Bird habitat associations in the lower Missouri River floodplain

By Wayne E. Thogmartin, Melinda G. Knutson, Jason J. Rohweder, and Brian R. Gray

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Executive Summary

Bird Habitat Associations on the Lower Missouri River Floodplain by Wayne E. Thogmartin, Jason J. Rohweder, Brian R. Gray, and Melinda G. Knutson

Floodplain forests provide some of the most dense and diverse assemblages of birds in North America; unfortunately, because of floodplain protection projects, the ecology of many rivers, including the lower Missouri River, have changed, potentially influencing avian floodplain abundance and diversity. We examined avian community composition associated with the floodplain of the lower Missouri River. Our specific objectives were to (1) describe the breeding bird assemblage and environmental factors associated with three stages of forest succession represented in the lower Missouri River floodplain: open areas dominated by wet prairie/forbs (wet prairie), early successional floodplain forests (early successional forest), and mature floodplain forests (mature forest); (2) describe the plant community associated with each habitat type and identify indicator bird species and species of conservation concern associated with each habitat type; (3) compare the breeding bird community of the lower Missouri River floodplain to published reports of large floodplain bird communities elsewhere (upper and middle Mississippi River and lower Mississippi Alluvial Valley); (4) describe the spring migrating bird assemblage associated with the three stages of forest succession represented in the lower Missouri River floodplain, comparing species assemblages between eastern and western Missouri study sites; (5) examine the environmental conditions associated with establishment of young forests vs. prairie in abandoned agricultural land subject to frequent floods; and (6) suggest approaches to future monitoring of the bird community with respect to the appropriate sampling intensity needed to detect change in relative abundance over time, including incorporation of detection probabilities.

Avian assemblages along the lower Missouri River were among the most diverse in North America, comprising >15% of all species occurring on the continent. One-hundred-twenty-one species were identified in early successional forest, 131 species in wet prairie, and 140 species in mature forest, representing sampling during the breeding and migration seasons. There was a longitudinal gradient in species richness, with richness increasing from west to east. There was considerable overlap in avian species composition between the spring migration period and the breeding period. Avian composition of the three land covers overlapped considerably as well. Nearly half of the species occurred among each of the three land cover types; 44.5% (n = 77) and 53.2% (n = 75) of species were found in the three land covers during the migration and breeding season, respectively. There were eight species indicative of wet prairie, including the Northern Harrier and Bobolink; one species, the Bell's Vireo, was indicative of early successional forest; and Northern Parula and Prothonotary Warbler were significantly indicative of mature forest. We examined environmental factors differentiating wet prairie and early successional forest site, important habitat for floodplain birds.

We found early successional forest sites were closer to the river and on lower elevation, but occurred on drier soils than wet prairie. In a regulated river such as the lower Missouri River, wet prairie sites are relatively isolated from the main channel as compared to early successional forest, despite occurring on relatively moister soils. We found the power to detect trends in bird abundance was a function of the trend magnitude, sample size, and species-specific sampling variance. We found for nine representative species that most individual management sites were too poorly sampled to allow for site-level estimation of trends in abundance. In

general, to detect trends of 3% per annum or greater at 80% power required an annual sample size of ≥50. Confounding our ability to calculate power to estimate trends was the imperfect detectability of species. This ability to detect species varied among taxa by habitat, time, and observer. In general, approximately half of individual birds were estimated to have been observed (i.e., half the individuals of a species were not observed during surveys).

We conclude this analysis with recommendations for additional research and a lengthy discussion regarding management implications of the research. For instance, the information gleaned regarding the fate of abandoned agricultural lands and land cover-specific bird community composition may allow us to predict the fate of acquired lands and their attendant consequences to the bird communities along the lower Missouri River. Our analyses of the vegetation factors describing the wet prairie and forest sites imply that future vegetation monitoring might be most efficient if it focuses on the collection of a subset of all of the variables measured for this study (e.g., litter depth, vegetation height, and proportion of the site in bare soil in wet prairies, total canopy cover, upper- and mid-canopy cover, and maximum diameter of trees at breast height in forest). Because too few surveys were conducted within individual study areas to detect moderate declines in bird abundance without substantial increases in sampling intensity, the only course of action are efforts to reduce sampling variance. Detection probability seems to be an important factor contributing to sampling variance.

A DVD is included containing all relational and geographic information systems databases used in the analyses herein.

Chapter One
Introduction

Floodplain forests rival all other habitat types in bird density and diversity (Best et al. 1995). A number of studies have reported high species richness and high abundances of birds in these habitats (Best et al. 1996, Knutson et al. 1996, Twedt and Portwood 1997, Knutson and Klaas 1998, Twedt et al. 1999). Unfortunately, large floodplain forests in the midwestern United States are now facing a number of ecological challenges. For example, the lower Missouri River (LMR) floodplains experienced severe and recurrent flood conditions in the 1990's (Chapman et al. 2003). As a result, large tracts of agricultural land were abandoned and young forests and open prairie habitats became established in the floodplain. A recent study of the bird assemblage of young forests and prairies regenerating on abandoned agricultural land compared with mature forests in the middle Mississippi River, which experienced similar flooding, found that bird species richness differed among these habitat types, with mature forests supporting the largest number of species and the most species of management concern (Knutson et al. 2005). The shrub/scrub and mature forest bird assemblages were distinct and shared few species, but the young forests had no identifiable bird species assemblage, sharing species found in both of the other habitat types.

The lower Missouri River floodplain system historically contained a complex of early and late successional floodplain forests, marshes, and wet prairie habitats supporting a high diversity of plant and animal communities (Big Muddy National Fish and Wildlife Refuge Final Environmental Impact Statement, US Fish and Wildlife Service). Many young forests and open prairie areas in the Missouri River floodplain are interspersed on abandoned farm land subjected to several years of flooding. The patchy distribution of these cover types is a puzzle because both plant communities are observed in what was a single farm field <10 years ago. One would expect that plant succession would be generally uniform across the same farm field, but this is not the case. A similar patchy distribution of these two habitat types was observed in work on the middle Mississippi River, an area subject to similarly recent flood events (Knutson et al. 2005).

Long-term conservation of floodplain wetland habitats and the associated rich songbird communities requires better understanding of the present altered system and how different types of floodplain habitats support songbirds. We provide baseline information on the status of songbirds in this landscape and elucidate landscape-level patterns helpful to managers developing bird conservation strategies. Our objectives were to (1) describe the breeding bird assemblage and environmental factors associated with three stages of forest succession represented in the lower Missouri River floodplain: open areas dominated by wet prairie/forbs, early successional floodplain forests, and mature forests; (2) describe the plant community associated with each habitat type and identify indicator bird species and species of conservation concern associated with each habitat type; (3) compare the breeding bird community of the lower Missouri River floodplain to published reports of large floodplain bird communities elsewhere (upper and middle Mississippi River and lower Mississippi Alluvial Valley) and discuss results with regard to current Fish and Wildlife Service refuge management issues in the lower Missouri River floodplain; (4) describe the spring migrating bird assemblage associated with the three stages of forest succession represented in the lower Missouri River floodplain: mature forests, young forests, and wet prairie, comparing species assemblages between eastern and western Missouri study sites; (5) examine the environmental conditions associated with establishment of

young forests vs. prairie in abandoned agricultural land subject to frequent floods; and (6) suggest approaches to future monitoring of the bird community with respect to the appropriate sampling intensity needed to detect change in relative abundance over time, including incorporation of detection probabilities.

Chapter Two
Study Area

Ten study sites were chosen within the lower Missouri River alluvial floodplain, stretching from northwestern Missouri (near St. Joseph) to east-central Missouri (near St. Louis)(Table 1, Fig. 1, Appendix A). These ten sites were located in three Fish and Wildlife Service refuges (Big Muddy National Fish and Wildlife Refuge, Swan Lake National Wildlife Refuge, Squaw Creek National Wildlife Refuge), three Missouri Department of Conservation Areas (Overton South, Eagle Bluffs, Howell Island), and the Department of Defense's Fort Leavenworth. All sites were on public land and all except two (Swan Lake National Wildlife Refuge, Squaw Creek National Wildlife Refuge) were riverward of a levee.

The study region is characterized by loess deposits ranging from 3─27 m deep, overlaying limestone bedrock and bounded by limestone and sandstone bluffs (U.S. Fish and Wildlife Service 1999). Soils are generally moderately well drained to well drained, consisting of Haynie and Waldron Soil Series soils (U.S. Fish and Wildlife Service 1999). The river floodplain varies in width from 3─16 km; low river benches, terraces, and the remains of former river channels are common (U.S. Fish and Wildlife Service 1999).

The western portion of the lower Missouri river occurs in the Central Dissected Tillplains ecological region, whereas the eastern portion occurs in the Ozark Highlands ecological region. As such, the western portion is characterized by a mix of clay, sand, gravel, and boulders deposited by glacial action and dissected by glacial runoff. The Ozark Highlands are characterized by a broad plateau dissected by erosion.

Landcover at the various study sites consisted of wet prairie (WTP), early successional forest (ESF), and mature forest (MTF). Floodplain wet prairie, possessing <5% tree coverage, was comprised of herbaceous and emergent plants and grasses, including horseweed (*Conyza* spp.), aster (*Symphyotrichum* spp.), goldenrod (*Solidago* spp.), smartweed (*Polygonum* spp.), pigweed (*Amaranthus* spp.), bulrushes (*Scirpus* spp.), cattail (*Typha* spp.), prairie cordgrass (*Spartina* spp.), sedges (*Carex* spp., *Cyperus* spp., *Eleocharis* spp.), rice cutgrass (*Leersia* spp.), reed canarygrass (*Phalaris arundinacea*), and millet (*Echinochloa* spp.) (Nelson 1987, Young et al. 2003). Early successional forest was comprised of densely forested habitat with trees <10 years of age. Dominant tree species were eastern cottonwood (*Populus deltoides*), willows (*Salix* spp.), box elder (*Acer negundo*), ash (*Fraxinus* spp.), dogwood (*Cornus* spp.), and mulberry (*Morus* spp.). Mature forest consisted of upper canopy trees >15 m tall with dominant species of eastern cottonwood, box elder, pin oak (*Quercus palustris*), swamp white oak (*Q. bicolor*), silver maple (*A. saccharinum*), slippery elm (*Ulmus rubra*), hackberry (*Celtis occidentalis*), mulberry, and willow; the understory of mature forest was typically open, with few shrubs and midstory trees (Young et al. 2004). Unsampled habitat included areas of tree plantings, areas targeted for Johnson grass treatment, agricultural fields, and open water.

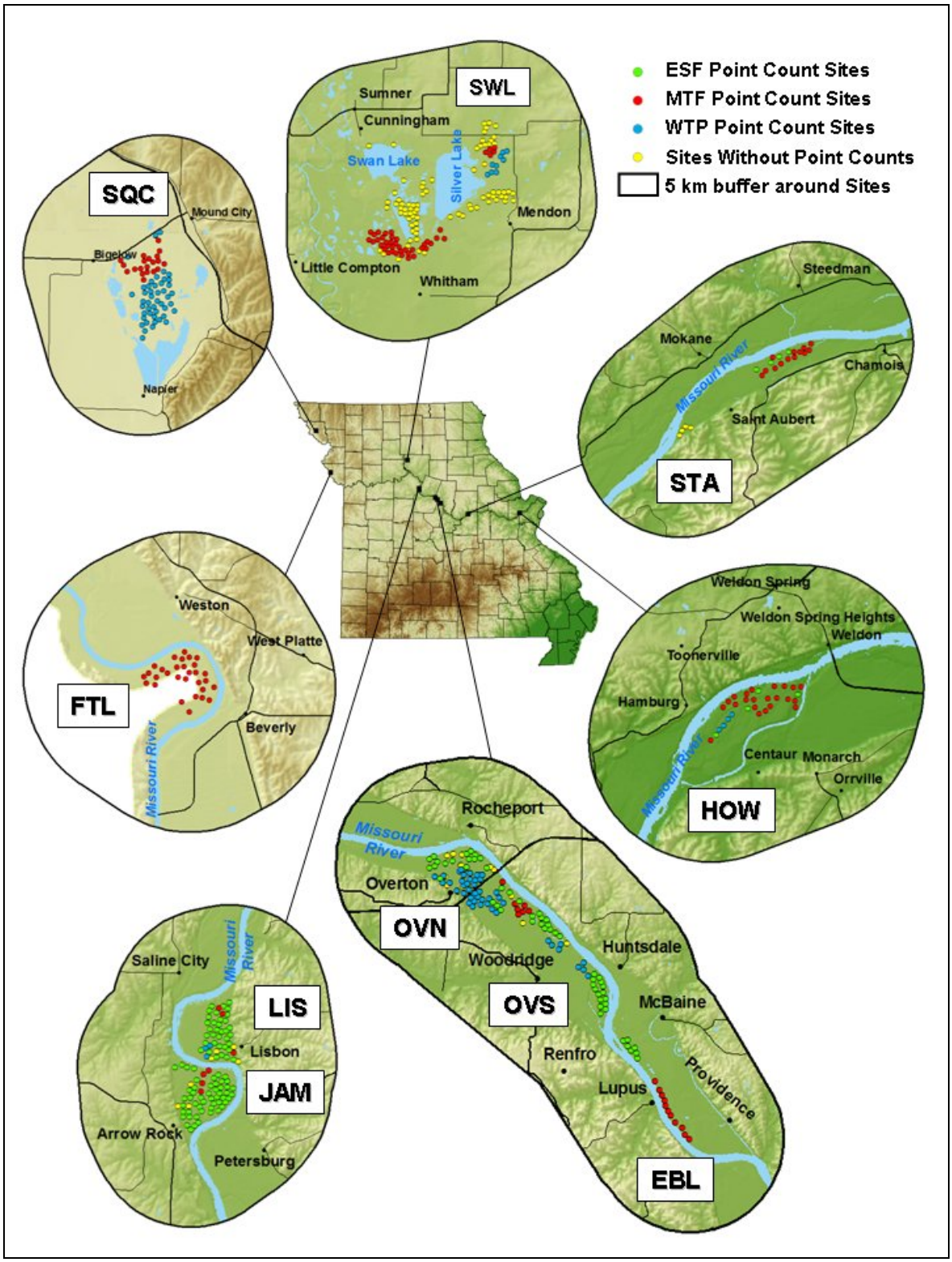


Figure 1. Study site locations along the lower Missouri River. See Table 1 for study area acronyms. ESF is early successional floodplain forest, MTF is mature forest, and WTP is wet prairie.

Table 1. Study area location and size and sample sizes of bird and vegetative surveys along the lower Missouri River, 2002–2004.

Study Area	Acronym	Longitude	Latitude	Estimated Sample Area (Ha)	Avian Survey Sites	No. of Point Counts Conducted	Vegetative Survey Sites	No. of Vegetative Surveys Conducted
Squaw Creek	SQC	95.257	40.100	891	66	770	66	175
Ft Leavenworth-Weston	FTL	94.899	39.380	430	30	173	30	30
Swan Lake	SWL	93.183	39.608	5,399	52	169	49	66
Jameson Island	JAM	92.928	39.083	640	55	260	49	81
Lisbon Bottoms	LIS	92.919	39.113	406	41	190	40	77
Overton Bottoms North	OVN	92.569	38.958	491	36	200	41	88
Overton Bottoms South	OVS	92.523	38.921	1,558	63	310	62	111
Eagle Bluffs	EBL	92.450	38.853	148	18	109	17	31
St Aubert Island	STA	91.848	38.659	346	17	92	16	23
Howell Island	HOW	90.699	38.666	408	30	133	30	37

Chapter Three
Bird-Habitat Associations

Approximately half of the avian species breeding in the midwestern United States have declined significantly in the last several decades (Thompson et al. 1993). These declines are attributed in part to the degradation and loss of migration and breeding habitat. The lower Missouri River was once marked by frequent flooding, a shifting, braided channel, and high turbidity (hence, the moniker "Big Muddy"), resulting in a dynamic mosaic of wet prairie, early successional forest, and mature forest that was particularly suited to sustaining a diverse assemblage of birds. In the past century, major modifications to the river have occurred for flood protection, navigation, irrigation, and power production. The result is that the lower one-third of the Missouri River is channelized, leveed, and its banks are stabilized, reducing the scouring of mature habitat and the formation of sandbars upon which new habitat is created.

Despite these anthopogenic modifications, the flood years of the early 1990s led to a reduction in agricultural production in the floodplain, presenting an opportunity for federal and state land management agencies to acquire new lands to add to the conservation estate (U.S. Army Corps of Engineers 2004). Unfortunately, many acquisitions are site specific and few have included explicit ecological objectives. Understanding the relations between the floodplain avifauna and the natural land covers of the lower Missouri River should allow for predicting the consequences of these acquisitions for the conservation of birds. Our objectives were to characterize the avian assemblages occurring in wet prairie, early successional forest, and mature forest during the spring migration and summer breeding seasons.

Methods

Surveys for Birds and Vegetation

Bird and vegetation data were collected each year during spring (15 April – 14 May) and summer (15 May – 30 June) during 2002–2004 at up to 365 locations (survey points), spaced $\geq$250 m apart (Table 1). Spring constituted the migration season and summer constituted the breeding season. Survey points were a stratified random sample from the three habitat types at the 10 study areas. The habitat types were defined based on digital maps of the study areas and field reconnaissance (Young et al. 2003).

All bird surveys were conducted using 5-min point counts within a 50-m radius circle (7,854 m^2; 0.8 ha)(Ralph et al. 1993). There were nine observers during the course of the survey, though some operated only in concert with another observer and never alone. The number of points surveyed varied each year, depending upon suitable weather conditions and other logistical limitations. Distance detection methods (Buckland et al. 2001, 2004) were employed; surveyors estimated the radial distance from the survey point to the bird location and classified the bird into one of two distance classes, ≤50 m or >50 m. Flyovers within these two distance classes were included in the total number counted but were ignored for the purposes of the detection analyses.

Stem counts of trees, shrubs, and snags/dead trees, and estimates of vegetation cover, soil type, and standing water were collected at the same locations as the bird point counts within 17.85 m (0.1 ha) radius circular plots (Table 2).

Table 2. Environmental measures collected at vegetative survey locations at 10 study areas along the lower Missouri River, 2002–2004. Measures collected on variable-sized plots were standardized to 17.85 m radius plot size.

Variable	Description
Species	USDA Plant Species code (USDA, NRCS 2004)
FOREST	
Soil	Soil texture at the site determined by the "Texture by Feel" method created by Thien (1979) after removal of debris from on top of the soil.
Total Canopy Cover (ocular)	The percentage of the combination of the upper-upper, upper, and mid-canopy closure in the plot determined by ocular estimate at the point center.
Total Canopy Cover (spherical densiometer)	Four readings from a convex spherical densiometer (Model A, Forest Densiometers, Batesville, OK) at 8.92 m from the center point in each cardinal direction; an alternative measure of canopy cover.
Upper-Upper (UU) Canopy	Ocular estimate of the percentage of the plot covered by canopies from trees >3 m in height. There must be at least 5 m difference in mean height between upper-upper canopy and upper canopy
Upper (U) Canopy	Ocular estimate of the percentage of the plot covered by canopies from trees >3 m in height.
Middle (M) Canopy	Ocular estimate of the percentage of the plot covered by canopies with >5 m difference in mean height between the upper canopy and mid-canopy.
Shrub (S) Canopy	Ocular estimate of the percentage of the plot covered by canopies from woody shrubs 1–3 m in height.
Ground Cover (GC) Canopy	Percentage of all live vegetation <1 m in height, whether herbaceous or wood.
Tree Height (UU)	Ocular estimate of the height (m) of the upper-upper canopy.
Tree Height (U)	Ocular estimate of the height (m) of the upper canopy
Tree Height (M)	Ocular estimate of the height (m) of the mid canopy
DBH	Diameter at breast height (DBH) measurement (cm) of each individual tree within a variable radius subplot.
Percent Canopy Cover by Species	Percentage of the particular canopy cover (UU, U, M, S) in the plot comprised by the given species
Stem Count	Numbers of stems for each individual species in a variable radius subplot.
GRASSLAND	
Percent Grass, Sedges, Forbs, Cattail, Woody Plants, Lying Litter, Standing Litter, and Bare Soil	Percent vegetation cover within a Daubenmire frame to the nearest 5%, separately for sedges, grasses, forbs, woody plants, cattail, litter (lying: <45%, and standing: 45–90%), and bare soil.
Grass/Sedge	Percent vegetation cover within a Daubenmire frame to the nearest 5%, combined for Grass and Sedge classes at Squaw Creek.
Woody Stem	Number of woody stems within each Daubenmire frame, differentiated between low stems (≤30 cm tall) and high stems (≥30 cm tall).
Litter Depth	Mean of four measurements (mm), height at which the meter stick is totally covered by horizontally lying dead plant material.
Vegetative Height	Mean of four measurements (cm) of the highest plant.
Visual Obstruction Reading	Mean of four measurements (dm) of Robel pole reading.

Statistical Analyses

Habitat and Bird Assemblage Multivariate Analyses

We focused our analysis on describing the bird assemblages associated with each habitat type. We also tested for group differences in community composition for years, seasons, and study areas. To this end, we used non-metric multidimensional scaling (NMS) to assess whether the bird assemblages were different between these factor variables (McCune and Mefford 1999). Non-metric multidimensional scaling is a non-parametric approach appropriate for highly skewed species data. The Bray-Curtis similarity metric was used to describe and ordinate similarities in bird community structure between sites (Legendre and Legendre 1998). The number of axes used in the ordination (two dimensional or three dimensional) was determined by stress level; stress is a measure of the distortion produced by compressing multi-dimensional data into a reduced set of dimensions and will increase as the number of axes (i.e.,, dimensions) is reduced. Low stress levels (i.e., <0.1) indicate that the relative position of samples in ordinate space are a good reflection of the similarity of the avian community; high stress levels (i.e., >0.25) indicate poor compression of the multidimensional data to a reduced set of dimensions (Clarke and Warwick 2001).

Before ordination, the species matrix was transformed to presence/absence to allow for the retention of 87 species which would have otherwise been deleted due to their rarity (i.e., <20 detections in 3 years). One site at which only European Starlings were recorded and another site in which only two Savannah Sparrows were recorded were deleted because their inclusion was overly influential in defining the ordinate space.

Variation in community composition among cover types, seasons, years, and study areas was investigated using the ANOSIM (Analysis of Similarities) procedure of PRIMER 5.2.9, analyzes the similarities of groups relative to random groups in ordinate space based upon a permutation of the original groups, testing the null hypothesis that there were no assemblage differences between groups (Clarke and Gorley 2001). We used 999 permutations for each analysis of similarity. An R_{ANOSIM} statistic results from these permuations as a relative measure of separation between the groups. R values can be categorized into three general groupings (Clarke and Gorley 2001):

1. R > 0.75 indicates large difference between groups (clearly separable),
2. R > 0.50 inidcates clear differences, but the groups are overlapping, and
3. R < 0.25 indicates little to no difference between groups (non-separable).

It was not possible to test for study area (n = 9) × cover type (n = 3) × season (n = 2) × year (n = 3) differences because partitioning the data into the total number of classes (n = 162) yielded too few subjects to detect differences between groups (mean $n \approx 11$ subjects per group). Thus, we tested for univariate differences except for the case of seasonal differences nested within years. We note that this univariate assessment risks confounding effects of one factor (e.g., study area) with another (e.g., cover type) and therefore circumspection of the results is advised.

We used SIMPER in PRIMER to explore the relative contributions of individual species to (dis)similarity among cover types (Clarke 1993). Dissimilarity is measured with the Bray-Curtis dissimilarity index. The consistency of species in different cover types is indicated by the standard deviation of the dissimiliarities. A large ratio of mean dissimilarity in species occurrence between cover types indicates that a species contributes substantially and consistently to dissimilarity in community composition among cover types.

Because of a concern that species assemblages may change longitudinally and latitudinally, we summarized species assemblages with study area-specific measures of species richness (*S*), Shannon-Wiener diversity (*H'*), Shannon-Wiener species evenness ($E = H'/\ln[S]$), and Simpson's diversity index (*D*') (Magurran 2003). Species richness is simply the number of species in an assemblage and is the most common measure of diversity. The Shannon-Wiener Index assumes all species are represented in a randomly obtained sample: $H' = -\sum_{i=1}^{S} p_i \ln p_i$, where p_i is the proportion of individuals found in the *i*th species and ln is the natural logarithm. Values for Shannon-Wiener generally range from 1.5 to 3.5, with *H'* increasing as both a greater number of species and a more even distribution of species is measured. Actual diversity compared to the maximum possible diversity is measured by evenness, and is constrained between 0 and 1. When there are similar proportions of all species, evenness is near one, whereas when abundances are very dissimilar (i.e., some rare and some common species), the value approaches zero. Simpson's Index is considered a dominance index because it weights towards the abundance of the more common species, and provides the probability of any two individuals drawn at random from an infinitely large community belonging to different species. The bias corrected form of Simpson's Index is:

$D_S = \sum_{i=1}^{S} \frac{(n_i(n_i - 1))}{(N(N-1))}$, where n_i is the number of individuals in the *i*th species.

We examined spatial patterning in study site measures of diversity by mapping and linearly regressing the diversity measures against latitude, longitude, and their interaction. We also controlled for species diversity increasing as a function of the number of samples by including the number of point counts as a covariate. We compared all possible combinations of the geographic coordinates and number of point counts against the responses with Akaike's Information Criterion (AIC; Burnham and Anderson 2002) and selected the best model with the lowest AIC.

Environmental Relations

To explore the role of the environmental measures recorded at the survey sites on bird community composition, we conducted a Kendall rank correlation between similarity matrices of the environmental variables and species occurrence (BIOENV in PRIMER; Clarke and Ainsworth 1993, Carr 1996). The similarity matrix of environmental variables was based on normalized Euclidean distances and standardized variables.

To identify how the bird species individually related to environmental characteristics measured at the study sites, we conducted a principal components analysis (on the correlation matrix) to reduce the dimensionality of the habitat data set, creating orthogonal (i.e., independent) linear combinations of the original environmental variables. The mean principal component of each species occurrence was calculated and plotted against the primary principal components.

Indicator Species

Indicator species analysis (Dufréne and Legendre 1997) was used to sort the species by cover type and score their associations to those cover types (PC-ORD, McCune and Mefford 1999, McCune et al. 2002). This analysis provides a statistical basis for assigning a bird species to a primary cover type and defining a bird assemblage for each cover type. Indicativeness differs from similarity in that indicativeness identifies those species most likely to be found in a cover type and not in the others, whereas similarity simply identifies those species most commonly found across

sites within a cover type class. Thus, species identified as commonly occurring in one cover type may not be indicative if it is also regularly found in another cover type.

The indicator method uses species abundance data at points and the exclusivity of a species within a cover type to define a species indicator value (IV). The species IV, in percent, is its relative abundance times its relative frequency—where both relative abundance and relative frequencies have definitions peculiar to IV analysis. Relative abundance is the mean abundance of a species in a group of plots divided by its mean abundance in all plots. Relative frequency is the percentage of the plots within a group in which a species is present (Dufréne and Legendre 1997, McCune and Mefford 1999). The index reaches its maximum (100) when all individuals of a species are found in a single cover type and when the species occurs at all sites of that cover type. Statistical significance of indicator values was tested using Monte Carlo permutation tests (PC-ORD, McCune and Mefford 1999, McCune et al. 2002), employing 1,000 permutations of the data with the resultant *P*-value as the proportion of permutations in which the IV-max from the randomized data set equaled or exceeded the observed IV-max. Thus, a significant IV-max indicates a species that is characteristic of a cover type and that the indicator value is larger than would be expected by chance in the permutation set (Dufréne and Legendre 1997, McCune and Mefford 1999).

An electronic database and geographic information systems project describing all vegetation and bird survey locations, counts, and species (by common and scientific name) are appended to this report on a DVD.

Results

Data Summarization: Bird Counts

One-hundred-thirty-one species were recorded during 869 point count surveys of wet prairie during 2002–2004. Red-winged blackbird, Common Yellowthroat, and Dickcissel (a species of conservation concern) were the most ubiquitous species (Appendix B), each occurring at a frequency of >50% and a mean count of >2 birds/visit. The majority of species (79%) were infrequently counted (mean count <0.1). Franklin's Gull was recorded once (10 May 2004) in wet prairie in a flock of 180 but was not counted again in this cover type.

One-hundred-twenty-one species were recorded from 673 surveys of early successional floodplain forest during 2002–2004 (Appendix C). Indigo Bunting, Northern Cardinal, and Common Yellowthroat were the most commonly occurring species in this land cover, each occurring with a frequency of >50%. In addition to Indigo Bunting and Northern Cardinal, American Goldfinch was an abundant species, averaging >1 bird per survey. Similar to wet prairie, the majority of species (72%) in early successional floodplain forest were infrequently counted (mean count <0.1).

One-hundred-forty species were recorded in mature forest during 2002–2004 (Appendix D). The most ubiquitous species were House Wren, Northern Cardinal, Indigo Bunting, and Red-bellied Woodpecker, each occurring with a frequency of >45% and a mean count of >1 bird/visit. As in the other land covers, 69% of species were infrequently counted (mean count <0.1).

Harvestable species observed on the lower Missouri River included Mallard, Ring-necked Pheasant, Northern Bobwhite, American Crow, Canada Goose, Blue- and Green-winged Teal, Wood Duck, Wild Turkey, Northern Shoveler, Mourning Dove, American Woodcock, and Northern Pintail.

Data Summarization: Vegetation

Wet prairie was typified by low woody cover (<12%), substantial laying litter cover (18–42%), and typically tall vegetation (43–109 cm) (Table 3), but varied substantially between study areas (Appendix E). Forbs cover and bare soil cover were generally inversely related.

Eastern cottonwood (*Populus deltoides*) was the dominant tree species in early successional forest plots (Table 4). Snags/dead trees were an equally dominant structure. Other important tree species included sandbar willow (*Salix interior*), black willow (*S. nigra*), and boxelder (*Acer negundo*). Grape (*Vitis* spp.) was the predominant understory plant. Early successional forest plots consisted of high cover in both the upper (33–61%) and ground canopies (55–84%) (Table 5, Appendix E). Mean diameter at breast height (3.4–8.4 cm) was typical of saplings (2.5 < DBH < 10 cm), whereas the mean tree height in the upper canopy ranged between 8.6 and 16.0 m. The median maximum tree height in the upper canopy was 20 m (16–33 m). Stem counts were high (12,000–165,000) and extremely variable (range of standard deviation: 17,000–235,000).

