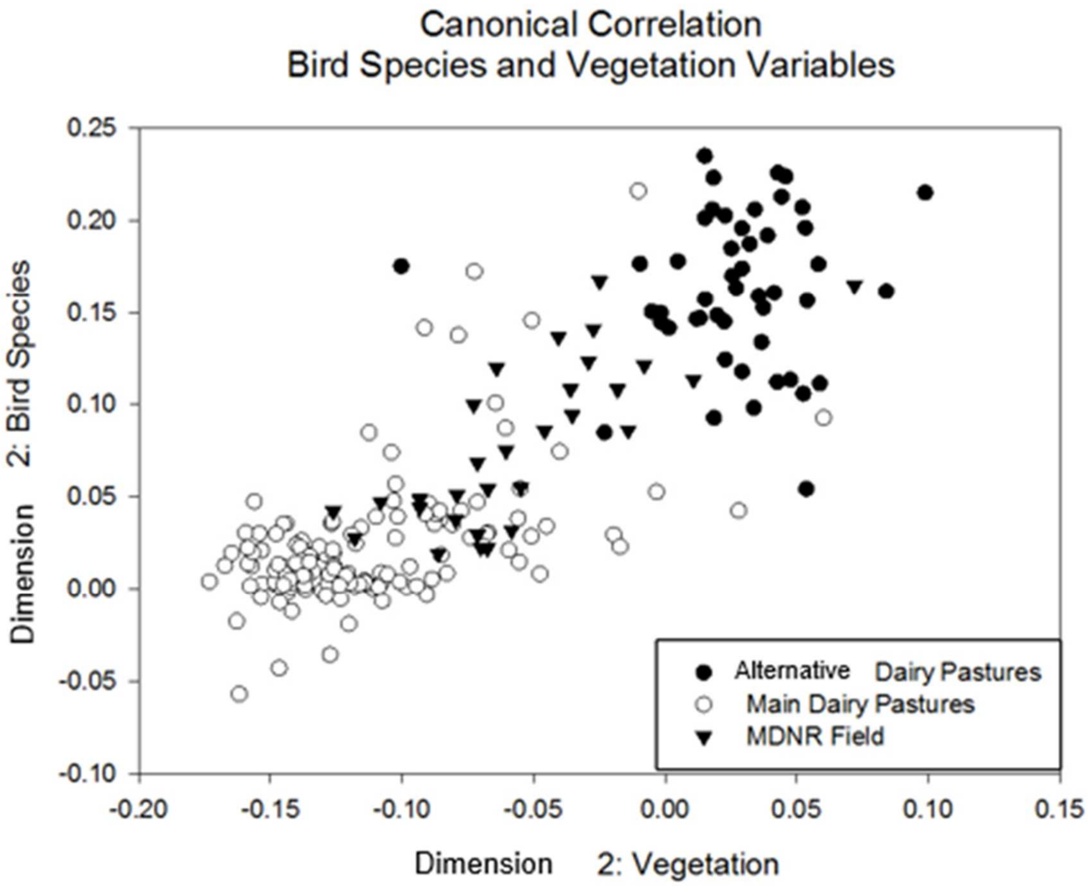

Table 1: List of Observed Bird Species. Table of all species observed during the bird surveys, the four letter abbreviations for each species, and the total number of individuals of each species observed.

Species	Scientific Names	Species Code	Total Species Observations
American Crow	*Corvus brachyrhynchos*	AMCR	7
American Goldfinch	*Spinus tristis*	AMGO	12
American Robin	*Turdus migratorius*	AMRO	20
American Tree Sparrow	*Spizella arborea*	ATSP	11
Bank Swallow	*Riparia riparia*	BANS	37
Barn Swallow	*Hirundo rustica*	BARS	164
Brown-headed Cowbird	*Molothrus ater*	BHCO	4
Bobolink	*Dolichonyx oryzivorus*	BOBO	258
Brown Thrasher	*Toxostoma rufum*	BRTH	7
Chipping Sparrow	*Spizella passerina*	CHSP	26
Cliff Swallow	*Petrochelidon pyrrhonota*	CLSW	6
Common Yellowthroat	*Geothlypis trichas*	COYE	49
Dickcissel	*Spiza americana*	DICK	1
Eastern Bluebird	*Sialia sialis*	EABL	1
Eastern Kingbird	*Tyrannus tyrannus*	EAKI	6
Eastern Meadowlark	*Sturnella magna*	EAML	27
European Starling	*Sturnus vulgaris*	EUST	24
Field Sparrow	*Spizella pusilla*	FISP	43
Grasshopper Sparrow	*Ammodramus savannarum*	GRSP	30
Henslow's Sparrow	*Ammodramus henslowii*	HESP	6
House Sparrow	*Passer domesticus*	HOSP	6
Indigo Bunting	*Passerina cyanea*	INBU	5
Killdeer	*Charadrius vociferus*	KILL	4
Mourning Dove	*Zenaida macroura*	MODO	3
Northern Flicker	*Colaptes auratus*	NOFL	2
Red-Tailed Hawk	*Buteo jamaicensis*	RTHA	1
Red Winged Blackbird	*Agelaius phoeniceus*	RWBL	417
Ruby Throated Hummingbird	*Archilochus colubris*	RTHU	1
Savannah Sparrow	*Passerculus sandwichensis*	SAVS	748
Song Sparrow	*Melospiza melodia*	SOSP	20
Tree Swallow	*Tachycineta bicolor*	TRES	4
Turkey Vulture	*Cathartes aura*	TUVU	1
Vesper Sparrow	*Pooecetes gramineus*	VESP	5

Table 2: **List of Total Bird Observations at Each Site** The total number of species found at each site, the total number of individual birds observations seen at each site, and the total number of birds seen.