The density of cottonwood on mature forest plots was ~3% of that occurring on early successional plots, having been replaced by boxelder, silver maple (*Acer saccharinum*), and red mulberry (*Morus rubra*) as the dominant mature forest tree species (Table 4). Cottonwood was relatively frequent in mature forest plots, however. The largest cottonwoods in mature forest were generally two or three times the DBH of those occurring in early successional forest plots. The density of boxelder on mature forest plots was approximately twice that on early successional plots, as well. As in early successional plots, snags were also common. The mature forest plots possessed a mean DBH (2.4–10.5 cm) that was generally typical of saplings (Table 6, Appendix E). The median maximum tree height, however, was 35 m (21–49 m). Jameson Island, Overton South, Squaw Creek, and St. Aubert's Island exhibited a mean maximum DBH less than adult sized trees, so describing these sites as mature based upon the largest sized trees may be incorrect except in a very loose sense. Stem counts (9–31,000) at mature forest sites were typically much less than that observed at early successional forests (with Eagle Bluffs as a notable exception); this was reflected in the ground and shrub canopy covers, which were generally quite sparse. The mature forest plots at Squaw Creek appeared aberrant relative to the other sites in that the recorded stem counts and maximum observed DBH were very low. Other notable peculiarities included the mean DBH for early successional and mature forest sites at Jameson Island, Squaw Creek, and Swan Lake were largely identical.

Table 3. Mean (and Standard Deviation) of vegetative measures from 309 surveys conducted in wet floodplain prairie sites along the lower Missouri River between 2002–2004. See Table 1 for study area acronyms; order of sites is from northwest to southeast.

Study Area	Mean Forbs Cover (%)	Mean Woody Cover (%)	Mean Standing Litter Cover (%)	Mean Laying Litter Cover (%)	Mean Bare Soil Cover (%)	Mean Cattail Cover (%)	Mean Grass/ Sedge Cover (%)	Mean Reed Canary Cover (%)	Mean Total No. of Woody Stems	Mean Litter Depth (mm)	Mean Vegetation Height (cm)	Mean Visual Obstruction Reading (dm)
SQC	24.6 (20.2)	0.2 (1.0)	4.7 (6.0)	18.6 (18.9)	6.4 (13.8)	1.4 (5.8)	16.7 (17.7)	25.3 (26.9)	0.1 (0.5)	34.7 (37.9)	71.9 (24.2)	5.6 (2.5)
SWL	17.7 (18.8)	0.8 (1.8)	4.6 (7.4)	18.8 (18.9)	4.3 (8.8)	0.0 (0.0)	11.9 (14.9)	31.1 (33.3)	0.4 (1.0)	33.0 (29.2)	76.3 (36.9)	5.7 (2.8)
LIS	9.6 (9.4)	0.0 (0.0)	4.1 (3.8)	31.5 (31.3)	37.0 (38.1)	NA	17.8 (9.0)	NA	0.0 (0.0)	9.3 (10.2)	43.0 (45.9)	1.8 (2.6)
OVN	29.5 (17.5)	7.4 (10.3)	3.1 (4.7)	41.5 (18.8)	7.3 (6.9)	NA	5.2 (9.3)	NA	1.9 (2.7)	16.4 (11.0)	78.9 (27.7)	6.8 (3.0)
OVS	24.1 (15.5)	11.4 (15.6)	4.4 (5.7)	31.8 (17.8)	13.9 (14.8)	NA	8.4 (11.7)	NA	2.4 (3.7)	16.4 (13.6)	69.6 (28.8)	4.6 (2.4)
HOW	8.9 (11.4)	5.3 (7.0)	4.1 (6.4)	39.8 (17.1)	26.3 (19.6)	NA	15.7 (11.2)	NA	1.7 (1.5)	20.5 (12.6)	108.6 (76.4)	7.8 (5.7)

Table 4. Median of the study areas for mean number of trees per ha and basal area of dominant trees as determined by surveys conducted in early successional and mature forest sites along the lower Missouri River during 2002–2004. Range in the study area medians is provided parenthetically.

Species Common Name	Number / ha
EARLY SUCCESSIONAL FOREST	
Cottonwood	1,616 (247–2,841)
Sandbar Willow	1,245 (182–2,547)
Boxelder	173 (50–212)
Black Willow	129 (59–179)
Dead Trees/Snags	1,886 (392–2,831)
MATURE FOREST	
Boxelder	338 (177–571)
Red Mulberry	220 (18–408)
Silver Maple	158 (63–197)
Cottonwood	53 (25–320)

Dead Trees/Snags	174 (15–302)

Table 5. Mean (and Standard Deviation) of vegetative measures from 214 surveys conducted in early successional floodplain forest sites along the lower Missouri River between 2002–2004. See Table 1 for study area acronyms.

Study Area	Mean Canopy Cover (%)	Upper-upper Canopy Cover (%)	Upper Canopy Cover (%)	Mid Canopy Cover (%)	Shrub Canopy Cover (%)	Ground Cover Canopy Cover (%)	Upper-Upper Canopy Height (m)	Upper Canopy Height (m)	Mid Canopy Height (m)	Total Normalized Stem Count	Maximum DBH (cm)[a]	Mean DBH (cm)[a]
LIS	64.2 (34.2)	0.0 (0.0)	49.0 (30.0)	12.8 (20.9)	13.5 (13.3)	69.5 (32.0)	0.00	10.7 (6.3)	2.8 (4.7)	86,606 (174,299)	19.4 (56.2)	5.0 (3.4)
JAM	45.9 (39.6)	0.6 (6.6)	32.5 (33.2)	10.0 (17.8)	10.4 (14.6)	55.4 (46.1)	0.00	8.6 (7.3)	2.0 (3.4)	62,218 (133,707)	11.8 (11.8)	3.4 (3.2)
OVN	79.9 (21.8)	0.0 (0.0)	61.1 (30.0)	30.0 (28.3)	15.8 (14.1)	76.1 (27.3)	0.00	12.4 (5.5)	4.4 (4.1)	165,642 (234,121)	17.7 (7.2)	4.8 (2.0)
OVS	63.4 (32.8)	0.0 (0.0)	53.8 (26.7)	26.7 (22.4)	15.0 (11.2)	75.7 (29.9)	0.00	12.9 (5.4)	5.4 (4.6)	104,094 (234,875)	18.7 (13.1)	4.9 (2.6)
EBL	76.8 (22.4)	3.8 (13.3)	59.3 (20.9)	31.3 (24.5)	13.4 (15.0)	84.0 (23.4)	2.6 (9.3)	16.0 (4.3)	6.3 (3.6)	11,921 (16,551)	32.5 (27.7)	8.4 (2.7)
STA	67.5 (25.6)	0.0 (0.0)	58.3 (15.7)	14.0 (17.5)	31.0 (27.3)	75.8 (22.5)	0.00	13.0 (3.7)	3.0 (3.1)	52,586 (65,008)	17.5 (5.1)	7.3 (2.4)
HOW	40.2 (36.4)	0.0 (0.0)	42.1 (32.2)	25.5 (23.6)	25.5 (17.9)	77.6 (36.1)	0.00	12.8 (5.7)	6.1 (4.9)	39,527 (49,056)	29.1 (20.6)	6.5 (5.3)

[a] 2.5-5 cm DBH are saplings and >25 cm DBH are adults.

Table 6. Mean (and standard deviation) of vegetative measures from 209 surveys conducted in mature forest sites along the lower Missouri River between 2002–2004. See Table 1 for study area acronyms.

Study Area	Mean Canopy Cover (%)	Upper-upper Canopy Cover (%)	Upper Canopy Cover (%)	Mid Canopy Cover (%)	Shrub Canopy Cover (%)	Ground Cover Canopy Cover (%)	Upper-Upper Canopy Height (m)	Upper Canopy Height (m)	Mid Canopy Height (m)	Total Normalized Stem Count	Maximum DBH (cm)[a]	Mean DBH (cm)[a]
SQC	44.4 (18.5)	0.0	36.4 (37.5)	12.2 (18.5)	0.1 (0.4)	55.2 (47.9)	0.0	17.4 (15.8)	4.9 (6.0)	9 (47)	10.0 (27.2)	4.7 (13.3)
FTL	48.1 (16.6)	0.0	31.7 (34.8)	36.1 (38.2)	13.1 (21.1)	37.9 (38.9)	0.0	17.7 (18.2)	5.3 (5.5)	2,579 (7,673)	34.4 (42.4)	8.5 (11.5)
SWL	34.9 (20.3)	1.6 (8.5)	30.8 (40.4)	18.7 (27.8)	3.6 (9.3)	27.4 (39.4)	1.5 (7.4)	8.2 (11.7)	3.3 (5.0)	1,798 (05,450)	27.3 (39.7)	7.3 (11.0)
LIS	67.2 (33.4)	29.2 (33.3)	38.1 (32.9)	44.0 (34.8)	29.2 (30.6)	52.7 (38.5)	17.4 (19.7)	17.7 (15.1)	6.3 (4.9)	20,798 (24,406)	46.9 (35.0)	8.0 (6.3)
JAM	24.9 (14.9)	0.0	22.3 (37.2)	10.0 (18.0)	8.6 (17.9)	18.6 (34.1)	0.0	5.6 (9.2)	2.1 (3.6)	24,319 (64,818)	22.6 (39.4)	3.7 (6.7)
OVS	27.4 (12.2)	0.0	19.6 (29.1)	17.5 (24.8)	5.2 (7.6)	35.0 (48.0)	0.0	7.3 (10.4)	2.2 (3.3)	9,175 (15,224)	15.6 (22.0)	2.5 (3.5)
EBL	86.5 (32.8)	30.4 (23.1)	52.6 (24.9)	44.4 (27.8)	17.9 (14.8)	48.8 (23.3)	23.1 (16.7)	16.9 (8.5)	6.9 (4.2)	31,134 (51,244)	61.5 (39.2)	10.5 (5.4)
STA	16.2 (9.6)	0.0	11.6 (26.6)	11.0 (24.3)	7.2 (17.6)	15.1 (32.9)	0.0	4.7 (10.1)	2.2 (5.0)	11,712 (34,630)	11.3 (25.3)	2.4 (6.1)
HOW	46.7 (26.9)	9.5 (18.0)	40.3 (39.8)	19.5 (24.0)	8.9 (14.8)	48.3 (46.1)	7.1 (14.3)	10.9 (10.9)	4.9 (4.8)	19,845 (65,394)	33.8 (39.8)	7.4 (8.3)

[a] 2.5-5 cm DBH are saplings and >25 cm DBH are adults.

Avian Community Composition and Diversity

Species composition and diversity varied appreciably between study areas. The bird species assemblage at Squaw Creek National Wildlife Refuge was the most species rich among the 10 study sites (Table 7; see Fig. 2 as well). Although there was no obvious visual patterning in the geographical distribution of the diversity measures (Fig. 2), there was a longitudinal gradient in diversity (Table 8; Fig. 3). For each measure, avian species diversity generally increased from west to east (Fig. 2). Squaw Creek is an outlier (Fig. 4). Taxonomic composition varied marginally over the course of the lower Missouri River (Global $R_{ANOSIM} = 0.385$, $P = 0.001$; Fig. 4). St. Aubert's Island had a species composition that overlapped that of Eagle Bluff, Jameson Island, and Lisbon Bottoms, primarily because the species recorded at St. Aubert's Island were fairly ubiquitous, the site was centrally located, and species richness was low; all other sites differed from one another to a credible extent (Appendix F).

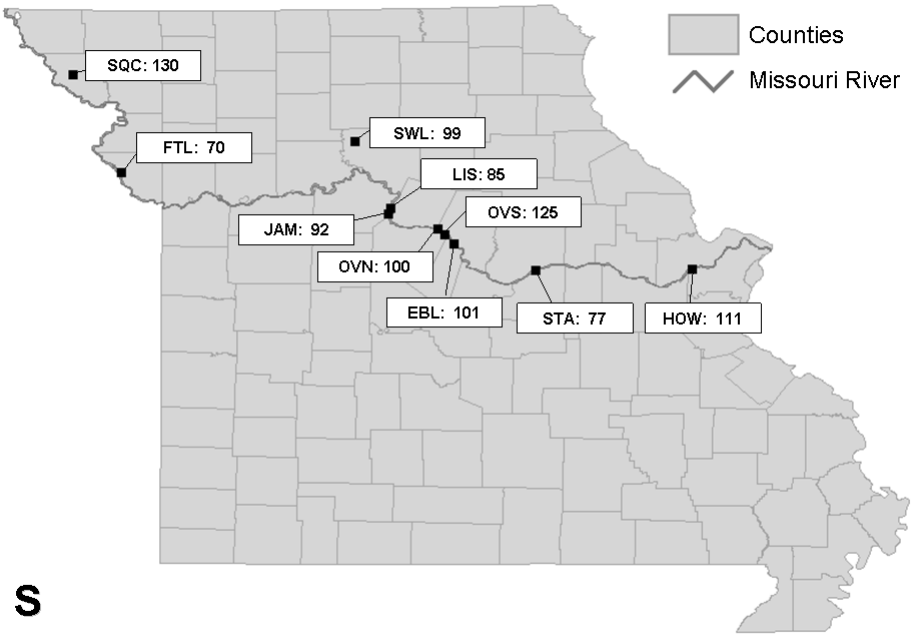
Table 7. Mean (standard deviation) number of observed species and indices of diversity for 10 sites along the lower Missouri River between 2002–2004. *S* is species richness, *H′* is Shannon-Wiener diversity, *E* is Shannon-Wiener species evenness, and *D′* is Simpson's diversity index. The mean across sites is an unweighted mean (and standard deviation). See Table 1 for study area acronyms.

Site	Mean	SD	*S*	*H′*	*E*	*D′*
SQC	26.8	68.9	130	3.734	0.767	0.958
FTL	11.0	24.9	70	3.606	0.849	0.966
SWL	12.2	24.3	99	3.875	0.843	0.972
LIS	10.1	23.7	85	3.645	0.820	0.964
JAM	15.0	34.5	92	3.675	0.813	0.965
OVN	8.9	21.4	100	3.697	0.803	0.962
OVS	18.9	39.9	125	3.879	0.803	0.970
EBL	8.1	15.7	101	3.921	0.850	0.974
STA	7.5	16.1	77	3.707	0.853	0.968
HOW	11.8	22.8	111	3.944	0.838	0.974
Mean	13.0	29.2	99 (19)	3.768 (0.124)	0.824 (0.028)	0.967 (0.005)

Table 8. Best models describing avian species diversity as a consequence of geography along the lower Missouri River between 2002–2004. The difference between the best model (the model with the lowest AIC) and the next best model is denoted by the difference in their Akaike's Information Criterion (ΔAIC) for a given metric. Variables in bold are predictors of the greatest importance. The model weight, or relative likelihood, for the best model relative to alternative models in each case was >0.5.

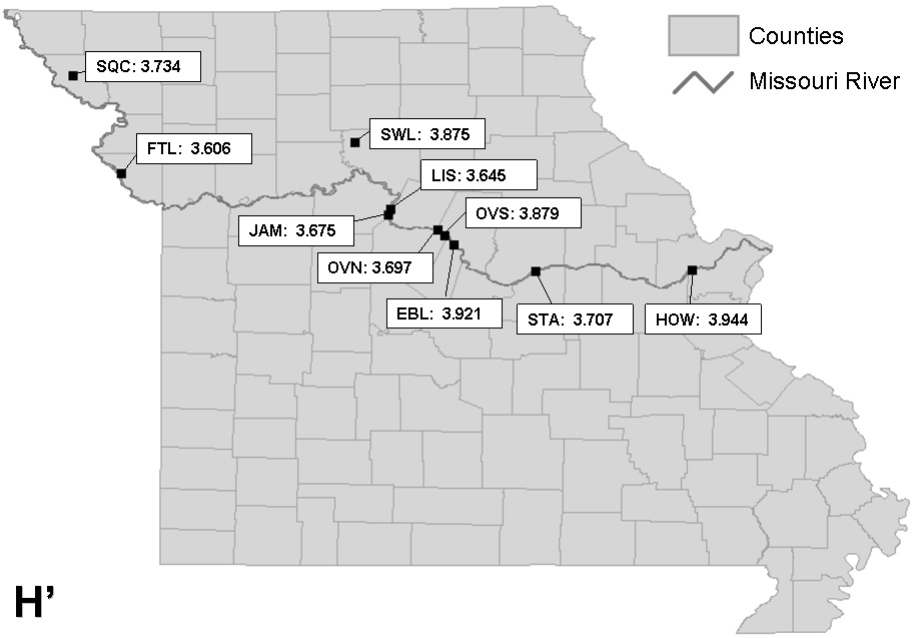
Diversity Measure	Best Model	ΔAIC	r^2
Species Richness, *S*	Longitude + Latitude + Longitude × Latitude + **No. of Point Counts**	1.11	0.69
Shannon-Wiener Diversity, *H'*	**Longitude** + Latitude	2.00	0.47
Shannon-Wiener Evenness, *E*	Longitude + Latitude + Longitude × Latitude + **No. of Point Counts**	1.85	0.74
Simpson's Diversity, *D'*	**Longitude**	1.60	0.42

Species Richness (*S*)



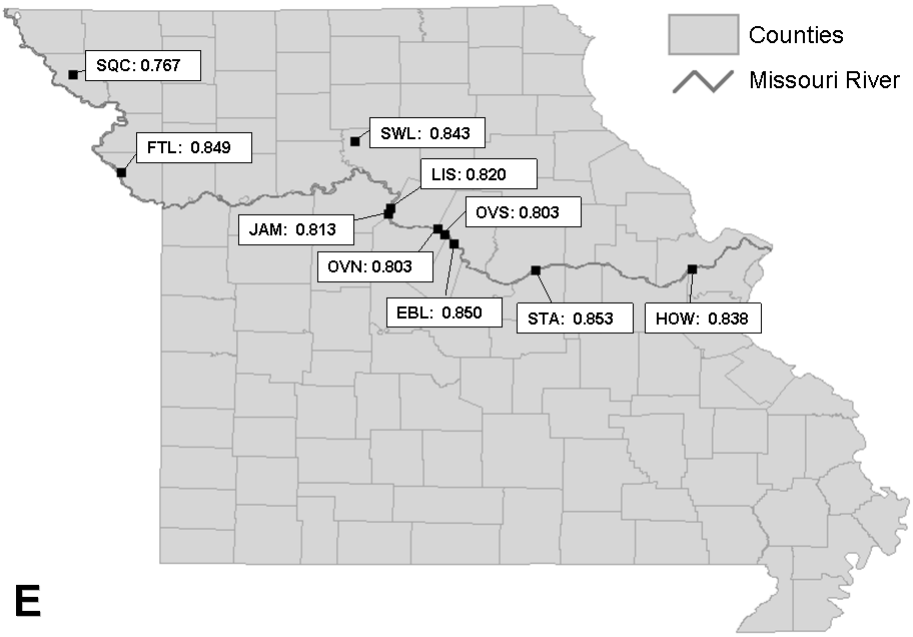
S

Shannon-Wiener Diversity (*H'*)



H'

Evenness (*E*)



Simpson's Diversity Index (*D'*)

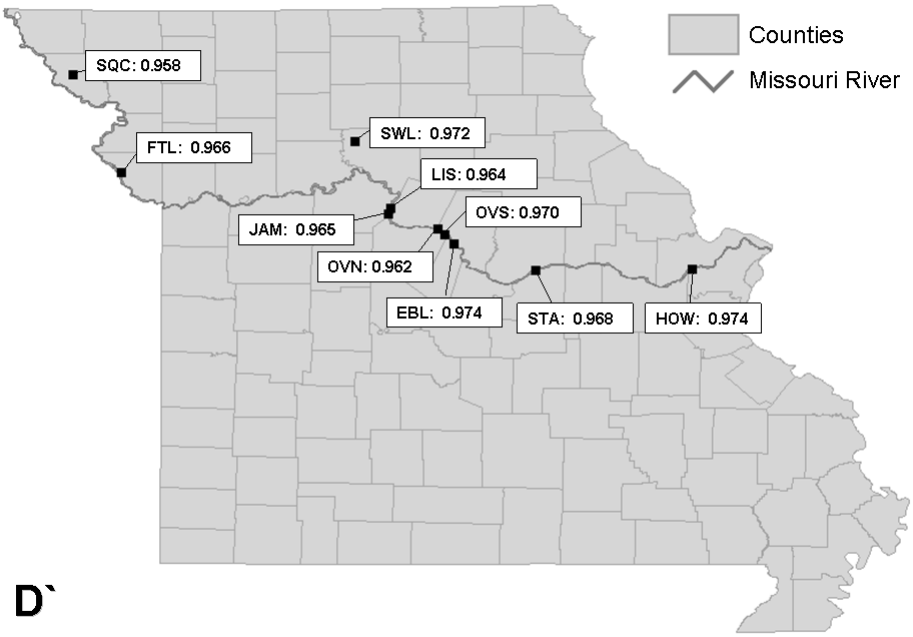


Figure 2. Geography of species diversity measures for avian assemblages along the lower Missouri River, 2002–2004.

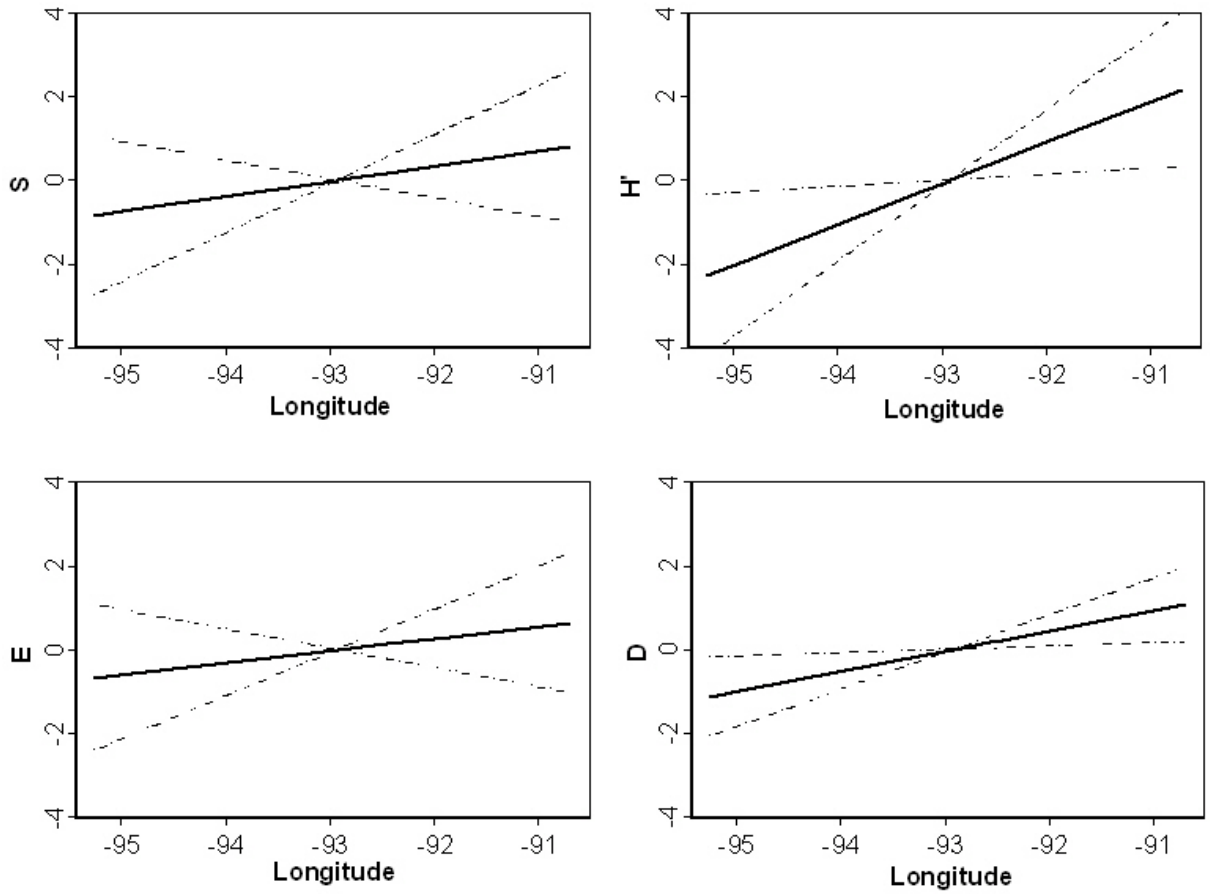


Figure 3. Plots of four avian species diversity measures as a partial function (with prediction intervals) of longitude from 10 locations along the lower Missouri River, 2002–2004. Note: west is on the left, east on the right.

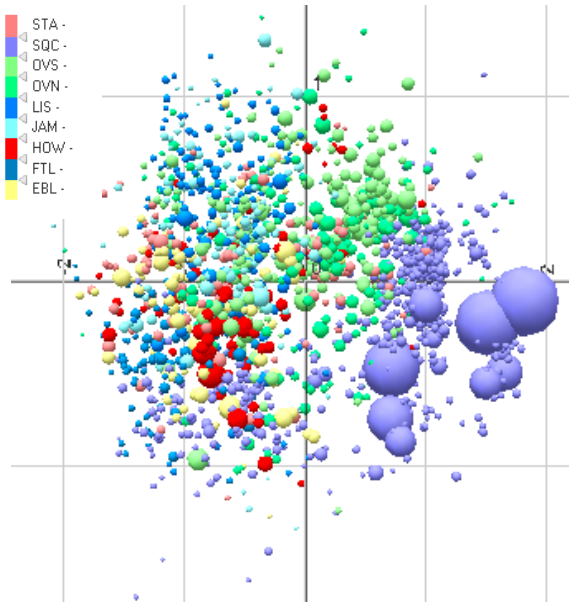


Figure 4. Avian community compositional differences between study area locations, lower Missouri River, 2002–2004, based on a non-metric multidimensional scaling of taxonomic differences (Stress = 0.18 for the two-dimensional solution). Bubble size corresponds to the number of species observed at the site. See Table 1 for study area acronyms.

Community composition overlapped among years and seasons (Global $R_{ANOSIM} = 0.611$, $P = 0.133$; Fig. 5). There was a suggestion of a seasonal difference (Fig. 5b), but the overlap in species composition between the migration and breeding seasons precluded inferring a seasonal difference.

(a) Year (Stress = 0.14) (b) Season (Stress = 0.18)

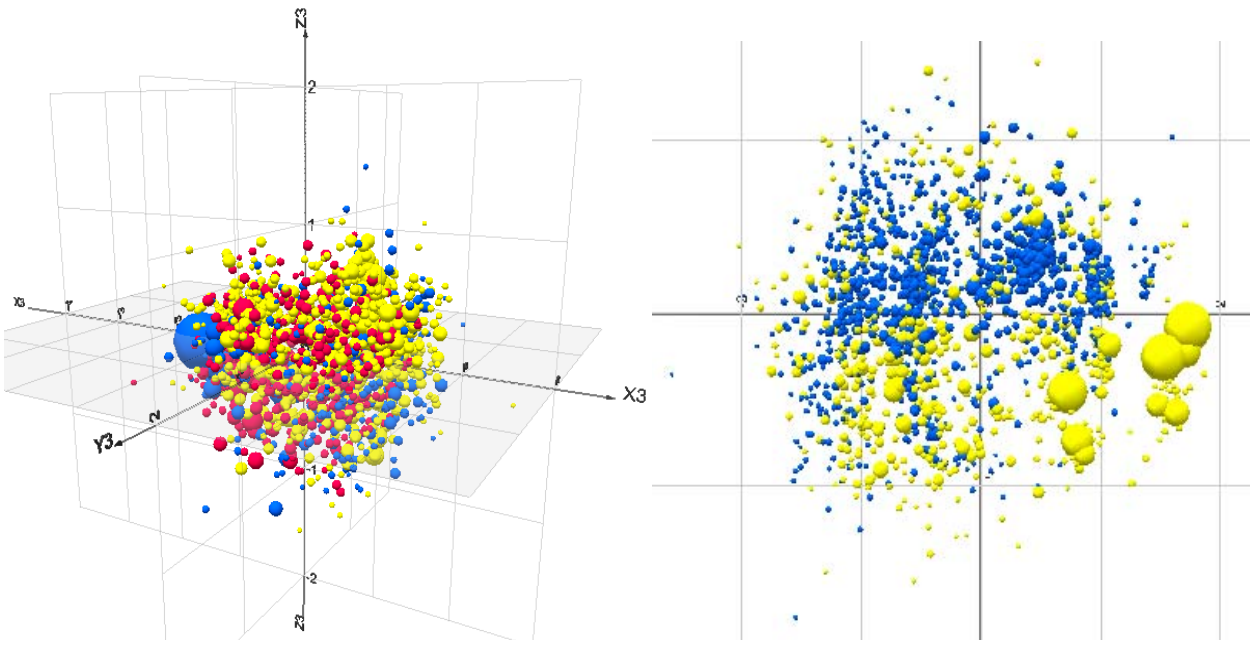


Figure 5. Avian community compositional differences between (a) years (2002 = Blue, 2003 = Yellow, 2004 = Red) and (b) seasons (Migration = yellow, Breeding = blue), lower Missouri River, 2002–2004, based upon a non-metric multidimensional scaling of taxonomic differences. Bubble size corresponds to the number of species observed at the site.

Cover classes were clearly separable (Global $R_{ANOSIM} = 0.683$, $P = 0.001$) but following the heuristic of Clarke and Gorley (2001) there was some degree of overlap in community composition between cover types. Mature forest tended to have a more diverse assemblage of species than wet prairie, but these difference were not substantial (Table 9). The bird communities of the three land covers were quite distinct. While the numerical difference in richness was small, the greatest difference in species composition occurred between wet prairie and mature forest ($R_{ANOSIM} = 0.857$; mean dissimilarity = 92.2%). Early successional floodplain forest and wet prairie were also highly different in their species composition ($R_{ANOSIM} = 0.721$; mean dissimilarity = 87.1%). There was no separability between early successional and mature forests in their avifauna ($R_{ANOSIM} = 0.272$; mean dissimilarity = 75.1%). Early successional forest appeared to have a species composition intermediate to mature forest and wet prairie, coincident with the notion that the avian species community is responding to a gradient in succession (Fig. 6).

Because we are able to dismiss annual differences in species composition, and there were marginal differences between seasons, we tested for a combined effect by calculating an analysis of similarities with season nested within cover class. Species composition did not differ

substantially between seasons (Global R_{ANOSIM} = 0.236, P = 0.001) within land cover; the variation in species composition could be attributed to cover class (Global R_{ANOSIM} = 0.889, P = 0.067).

Nearly half of the species occurred among the three land cover types; 44.5% (n = 77) and 53.2% (n = 75) of species were found in the three land covers during the migration and breeding season, respectively, though we would caution that some number of observations appeared to be incidental occurrences (e.g., Bell's Vireo in mature forest). At least twice as many species were unique to wet prairie (n = 33 and 28 during migration and breeding, respectively) relative to the number unique to either early successional forest (n = 3 and 3) or mature forest (n = 15 and 14). A number of birds found in mature forest but not early successional forest were observed in wet prairie during migration (House Wren, Myrtle Warbler, Orange-crowned Warbler, Willow Flycatcher, Wilson's Warbler, and Yellow-throated Warbler). Conversely, a couple species predominantly occurring in wet prairie were noted in mature forest (but not early successional forest) during migration (Killdeer).

Nineteen to 20% of the wet prairie avifauna was unique to wet prairie, including American Bittern, American White Pelican [only observed in migration], Grasshopper Sparrow, Greater Yellowlegs, Henslow's Sparrow, Horned Lark, Nelson's Sharp-tailed Sparrow, Ring-necked Pheasant, and Sora. Eight percent of the avifauna that occurred in wet prairie in breeding were not observed during the migration period in wet prairie. Nearly a quarter of species observed in wet prairie were noted only during the migration period and not breeding.

Only 2% of the early successional forest avifauna was unique to early successional forest, with the Philadelphia Vireo being the most notable species. Fourteen species were unique to mature forest in both migration and breeding, with notable species including Barred Owl, Chimney Swift, Green-winged Teal (in migration), and Red-shouldered Hawk (in migration). Yellow-rumped and Yellow-throated Warblers were observed during the breeding season only in mature forest.

Table 9. Mean and standard deviation of observed number of bird species and indices of diversity for 3 cover types (wet floodplain prairie, WTP; early successional floodplain forest, ESF; and mature forest, MTF) along the lower Missouri River, 2002–2004. *S* is species richness, *H* is Shannon-Wiener diversity, *E* is Shannon-Wiener species evenness (*H*′/ln[*S*]), and *D*′ is Simpson's diversity index.

Site	Mean	SD	*S*	*H*′	*E*	*D*`
WTP	28.7	91.9	131	3.497	0.717	0.937
ESF	34.9	78.0	127	3.799	0.784	0.967
MTF	67.3	124.5	139	3.978	0.806	0.975
Mean	43.6	98.1	132.3	3.758	0.769	0.960

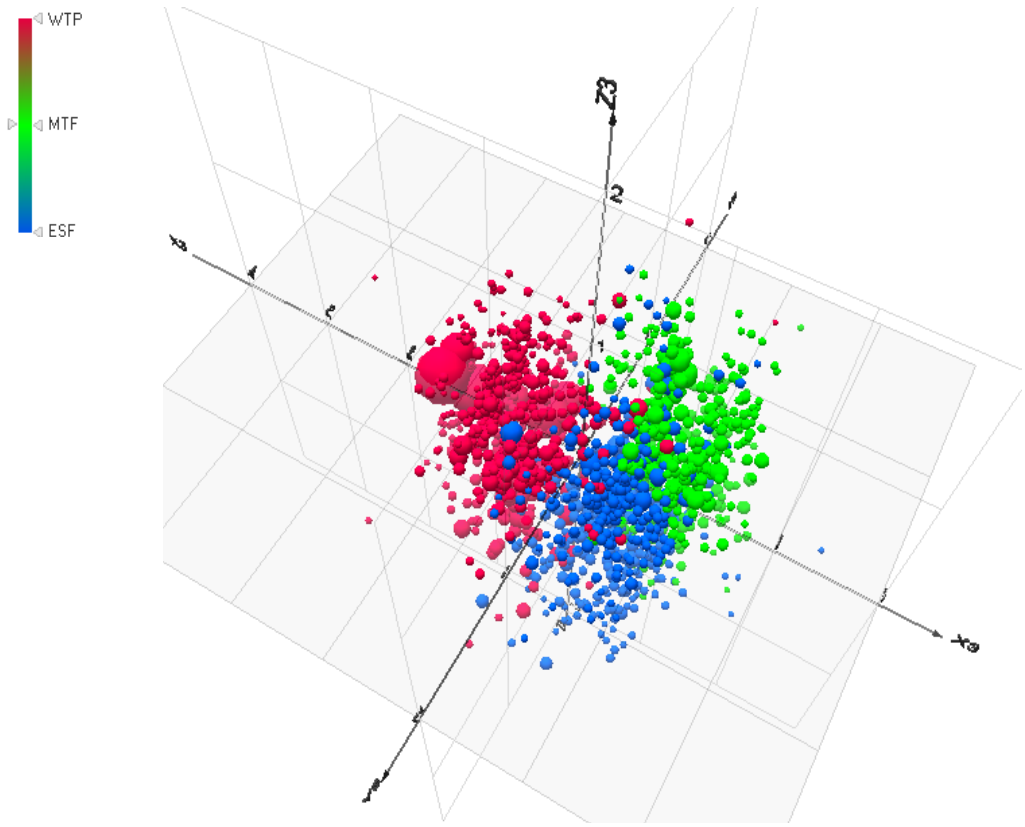


Figure 6. Avian community compositional differences between cover classes, lower Missouri River, 2002–2004. Bubble size corresponds to the number of species observed at the site.

Environmental Relations

The multivariate Spearman rank correlation analysis between avian community composition and site-level environmental variables indicated canopy cover, mean vegetation density, mean vegetative height, height of the upper canopy, and total canopy closure were the site-level vegetation variables describing the preponderance of the variance in avian community composition ($r = 0.41$).

Mean similarity among sites within a cover type suggested approximately one-third of the avian species composition at a site was shared by sites within the same cover type designation. The mean similarity for wet prairie sites was 38.9%, with Red-winged Blackbird, Common Yellowthroat, and Dickcissel most responsible for site similarity. Principal component analysis indicated litter depth (Principal Component 1, loading = 0.930), vegetation height (Principal Component 2, loading = 0.913), forbs cover (Principal Component 3, loading = -0.537), and laying litter (Principal Component 3, loading = 0.778) were the variables most responsible for discriminating among wet prairie survey locations and thus responsible for patterns in species similarity (Table 10, Fig. 7).

Table 10. Habitat variables and associated principal component scores measured at wet prairie survey locations along the lower Missouri River. The first four components described 37%, 22%, 16%, and 10% of the variance, respectively. Variables with loadings <|0.1| were not included.

Variable	PC1	PC2	PC3	PC4
Forbs Cover (%)		0.213	-0.537	-0.655
Woody Cover (%)				
Litter Depth - Standing				
Litter Depth - Laying	-0.220	0.115	0.778	-0.285
Bare Soil (%)	-0.111	-0.176	-0.181	
Grass/Sedge Cover (%)			-0.174	0.657
Number of Woody Stems				
Litter Depth	0.930	-0.265	0.192	
Vegetation Height	0.256	0.913		0.221
Visual Obstruction				

Mean similarity for early successional floodplain forests was 31.8%, with Indigo Bunting, Northern Cardinal, Northern Oriole, Common Yellowthroat, and Yellow-billed Cuckoo as the species most regularly occurring on these sites. Mean site similarity for mature forests was 31.6%, with Red-bellied Woodpecker, Northern Cardinal, and House Wren primarily responsible for the similarity among sites. Principal component analysis indicated the primary environmental characteristic differentiating sites was total canopy cover, height of the upper canopy, mean diameter at breast height, and mid-canopy cover (Table 11). The bird species most important to the similarity among sites within forest were also the species most responsible for the differences between early successional and mature forest; because mean dissimilarity between early successional and mature forest was 75.1%, only approximately one-quarter of the species composition was shared between early successional and mature forest.

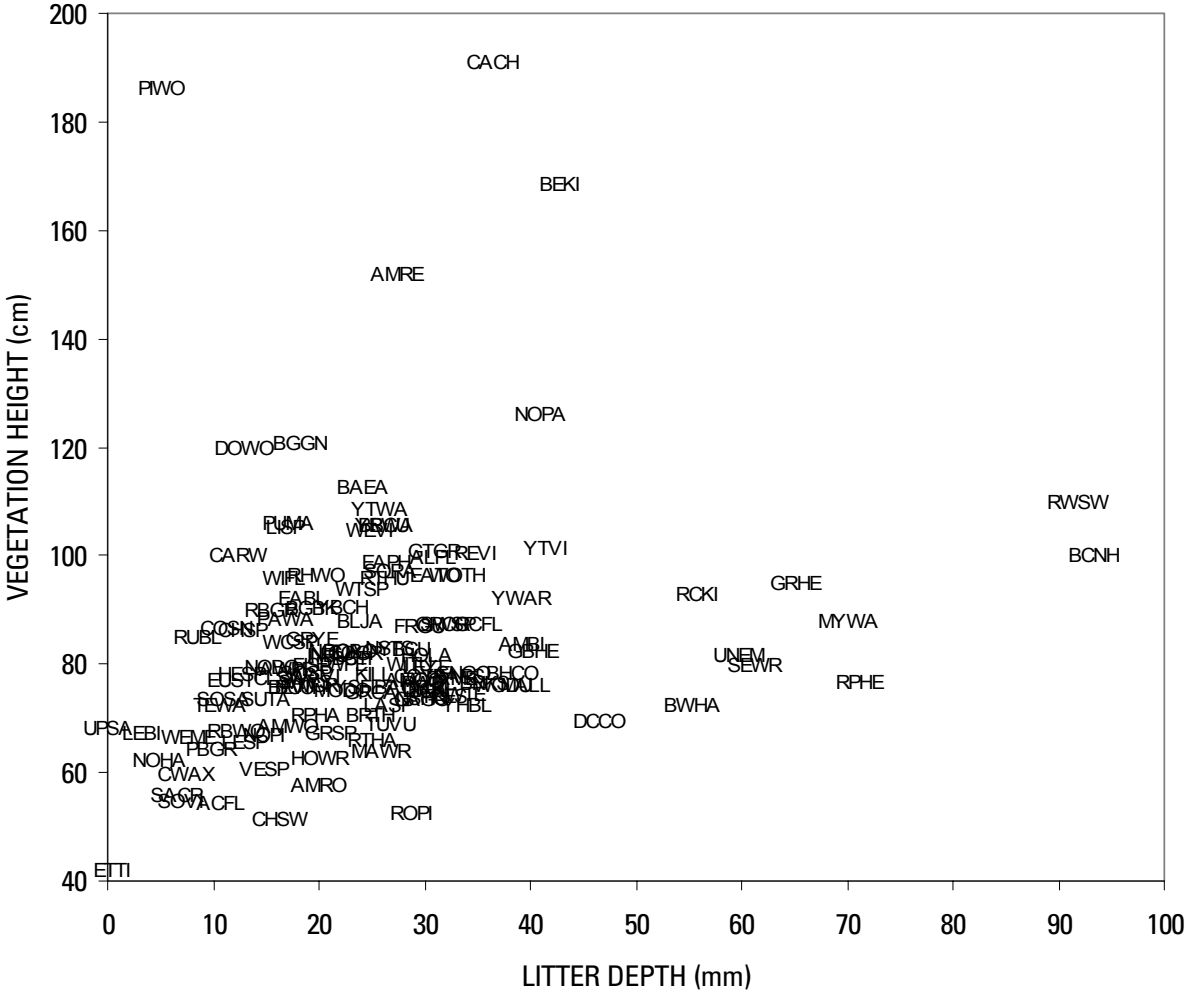


Figure 7. Avian species occurrence (denoted by species acronym, Appendix B) relative to the two most important variables describing study locations in wet prairie along the lower Missouri River.

Indicator Species

Eight species were significantly indicative of wet prairie (Red-tailed Hawk, Tree Swallow, Northern Harrier, Bobolink, Nelson's Sharp-tailed Sparrow, Northern Rough-winged Swallow, Dickcissel, Savannah Sparrow), and ten others were marginally indicative (Mallard, Broad-winged Hawk, Killdeer, Eastern Kingbird, Eastern Meadowlark, Barn Swallow, European Starling, Red-winged Blackbird, Wood Duck, Chipping Sparrow) (Appendix G). The Northern Harrier and Bobolink were entirely indicative of wet prairie (100% indicator value). Only one species was significantly indicative of early successional floodplain forest, the Bell's Vireo (indicator value = 86%; Appendix G). Northern Parula and Prothonotary Warbler were significantly indicative of mature forest, with Chestnut-sided Warbler, Acadian Flycatcher, and Summer Tanager marginally indicative (Appendix G). In addition, species indicative of wet prairie (mean indicativeness = 54.7% [95% confidence interval = 51.1–58.4%]) were relatively

more indicative than those species indicative of early successional (39.2% [33.1–45.4%]) and mature forests (44.6% [40.4–48.8%]).

Table 11. Habitat variables and associated principal component scores measured at early successional and mature forest survey locations along the lower Missouri River. The first four components described 33%, 17%, 10%, and 8% of the variance, respectively. Variables with loadings <|0.1| were not included.

Variable	PC1	PC2	PC3	PC4
Total Canopy Cover (%)	-0.408	-0.133		
Total Canopy Cover (%) N	-0.381	-0.181		
Total Canopy Cover (%) E	-0.348	-0.161		
Total Canopy Cover (%) S	-0.385	-0.142	-0.147	
Total Canopy Cover (%) W	-0.366	-0.134		
Upper-Upper Canopy (%)	-0.126			0.619
Upper Canopy (%)	-0.244	-0.114	-0.34	-0.249
Mid Canopy (%)	-0.221	0.112	0.558	
Shrub Canopy (%)		-0.224	0.472	-0.307
Ground Cover Canopy (%)		0.139	-0.302	-0.545
Ocular Height U (m)	-0.227	0.458		-0.165
Ocular Height M (m)	-0.197	0.346	0.334	-0.139
Maximum DBH (cm)	-0.194	0.387		0.145
Mean DBH (cm)	-0.130	0.488	-0.244	
Total Stem Count		-0.270	0.179	-0.276

Discussion

The assemblage of birds recorded for the lower Missouri River comprised >15% of the 836 species occurring in continental North America, a proportion which is among the greatest in North America (Tramer 1974). Loehle et al. (2005) reported generally fewer than 80 species from pine, hardwood, and mixed forest sites in the southeastern United States. Cushman and McGarigal (2003) reported 82 species from the Oregon Coast Range. Jones et al. (2005) reported 64 species in north-central Florida. Cody (1966) suggested that 10 species were typically the norm for grasslands, compared to the 131 species recorded for wet prairie habitat along the lower Missouri River.

For the lower Missouri River floodplain, we found avian diversity generally varied with cover type, season, and regional location. The greatest diversity occurred in the breeding season in mature forest in the eastern portion of the floodplain; the least diverse bird community occurred during migration in wet prairie in the western portion of the floodplain.

The bird assemblages we studied were likely the result of both floristic diversity and structural heterogeneity (MacArthur and MacArthur 1961; MacArthur et al. 1962, 1966; Willson 1974). Snags and other dead woody material are important structural components within mature forest that were less abundant in early successional forest and largely missing in wet prairie.

Snags are especially important to large-bodied cavity nesters such as Red-headed Woodpeckers, Northern Flickers, Red-bellied Woodpeckers, and Pileated Woodpeckers (Renken and Wiggers

Box 1. Species abundance should approximate a lognormal distribution.

We should expect the collection of individual species abundance to follow a lognormal distribution (Preston 1948, Krebs 1989); that is, few species are very abundant or very rare and most species are moderately abundant. The lognormal model has been frequently observed in large samples of species (e.g., Preston 1962*a*,*b*; Plotkin and Muller-Landau 2002; Rosenzweig 1995; see Williamson and Gaston 2005 for a contrary exposition). However, this lognormal distribution is not what we found for species surveyed on the lower Missouri River (Fig. 15). The observed distribution of total individual species counts differed markedly from the theoretical distribution (Shapiro-Wilks GOF $W = 0.969$, $P = 0.00059$). Rare and very common species were overcounted whereas moderately rare species were undercounted relative to our theoretical expectation. Limpert et al. (2001) reported a typical multiplicative standard deviation (the standard deviation of the logarithm) for avian species-abundance data was 11.6, whereas in this case we observed a sdlog = 2.24. This distribution is, thus, underdispersed relative to our expectation. This underdispersion presents problems when trying to determine power to detect trends.

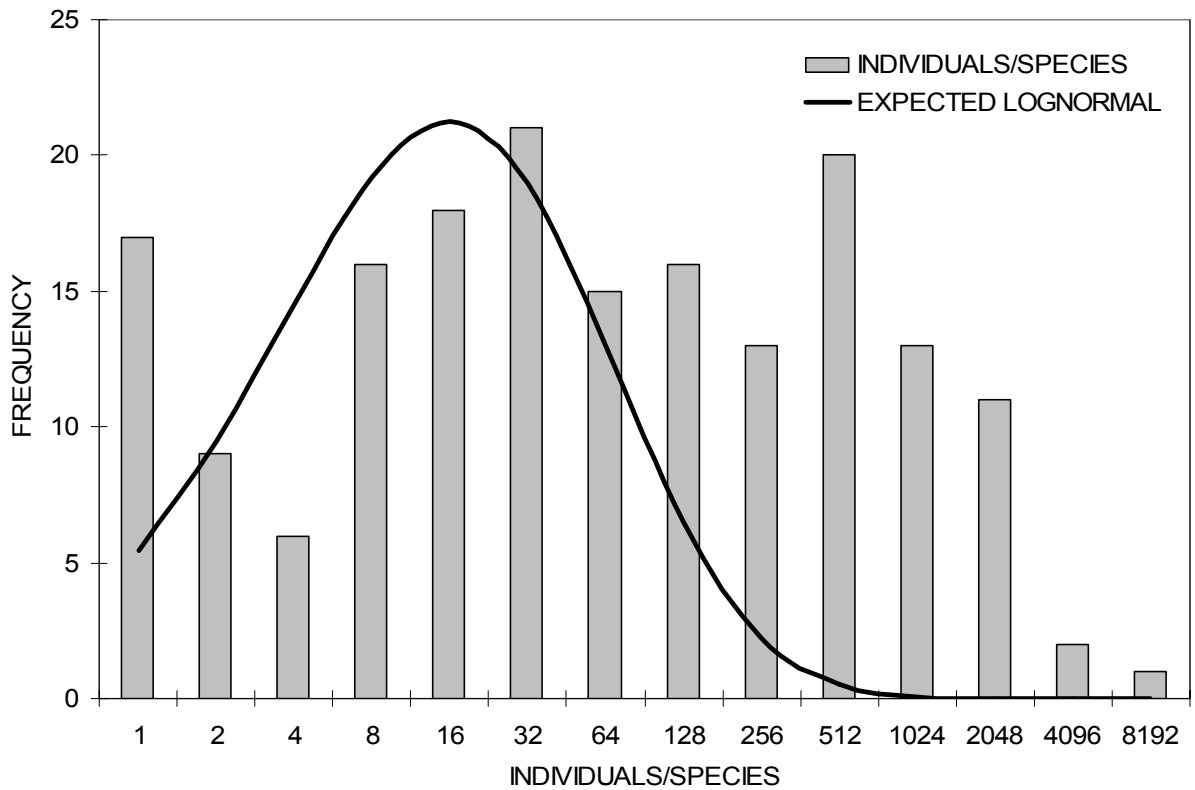


Figure 8. The lognormal observed number of individuals counted per species relative to the expected distribution for birds surveyed on the lower Missouri River, 2002–2004.

1993, Conner et al. 1994, Ingold 1994). The abundance of snags in mature forest likely accounted for the indicativeness of the Prothonotary Warbler for this forest type, as this species is an exclusive nester in cavities of large trees (Petit 1999).

Twedt et al. (1999) identified indicator bird species for bottomland hardwood forests and cottonwood plantations in the Mississippi Alluvial Valley whereas Knutson et al. (2005) identified indicator bird species for shrub/scrub, early successional, and mature forest of the middle Mississippi River. The Northern Parula and Prothonotary Warbler were indicative of mature forest on the lower Missouri River, but not on the middle Mississippi River. The Northern Parula generally builds nests in hanging bunches of epiphytic growth, beard moss (*Usnea* lichen) or lace lichen (*Ramalina reticulata*) (Petit 1999); thus, nesting sites are most often in areas where these epiphytes grow. Preferred nesting sites for the Prothonotary Warbler are usually near water, e.g., river bottoms, sloughs, swamps, almost always over or within 5 m of standing water or in low-lying, easily flooded areas. Cavity trees, often willow, 15–20 cm in diameter at breast height (Blem and Blem 1991) are preferentially selected. The only species commonly indicative to both the Mississippi Alluvial Valley and the lower Missouri River in mature forest (bottomland hardwood forest in Twedt et al. 1999) was the Acadian Flycatcher. These differences in indicativeness among the lower Missouri River, middle Mississippi River, and Mississippi Alluvial Valley likely represent the accumulation of differences in species ranges as one moves west to east (and to a lesser extent from south to north) (Tramer 1974 [fig. 3], Short 1979, Bock 1984).

There was quite a bit of similarity in the bird species assemblage composition and abundance between this study and studies on the middle Missippi River to the east (Knutson et al. 2005, fig. 2 and appendix B) and near Ft. Leavenworth to the west (Zimmerman and Tatschel 1975). For example, the relative abundance of Yellow-billed Cuckoos in early successional forest in this study and that of Knutson et al. (2005) was 0.8, and relative abundance of Indigo Buntings in the same cover type was 3.1 in this study and 2.7 in the middle Mississippi study.

Bell's Vireo, inferred as indicative of early successional forest in this study, is described as occurring in dense, low, shrubby vegetation, generally early successional stages in riparian areas, brushy fields, and young second-growth forest or woodland (Brown 1993). Despite its indicativeness, the Bell's Vireo was not greatly common in early successional forest, as it was only the 31st most frequently observed species in this cover type.

The bird species assemblages associated with wet prairie were typical of grasslands in central Missouri (Skinner et al. 1984, McCoy et al. 1999, Winter and Faaborg 1999) and eastern Kansas (near Ft. Leavenworth; Zimmerman and Tatschel 1975). Red-winged Blackbirds were the most common species in wet prairie, and were the only species indicative to both wet prairie in the lower Missouri River and shrub/scrub of the middle Mississippi River (Knutson et al. 2005). Because Red-winged Blackbirds are considered a pest species in agricultural ecosystems (Linz et al. 1993), farmers operating fields within the daily foraging range of this abundant species may negatively interpret the conservation of wet prairie habitat on the Refuge. However, numerous species of conservation concern occurred in wet prairie habitat along the lower Missouri River, including the Dickcissel, Orchard Oriole, Yellow-breasted Chat, Eastern Meadowlark, Field Sparrow, Bell's Vireo, Henslow's Sparrow, and Grasshopper Sparrow (see Appendix B). Dickcissels were the third most observed wet prairie species, after the Red-winged Blackbird and Common Yellowthroat. Dickcissels have undergone a substantial population decline since the mid-1960s (-1.9% per year; Sauer et al. 2005) and were ranked third in

conservation concern for grassland birds in the midwestern United States by Herkert et al. (1996).

Some rather unique observations were made during the course of this study. A Peregrine Falcon was observed in the breeding season on 21 May 2003 in wet prairie/early successional forest habitat at Overton Bottom South; the Big Muddy National Fish and Wildlife Refuge Final Environmenal Impact Statement indicated the previous sighting of a Peregrine Falcon along the lower Missouri River outside of the urban areas of Kansas City and St. Louis occurred in mid-May 1996. This falcon was once a common breeder on bluffs along the Missouri River (Widmann 1907). Robbins and Easterla (1992) suggested that this species may now breed along the river though no documentation of this exists. Black-crowned Night-Herons, a Missouri State Rare species, were sighted twice, in 15 June 2002 and 6 May 2003 in wet prairie habitat at Overton Bottoms South and Squaw Creek, respectively; this heron was previously observed along the lower Missouri River at Eagle Bluffs in spring-summer of 1996 (U.S. Fish and Wildlife Service 1999). Sandhill Cranes were observed on two occasions during the migration season, 30 April 2002 and 7 May 2004, at Squaw Creek. A single Bald Eagle was sighted on 14 May 2004 in wet prairie habitat at Squaw Creek; the Bald Eagle reportedly nests and winters in large numbers along the lower Missouri River (U.S. Fish and Wildlife Service 1999), so it may be somewhat unusual that only 1 individual of this species was observed during this study.

The bird counts we report are likely confounded by species detectability, as we found that for many species, detectability varied among season and cover type (Chapter Six). Unfortunately, there did not appear to be a consistent factor (e.g., season, cover type) across species which might be accommodated to correct counts. Because of this lack of consistency in influential factors, and because sample sizes were often too small for robust analyses for every species, it was not possible to apply to each species a common correction factor. Thus, integrations of species counts for the enumeration of diversity metrics must be viewed with caution because some species, when particularly rare, will be missed.

Chapter Four
Factors Associated with the Succession of Abandoned Agricultural Lands

The Final Environmental Impact Statement of the Big Muddy National Fish and Wildlife Refuge presented the possibility of incorporating recent abandoned agricultural land into the refuge, expanding the size of the refuge from 6,729 ha to ~24,280 ha (U.S. Fish and Wildlife Service 1999). It is of interest to the refuge to be able to project whether these abandoned agricultural lands will succeed into forest or wet prairie habitats, as the wildlife assemblage is expected to differ between the two habitats. Our objective (No. 5 for the study) was to examine the environmental conditions associated with establishment of young forests vs. prairie in abandoned agricultural land subject to flooding. Flood pulses are critical in the dynamics of seed dispersal, plant establishment, nutrient cycling, scouring, sediment deposition, and maintenance of species richness (Johnson et al. 1976, Skoglund 1990, Stromberg et al. 1993, Bendix 1994, Nilsson et al. 1997, Friedman and Auble 1999, Perez et al. 1999). Floods also govern much of the spatial pattern in floodplains (Bayley 1995, Miller et al. 1995) and, as such, the heterogeneity of large river floodplains is maintained by the flood regime (Ward and Stanford 1995, Gergel et al. 2002).

We hypothesized that factors associated with flooding would preclude succession of abandoned agricultural sites to climax forest along the lower Missouri River. Sites closer to the river, which are subject to greater frequency and severity of flooding, would remain in an early successional state (i.e., wet prairie) by frequent scouring, whereas areas less affected by flooding would have the potential to succeed to early successional forest conditions. To examine this hypothesis, we modeled factors associated with sites that were wet prairie or early successional forest as a hierarchical, mixed effects model.

Methods

The hierarchy of study area accommodates effects imposed by unmeasured variables at the level of the study area, allowing for the unbiased assessment of the effect of environmental covariates on habitat. Flood frequency, drainage condition of the soil, distance to the main channel of the Missouri River, and elevation were included as fixed effect covariates. Because the mean elevation of the study areas declines as one moves west to east along the Missouri River, we standardized the survey point elevation by differencing out the study area mean elevation. Thus, sites with a negative value were low relative to the area mean elevation, whereas positive values were from locations high relative to the area mean elevation. Elevation was acquired from EarthData International, LLC (Gaithersburg, Maryland), as a 3 cm vertical resolution, 4.57 m (15 ft) horizontal resolution digital elevation model (DEM) for the eight riverside study areas (Fig. 8). Squaw Creek and Swan Lake were excluded because of the lack of elevation data and their situation on the landward side of the levees. Flood frequency and drainage condition of the soil were obtained from SSURGO soils coverages (Flood Frequency Class [Maximum] and Soil Drainage Class [Wettest], respectively, in SSURGO; http://soildatamart.ncrs.usda.gov/SSURGOMetadata.aspx). Flood frequency was the annual probability of a flood event expressed as a class (rare [<5% chance of flooding], occasional [5–50% chance of flooding], and frequent [>50% chance of flooding]). The natural drainage condition of the soil described the frequency and duration of wet periods as a class (excessively

drained, well drained, moderately well drained, somewhat poorly drained, very poorly drained). Because sites within study areas may be more similar than sites between study areas, we included study area as a random effect.

Rather than model the three states, wet prairie, early successional forest, and mature forest, as a conjoint response, we examined two classes of models, wet prairie versus early successional forest, and early successional forest versus mature forest. We did not model the three states together as it was not clear that the three states describe an underlying but latent continuous response that might occur if one were to suppose that wet prairie succeeds to early successional forest and then to mature forest. Persistent disturbance or other factors such as soil characteristics may preclude some sites from succeeding from one state to another, obviating a latent process organizing the vegetation communities.

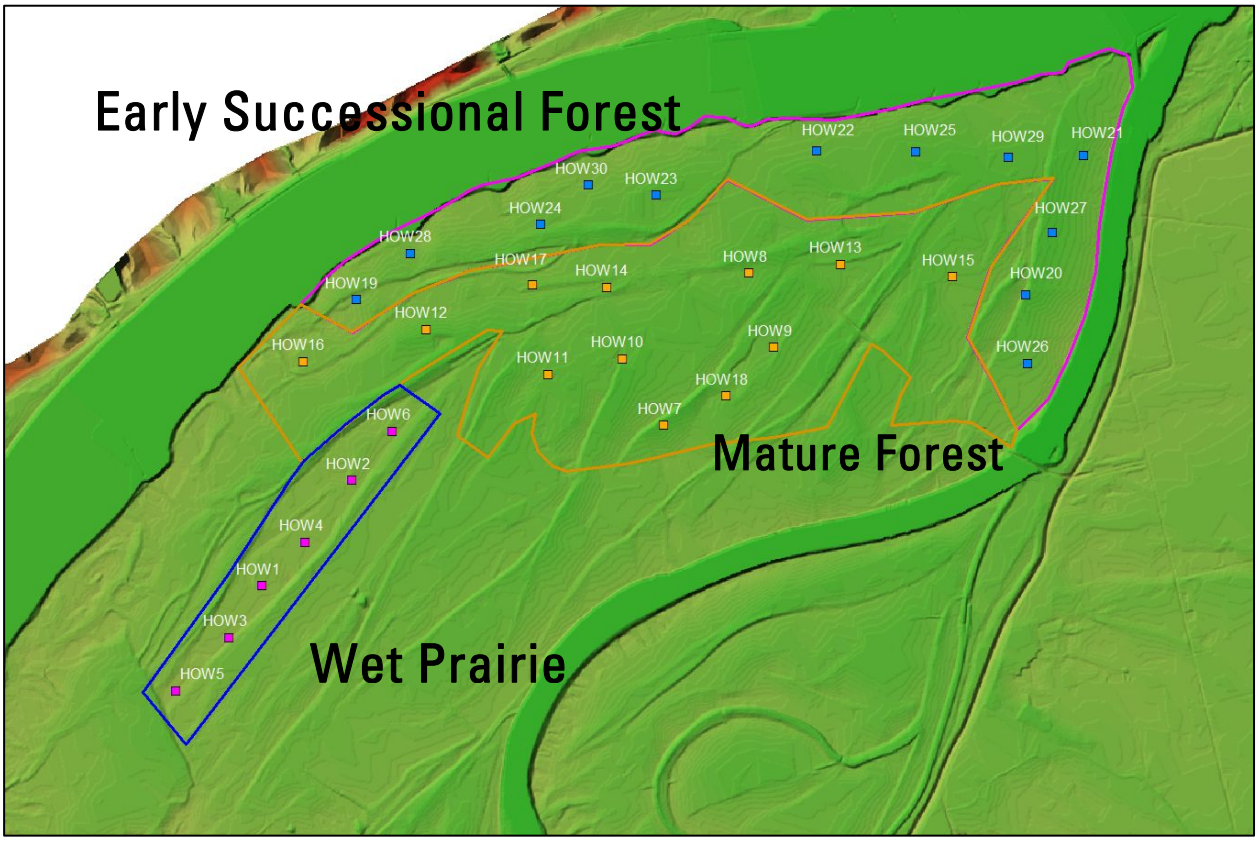


Figure 9. Bird survey points by land cover at the Howell Island study area, relative to elevation derived from 1.22 m (4 ft) vertical resolution, 4.57 m (15 ft) horizontal resolution digital elevation model. In this figure, red squares identify plots described as wet prairie, blue squares identify early successional forest, and orange squares identify mature forest.