Site	Number of Species	Total Number of Birds observed
Main Dairy	24	1408
Secondary Dairy	23	458
MDNR	14	158
Total	33	2024

Table 3: List of Principle Components. Ecological gradients of each PC from the four PCAs on the vegetation characteristics

MDNR Distributional Group	Ecological Description of PC Gradients of Vegetation Characteristics
PC 1	Short, dense, insect attracting vegetation → Tall, dense, seeded vegetation
PC 2	Old/dead vegetation litter → Living tall vegetation
PC 3	Wild grasses → Wildflowers
PC 4	Short vegetation → Tall vegetation
PC 5	Patchy vegetation → Single stalked vegetation
PC 6	Hawkweed presence
Main Dairy Distributional Group	**Ecological Description of PC**
PC 1	High vegetation species richness → Low vegetation species richness
PC 2	Tall vegetation → Short vegetation
PC 3	Lots of vegetation cover → Little vegetation cover
Both Dairy Distributional Group	**Ecological Description of PC**
PC 1	Low vegetation species richness → High vegetation species richness
PC 2	Lots of Vegetation Cover → No vegetation cover
PC 3	Height
PC 4	Red Clover
All Sites Distributional Group	**Ecological Description of PC**
PC 1	Wild grasses and flowers
PC 2	High vegetation species richness → Low vegetation species richness
PC 3	Flat Goldenrod
PC 4	Patchy, bunchgrass vegetation attractive to insects
PC 5	Tall vegetation → Short vegetation
PC 6	Virginia Peppergrass

Table 4: MDNR Distributional Group Models. Species-specific models for the MDNR observational group. Number of models is the number of "best models" used in the model averaging. PCs 1-6 are the principle components used as the independent variables (Table 3). Ns represents the PCs that were found to be not significant in the final model. Positive (+) and negative (–) symbols indicate the direction of the significant relationship of the PC and the species. Any blank spaces represents a PC that was not represented in any of the "best models". R-squared is goodness of fit of the predicted occupancy for each of the model averaged models.

Species	No. of Models	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6	R-Squared
AMGO	6		Ns	Ns		+	Ns	0.295
ATSP	4	Ns	Ns	Ns		-	Ns	0.497
COYE	5			Ns	Ns	Ns	Ns	0.031
FISP	1	-		+		-		0.354

Table 5: Main Dairy Distributional Group Models. Species-specific models for the Main Dairy observational group. Number of models is the number of "best models" used in the model averaging. PCs 1-3 are the principle components used as the independent variables (Table 3). Ns represents the PCs that were found to be not significant in the final model. Positive (+) and negative (–) symbols indicate the direction of the significant relationship of the PC and the species. Any blank spaces represents a PC that was not represented in any of the "best models". R-squared is goodness of fit of the predicted occupancy for each of the model averaged models.

Species	No. of Models	PC 1	PC 2	PC 3	R- Squared
EAML	3		+	Ns	0.020
GRSP	5	Ns	Ns	Ns	0.016
SOSP	4	Ns	Ns	Ns	0.001

Table 6: Dairy Distributional Group Models. Species-specific models for observational group including both dairy sites. Number of models is the number of "best models" used in the model averaging. PCs 1-4 are the principle components used as the independent variables (Table 3). Ns represents the PCs that were found to be not significant in the final model. Positive (+) and negative (–) symbols indicate the direction of the significant relationship of the PC and the species. Any blank spaces represents a PC that was not represented in any of the "best models". R-squared is goodness of fit of the predicted occupancy for each of the model averaged models.

Species	No. of Models	PC 1	PC 2	PC 3	PC 4	R-Squared
AMRO	5	Ns	+	Ns	Ns	0.113
BOBO	6	+	Ns	Ns	Ns	0.162
EUST	3	+	Ns	+	Ns	0.100
RWBL	2	+	Ns	+	+	0.426
SAVS	2	Ns	+	+	-	0.160

Table 7: All sites Distributional Group Models. The final species specific model for the species in the observational group from all three sites. Number of models is the number of "best models" used in the model averaging. PCs 1-6 are the principle components used as the independent variables (Table 3). Ns represents the PCs that were found to be not significant in the final model. Positive (+) and negative (–) symbols indicate the direction of the significant relationship of the PC and the species. Any blank spaces represents a PC that was not represented in any of the "best models". R-squared is goodness of fit of the predicted occupancy for each of the model averaged models.

Species	No. of Models	PC 1	PC 2	PC 3	PC 4	PC5	PC 6	R-Squared
CHSP	4	+		Ns	Ns	Ns		0.114

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