We followed a Bayesian approach to modeling. Diffuse or noninformative priors and hyper-priors were assigned to each parameter to represent an initial expectation of the variables on bird counts. Fitting and prediction were conducted in WinBUGS 1.4.1 (Spiegelhalter et al. 2003), a statistical package conducting Bayesian inference with Markov chain Monte Carlo. For each model, we ran the Markov chain until convergence occurred (1,000 iterations) and an

additional 50,000 iterations past convergence. This chain creation was conducted three times to create replicate chains for the Gelman-Rubin diagnostic (Spiegelhalter et al. 2003), comparing within-chain and between-chain variability. Of the 150,000 samples collected (3 chains × 50,000 iterations), parameter estimates were summarized for every fifth iteration of the iteration histories to reduce autocorrelation (final n = 30,000). Multicollinearity in the environmental variables was guarded against by inspecting the multi-chain iteration histories and the Gelman-Rubin diagnostic plots of the model parameters.

We employed an information-theoretic approach to our modeling by comparing the Deviance Information Criterion (DIC) among models; DIC is an information criterion analogous to Akaike's Information Criterion, with the most parsimonious model possessing the smallest DIC (Spiegelhalter et al. 2002). Our model set included a null model, a model with the four main fixed effects, and then models with one, two, and three two-way interaction terms. We did not assess more than three two-way interactions or any interactions of higher order because of difficulties with model fit and interpretability.

Results

Fate of Abandoned Agricultural Land: Wet Prairie Versus Early Successional Forest

Within the context of the four environmental factors, study areas differed in their response to whether a site was wet prairie or forest. Overton Bottoms North and South were predisposed to wet prairie cover whereas Jameson Island was predisposed to forest (Fig. 10). The odds of a site being early successional forest declined as distance from the main channel and the difference in elevation between the site and the river increased. There was a marginal relationship with an interaction of soil drainage class and elevation (Table 12); it appeared that wetter sites and higher sites had an increased probability of being wet prairie. Ponded or soils wet to the surface (Soil Drainage Class 4) were almost entirely wet prairie rather than early successional forest. Some circumspection is required for this interaction term as its credibility interval marginally bounded zero for the parameter estimate (and one for the odds ratio) (Fig. 11). The coefficient with the greatest magnitude and tightest credibility limit belonged to that of the distance to the main channel; as the distance from the main channel increased, the probability of a site being wet prairie increased (Fig. 12). Flood frequency had little apparent influence on whether a site was wet prairie or early successional forest.

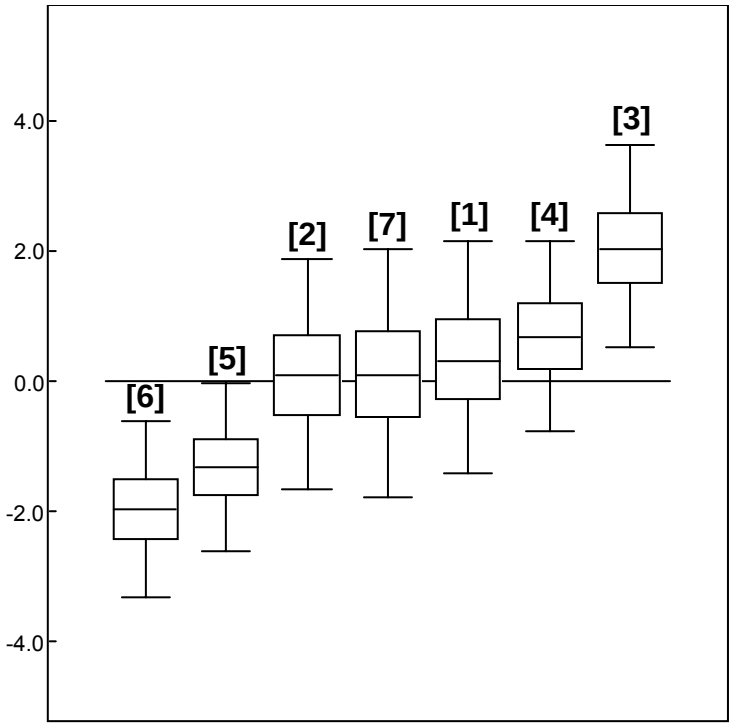


Figure 10. Boxplot of the effect of study area on the relationship between wet prairie and early successional floodplain forest. Boxes represent the inter-quartile ranges bisected by the median study area effect; the arms extend to the 2.5% and 97.5% quantiles. The study areas are (1) EBL, (2) HOW, (3) JAM, (4) LIS, (5) OVN, (6) OVS, and (7) STA. Values on the negative side favor the formation of wet prairie whereas values on the positive side favor the creation of early successional forest. See Table 1 for study area acronyms.

Table 12. Parameter estimates (slope and 95% credibility intervals) for the hierarchical, mixed effects logistic regression describing the differences between wet prairie and forest on the lower Missouri River. The odds ratios for wet prairie and their 95% credibility intervals are included as well. Confidence intervals excluding zero (parameter estimates) or one (odds ratios) were deemed important. See Table 1 for study area acronyms.

Parameter	2.50%	Median	97.50%	2.5% CL	Odds Ratio	97.5% CL
Intercept	-0.696	1.523	3.890	0.499	4.586	48.911
Flood Frequency	-0.630	0.985	2.744	0.533	2.677	15.549
Soil Drainage Class	-0.718	-0.147	0.424	0.488	0.864	1.527
Distance to Main Channel	-2.566	-1.837	-1.190	0.077	0.159	0.304
Elevation Difference	-2.785	-1.450	-0.232	0.062	0.235	0.793
Drainage X Elevation	-0.023	0.524	1.087	0.977	1.688	2.965
Study[EBL]	-1.408	0.320	2.162	0.245	1.378	8.688
Study[HOW]	-1.636	0.092	1.874	0.195	1.097	6.514
Study[JAM]	0.515	2.040	3.636	1.673	7.691	37.940
Study[LIS]	-0.762	0.687	2.163	0.467	1.989	8.697
Study[OVN]	-2.578	-1.318	-0.043	0.076	0.268	0.958
Study[OVS]	-3.326	-1.948	-0.628	0.036	0.143	0.534
Study[STA]	-1.778	0.105	2.006	0.169	1.110	7.434

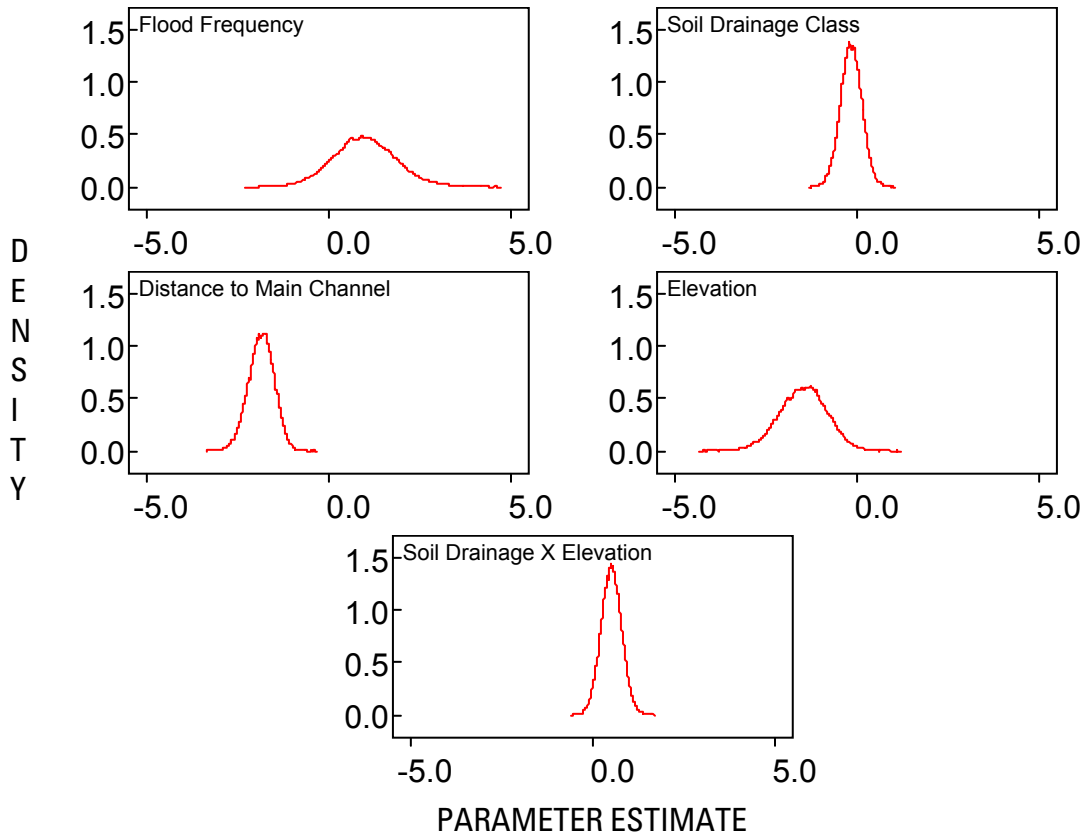
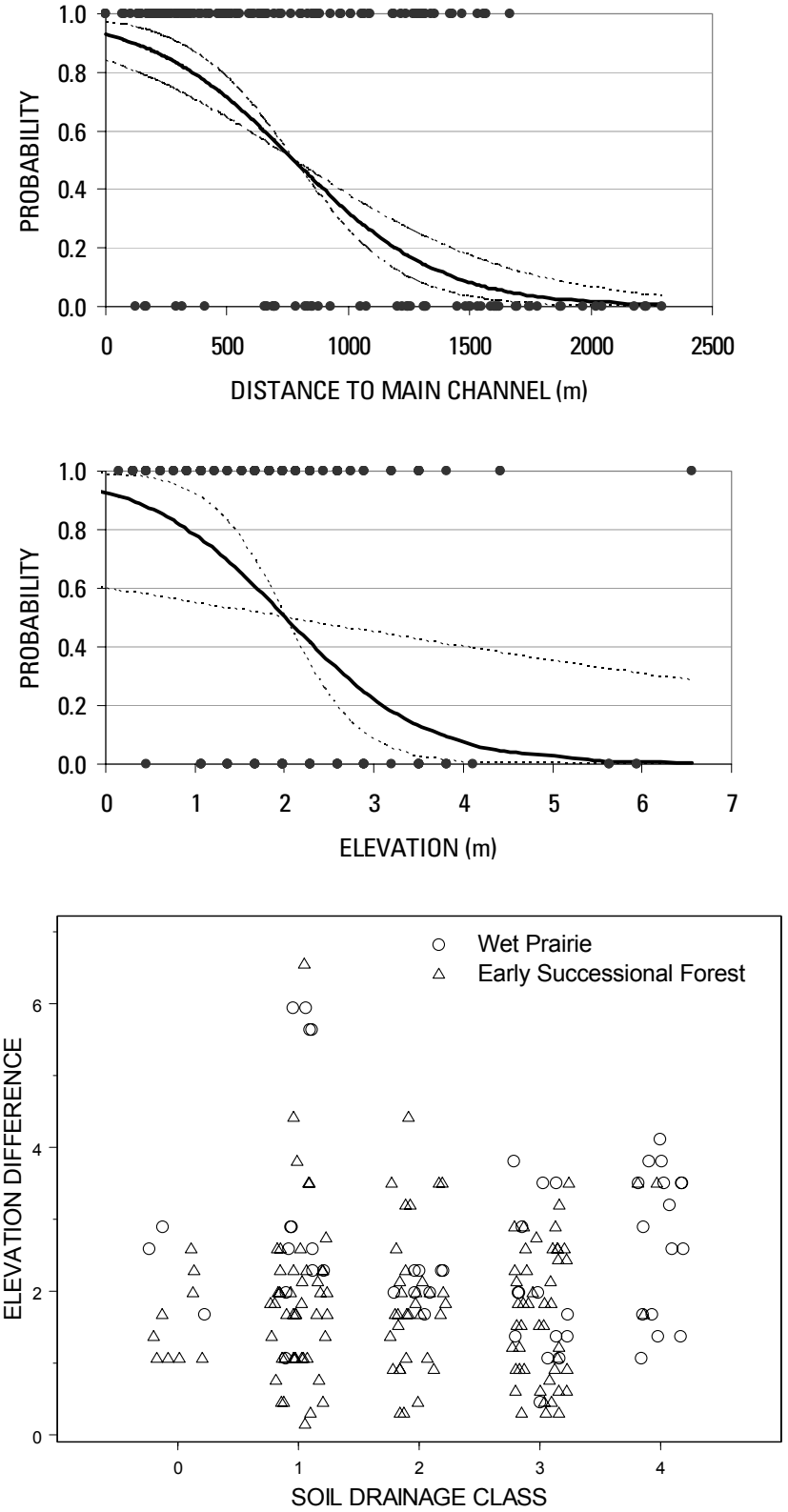


Figure 11. Plots of the posterior marginal sample distributions of the fixed effects from the hierarchical mixed effects logistic regression describing the difference between wet prairie and early successional forest along the lower Missouri River.

Figure 12. The probability of a lower Missouri River site being forest (1) rather than wet prairie (0) declined with distance from the main channel and an increase in the difference between site elevation and that of the river. Black dots are the observed occurrences in each class. The interaction of the difference in elevation and soil drainage class (ordered from driest [0] to wettest [4]) had a marginal influence on discriminating between wet prairie and early successional forest (note the near absence of early successional forest in the wettest soil). The symbols are jittered on the abcissa to aid discrimination between responses.



Early Successional Versus Mature Forest

In our analysis of the factors discriminating early successional forest from mature forest, we found here too an important effect of study area that could not be explained by the four environmental variables we studied (Fig. 13). Fort Leavenworth did not have any early successional forest, and thus scored high along with Howell Island for mature forest. Overton Bottoms North and South, Jameson Island, and Lisbon Bottoms favored the formation of early successional fores. Flood frequency class and, to a lesser extent, elevation also influenced whether a site on the lower Missouri River was early successional or mature forest (Table 13, Fig. 14). As flood frequency and elevation increased, the probability of a site being mature forest increased.

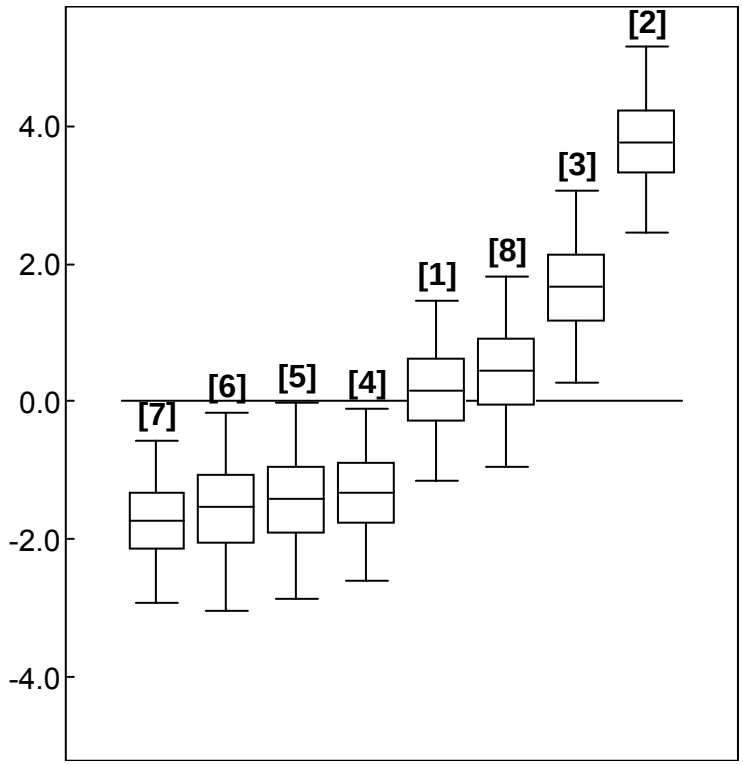


Figure 13. Boxplot of the effect of study area on the relationship between early successional and mature forest. Boxes represent the inter-quartile ranges bisected by the median study area effect; the arms extend to the 2.5% and 97.5% quantiles. The study areas are (1) EBL, (2) FTL, (3) HOW, (4) JAM, (5) LIS, (6) OVN, (7) OVS, and (8) STA. Values on the negative side favor the formation of early successional forest whereas values on the positive size favor the creation of mature forest. See Table 1 for study area acronyms.

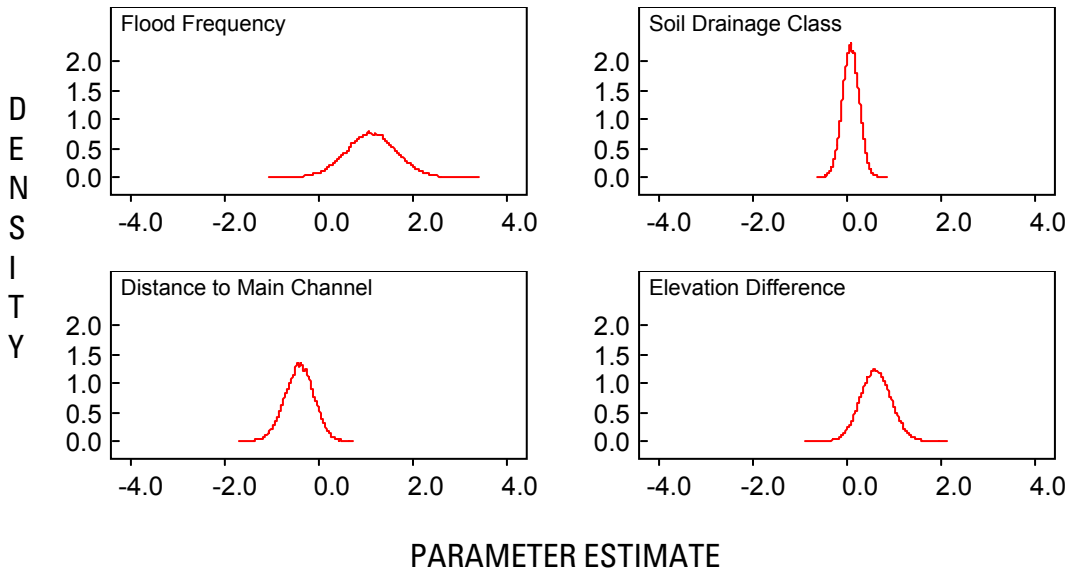


Figure 14. Posterior marginal sample distributions of the fixed effects from the hierarchical mixed effects logistic regression describing the difference between early successional and mature forest along the lower Missouri River.

Table 13. Parameter estimates (slope and 95% credibility intervals) for the hierarchical, mixed effects logistic regression describing the differences between early successional and mature forest on the lower Missouri River. The odds ratios for early successional forest and their 95% credibility intervals are included as well. See Table 1 for study area acronyms.

Parameter	2.50%	Median	97.50%	2.5% CL	Pr(y=1|x)	97.5% CL
Intercept	-4.149	-2.291	-0.514	0.016	0.101	0.598
Flood Frequency	0.085	1.115	2.158	1.089	3.050	8.654
Soil Drainage Class	-0.263	0.083	0.430	0.769	1.087	1.537
Distance to Main Channel	-1.025	-0.405	0.164	0.359	0.667	1.178
Elevation Difference	-0.015	0.610	1.262	0.985	1.840	3.532
Study[EBL]	-1.162	0.163	1.468	0.313	1.177	4.341
Study[FTL]	2.450	3.772	5.142	11.588	43.467	171.058
Study[HOW]	0.269	1.663	3.063	1.309	5.275	21.392
Study[JAM]	-2.587	-1.324	-0.108	0.075	0.266	0.898
Study[LIS]	-2.851	-1.410	-0.026	0.058	0.244	0.974
Study[OVN]	-3.018	-1.540	-0.156	0.049	0.214	0.856
Study[OVS]	-2.914	-1.722	-0.568	0.054	0.179	0.567
Study[STA]	-0.931	0.435	1.817	0.394	1.544	6.153

Discussion

Distance to the main channel of the Missouri River was the best predictor as to whether a site was wet prairie or early successional forest, with sites further removed from the main channel in wet prairie habitat and sites near the main channel in forest. This is counter-intuitive, as we had suspected that near-river sites would be affected by flooding and scouring, and thus set back to an early successional state (McKenzie 1936, Sigafoos 1964). There are reasons,

however, to believe that this natural process can no longer be the basis for our *a priori* perspective.

It is generally understood that operation of floodplain protection projects alters the hydrologic regime of a river system (Dynesius and Nilsson 1994, Nilsson and Svedmark 2002) and results in large disruptions to the biota of the attendant floodplain (Nilsson and Dynesius 1994). Two major alterations are a reduction of peak annual flow (mean annual flood), because of impoundment of excess runoff, and reduction of sediment load, because of sediment deposition in the upstream reservoirs (Johnson et al. 1982). Streamflow for June (mid-growing season) is now lower than June flows recorded in the drought years of the 1930s (Johnson et al. 1982). At other times of the year, excess water is distributed to nearby agricultural lands rather than to an increased in-stream flowrate. This reduced flow results in a reduction in bank erosion (25% of pre-dam levels), reduced river meandering (accretion rates having fallen to 1%), and, in turn, to the prolonged persistence of forest vegetation. Further, the reduction in peak flows reduces or eliminates recharge of upper soil layers, creating perpetual drought conditions in floodplain soils (Cooper et al. 2003, Williams and Cooper 2005) which may be inconducive to riparian grassland formation (Henszey et al. 2004). However, these drought conditions are also linked to declines in riparian cottonwood (Reily and Johnson 1981, Williams and Cooper 2005), a major component in the early successional forests on the lower Missouri River.

Once early floodplain forests are established, post-dam construction flow patterns are out of phase with vernal growth patterns typical of these communities. Cottonwood and willow species germinate and persist on exposed alluvium resulting from river meandering. But when these early successional communities are uneroded, they mature, with the overstory being replaced by admixtures of boxelder, silver maple, pin oak, swamp white oak, and slippery elm, and the occasional large cottonwood. Therefore, flooding regimes, natural or otherwise, will be necessary to maintain bird species (e.g., Bell's Vireo) most commonly associated with early successional floodplain forest.

Most flooding, however, has been eliminated on terraces more than 2 m above mean river level, reducing moisture and nutrient influx to higher terraces. This 2 m benchmark represents a threshold in the prediction between wet prairie and early successional forest (see the middle panel in Fig. 12). Sites within 2 m elevation of the main channel were more likely to be early successional forest sites. Perhaps unsurprising then was that soil drainage and flood frequency did not seem to influence the classification of a lower Missouri River site into wet prairie or forest in this highly altered habitat. It appears that intermittent or infrequent flooding (as would occur for sites of <2 m difference in elevation) may be sufficient for determining the fate of a floodplain location. Our notion that frequent scouring and overtopping by floods leading to conditions favorable to wet prairie (McKenzie 1936, Sigafoos 1964) are discounted, and thus we are compelled to look elsewhere to explain the occurrence of wet prairie in the lower Missouri River floodplain.

Differences between study areas that were unattributable to the four environmental factors we studied suggest there are other additional factors which may also influence whether abandoned agricultural sites naturally restore to wet prairie or early successional forest. Further site-level study into what these factors may be are warranted; likely candidates are soil composition, subsurface water gradients, and water table depth, among others.

Chapter Five
Power to Detect Trend in Bird Abundance

Power is a statistical measure describing the risk of not detecting a trend in a population when one actually exists. Failure to confidently identify trends may result in a failure to recognize a population headed toward extinction. The adequacy of monitoring programs depends on interactions between sample size (number of counts), duration (years of monitoring), frequency of surveys, and the ability to control variability in counts because of other factors (e.g. weather, observer differences, habitat effects). If the power of monitoring programs is not assessed, managers run the risk of wasting resources because the sampling regime may be inadequate to detect reasonable trends.

Power is defined as $(1 - \beta)$ where β is the probability of wrongly accepting a null hypothesis when it is actually false (Type II errors; Gerrodette 1987). Increasing power requires a trade off against the possibility of a Type I error (i.e., saying a trend exists [$P = \alpha$] when it does not). Setting conservative α levels ($p < 0.05$) lowers the power to detect trends, but guards against wrongly alerting managers to significant, but potentially nonexistent, population declines.

Power is often expressed as a percentage or probability. For example, if power = 80%, the statistical power of the monitoring program is 80% to detect a population trend of a specified magnitude. Similarly, this means a failure to detect a biologically significant trend (Type II error) will be avoided with a probability of 0.8.

An effective monitoring program aims to maximize accuracy and minimize the possibility of wrongly concluding the magnitude and direction of population trends. Type II errors can be costly for conservation managers. If a significant decline in a threatened species is not identified, then a species may decline in abundance beyond a threshold where recovery is possible. In contrast, if managers respond to a perceived decline that is not real (managing a species that is not declining), then resources may be wasted in the short term; fortunately, this sort of 'false alarm' is likely to be quickly recognized, mitigating the severity of this sort of error. If sample sizes and survey frequencies are insufficient, a monitoring program will fail to provide the precision needed to detect population changes over time. In short-term studies based on a few years data, as in this lower Missouri River study, there is only a small probability that a trend would be detected even if an actual trend existed (Hayes and Steidl 1997).

The sixth objective of this study was to suggest approaches to future monitoring of the bird community with respect to the appropriate sampling intensity needed to detect change in relative abundance over time, including incorporation of detection probabilities. We tackled this objective by determining the power to detect trends in bird abundance in this chapter and species detectability in the subsequent chapter (Chapter Six). We then followup with recommendations which synthesize the results and implications of these two chapters in Chapter Seven.

Methods

We chose nine species which were fairly representative of the three land cover classes and, when possible, represented species of conservation concern. The Dickcissel and Song Sparrow were representative of wet prairie habitat, and the Dickcissel was a species of regional conservation concern. The Indigo Bunting, Northern Oriole, and Tufted Titmouse represented early successional forest. The Red-bellied Woodpecker, Wood Thrush, and Yellow-billed

Cuckoo represented mature forest. Another requirement was that the species was adequately sampled.

Power to detect trends in bird abundance was estimated by presuming sampling and group (annual, site and annual×site) sources of variation. Sampling variance is typically estimated on the probability scale and, for this reason, was translated to the log scale (the scale at which group effects are typically measured) via the delta method. This method yields $\sigma^2_{\log\mu}$, the sampling variance of a mean on the log scale as, approximately, $[CV\ ]^2/n$ (B.R. Gray, unpublished ms.), where CV denotes the coefficient of variation (= (σ or standard deviation) / mean). Annual variation or actual changes in the mean number of birds among years was denoted τ_{yr}^2.

The sum of the two variance components, $\sigma^2_{\log\mu} + \tau_{yr}^2$, represents the variance of a sample mean estimated at a single site; dividing by S_{xx}, the sum of squares associated with elapsed time, yields the variance, on the log scale, of any slope associated with time. Power estimation proceeded by referring to a noncentral T distribution with (groups - 2) degrees of freedom. The noncentrality parameter was defined as slope = log(1 + *r*) divided by the variance of the slope (Neter et al. 1985, eqn. 3.26), where *r* is the trend or change per time or distance unit. The false positive error rate was set at 0.10.

The variance components σ^2 and τ_{yr}^2 were estimated using Poisson regression, with the exception that under- or over-dispersion with respect to that of a Poisson-distributed random variable was estimated using a moment-based multiplier, ϕ. Given that the variance of a Poisson random variable equals the mean, μ, the sampling variance of the observed counts, with adjustment for over- or under dispersion was estimated as $\phi\mu$. σ^2 and τ_{yr}^2 were estimated conditional on site and year(site) effects; the variations among these latter effects were denoted τ_{site}^2 $\tau_{yr(site)}^2$, respectively, but were not always estimable (due primarily to small number of years and sites). Note that the CV was estimated at the *median* of the year, site, and year(site) group effects. If year effects were not estimable, they were set to 0. Poisson regression proceeded using pseudolikelihood, and SAS®' generalized linear mixed modeling procedure (GLIMMIX; Wolfinger and O'Connell 1993, SAS 2005). To limit small-sample issues, species-site-year combinations were omitted if they contained fewer than 10 counts. Also, to allow estimation of τ_{yr}^2, only sites with two or more sampling episodes (each with ≥10 counts) were retained. Power estimates were not adjusted for species detectability.

Results

The sampling variance of observed counts was roughly equal to the mean ($\psi \approx 1$) for Northern Oriole, Dickcissel, and Indigo Bunting, but roughly half that of the mean ($\psi \approx 0.5$) for Red-bellied Woodpecker, Song Sparrow, Tufted Titmouse, Wood Thrush and Yellow-billed Cuckoo (Table 14). These latter species thus exhibited nonignorable levels of underdispersion. Estimates of the coefficient of variation (CV) varied from 0.47 to 0.73, while variation among years, sites and years×sites was estimated as generally negligible.

Power to detect trends was an increasing function of the trend magnitude and of sample size, and a decreasing function of the estimated species-specific sampling variance (Table 14). Estimated power increased from lows at trends of 1% per year and *n* = 10 to 1 at *r* = -10% per year and, depending on the species and sample size, -5% per year. Given essentially zero interannual variance estimates, power was lower for species with the highest CV and hence sampling variance (Northern Oriole), intermediate for the species with the intermediate CV value

(Indigo Bunting) and roughly equivalent for the balance of the species (Table 14, Fig. 15). Interannual variance estimates were substantially larger for Dickcissel and Yellow-billed Cuckoo and, for these species, power was lower than for species with similar CV estimates but lower τ^2_{yr} estimates (e.g., holding sample size constant, compare power for these species with that for Red-bellied Woodpecker). Early successional forest appeared to be associated with species with relatively higher sampling variances.

Of the ten sites considered in this analysis, only four sites were sufficiently sampled to provide confidence of site-level estimates of population trajectory. Each of these four sites, Squaw Creek, Swan Lake, Jameson Island, and Overton Bottom South, had >50 survey sites each. These >50 survey sites, if annually sampled, would provide warning for most species exhibiting 10%, 5%, and, in some cases, 3% annual declines. Surveys conducted at the other six sites were too few in number to possibly hope to identify anything but the greatest declines and thus would only be useful in informing regional trends.

Table 14. Estimates of sampling (σ^2), among-site (τ^2_{site}), among-year (τ^2_{yr}) and among-site-year ($\tau^2_{yr(site)}$) variation by species. The quasi-likelihood multiplier (ψ) of the variance-covariance matrix accommodated the observed underdispersion; $\psi < 1$ indicates substantial underdispersion.

Species	Sites	Years	Years (sites)	Median Count	ψ	σ^{2a}	CV[a]	τ^2_{site}	τ^2_{yr}	$\tau^2_{yr(site)}$
BAOR	3	3	8	1.97	1.22	2.41	0.79	0.015	na	na
DICK	3	3	8	3.84	1.04	3.99	0.52	0.049	0.039	0.034
INBU	5	3	12	3.37	1.26	4.25	0.61	0.033	0.001	0.008
RBWO	6	3	13	1.55	0.41	0.63	0.51	0.008	na	na
RNPH	1	2	2	1.46	0.32	0.47	0.47	na	0.015	na
SOSP	2	3	5	1.69	0.54	0.91	0.57	na	0.006	na
TUTI	6	3	13	1.67	0.47	0.78	0.53	0.022	0.005	na
WOTH	5	2	10	1.71	0.44	0.75	0.51	0.034	na	na
YBCU	2	3	6	1.89	0.57	1.07	0.55	0.002	0.023	na

[a]Estimated at median of site, year, and site-year effects.

Discussion

Power to detect trends in bird abundance assumes reasonable variance component estimates, an assumption that, for the current study, may bear some consideration. For example, sampling variances appeared similar to or substantially lower than that expected under a Poisson distributional assumption (Table 14). However, observed counts are typically substantially overdispersed with respect to that of Poisson random variables (Cameron and Trivedi 1999), a phenomenon typically observed in bird counts (Thompson et al. 2002, Purcell et al. 2005). Sources of underdispersion might include spatial correlation within sites, observer effects combined with only one or a few observers per site, and detection probabilities that decrease at locations at which bird counts are extreme (i.e., unusually rare or abundant). Also, because breeding birds are often territorial, they are more likely to be distributed in space in a manner resulting in underdispersion (Royle and Nichols 2003).

The study data also suggested small site-to-site and year-to-year variation. Further investigation should be undertaken to determine whether these estimates are deflated due to, for example, spatial and temporal correlation, respectively. Note that, in the presence of substantial inter-observer variability, strong and positive site-observer associations will induce temporal

correlation among means from the same site and a tendency for one or a few observers to work only in neighboring sites will induce spatial correlation among site means. Adjusting interannual variance estimates upward will yield decreased power estimates, regardless of within-year sample size (Urquhart et al. 1998). The annual and site variation estimates derive from very small numbers of year and site estimates; the accuracy of these variance estimates will increase as the number of years and sites increases (Table 14).

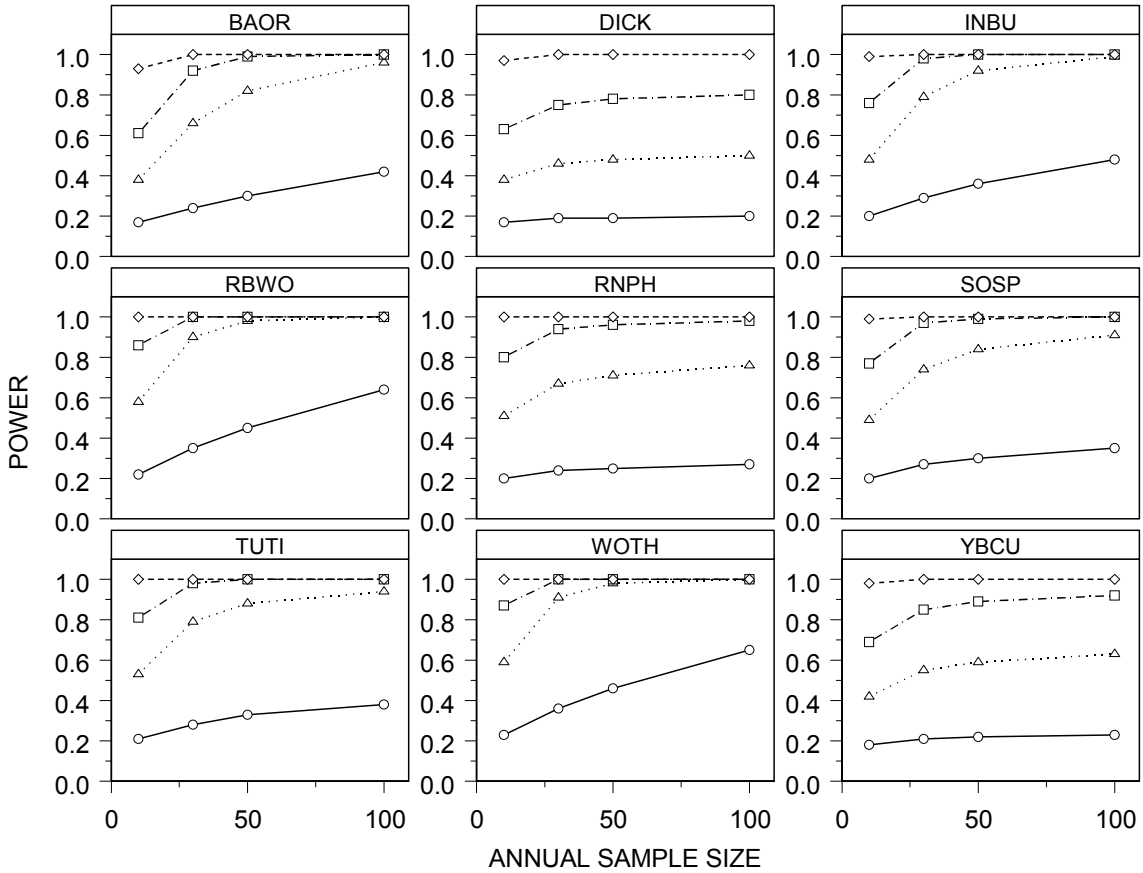


Figure 15. Power to detect a decline in avian abundance along the lower Missouri River as a function of sample size (along the ordinate), species (by panel), and trend. The trends assessed were declines of 1% (○), 3% (△), 5% (□), and 10% (◇) per annum. Species detectability was not incorporated in this calculation of power.

The importance of interannual variation is seen by estimating the variance of a mean at different sample sizes. For example, the proportion of variance of a mean attributable parameter or group variance in the current study for YBCU at $n = 10$ was 43% [$\tau_{yr}^2/(\tau_{yr}^2 + \sigma^2_{\log \mu} = CV^2/n_i)$ = 0.023 / (0.023 + 0.550^2 /10)], a value that increased to 60% at $n_i = 20$; these nontrivial variance components represent that fraction of the variation of a mean that is unaffected by increases in within-group sample size. If among-site differences in means are, as estimated, minor, then this suggests fewer sites will be needed to characterize trends across a region. If site effects are

ultimately found to be important then an argument may be made for trading annual sampling for sampling more sites but on a less than annual basis (Larsen et al. 2004).

The power estimates provided here represent power at a typical or median site. Given that the CV and, hence, sampling variation on the log scale, is a decreasing function of the mean, power may be expected to increase at sites for which a species is more abundance and decrease at a site at which the species is less abundant. This association between power and abundance becomes stronger as abundance nears zero and becomes less consequential at abundances exceeding 2 [units]. See Larsen et al. (2004) for issues associated with estimating variance components and power across multiple populations. Further, if further investigation ultimately yields sampling variances that are revised upward, then power will decrease. Such decreases would be seen most at small sample sizes—where the relative influence of sampling variance is greatest.

Chapter Six
Bird Species Detectability

Research on terrestrial birds relies primarily on counts of birds to make inferences regarding relative abundance over space and time (Rosenstock et al. 2002, Diefenbach et al. 2003). Estimates of the species abundance and, hence, the sampling variance may be biased if birds are imperfectly detected (Thompson 2002) unless the probability of detection remains constant (Rosenstock et al. 2002, Thompson 2002). A number of studies have demonstrated that the probability of detection often varies according to observer ability (Ramsey and Scott 1981), environmental variables (Anderson and Ohmart 1977), and bird-species calling characteristics (Calder 1990). Failure to accommodate these factors could invalidate the use of bird counts to monitor population trends or ascribe differences among treatments (Diefenbach et al. 2002).

To determine the degree to which species are imperfectly detected in surveys of birds along the lower Missouri River, we conducted detectability analyses. Ten species were selected to determine the probability of detection, effective detection radius, and factors associated with their detection. These species were representative of the land cover classes and, where possible, were the same as those modeled for power to detect trend (Chapter Five). The Dickcissel (a species of conservation concern) and Song Sparrow represented wet prairie habitat, Bell's Vireo (a species of conservation concern), Indigo Bunting, Northern Oriole, and Yellow-billed Cuckoo represented early successional forest habitat, and the Prothonotary Warbler, Red-bellied Woodpecker, and Wood Thrush represented mature forest habitat.

Methods

Using distance techniques requires that the counts be made at known or binned distances from the survey location. Along the lower Missouri River, counts were collected and ascribed to <50 m and >50 m from the survey location. We assumed the majority of birds recorded for the area beyond 50 m from the survey location were observed out to a maximum distance of 100 m. We arbitrarily anchored our detection functions to distances of 25 m (one-half of the 50 m cutoff) and 75 m (one-half of the 50-100 m interval).

Counts by distance category were analyzed using DISTANCE 5.0 Beta Release 4 (Thomas et al. 2005). The program DISTANCE uses the radial distance of each bird from the survey point to generate a histogram of the number of detections by distance. A monotonic, decreasing key function (half-normal) was used to model the detection function. Detection functions were used to estimate the detection probability for half-widths of 25 and 75 m from the point survey. Covariates examined in modeling detection included year, season, observer, study area, and cover type. A chi-square goodness-of-fit test was used to assess model fit, and Aikike's Information Criterion was used to select the most parsimonious model (Buckland et al. 2001). By modeling the detection function, an estimate of p, the proportion of individuals detected in the area surveyed, and EDR, the effective detection radius, was obtained. The effective detection radius is the distance d at which as many species beyond d are detected as are missed within d. Methods for fitting detection functions are described in Buckland et al. (2001, 2004).

Results

The 10 species for which detectability was examined differed markedly in their results. The most detectable species, the Yellow-billed Cuckoo (Global P_a = 0.54) was approximately three times more detectable than the least detectable species, the Prothonotary Warbler (Global P_a = 0.17) (Table 15). The effective detection radius for most of the species was approximately 50 m.

Table 15. Global unconditional probability of detection (P_a) and effective detection radius (EDR), with 95% confidence intervals, for selected species in floodplain habitat of the lower Missouri River, 2002–2004. EDR (m) is the estimated plot radius within which the number of birds missed equals the number of birds observed further away.

Species	P_a	EDR (m)
WET PRAIRIE		
Dickcissel	0.265 (0.249, 0.283)	51.5 (49.9, 53.2)
Song Sparrow	0.324 (0.228, 0.460)	56.9 (47.7, 67.9)
EARLY SUCCESSIONAL FOREST		
Bell's Vireo	0.264 (0.164, 0.423)	51.3 (40.4, 65.2)
Indigo Bunting	0.231 (0.221, 0.241)	48.1 (47.0, 49.1)
Northern Oriole	0.229 (0.218, 0.241)	47.9 (46.7, 49.1)
Yellow-billed Cuckoo	0.544 (0.519, 0.570)	73.8 (72.1, 75.5)
MATURE FOREST		
Prothonotary Warbler	0.166 (0.134, 0.206)	40.8 (36.6, 45.4)
Red-bellied Woodpecker[a]	0.343 (0.313, 0.377)	58.6 (56.0, 61.4)
Wood Thrush	0.324 (0.303, 0.345)	56.9 (55.0, 58.8)

[a] Indicator analysis also classified this species with the wet prairie species, though the indication was not significant.

Detection of singing Dickcissels was fitted by a half-normal function (Fig. 16) and appeared to vary as a function of observer (Fig. 17), though too few data existed for three observer combinations. The ability to detect Dickcissels varied by a magnitude of 5 between the worst observer and the best observer.

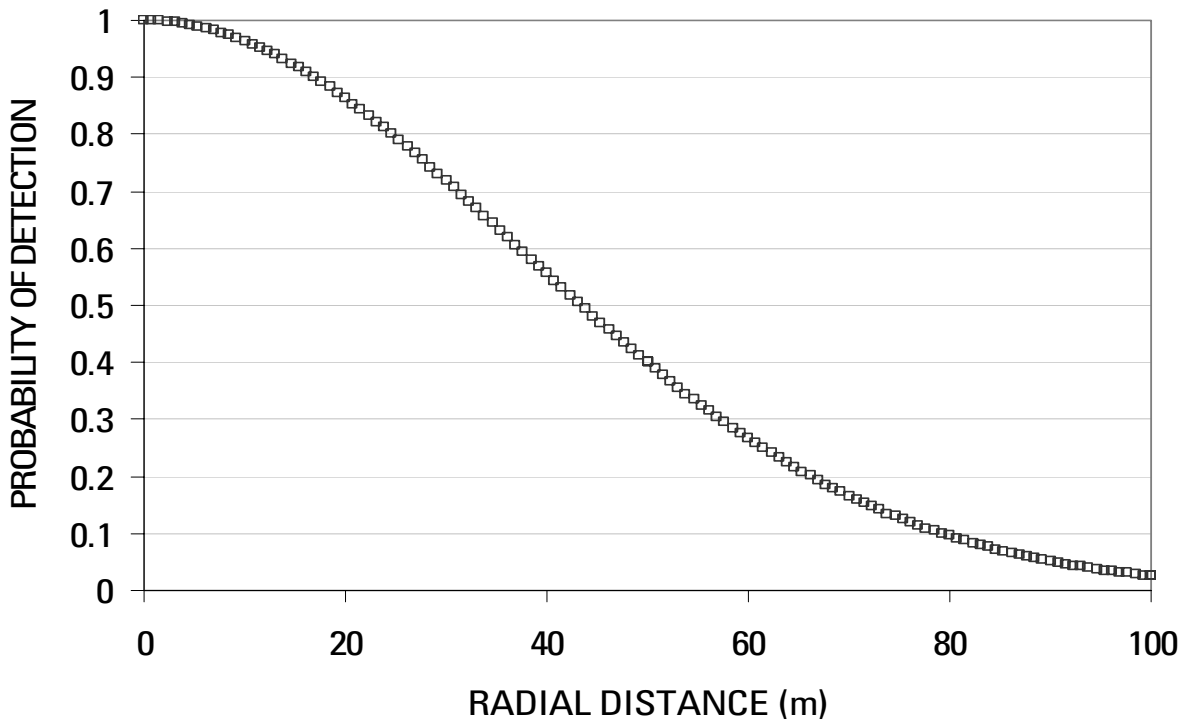


Figure 16. The estimated detection probability of Dickcissels occurring in habitat of the lower Missouri River, 2002–2004 (n = 1,763 detections) as a function of distance (meters) observed from survey point. The fit of the half-normal function to untruncated global data is shown.

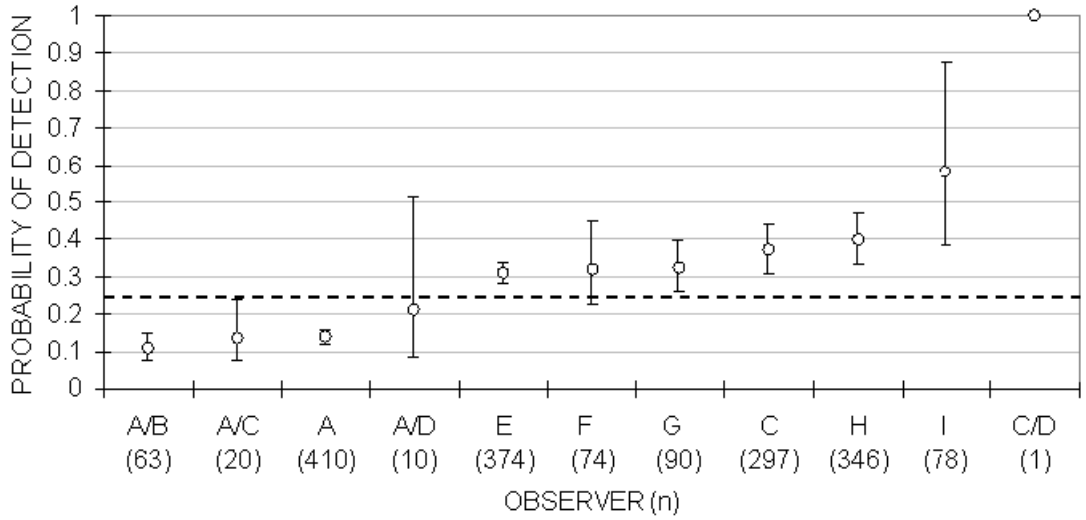


Figure 17. Proportion of singing Dickcissels detected (P_a), by observer, in wet prairie habitat of the lower Missouri River, 2002–2004 (n = 1763 detections). Grand mean is denoted by the dashed line.

Detection of singing Song Sparrows was best modeled as a half-normal function with season and year as covariates (Fig. 19), though correlation between season and year and small sample sizes per treatment makes this result tentative. Regardless, the next best performing models of Song Sparrow detectability included year alone (ΔAIC = 3.51 from the season × year model; P_a = 0.34; EDR = 58.3 m) and season alone (ΔAIC = 3.74; P_a = 0.36; EDR = 59.8 m). Cover type, observer, and study area were not useful in describing detection of Song Sparrows.

In migration in 2004, Song Sparrows were detected with a 90% probability out to 100 m, whereas in 2002 during the breeding season, the species was virtually undetectable beyond 70 m. In general, an 80% probability of detection occurred within a detection radius of 20 m.

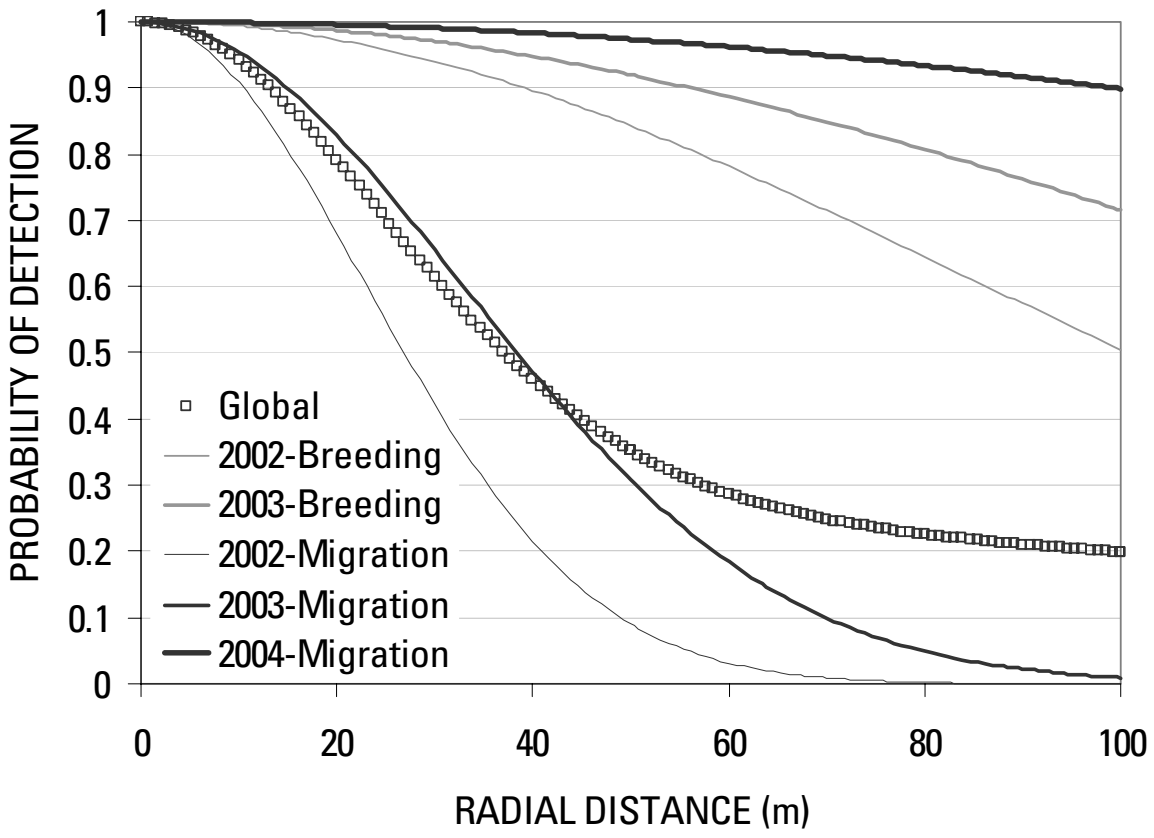


Figure 18. The estimated detection probability of Song Sparrows occurring in habitat of the lower Missouri River, 2002–2004 (n = 66 detections) as a function of distance (meters) observed from survey point, year, and season.

Detection of Bell's Vireo, though obviously constrained by the limited sample size (n = 24), was best modeled as a function of season (Fig. 20). With a caution to this sample size constraint, it appears that the probability of detecting birds at 50m from the survey location during the migratory period was approximately a third that of the breeding season (<0.2 versus ~0.55).

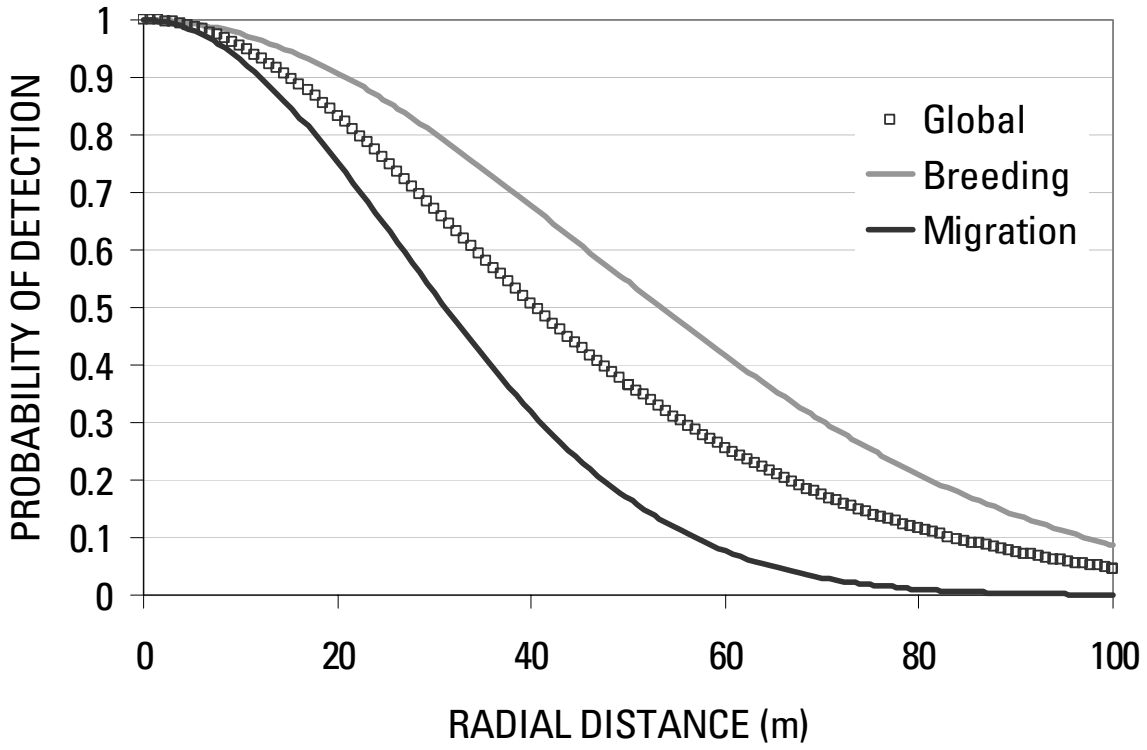


Figure 19. The estimated detection probability of Bell's Vireo occurring in habitat of the lower Missouri River, 2002–2004 (n = 24 detections) as a function of distance (meters) observed from survey point and season.

Detection of Indigo Bunting was best modeled as a function of season stratified by cover type (Fig. 21). Detection probability (WTP: P_a = 0.256 [0.243–0.271]; ESF: P_a = 0.226 [0.217–0.235]; MTF: P_a = 0.214 [0.212–0.226]) and effective detection radius (WTP: EDR (m) = 50.6 [49.3–52.1]; ESF: EDR (m) = 47.5 [46.5–48.5]; MTF: EDR (m) = 46.2 [44.9–47.5]) appeared to decline as vegetative structure increased from WTP through ESF to MTF. The differences were generally small however, with only detection probability for Indigo Buntings in mature forest during the migration period appreciably smaller than the other cover type × year combinations (Fig. 21). In general, it appears an 80% probability of detection occurred only for those birds within ~25 m of the surveyor.

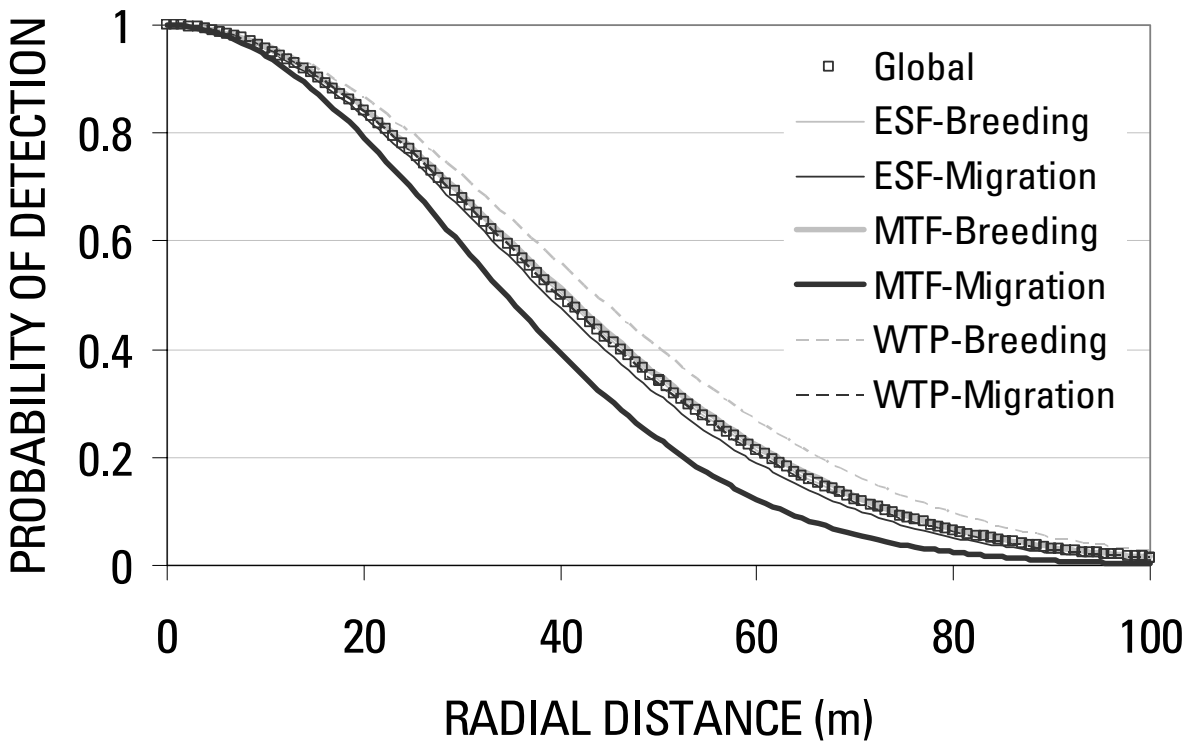


Figure 20. The estimated detection probability of Indigo Bunting occurring in habitat of the lower Missouri River, 2002–2004 (n = 3,655 detections) as a function of distance (meters) observed from survey point, cover type, and season. ESF is early successional forest, MTF is mature forest, and WTP is wet prairie.

Detection of Northern Oriole was a function of cover type and year (Fig. 22), with detection highest in wet prairie, intermediate in early successional forest, and lowest in mature forest. Northern Orioles had the lowest probability of detection in 2003 and the highest in 2004, with detections in 2002 intermediate between the years. An 80% probability of detection occurred only for those birds within ~20 m of the surveyor.

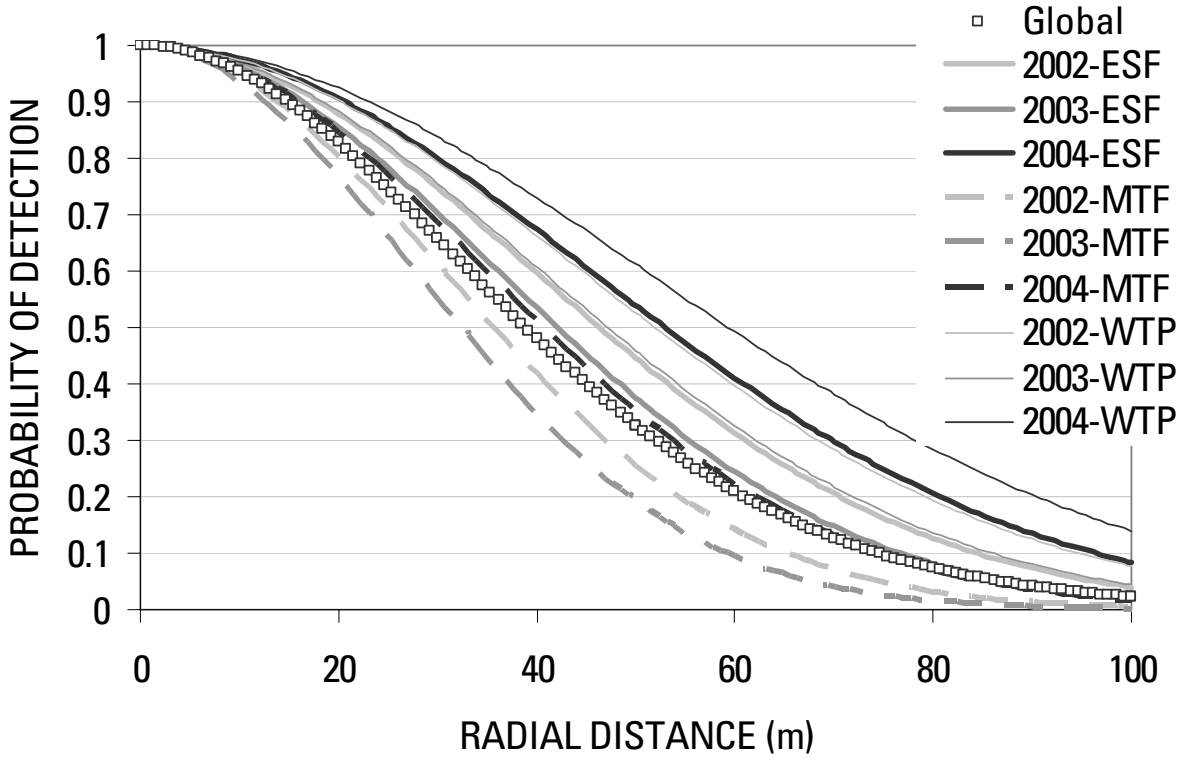


Figure 21. The estimated detection probability of Northern (Baltimore) Oriole occurring in habitat of the lower Missouri River, 2002–2004 (n = 1,325 detections) as a function of distance (meters) observed from survey point, cover type, and year. ESF is early successional forest, MTF is mature forest, and WTP is wet prairie.

Yellow-billed Cuckoo, a species which is very noisy if infrequent in its calling, was the most easily detected species of the ones we considered. Detection of Yellow-billed Cuckoo was a function of cover type and year (Fig. 23). Detection probability was lower in early successional forest plots relative to mature forest, and lowest in 2002 versus 2003 and 2004. Cuckoos within ~40 m of the surveyor were detected with an 80% probability.

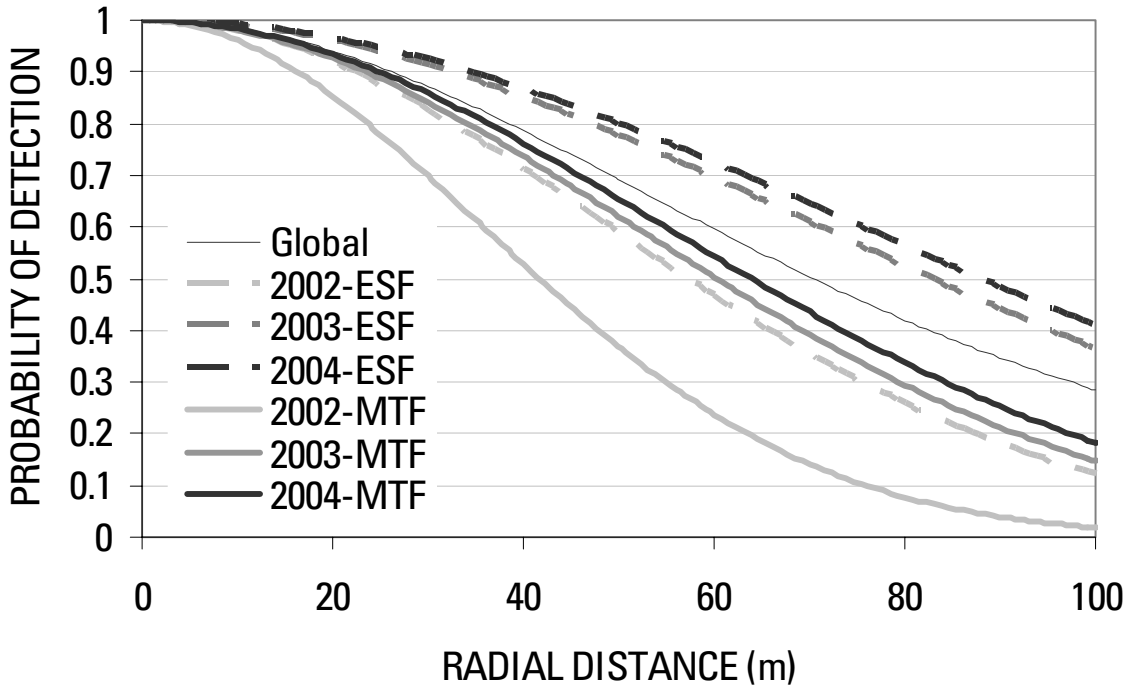


Figure 22. The estimated detection probability of Yellow-billed Cuckoo occurring in habitat of the lower Missouri River, 2002–2004 (n = 834 detections) as a function of distance (meters) observed from survey point, forest type, and year. ESF is early successional forest, MTF is mature forest, and WTP is wet prairie.

Perhaps surprising, the Prothonotary Warbler was the most difficult to detect despite its very noisy nature. Detection of Prothonotary Warbler was best described as a function of year, though a model with season and season by year was 2.00 and 1.89 AIC units removed from the best model, suggesting that season was also a potential contributor to detecting Prothonotary Warblers. The highest probability of detection occurred in 2002, and dropped substantially in subsequent years (Fig. 24); conversely, the difference between migration and breeding season probability of detection was small but consistent, with migration always lower than breeding in each of the three years.

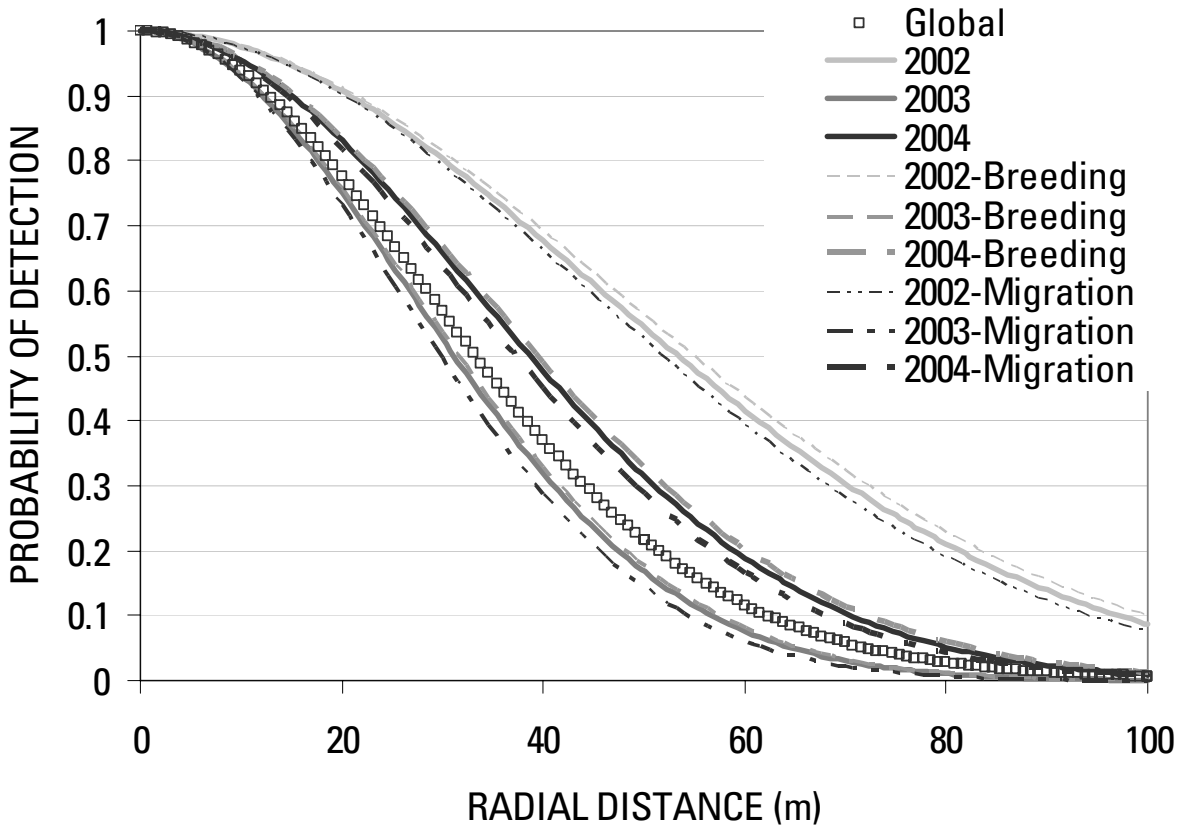


Figure 23. The estimated detection probability of Prothonotary Warbler occurring in habitat of the lower Missouri River, 2002–2004 (n = 80 detections) as a function of distance (meters) observed from survey point and year.

Detection of Red-bellied Woodpecker was best described as a function of cover type (ESF vs MTF), but here the difference between the two cover types in detection probability (ESF: P_a = 0.677 [0.354–1.000]; MTF: P_a = 0.316 [0.266–0.376]) and effective detection radius (ESF: EDR (m) = 82.3 [59.1–114.4]; MTF: EDR (m) = 56.2 [51.5–61.3]) was substantial (Fig. 25). Birds within ~25 m of the surveyor were detected with a probability of 80%.

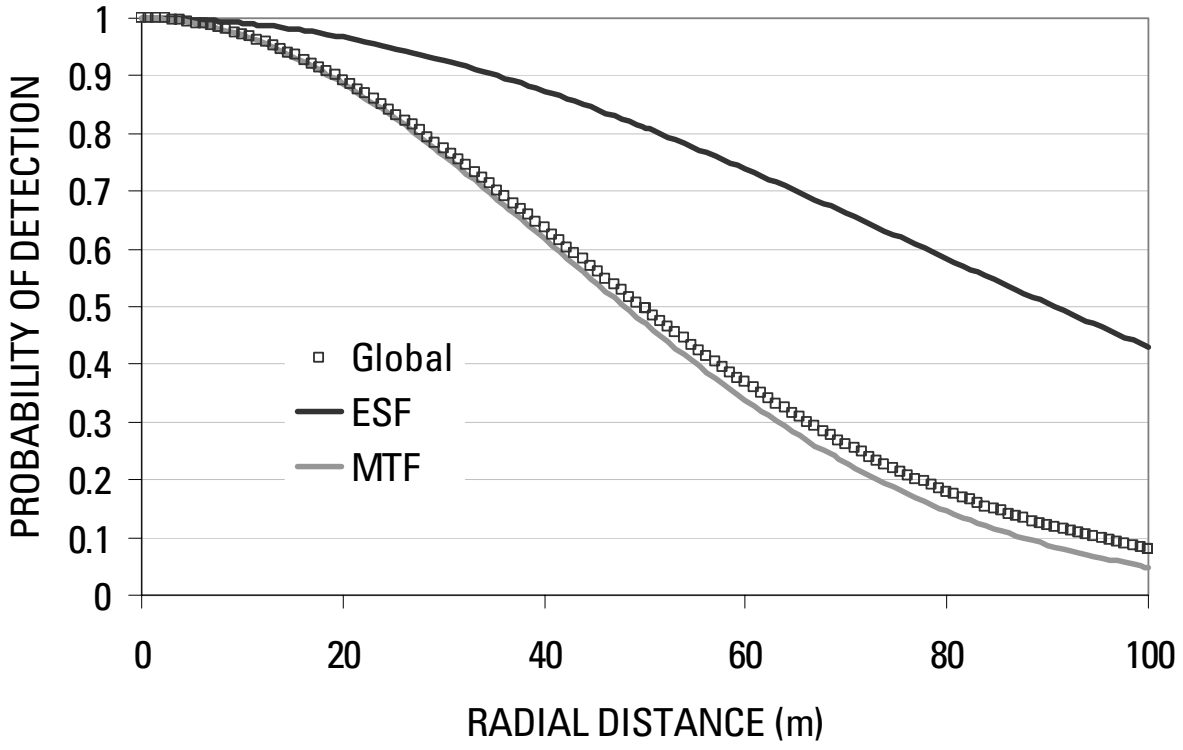


Figure 24. The estimated detection probability of Red-bellied Woodpeckers occurring in habitat of the lower Missouri River, 2002–2004 (n = 321, including 10 detections in wet prairie habitat) as a function of distance (meters) observed from survey point and forest type. ESF is early successional forest and MTF is mature forest.

Detection of Wood Thrush was best described as a function of cover type (ESF vs MTF) and year (2002 vs 2003 vs 2004). The difference between the two cover types in detection probability (ESF: P_a = 0.305 [95% Confidence Interval = 0.238–0.391]; MTF: P_a = 0.330 [0.289–0.377]) and effective detection radius (ESF: EDR (m) = 55.2 [48.8–62.6]; MTF: EDR (m) = 57.4 [53.7–61.4]) was small (Fig. 26). The most pronounced difference between years was seen for surveys conducted in 2004; the probability of detecting a Wood Thrush was <0.30 in 2004 (P_a = 0.292 [0.246–0.347]) compared to ≥0.35 in 2002 and 2003 (P_a = 0.360 [0.2546–0.509] and P_a = 0.350 [0.292–0.419], respectively). Albeit small, the greatest difference in probability of detection was between mature forest in 2003 and early successional forest in 2004.

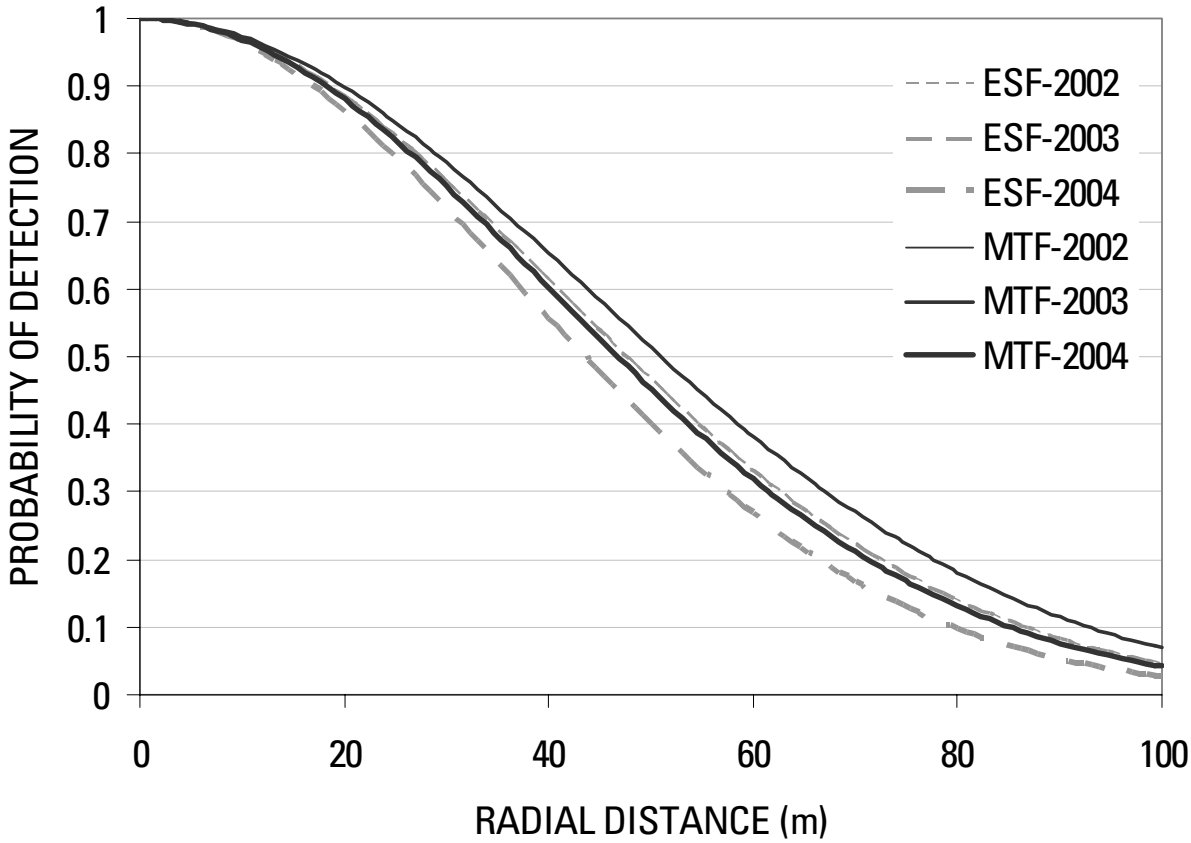


Figure 25. The estimated detection probability of Wood Thrush occurring in habitat of the lower Missouri River, 2002–2004 (n = 612) as a function of distance (meters) observed from survey point, forest type, and year. ESF is early successional forest, MTF is mature forest, and WTP is wet prairie.

Discussion

Probability of detection is influenced by characteristics of the song (singing rate, sound intensity, sound pitch, and sound modulation), distance from the observer, and observer skill. We found in the sampling of species that we studied considerable differences in the estimated

probability of and the covariates influencing species detection. The detectability of one species, the Dickcissel, was markedly affected by observer; the best observer detected Dickcissels at fives times the rate of the worst observer combination. Differences in detectability among observers was previously described by Ramsey and Scott (1981). The nine other species we studied, however, did not show a pronounced influence of observer on detection probability.

A large portion of the species we studied exhibited temporal variability in their detectability. Song Sparrow, Bell's Vireo, and Indigo Bunting differed seasonally in their detectability, with birds less detectable during the migration season as compared to the breeding season. Song Sparrow, Northern Oriole, Yellow-billed Cuckoo, Prothonotary Warbler, and Wood Thrush each exhibited annual differences in detectability. The magnitude of these temporal differences in detectability varied dramatically by species, with the greatest differences seemingly occurring with the Song Sparrow.

Half of the species studied, Indigo Bunting, Northern Oriole, Yellow-billed Cuckoo, Red-bellied Woodpecker, and Wood Thrush, differed in detection by cover type, with detectability least in mature forest and greatest in wet prairie. Our estimates of detectability for the Wood Thrush (P_a = 0.324) and Prothonotary Warbler (P_a = 0.166) were approximately the same as that reported by Smith and Twedt (1999) in bottomland hardwood forests of west-central Mississippi (P_a = 0.322 and 0.155, respectively). Simons et al. (2000) reported effective detection radii (EDR range = 91–123 m) for Wood Thrush that were nearly twice that we observed (EDR = 57 m). Our estimates of detectability for the Red-bellied Woodpecker (P_a = 0.343) were 40–60% of that reported by Gutzwiller (1993) in central Texas in winter (P_a = 0.544) and Smith and Twedt (1999) (P_a = 0.762). Our estimates of detectability were lower for the Indigo Bunting (P_a = 0.231 vs. 0.418) but higher for the Yellow-billed Cuckoo (P_a = 0.544 vs. 0.419) as compared to the results of Smith and Twedt (1999).

A difficulty that we faced in our analysis of species detectability was the ad hoc delineation of the survey area. Because we had only counts from <50 m and >50 m, we arbitrarily anchored our detection functions to distances of 25 m (one-half of the 50 m cutoff) and 75 m (one-half of the 50-100 m interval). We assumed the majority of birds recorded for the area beyond 50 m from the survey location were observed out to a maximum distance of 100 m. If we assume that the birds detected in the outer band are adequately approximated as having been observed at a distance of 75 m, then approximately 25% or Prothonotary Warblers, 35% of Song Sparrows, Bell's Vireos, Indigo Buntings, and Northern Orioles, 40% of Dickcissels, 50% of Red-bellied Woodpeckers and Wood Thrushes, and 70% of Yellow-billed Cuckoos were detected within the inner 50 m listening radius.

However, had we decided that the effective maximum survey radius was 125 m, 150 m, or 175 m, we would have obtained different estimates of the mean probability of detection and the effective detection radius (Fig. 27). For example, the effective detection radii would be 54, 69, 80, and 94 m, respectively. This is a mathematical necessity resulting from fitting a (half-normal) function to only two points. Because of this ad hoc delineation of the surveyed area, we did not utilize one of the most powerful capabilities of distance detection, and that is density estimation. Because we can not estimate the true area to which counts apply, we could not estimate species density without considerable reservation.

Despite the problems in defining the appropriate survey area, the differences that we observed between observers, seasons, years, and cover types in their influence on probability of detection are nevertheless robust and presumably exist in some combination for those species that we did not analyze. Secretive waterbirds such as the bitterns, herons, and rails and night

birds such as the owls and nightjars are likely under-counted by the methods used in this study, and therefore, any inferences derived from these data must be cognizant of this problem. Wide-ranging birds such as the hawks, eagles, and vultures are also probably not well-represented by the methods employed here.

Underdetection will ultimately influence trend detection (Chapter Five). Even if, for a given species, underdetection were constant across observers, study areas, seasons, and years, adjusting for underdetection would lead to a larger mean count and, hence, to lower (possibly trivially lower) sampling variances on the modeling scale. Variation in detection probabilities across components that were treated as random (years and study areas) will also lead to different year-, site- and year×site-level variance estimates and, hence, to altered power estimates. More sampling events, combined with improved sampling designs (see below), will allow power estimation to include detection considerations.

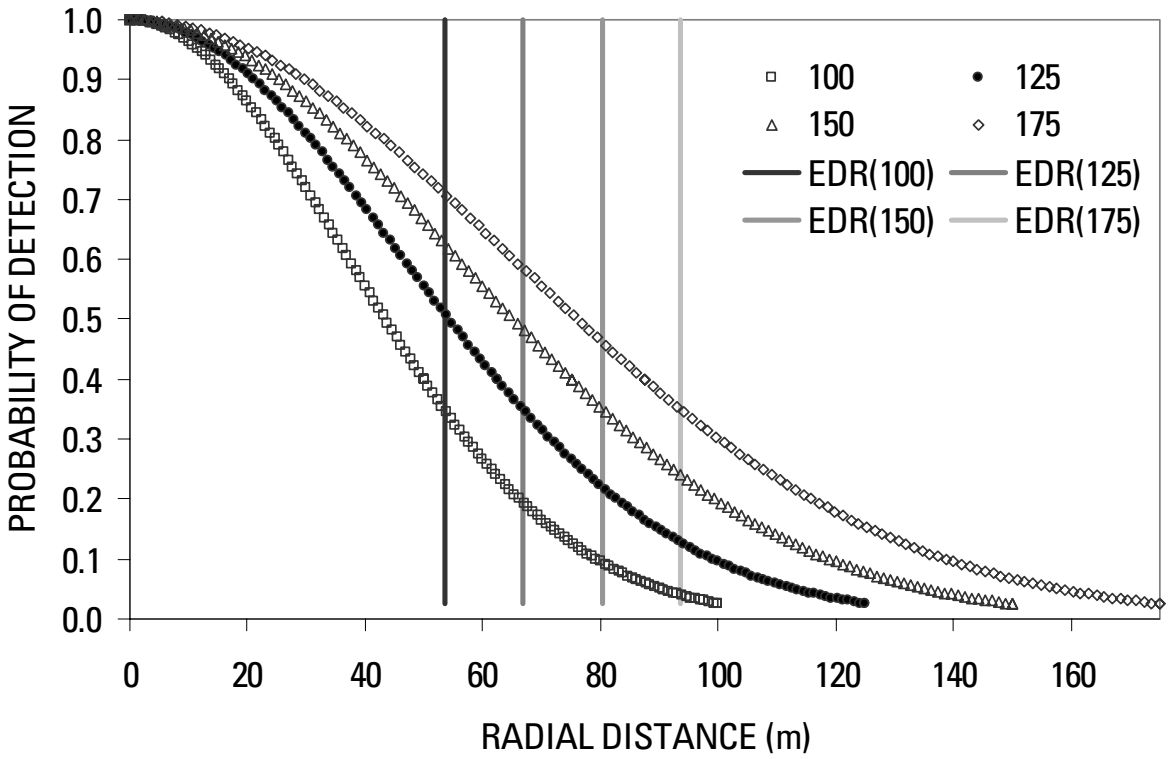


Figure 26. Hypothetical influence of the effective maximum survey area on the estimate probability of detection and the effective detection radius (EDR), as determined by a half-normal function on two distance intervals. The maximum survey areas estimated were 100 (as used in the current study), 124, 150, and 175 m.

Chapter Seven
Recommendations

Our recommendations resulting from the analyses we have conducted take two forms, those relating to potential research and those relating to management.

Research Recommendations

The information gleaned regarding the fate of abandoned agricultural lands and land cover-specific bird community composition may allow us to predict the fate of acquired lands and their attendant consequences to the bird communities along the lower Missouri River. Mapping the agricultural lands by their predicted fate would be relatively easy to accomplish, but uncertainties in the site-level differences that we identified as important may preclude robust conclusions. Thus, additional study would be required of the site-level differences in vegetation and landform to heighten the credibility of these mapped predictions.

Focused studies of fitness (i.e., survival and reproduction) for indicative species, including the Dickcissel for wet prairie, Bell's Vireo for early successional forest, and Northern Parula and/or Prothonotary Warbler for mature forest, would illuminate the effect of potential management strategies. Changes observed in these species would be reflective of the land cover class and the attendant bird community.

Examining habitat-specific patterns in species occupancy may be useful in determining population abundance, as recent work allows for translating patterns in occurrence into (habitat-specific) estimates of density (Royle and Nichols 2003, MacKenzie and Nichols 2004, MacKenzie et al. 2004, 2005, Royle et al. 2005). Because the distance methods employed in this study preclude robust density estimation, we recommend re-analyzing the data considered here from an occupancy standpoint in an effort to derive the inference regarding bird population abundance.

Management Recommendations

Our analyses of the vegetation factors describing the wet prairie and forest sites imply that future vegetation monitoring might be most efficient if it focuses on the collection of a subset of all of the variables measured for this study. For instance, litter depth, vegetation height, and the proportion of the site in bare soil would adequately describe more than half of the variance in site characteristics at wet prairies. Additional variables would need to be measured for forests, but because of the correlated nature of many of the measurements, much of the site variance could be captured in forests through the collection of total canopy cover, upper- and mid-canopy cover, and maximum diameter at breast height. Total stem count, which can be exceedingly tedious to collect, could probably safely be avoided at least for the purposes of monitoring site characteristics.

Only annual declines in bird abundance of 10% were reliably estimated at reasonable sample sizes. Because too few surveys were conducted within the individual study areas to detect moderate declines in bird abundance without substantial increases in sampling intensity, the only course of action are efforts to reduce sampling variance. Detection probability seems to be an important factor contributing to sampling variance.

If environmental factors are held constant then the main factors influencing detection are the density of the species, number of samples, and the distribution of the species within a study area. The fact that observers differ, in some cases dramatically so, in their ability to detect particular species of birds means that proper analyses of point count data requires a model-based approach. Unfortunately, there is no easy way to accommodate observer differences in multivariate analyses, particularly when the observer differences are imprecisely known and differ among the species. Because of this problem, we recommend that observer quality be increased through on-the-job training (Kepler and Scott 1981), the testing of hearing ability (Ramsey and Scott 1981), and the hiring of only experienced individuals (Faanes and Bystrak 1981). Further, randomization of observers across the monitoring region is highly desirable, as it will guard against the confounding of site-level factors with observer error.

Because of the difficulties in correctly ascribing distances to observations, we further recommend considering dispensing with distance methods in favor of other more easily implemented methods. For instance, increasing the frequency within a season in which stops are surveyed would allow robust detection approaches to be employed (Royle and Nichols 2003).

Implications for Monitoring Programs on Managed Lands

A successful monitoring program depends upon clear, measurable objectives and the selection of appropriate metrics (Adamcik et al. 2004, Holthausen et al. 2005). The analysis of pilot data, as presented in this report, can help refine objectives and guide the selection of appropriate metrics for future monitoring (Elzinga et al. 2001). Monitoring methods should be accurate and reliable, cost-effective, and feasible (Tear et al. 2005). In addition, the metrics or indicators used in the monitoring program must be measurable, precise, consistent, and sensitive (Tear et al. 2005). A pilot project will provide information needed to judge how well the methods and metrics are meeting these criteria. There are often trade-offs between extensive and intensive sampling that can be evaluated (modeled) with pilot data (Field et al. 2005).
We present some examples of bird community monitoring objectives and demonstrate how the pilot data from this study can be used to refine objectives and clarify the appropriate metrics. The examples below will apply to wildlife monitoring plans generally, but the specifics (species, metric values) apply primarily to Lower Missouri River sites. In some cases, more analyses of the inventory data will be needed to yield the most appropriate metrics for a particular objective. These examples illustrate the importance of clarifying objectives. The data analysis approach varies depending upon the objectives of future monitoring. For example, it is costly to model detection probabilities for every species. Clarifying the focal species based on preliminary analyses will ensure that the analysis supports the monitoring objectives. We organize these examples based on the following major wildlife inventory and monitoring objectives common to wildlife management agencies (adapted from the Lower Mississippi Valley Joint Venture website http://www.lmvjv.org/songbird_monitoring_program.htm).

a. Baseline inventory
b. Evaluation of management actions
c. Testing assumptions or parameters underlying biological models
d. Detecting trends

a. Baseline Inventory

Suggested objectives:

1. Develop a species list comprised of at least 90% of the bird species using mature forest, early successional forest, and wet prairie habitats during breeding and during migration, with estimates of occupancy, detection probability, and abundance for selected species.
2. Develop guidelines for a future inventory method that includes metrics, sampling methods, and sample sizes needed to meet the above objective.

The current study was designed to provide baseline bird inventory information for targeted habitat types (wet prairie, early successional forest, and mature forest) during spring migration and summer breeding seasons and to provide data to guide future monitoring. The analyses in this report focused primarily on differentiating among the habitat types in terms of bird species composition, abundance, and habitat characteristics. However, some analyses were done to address future monitoring objectives. Species accumulation curves indicate that for a baseline bird species inventory of lower Missouri River refuges during the breeding season, about 162 sample points are needed to detect 90% of the bird species we found in mature forest, 193 points in early successional forest, and 314 points in wet prairie (Fig. 28). The species accumulation curves for migration do not reach an asymptote (Fig. 29), indicating that our inventory data failed to identify all species using these habitats during migration. However, to identify 90% of the bird species we found using lower Missouri River refuges during migration, 84 sample points are needed in mature forest, 115 in early successional forest, and 244 in wet

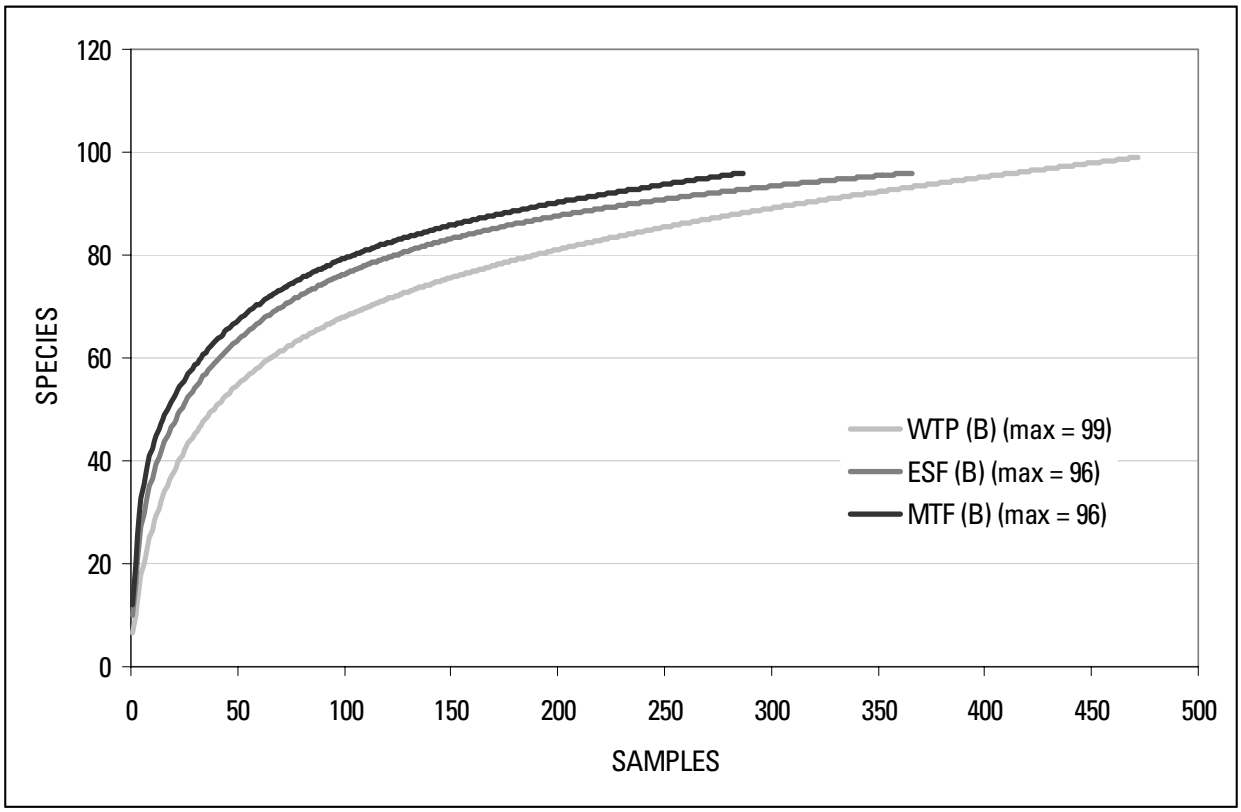


Figure 27. Species accumulation curves used to determine the number of samples needed to estimate bird species richness during the breeding season in mature forest (MTF), early

successional forest (ESF), and wet prairie (WTP). Maximum values indicate total species richness during the breeding season by habitat type in our study.

prairie. The sample size needed to identify all the species actually using these habitats during migration is difficult to estimate from our inventory data, but probably exceeds 350 points (Fig. 29). This suggests that multiple managed lands (refuges, parks, state wildlife management areas) would likely need to work together to develop bird species inventories for both breeding and migration seasons within ecoregions, rather than individual refuges working alone. We recommend the following protocol for conducting a baseline inventory at sites along the lower Missouri River, based on our data analysis.

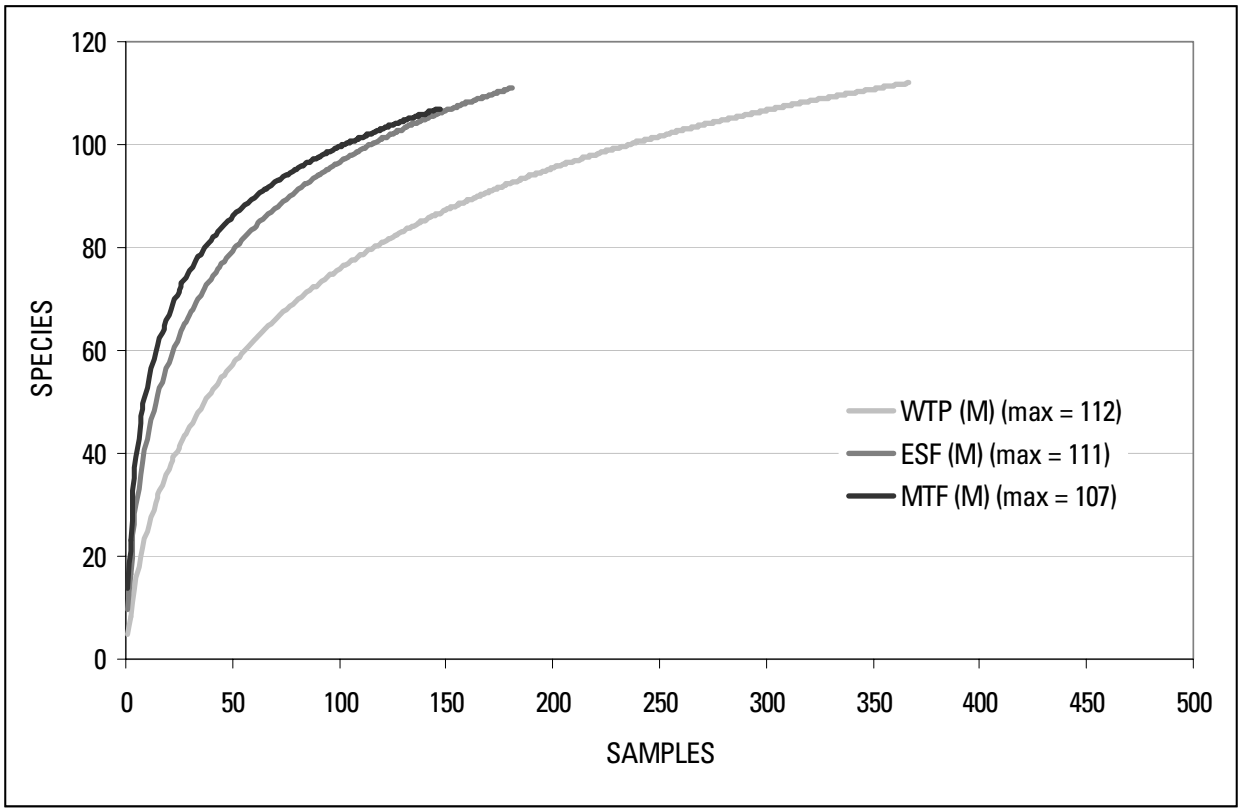


Figure 28. Species accumulation curves used to determine the number of samples needed to estimate bird species richness during the migration season in mature forest (MTF), early successional forest (ESF), and wet prairie (WTP). Maximum values indicate total species richness during the migration season by habitat type in our study.

Breeding season:

1. Point counts should be randomly distributed within each habitat type. For a baseline bird species inventory of the lower Missouri River during the breeding season, survey 170 sample points in mature forest, 200 points in early successional forest, and 320 points in wet prairie are warranted. (In consideration of the issues of underdispersion of sampling variance observed in the inventory data, these are minimum sample sizes.)
2. Data should be collected that allow estimation of detection probabilities and occupancy (proportion of sample points occupied). There are 3 methods currently available that meet this criterion.

   a. Distance estimation: The observer estimates the distance in m to each bird observed, usually in 10 m increments up to at least 100 m. This is the most commonly employed approach; a range-finder is a useful tool. The inventory data set employed only two categories of distance, which we consider insufficient for future sampling.
   b. Double-observer: Two observers visit each point, both record all birds seen or heard.
   c. Multiple visits: A lone observer visits multiple times in a single breeding season, no more than 10 days apart. At least 2 visits are necessary, 3 visits provide more robust results. Repeat visits on a random subset of points may provide enough information; repeat visits to all sites may not be necessary.
3. Most point count protocols employ distance estimation. In habitats with high densities of birds, using a range-finder will probably require at least a 10-minute listening period. The other two options will require at least twice as many observers to cover the same number of sampling points.
4. Observers should be trained and tested before the field season starts to ensure high quality data (Fig. 17). Observers should be randomly assigned to locations and rotated to avoid the same observer repeatedly visiting the same site.
5. At a minimum, estimate litter depth, vegetation height, and the proportion of the site in bare soil in wet prairie habitats.
6. At a minimum, estimate total canopy cover, upper and mid-canopy cover, canopy height, shrub cover, and mean and maximum diameter at breast height (Table 11) in early successional and mature forest habitats. These variables can be rapidly estimated within the standard 11.3 m radius circle (0.04 ha) surrounding the bird sampling point. Tree DBH sampling could be limited to measuring the distance to and DBH of the closest tree in each of 4 quadrants centered on the point (point-centered quarter method).

Migration season:

1. Point counts should be randomly distributed within each habitat type. A minimum of ~300 sample points are needed to derive 90% of the bird species using each of the three habitat types during migration.
2. Data should be collected that allow estimation of detection probabilities and calculation of occupancy. (See above)
3. Migration monitoring is very sensitive to timing. Large numbers of migrants may be present for only one day. Monitoring should be targeted to include peak migration dates and times.
4. More research is needed to identify the most robust ground-based inventory strategies during migration (point count, transect, area search). In addition, the role of more intensive sampling techniques such as mist netting to inventory migrating birds needs to be evaluated. Remote sensing techniques such as radar are used to provide crude estimates of the volume and direction of travel of birds in migration, but are poor at estimating species or numbers.
5. More research is needed to identify important habitat variables to measure during migration.

b. Evaluation of Management Actions

Suggested objective:

1. Evaluate the effects of future management actions on one or more breeding bird species using mature forest, early successional forest, and wet prairie habitats, with estimates of differences in occupancy and abundance for selected species.

If the management objective is to evaluate the effects of future management actions in the habitats studied, the species abundance (and occupancy) estimates from the inventory data can be used as benchmark values to evaluate the effects of these future management actions. Examples of management actions include timber harvest or stand improvement in mature forests or early successional forests and grassland management such as burning or mowing in wet prairies. Comparing bird species abundances or occupancy (Appendix C) before and after the management action or on control versus treatment plots for species indicative of that habitat type should elucidate the effects of that management action on the bird community. Also, the abundance estimates we obtained can now be compared among other similar habitats within and across ecoregions.

If we wish to monitor the effects of future management actions on early successional forest, we need to identify the most appropriate target species and run analyses of detection probabilities (with confidence intervals) for that species using our existing data. Power estimates for specific sample sizes can also be assessed from the inventory data. To monitor for change in abundance or occupancy over time, we need to improve the sampling protocol to include more robust estimation of detection probabilities.

As an example, if the 95% CI for occupancy by Indigo Buntings in early successional forest is 0.75–0.92 (Appendix C) and we expect that after the management action, the 95% CI for occupancy by Indigo Buntings will decrease to 0.65–0.81, we can use these values as benchmarks in our monitoring plan. To achieve power of 80% to detect a change of 3% per annum in mean occupancy, we estimate that we need a ≥30 points (more if the underdispersion of count variances in the inventory data are anomalies). (This is only a hypothetical example; more analysis of our inventory data will be needed to define these metric values. Our existing data analyses did not focus on occupancy.)

c. Testing Assumptions or Parameters Underlying Biological Models

Partners in Flight and the Joint Ventures are in the process of developing models that will project the number of breeding pairs per ha of high priority species in specific habitats. They are also developing recommendations for management actions at several spatial scales that will increase populations of these species. Data on bird densities from a wide variety of habitats and species is needed to support these models. These data from the lower Missouri River will be important pieces of a larger puzzle needed to elucidate broad habitat associations for high priority species (Appendices B, C, and D). The indicator species analyses will also be useful to compare with other similar analyses elsewhere and these investigations will ultimately yield a set of bird species indicative of different habitats that are potential targets for future monitoring efforts. This will be especially important when the high priority species occur in such low densities that monitoring becomes impractical except for Threatened or Endangered species. Detection probabilities have a strong influence on density estimates; this is an important reason

to estimate detection probabilities, particularly for species considered indicative of specific habitat types or high priority for other reasons such as risk of population declines.

d. Detecting Trends

Suggested objectives:

1. Track the status of the breeding bird community as forest succession progresses from early successional to mature forest, with estimates of differences in occupancy and abundance for selected species.
2. Use the pilot data to define target bird species, benchmarks for occupancy and abundance, and a sampling design.
3. Define habitat variables that should be collected in association with the bird survey data.

We identified the Indigo Bunting, Bell's Vireo, Yellow-billed Cuckoo, Prothonotary Warbler, Northern Parula, and Acadian Flycatcher as potential target species to monitor, based on abundance in the target habitats, known habitat associations elsewhere (Twedt et al. 1999; Knutson and McColl 2003), and the indicator species analysis (Appendix G). We note, after extracting the data from Appendices C and D (Table 16) that the Bell's Vireo may not be a good candidate for monitoring, despite our finding that it was indicative of early successional forest, because it is relatively rare in both habitats. It will be difficult to detect change in abundance or occupancy over time for this species. The other species will likely be useful focal species for our monitoring plan. We can use the benchmark estimates of relative abundance or occupancy in Table 16 as targets. For example, we might plan to monitor the Indigo Bunting, Yellow-billed Cuckoo, Prothonotary Warbler, Northern Parula, and Acadian Flycatcher one breeding season every 5 years over a 25-year time frame. At each monitoring period we would expect that occupancy would decline for the Indigo Bunting and Yellow-billed Cuckoo, and increase for the Prothonotary Warbler, Northern Parula, and Acadian Flycatcher until the occupancy of each species is similar to what we observed in the mature forest habitats in our inventory data set. After that point, we assume that from a bird's perspective these forests are functionally mature forests. Our objective of tracking the status of the bird community as forest succession progresses is achieved. Therefore, monitoring ends or a new objective is established along with a new monitoring plan.

Table 16. Potential target species for a monitoring plan to assess changes in bird community as forest matures from early successional to mature forest.

	Early successional forest		Mature forest	
Species	Relative abundance	Occupancy	Relative abundance	Occupancy
Indigo Bunting	3.13	0.84	1.18	0.50
Bell's Vireo	0.15	0.09	0	0
Yellow-billed Cuckoo	0.82	0.47	0.47	0.31
Prothonotary Warbler	0.03	0.02	0.43	0.28
Northern Parula	0.06	0.05	0.30	0.24
Acadian Flycatcher	0.03	0.02	0.22	0.16

Among these species, power analyses for the Indigo Bunting and the Yellow-billed Cuckoo are available and indicate that a minimum of 50 samples are needed to detect a decline in abundance of 5% or more with a minimum power of 80%. It would be useful to compare these results with a power analysis of occupancy metrics. We did not conduct power analyses for relatively rare species (relative abundance <0.3 in all habitats). We anticipate that 100 or more sample points may be needed to detect a similar change in abundance per annum for rare species. This suggests that trend estimation for all but the most common bird species is not a reasonable goal unless multiple managed lands (refuges, parks, state wildlife management areas) work together to boost sample sizes within an ecoregion. The best chance for success is to work within regional partnerships to prioritize and identify the focal species and design an appropriate sampling design and protocol.

We could also plan to monitor habitat variables, such as total canopy cover, upper and mid-canopy cover, canopy height, shrub cover, and mean and maximum diameter at breast height (Tables 5 & 6, Appendix E), along with the bird monitoring, as described under 'inventory' above (Table 17). We observe that mid canopy cover and mean DBH may not differ enough between the two habitats to be useful metrics for our purposes (Table 17). However, they were fairly strong variables in our principal component analysis (Table 11) so we will track them because they do not take much extra field time to collect. These habitat metrics provide benchmarks for tracking habitat change in the same way that relative abundance or occupancy provide benchmarks for tracking bird species change.

We could also use existing data to develop models to test whether relative abundance or occupancy is a more robust response metric for detecting change over time. If, for example, we conclude that occupancy is the most robust metric, this information will inform subsequent sampling protocols. If occupancy is the desired metric, we only require presence/absence information on the target species at each point, increasing the efficiency of the sampling process. Also, occupancy as a target metric might lead us to use multiple visits during a season rather than distances to estimate detection probabilities.

Table 17. Potential target habitat metrics for a monitoring plan to assess changes in bird habitat as forest matures from early successional to mature forest, as determined by unweighted averages across ten study areas along the lower Missouri River.

Habitat metric	Early successional forest Mean (CI)	Mature forest Mean (CI)
Total canopy cover (%)	78 (76–80)	86 (83–89)
Upper canopy cover (%)	64 (62–67)	67 (63–71)
Mid canopy cover (%)	42 (39–45)	49 (44–53)
Canopy height (m)	74 (70–77)	95 (89–100)
Shrub cover (%)	17 (15–19)	16 (13–20)
Mean DBH (cm)	12 (10–13)	18 (17–20)
Max DBH (cm)	46 (41–50)	73 (68–73)

Refining Objectives Using Pilot Data

Managers can use monitoring data to refine future monitoring objectives in an iterative process of preliminary data analysis, refinement of objectives, followed by more focused data analyses. Much time can be expended on detailed analyses that fail to answer specific

operational objectives. Once the specific future habitat and population management objectives are determined, more focused analyses of our inventory data can be undertaken to derive 95% CI's for the target bird species and selected habitat variables, model detection probabilities, and conduct power analyses. These focused data analyses will ensure that our monitoring criteria are measurable, precise, consistent, and sensitive. Those metrics that fail to meet the criteria can be rejected based on the pilot data. It is even possible to model the relationships between sample size, power to detect change, and budget limitations using pilot data. Field et al. (2005) present an adaptive management process that uses pilot data to make decisions about the optimal sampling.

We could also use our existing data to develop models to test whether relative abundance or occupancy is a more robust response metric for detecting change over time. If, for example, we conclude that occupancy is a suitable metric, this information will inform our sampling protocols. If occupancy is our desired metric, we only require presence/absence information on the target species at each point, increasing the efficiency of the sampling process.

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References Cited

Adamcik, R. S., E. S. Ballantoni, D. C. DeLong, Jr., J. H. Schomaker, D. B. Hamilton, M. K. Laubhan, and R. L. Schroeder. 2004. Writing refuge management goals and objectives: a handbook. U.S. Fish and Wildlife Service, Arlington, VA. 30 pp.

Anderson, B. W., and R. D. Ohmart. 1977. Climatological and physical characteristics affecting avian population estimates in southwestern riparian communities using transect counts. Pages 193–200 in Importance, preservation, and management of riparian habitat: a symposium (R. R. Johnson and D. A. Jones, eds). U.S. Department of Agriculture, Forest Service General Technical Report RM-43.

Auble, G. T. and M. L. Scott. 1998. Fluvial disturbance patches and cottonwood recruitment along the upper Missouri River, Montana. Wetlands 18:546–556.

Ballard, G., G. R. Geupel, N. Nur, and T. Gardali. 2003. Long-term declines and decadal patterns in population trends of songbirds in western North America, 1979-1999. Condor 105:737-755.

Bayley, P. B. 1995. Understanding large river-floodplain ecosystems. BioScience 45:153–158.

Bendix, J. 1994. Among-site variation in riparian vegetation of the southern California Transverse Ranges. American Midland Naturalist 132:136–151.

Best, L. B., K. E. Freemark, J. J. Dinsmore, and M. Camp. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. American Midland Naturalist 134:1–29.

Best, L. B., K. E. Freemark, B. S. Steiner, and T. M. Bergin. 1996. Life history and status classifications of birds breeding in Iowa. Journal of the Iowa Academy of Science 103:34–45.

Beyer, W. H. (ed). 1987. CRC Standard Mathematical Tables, 28 ed. CRC Press, Boca Raton, Florida, USA.

Blem, C. R., and L. B. Blem. 1991. Nest-box selection by Prothonotary Warblers. Journal of Field Ornithology 62:299–307.

Bock, C. E. 1984. Geographical correlates of abundance vs. rarity in some North American winter landbirds. Auk 101:266–273.

Brooks, S., and A. Gelman. 1998. General methods for monitoring convergence of iterative simulations. Journal of Computational and Graphical Statistics 7:434–455.

Brown, B. T. 1993. Bell's Vireo. *In* The Birds of North America, No. 35 (A. Poole, P. Stettenheim, and F. Gill, editors). The Academy of Natural Sciences, Philadelphia, Pennsylvania, USA.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas. 2001. Introduction to distance sampling. Oxford University Press, Oxford, UK.

Buckland, S. T., D. R. Anderson, K. P. Burnham, J. L. Laake, D. L. Borchers, and L. Thomas, editors. 2004. Advanced distance sampling. Oxford University Press, Oxford, UK.

Burnham, K. P., and D. R. Anderson. 2002. Model selection and multimodel inference: a practical information-theoretic approach. 2nd Edition. Springer-Verlag, New York, New York, USA.

Calder, W. A., III. 1990. The scaling of sound output and territory size: are they matched? Ecology 71:1810–1816.

Carr, M. R. 1996. PRIMER: Plymouth routines in multivariate ecological research. Plymouth Marine Laboratory, Plymouth, United Kingdom.

Chapman, D. C., E. A. Ehrhardt, J. F. Fairchild, R. B. Jacobson, B. C. Poulton, L. C. Sappington, B. P. Kelly, and W. R. Mabee. 2003. Ecological dynamics of wetlands at Lisbon Bottom, Big Muddy National Fish and Wildlife Refuge, Missouri. Final Report to U.S. Fish and Wildlife Service, Big Muddy National Fish and Wildlife Refuge. U.S. Geological Survey, Columbia Environmental Research Center, Columbia, Missouri, USA.

Clarke, K. R. 1993. Non-parametric multivariate analyses of changes in community structure. Australian Journal of Ecology 18:117–143.

Clarke, K. R., and M. Ainsworth. 1993. A method of linking multivariate community structure to environmental variables. Marine Ecology Progress Series 92:205–219.

Clarke, K. R. amd R. N. Gorley. 2001. PRIMER v5: users manual/tutorial. PRIMER-E Ltd, Plymouth, United Kingdom.

Clarke, K. R., and R. M. Warwick. 2001. Change in marine communities: an approach to statistical analysis and interpretation, 2nd edition. PRIMER-E Ltd, Plymouth, United Kingdom.

Cody, M. L. 1966. The consistency of intra- and inter-continental grassland bird species counts. American Naturalist 100:371–376.

Conner, R. N., S. D. Jones, and G. D. Jones. 1994. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bulletin 106:242-257

Cooper, D. J., D. C. Andersen, and R. A. Chimner. 2003. Multiple pathways for woody plant establishment on floodplains at local to regional scales. Journal of Ecology 91:182–196.

Cushman S.A., and K. McGarigal. 2003. Landscape-level patterns of avian diversity in the Oregon Coast Range. Ecological Monographs 73:259–281.

Diefenbach, D. R., D. W. Brauning, and J. A. Mattice. 2003. Variability in grassland bird counts related to observer differences and species detection rates. Auk 120:1168–1179.

Dobkin, D. S., and A. C. Rich. 1998. Comparison of line-transect, spot-map, and point-count surveys for birds in Riparian habitats of the Great Basin. Journal of Field Ornithology 69:430-443.

Dufrene, M. and P. Legendre. 1997. Species assemblages and indicator species: the need for a flexible asymmetrical approach. Ecological Monograph 67:345–366.

Dynesius, M., and C. Nilsson. 1994. Fragmentation and flow regulation of river systems in the northern 3rd of the world. Science 266:753–762.

Elzinga, C. L., D. W. Salzer, J. W. Willoughby, and J. P. Gibbs. 2001. Monitoring plant and animal populations. Blackwell Science, Malden, MA.

Faanes, C. A., and D. Bystrak. 1981. The role of observer bias in the North American breeding bird survey. Studies in Avian Biology 6:353–359.

Field, S. A., A. J. Tyre, and H. P. Possingham. 2005. Optimizing allocation of monitoring effort under economic and observational constraints. Journal of Wildlife Management 69:473-482.

Friedman, J. M., and G. T. Auble. 1999. Mortality of riparian box elder from sediment mobilization and extended inundation. Regulated Rivers: Research and Management 15:463–476.

Gauthreaux, S. A., and C. G. Belser. 2003. Radar ornithology and biological conservation. Auk 120:266-277.

Gelman, A., J. B. Carlin, H. S. Stern, and D. B. Rubin. 1995. Bayesian data analysis. Chapman and Hall, New York, USA.

Gergel, S. E., M. D. Dixon, and M. G. Turner. 2002. Consequences of human-altered floods: levees, floods, and floodplain forests along the Wisconsin River. Ecological Applications 12:1755–1770.

Gerrodette, T. 1987. A power analysis for detecting trends. Ecology 68:1364–1372.

Gutzwiller, K. J. 1993. Refining the use of point counts for winter studies of individual species. Wilson Bulletin 105:612–627.

Hansen, P. L., R. D. Pfister, K. Boggs, B. J. Cook, J. Joy, and D. K. Hinckley. 1995. Classification and management of Montana's riparian and wetland sites. Miscellaneous Publication 54, Montana Forest and Conservation Experiment Station, University of Montana, Missoula, Montana, USA.

Hayes, J. P., and R. J. Steidl. 1997. Statistical power analysis and amphibian population trends. Conservation Biology 11:273–275.

Henszey, R. J., K. Pfeiffer, and J. R. Keough. 2004. Linking surface- and ground-water levels to riparian grassland species along the Platte River in central Nebraska, USA. Wetlands 24:665–687.

Herkert, J. R., D. W. Sample, and R. E. Warner. 1996. Management of midwestern grassland landscapes for the conservation of migratory birds. Pp. 89–116, in F. R. Thompson III (editor). Management of midwestern landscapes for the conservation of neotropical migratory birds. USDA Forest Service Gen. Tech. Rep. NC-187. USDA Forest Service North Central Forest Experiment Station, St. Paul, Minnesota, USA.

Holthausen, R., R. L. Czaplewski, D. DeLorenzo, G. Hayward, W. B. Kessler, P. Manley, K. S. McKelvey, D. S. Powell, L. F. Ruggiero, M. K. Schwartz, B. Van Horne, and C. D. Vojta. 2005. Strategies for monitoring terrestrial animals and habitats, Gen. Tech. Rep. RMRS-GTR-161. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO. 34 pp. (http://www.treesearch.fs.fed.us/pubs/20915)

Ingold, D. 1994. Nest site characteristics of Red-bellied and Red-headed woodpeckers and Northern Flickers in eastcentral Ohio. Ohio Journal of Science 94:2–7.

Johnson, W. C., R. L. Burgess, and W. R. Keammerer. 1976. Forest overstory vegetation and environment on the Missouri River floodplain in North Dakota. Ecological Monographs 46:59–84.

Johnson, W. C., P. W. Reily, L. S. Andrews, J. F . McLellan, and J. A. Brophy. 1982. Altered hydrology of the Missouri River and its effects on floodplain forest ecosystems. Bulletin 139, Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, Blacksburg, Virginia, USA.

Jones, G. A., K. E. Sieving, and S. K. Jacobson. 2005. Avian diversity and functional insectivory on north-central Florida farmlands. Conservation Biology 19:1234–1245.

Kepler, C. B., and J. M. Scott. 1981. Reducing bird count variability by training observers. Studies in Avian Biology 6:366–371.

Kery, M., J. A. Royle, and H. Schmid. 2005. Modeling avian abundance from replicated counts using binomial mixture models. Ecological Applications 15:1450-1461.

Knutson, M. G., J. P. Hoover, and E. E. Klaas. 1996. The importance of floodplain forests in the conservation and management of neotropical migratory birds in the Midwest. Pages 168-188 in Management of Midwestern landscapes for the conservation of neotropical migratory birds. General Technical Report NC-187 (F. R. Thompson, Ed.). U.S. Forest Service, North Central Forest Experiment Station, St. Paul, Minnesota, USA.

Knutson, M. G., and E. E. Klaas. 1998. Floodplain forest loss and changes in forest community composition and structure in the Upper Mississippi River: a wildlife habitat at risk. Natural Areas Journal 18:138–150.

Knutson, M. G., and L. E. McColl. 2003. Breeding birds of young floodplain forests growing on abandoned agricultural land. Quick Response Project QR-F3-00-03 Final Report. U.S. Geological Survey Upper Midwest Environmental Sciences Center, La Crosse, Wisconsin. 64 pp.

Knutson, M. G., L. E. McColl, and S. A. Timm. 2005. Breeding bird assemblages associated with stages of forest succession in large river floodplains. Natural Areas Journal 25:55–70.

Krebs, C. J. 1989. Ecological methodology. Harper and Row, New York, New York, USA.

Larsen, D. P., P. R. Kaufmann, T. M. Kincaid and N. S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Canadian Journal of Fisheries and Aquatic Sciences 61:283–291.

Legendre, P. and L. Legendre. 1998. Numerical ecology. 2nd English edition. Elsevier Science BV, Amsterdam, Netherlands.

Linz, G. M., R. A. Dolbeer, J. J. Hanzel, and L. E. Huffman. 1993. Controlling blackbird damage to sunflower and grain crops in the Northern Great Plains. U.S. Department of Agriculture, Agriculture Information Bulletin 679, Washington, D. C., USA.

Loehle C., T. B. Wigley, S. Rutzmoser, J. A. Gerwin, P. D. Keyser, R. A. Lancia, C. J. Reynolds, R. E. Thill, R. Weih, D. White, and P. B. Wood. 2005. Managed forest landscape structure and avian species richness in the southeastern US. Forest Ecology and Management 214:279–293.

MacArthur, R. H., and J. W. MacArthur. 1961. On bird species diversity. Ecology 42:594–598.

MacArthur, R. H., J. W. MacArthur, and J. Preer. 1962. On bird species diversity: II. Prediction of bird census from habitat measurements. American Naturalist 96: 167–174.

MacArthur, R. H., H. Recher, and M. Cods. 1966. On the relation between habitat selection and species diversity. American Naturalist 100:319–322.

MacKenzie, D. I., and J. D. Nichols. 2004. Occupancy as a surrogate for abundance estimation. Animal Biodiversity and Conservation 27: 461–467.

MacKenzie, D. I., J. D. Nichols, J. A. Royle, K. H. Pollock, L. L. Bailey, and J. E. Hines. 2005. Occupancy estimation and modeling: Inferring patterns and dynamics of species occurrence. Academic Press, San Diego, California, USA.

MacKenzie, D. I., J. A. Royle, J. A. Brown, and J. D. Nichols. 2004. Occupancy estimation and modeling for rare and elusive populations. Pages 149–172 in W. L. Thompson (ed), Sampling Rare or Elusive Species. Island Press, Washington, D.C., USA.

Magurran, A. E. 2003. Ecological diversity and its measurement. Princeton University Press, Princeton, New Jersey, USA.

Marra, P. P., C. M. Francis, R. S. Mulvihill, and F. R. Moore. 2005. The influence of climate on the timing and rate of spring bird migration. Oecologia 142:307-315.

McCoy, T. D., M. R. Ryan, E. W. Kurzejeski, and L. W. Burger Jr. 1999. Conservation reserve program: Source or sink habitat for grassland birds in Missouri? Journal of Wildlife Management 63:530–538.

McCune, B., and M. J. Mefford. 1999. PC-ORD. Multivariate analysis of ecological data. Version 4.0 for Windows. MjM Software Design, Gleneden Beach, Oregon, USA.

McCune, B., J. B. Grace, and D. L. McCune. 2002. Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon, USA.

McKenzie, M. A. 1936. Flood injury to trees. Science 83:412–413.

Miller, J. R., T. T. Schulz, N. T. Hobbs, K. R. Wilson, D. L. Schrupp, and W. L. Baker. 1995. Changes in the landscape structure of a southeastern Wyoming riparian zone following shifts in stream dynamics. Biological Conservation 72:371–379.

Nelson, P. W. 1987. The terrestrial natural communities of Missouri. Missouri Department of Natural Resources and the Missouri Department of Conservation, Jefferson City, Missouri, USA.

Neter, J., W. Wasserman and M. H. Kutner. 1985. Applied Linear Statistical Models. Second edition. Richard Irwin, Homewood, IL, USA.

Nichols, J. D., J. E. Hines, J. R. Sauer, F. W. Fallon, J. E. Fallon, and P. J. Heglund. 2000. A double-observer approach for estimating detection probability and abundance from point counts. Auk 117:393-408.

Nilsson, C., and M. Dynesius. 1994. Ecological effects of river regulation on mammals and birds - a review. Regulated Rivers-Research and Management 9:45–53.

Nilsson, C., R. Jansson, and U. Zinko. 1997. Long-term response of river-margin vegetation to water-level regulation. Science 276:798–800.

Nilsson, C., and M. Svedmark. 2002. Basic principles and ecological consequences of changing water regimes: riparian plant communities. Environmental Management 30:468–480.

Olsen, J. R., and E. Z. Stakhiv. 2000. Flood hydroclimatology in the upper Mississippi and Missouri River basins, final draft. Institute for Water Resources, U.S. Army Corps of Engineers, Alexandria, Virginia, USA.

Petit, L. J. 1999. Prothonotary Warbler (*Protonotaria citrea*). *In* The Birds of North America, No. 408 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, Pennsylivania, USA.

Plotkin, J. B. and H. C. Muller-Landau. 2002. Sampling the species composition of a landscape. Ecology 83:3344–3356.

Preston, F. W. 1948. The commonness and rarity of species. Ecology 29:254–283.

Preston, F. W. 1962*a*. The canonical distribution of commonness and rarity. Ecology 43:185–215.

Preston, F. W. 1962*b*. The canonical distribution of commonness and rarity. Ecology 43:410–432.

Purcell, K. L., S. R. Mori, and M. K. Chase. 2005. Design considerations for examining trends in avian abundance using point counts: examples from the oak woodlands. Condor 107:305–320.

Ralph, C. J., G. R. Geupel, P. Pyle, T. E. Martin, and D. F. DeSante. 1993. Handbook of field methods for monitoring landbirds. U.S. Department of Agriculture General Technical Report PSW-GTR-144.

Ramsey, F. L., and J. M. Scott. 1981. Tests of hearing ability. Studies in Avian Biology 6:342–345.

Reily, P.W., and W. C. Johnson. 1982. The effects of altered hydrologic regime on tree growth along the Missouri River in North Dakota. Canadian Journal of Botany 60:2410–2423.

Renken, R. B., and E. P. Wiggers 1993. Habitat characteristics related to Pileated Woodpecker densities in Missouri. Wilson Bulletin 105:77–83.

Robbins, M. B., and D. A. Easterla. 1992. Birds of Missouri: their distribution and abundance. University of Missouri Press, Columbia, Missouri, USA.

Rosenstock, S. S., D. R. Anderson, K. M. Giesen, T. Leukering, and M. F. Carter. 2002. Landbird counting techniques: current practices and an alternative. Auk 119:46–53.

Rosenzweig, M. L. 1995. Species diversity in space and time. Cambridge University Press, Cambridge, United Kingdom.

Royle, J. A., and J. D. Nichols. 2003. Estimating abundance from repeated presence-absence data or point counts. Ecology 84:777–790.

Royle, J. A., J. D. Nichols, and M. Kery. 2005. Modeling occurrence and abundance of species when detection is imperfect. Oikos 110:353–359.

SAS Institute Inc. 2005. The GLIMMIX Procedure. URL: <http://www.sas.com/statistics/doc.html> (accessed 3 June 2005).

Sauer, J. R., J. E. Hines, and J. Fallon. 2005. The North American Breeding Bird Survey, Results and Analysis 1966 - 2004. Version 2005.2. USGS Patuxent Wildlife Research Center, Laurel, Maryland, USA. URL: <http://www.mbr-pwrc.usgs.gov/cgi-bin/atlasa99.pl?06040&1&04> (accessed 3 June 2005).

Scott, M. L., G. T. Auble, and J. M. Friedman. 1997. Flood dependency of cottonwood establishment along the Missouri River, Montana, USA. Ecological Applications 7:677–690.

Short, J. J. 1979. Patterns of alpha-diversity and abundance in breeding bird communities across North America. Condor 81:21–27.

Sigafoos, R. S. 1964. Botanical evidence of floods and floodplain deposition. U.S. Geological Survey Professional Paper 485-A, 35 p.

Simons, T. R., G. L. Farnsworth, and S. A. Shriner. 2000. Evaluating Great Smoky Mountains National Park as a population source for Wood Thrush. Conservation Biology 14:1133–1144.

Skinner, R. M., T. S. Baskett, and M. D. Blenden. 1984. Bird habitat on Missouri prairies. Terrestrial Series #14. Missouri Department of Conservation, Jefferson City, Missouri, USA.

Skoglund, S. J. 1990. Seed dispersing agents in two regularly flooded rivers. Canadian Journal of Botany 68:754–760.

Smith, W. P., and D. J. Twedt. 1999. Temporal differences in point counts of bottomland forest landbirds. Wilson Bulletin 111:139–143.

Spiegelhalter, D. J., N. G. Best, B. P. Carlin, and A. Van Der Linde. 2002. Bayesian measures of model complexity and fit. Journal of the Royal Statistical Society B 64:583–639.

Spiegelhalter, D. J., A. Thomas, and N. G. Best. 2003. WinBUGS Version 1.4 user manual. MRC Biostatistics Unit, Cambridge, United Kingdom. URL: <http://www.mrc-bsu.cam.ac.uk/bugs/winbugs/manual14.pdf> (accessed Sept. 13, 2004).

Stromberg, J. C., B. D. Richter, D. T. Patten, and L. G. Wolden. 1993. Response of a Sonoran riparian forest to a 10-year return flood. Great Basin Naturalist 53:118–130.

Tear, T. H., P. Kareiva, P. L. Angermeier, P. Comer, B. Czech, R. Kautz, L. Landon, D. Mehlman, K. Murphy, M. Ruckelshaus, J. M. Scott, and G. Wilhere. 2005. How much is enough? The recurrent problem of setting measurable objectives in conservation. Bioscience 55:835-849.

Thein, S. J. 1979. A flow diagram for teaching texture-by-feel analysis. Journal of Agronomic Education 8:54–55.

Thomas, L., J. L. Laake, S. Strindberg, F. F. C. Marques, S. T. Buckland, D. L. Borchers, D. R. Anderson, K. P. Burnham, S. L. Hedley, J. H. Pollard, J. R. B. Bishop, and T. A. Marques. 2005. Distance 5.0. Beta Release 4. Research Unit for Wildlife Population Assessment, University of St. Andrews, UK. URL: <http://www.ruwpa.st-and.ac.uk/distance> (accessed Sept. 13, 2004).

Thompson III, F. R. 2002. Towards reliable bird surveys: accounting for individuals present but not detected. Auk 119:18–25.

Thompson III, F. R., D. E. Burhans, and B. Root. 2002. Effects of point count protocol on bird abundance and variability estimates and power to detect population trends. Journal of Field Ornithology 73:141–150.

Thompson III, F. R., S. J. Lewis, J. Green, and D. Ewert. 1993, Status of Neotropical migrant landbirds in the Midwest: Identifying species of management concern: Pages 145–158 in Status and Management of Neotropical Migratory Birds (D. M. Finch and P. W. Stangel, Eds.). U.S. Department of Agriculture, Forest Service General Technical Report RM-229.

Tramer, E. J. 1974. On latitudinal gradients in avian diversity. Condor 76:123–130.

Twedt, D. J., and J. Portwood. 1997. Bottomland hardwood reforestation for neotropical migratory birds: are we missing the forest for the trees? Wildlife Society Bulletin 25:647–652.

Twedt, D. J., R. R. Wilson, J. L. Henne-Kerr, and R. B. Hamilton. 1999. Impact of forest type and management strategy on avian densities in the Mississippi Alluvial Valley, USA. Forest Ecology and Management 123:261–274.

U.S. Army Corps of Engineers. Missouri River bank stabilization and navigation project, fish and wildlife mitigation project, annual implementation report. U.S. Army Corps of Engineers, Omaha District, Omaha, Nebraska, and Kansas City District, Kansas City, Missouri. *URL:<http://www.nwd.usace.army.mil>* (accessed Sept. 13, 2005).

USDA, NRCS. 2004. The PLANTS Database, Version 3.5. National Plant Data Center, Baton Rouge, Louisiana, USA. URL: <http://plants.usda.gov> (accessed Sept. 13, 2005).

U.S. Fish and Wildlife Service. 1999. Big Muddy National Fish and Wildlife Refuge Final Environmental Impacts Statement, Puxico, Missouri, USA.

Urquhart, N. S., S. G. Paulsen and D. P. Larsen. 1998. Monitoring for policy-relevant regional trends over time. Ecological Applications 8:246-257.

Ward, J. V., and J. A. Stanford. 1995. Ecological connectivity in alluvial river ecosystems and its disruption by flow regulation. Regulated Rivers: Research and Management 11:105–119.

Widmann, I. 1907. A preliminary catalog of the birds of Missouri. Missouri Academy of Science, St. Louis, Missouri, USA.

Williams, C. A., and D. J. Cooper. 2005. Mechanisms of riparian cottonwood decline along regulated rivers. Ecosystems 8:382–395.

Williamson, M. & K. J. Gaston. 2005. The lognormal distribution is not an appropriate null hypothesis for the speciesabundance distribution. Journal of Animal Ecology 74:409-422.

Willimont, L. A., S. E. Senner, and L. J. Goodrich. 1988. Fall migration of ruby-throated hummingbirds in the northeastern United States. Wilson Bulletin 100:482-488.

Willson, M. F. 1974. Avian community organization and habitat structure. Ecology 55:1017–1029.

Wilson, R. R., D. J. Twedt, and A. B. Elliott. 2000. Comparison of line transects and point counts for monitoring spring migration in forested wetlands. Journal of Field Ornithology 71:345-355.

Winter, M. and J. Faaborg. 1999. Patterns of area sensitivity in grassland-nesting birds. Conservation Biology 13:1424–1436.

Wolfinger, R. and M. O'Connell. 1993. Generalized Linear Mixed Models: A pseudo-likelihood approach. Journal of Statistical Computation and Simulation 4:233–243.

Yin, Y., J. C. Nelson, and K. S. Lubinski. 1997. Bottomland hardwood forests along the Upper Mississippi River. Natural Areas Journal 17:164–173.

Young, N. B., M. A. Gallagher, and S. G. Papon. 2004. Distribution and abundance of migrant and breeding songbirds in floodplain habitats of the lower Missouri River watershed – 2003 Annual Report. U.S. Fish and Wildlife Service Big Muddy National Fish and Wildlife Refuge, Columbia, Missouri, USA.

Zimmerman, J. L., and J. L. Tatschel. 1975. Floodplain birds of Weston Bend, Missouri River. Wilson Bulletin 87:196–206.

Appendices

Appendix A. Study area maps depicting photo-interpreted and remotely sensed land cover, water bodies, roads, and administrative boundaries for ten locations along the lower Missouri River.

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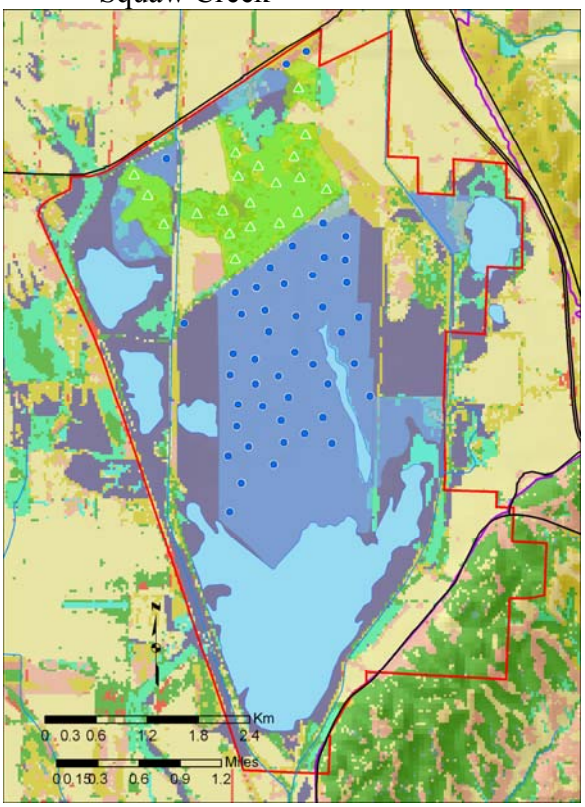
Squaw Creek



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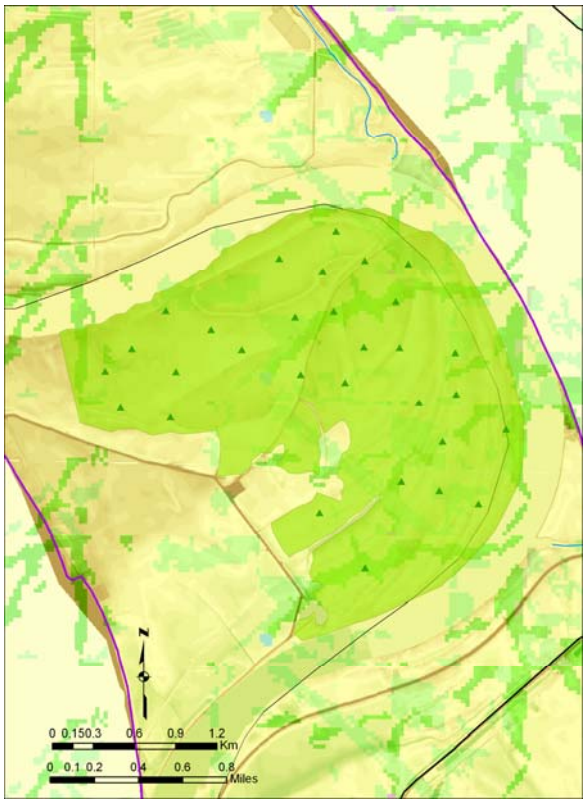

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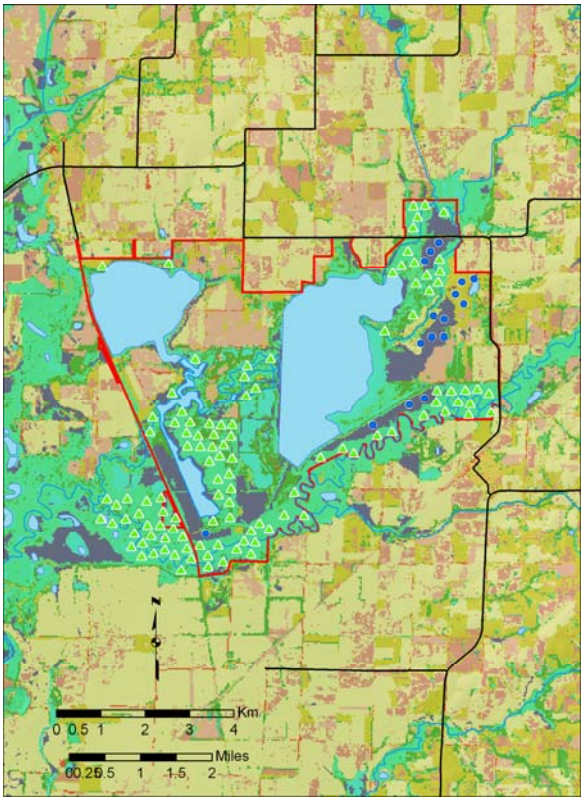
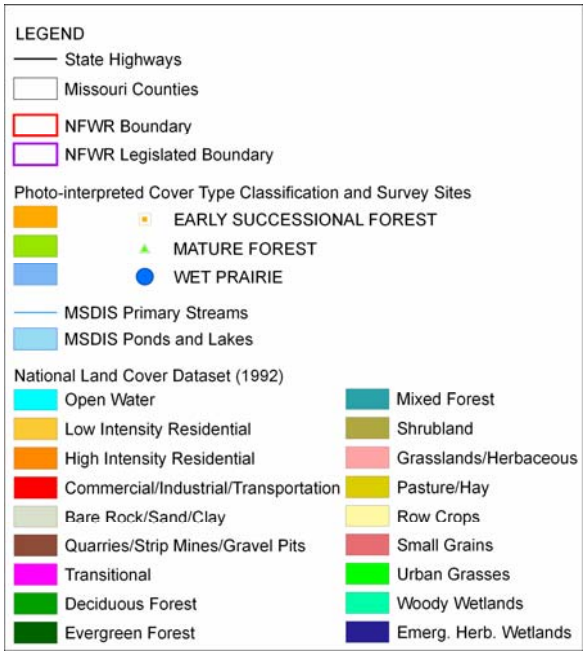
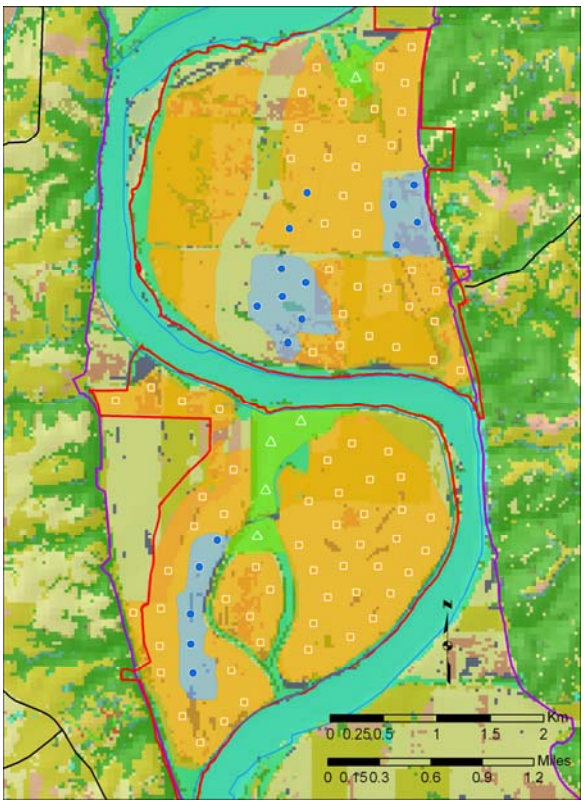
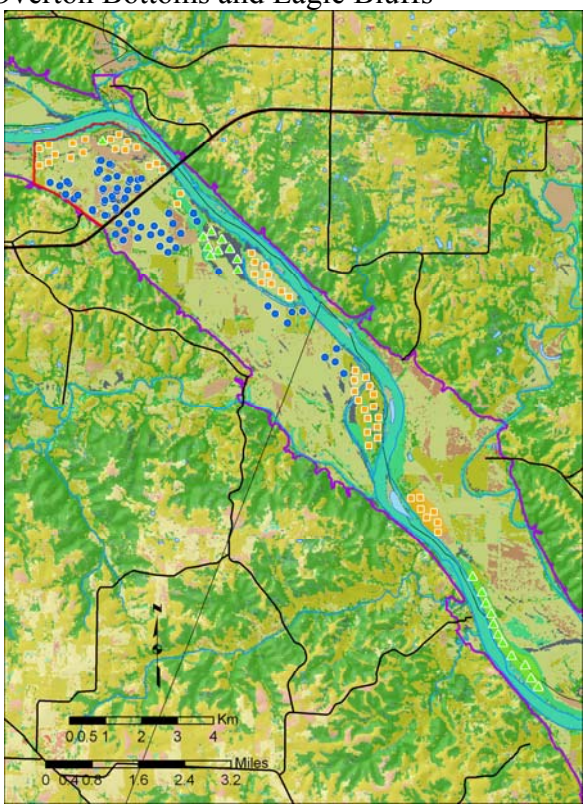




Lisbon Bottoms and Jameson Island

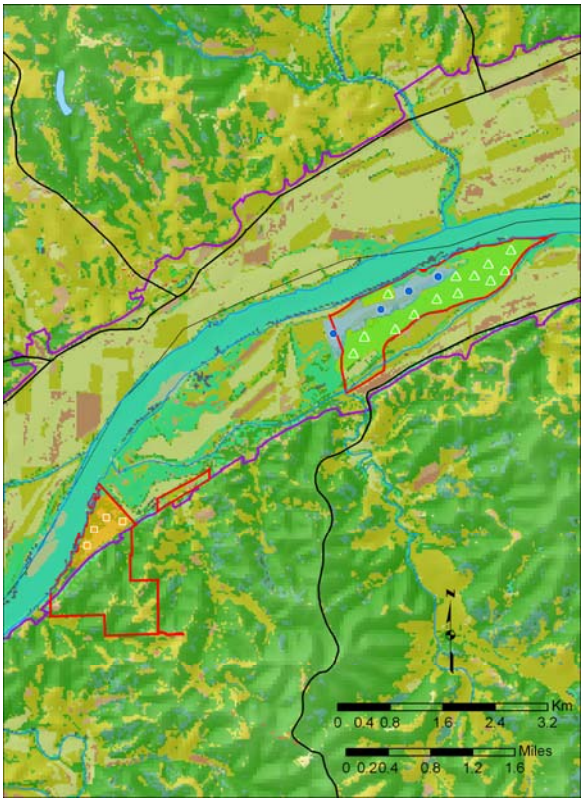


Overton Bottoms and Eagle Bluffs



St. Aubert's Island

Howell Island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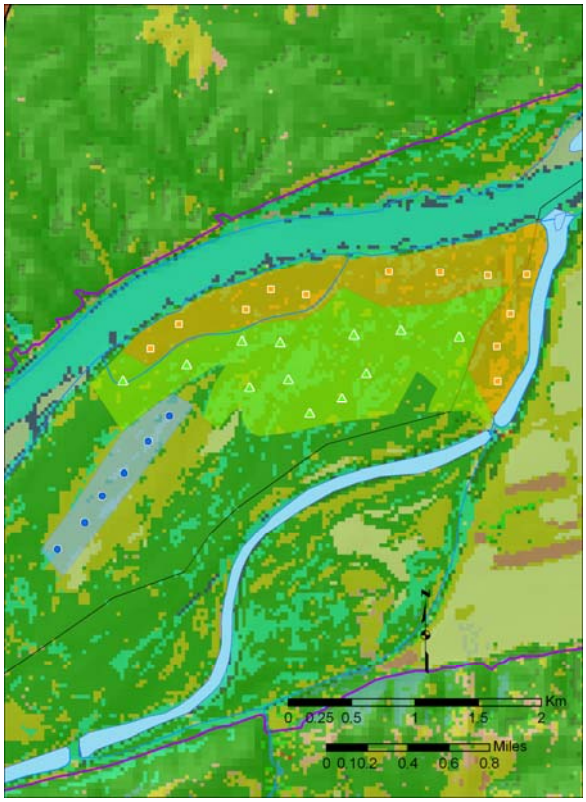
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Appendix B. Summarization of counts, ordered from most abundant to least abundant, for 869 surveys conducted in wet floodplain prairie sites along the lower Missouri River between 2002–2004. The maximum observed was the maximum count in any single visit.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Red-winged Blackbird	RWBL	814	0.937	7,494	8.624	15.007	238
Common Yellowthroat	COYE	647	0.745	1,766	2.032	1.780	9
Dickcissel*	DICK	492	0.566	1,749	2.013	2.400	16
Cliff Swallow	CLSW	147	0.169	861	0.991	3.154	30
Indigo Bunting	INBU	204	0.235	562	0.647	1.453	9
Brown-headed Cowbird	BHCO	142	0.163	422	0.486	2.495	60
American Goldfinch	AMGO	154	0.177	410	0.472	1.432	19
Suspect counts (probably RPHE)	RPHA^	222	0.255	335	0.386	0.750	4
Sedge Wren	SEWR	122	0.140	330	0.380	1.183	11
Song Sparrow	SOSP	170	0.196	286	0.329	0.786	6
Tree Swallow	TRES	89	0.102	286	0.329	1.341	14
Mallard#	MALL	73	0.084	193	0.222	1.063	20
Ring-necked Pheasant	RPHE	109	0.125	189	0.217	0.665	6
Northern Bobwhite	NOBO	106	0.122	184	0.212	0.657	5
Bank Swallow	BNKS	33	0.038	180	0.207	1.265	15
Franklin's Gull	FRGU	1	0.001	180	0.207	6.106	180
Common Grackle	COGR	24	0.028	167	0.192	2.000	43
American Crow	AMCR	74	0.085	130	0.150	0.608	7
Orchard Oriole*	OROR	75	0.086	129	0.148	0.572	5
Barn Swallow	BARS	69	0.079	128	0.147	0.638	7
Savannah Sparrow	SAVS	49	0.056	120	0.138	0.705	7
Canada Goose	CAGO	25	0.029	116	0.133	1.263	21
Blue-winged Teal#	BWTE	38	0.044	109	0.125	1.149	30
Blue Jay	BLJA	43	0.049	108	0.124	1.297	27

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.

^ This species may be Red-necked Phalarope, Wilson's Phalarope, or, more likely, Ring-necked Pheasant, or some combination.

Appendix B. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
European Starling	EUST	7	0.008	102	0.117	2.325	65
Mourning Dove	MODO	57	0.066	89	0.102	0.432	4
Northern Cardinal	NOCA	70	0.081	88	0.101	0.377	3
Eastern Kingbird	EAKI	45	0.052	76	0.087	0.420	4
Yellow-breasted Chat*#	YBCH	51	0.059	69	0.079	0.365	4
Eastern Meadowlark*#	EAME	45	0.052	64	0.074	0.371	5
Field Sparrow*	FISP	37	0.043	61	0.070	0.419	6
Warbling Vireo	WAVI	49	0.056	54	0.062	0.264	2
Baltimore Oriole	BAOR	35	0.040	53	0.061	0.359	4
Wood Duck	WODU	22	0.025	52	0.060	0.462	9
Yellow-billed Cuckoo	YBCU	35	0.040	49	0.056	0.292	2
Killdeer	KILL	32	0.037	45	0.052	0.293	3
Black-crested Titmouse	BCTI	30	0.035	43	0.049	0.331	6
Bell's Vireo*◇	BEVI	26	0.030	42	0.048	0.315	4
American White Pelican	AWPE	2	0.002	41	0.047	1.152	33
Turkey Vulture	TUVU	25	0.029	40	0.046	0.308	4
Red-bellied Woodpecker	RBWO	29	0.033	35	0.040	0.229	2
Yellow Warbler	YWAR	24	0.028	35	0.040	0.262	3
White-crowned Sparrow	WCSP	14	0.016	34	0.039	0.376	6
Henslow's Sparrow*#	HESP	22	0.025	32	0.037	0.256	3
Great Blue Heron	GBHE	22	0.025	32	0.037	0.269	4
Grasshopper Sparrow*	GRSP	21	0.024	30	0.035	0.238	3
Black-capped Chickadee	BCCH	24	0.028	29	0.033	0.215	3
American Robin	AMRO	21	0.024	26	0.030	0.207	3
Lesser Yellowlegs	LEYE	6	0.007	25	0.029	0.621	18
Eastern Towhee	EATO	15	0.017	24	0.028	0.238	4

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.
◇ Missouri State Watch list.

Appendix B. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Greater Yellowlegs[#]	GRYE	7	0.008	24	0.028	0.482	13
Gray Catbird	GRCA	18	0.021	22	0.025	0.190	3
Northern (Yellow-shafted) Flicker	NOFL	18	0.021	21	0.024	0.175	2
Brown Thrasher	BRTH	17	0.020	20	0.023	0.172	2
Rock Pigeon	ROPI	3	0.003	17	0.020	0.430	12
Red-headed Woodpecker*[#]	RHWO	13	0.015	14	0.016	0.135	2
Swamp Sparrow	SWSP	8	0.009	14	0.016	0.172	2
Red-eyed Vireo	REVI	12	0.014	13	0.015	0.131	2
Eastern Wood-Pewee*	EWPE	10	0.012	13	0.015	0.147	2
American Bittern[+]	AMBI	10	0.012	13	0.015	0.155	3
Horned Lark	HOLA	7	0.008	13	0.015	0.227	6
Great-tailed Grackle	GTGR	6	0.007	13	0.015	0.237	6
American Redstart	AMRE	5	0.006	13	0.015	0.237	6
Nelson's Sharp-tailed Sparrow	NSTS	8	0.009	12	0.014	0.151	2
Eastern Bluebird	EABL	8	0.009	12	0.014	0.173	4
Red-tailed Hawk	RTHA	10	0.012	11	0.013	0.122	2
Rose-breasted Grosbeak*	RBGR	8	0.009	11	0.013	0.147	3
Cedar Waxwing	CWAX	4	0.005	11	0.013	0.200	4
Marsh Wren	MAWR	5	0.006	11	0.013	0.200	5
Chipping Sparrow	CHSP	5	0.006	10	0.012	0.159	3
Blue-gray Gnatcatcher	BGGN	5	0.006	10	0.012	0.159	3
Palm Warbler	PAWA	5	0.006	10	0.012	0.192	5
Bobolink	BOBO	3	0.003	10	0.012	0.220	5
White-eyed Vireo*	WEVI	8	0.009	9	0.010	0.112	2
House Wren	HOWR	8	0.009	9	0.010	0.112	2
Sora	SORA	7	0.008	9	0.010	0.122	2
Wild Turkey	WITU	8	0.009	8	0.009	0.096	1

[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.
[+] State endangered.

Appendix B. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Chimney Swift	CHSW	5	0.006	8	0.009	0.135	3
Downy Woodpecker	DOWO	7	0.008	7	0.008	0.089	1
Great-Crested Flycatcher*	GCFL	6	0.007	6	0.007	0.083	1
Western Meadowlark	WEME	5	0.006	6	0.007	0.096	2
Common Snipe	COSN	4	0.005	6	0.007	0.117	3
Ruby-throated Hummingbird	RTHU	4	0.005	6	0.007	0.117	3
Willow Flycatcher	WIFL	5	0.006	5	0.006	0.076	1
Acadian Flycatcher	ACFL	4	0.005	5	0.006	0.090	2
Yellow-headed Blackbird△	YHBL	4	0.005	5	0.006	0.090	2
White-throated Sparrow	WTSP	4	0.005	5	0.006	0.090	2
Lincoln's Sparrow	LISP	4	0.005	5	0.006	0.090	2
Double-crested Cormorant	DCCO	3	0.003	5	0.006	0.102	2
Northern Shoveler	NSHO	3	0.003	5	0.006	0.102	2
Green Heron	GRHE	4	0.005	4	0.005	0.068	1
Lark Sparrow	LASP	4	0.005	4	0.005	0.068	1
Northern Parula	NOPA	4	0.005	4	0.005	0.068	1
American Woodcock	AMWO	3	0.003	4	0.005	0.083	2
Northern Harrier	NOHA	3	0.003	4	0.005	0.083	2
Eastern Phoebe	EAPH	3	0.003	4	0.005	0.083	2
Vesper Sparrow	VESP	3	0.003	4	0.005	0.083	2
Northern Rough-winged Swallow	RWSW	3	0.003	4	0.005	0.083	2
Pied-billed Grebe△	PBGR	3	0.003	3	0.003	0.059	1
Blue Grosbeak	BGBK	2	0.002	3	0.003	0.076	2
Purple Martin	PUMA	2	0.002	3	0.003	0.076	2
Tennessee Warbler	TEWA	2	0.002	3	0.003	0.076	2
Wood Thrush*#	WOTH	2	0.002	3	0.003	0.076	2
Sandhill Crane	SACR	1	0.001	2	0.002	0.068	2

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.
△ Missouri State Rare list.

Appendix B. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Black-crowned Night-Heron△	BCNH	2	0.002	2	0.002	0.048	1
Alder Flycatcher	ALFL	2	0.002	2	0.002	0.048	1
Le Conte's Sparrow	LESP	2	0.002	2	0.002	0.048	1
Snow Goose	SNGO	1	0.001	2	0.002	0.068	2
Rusty Blackbird	RUBL	1	0.001	2	0.002	0.068	2
Northern Pintail	NOPI	1	0.001	1	0.001	0.034	1
Least Bittern◇	LEBI	1	0.001	1	0.001	0.034	1
Solitary Sandpiper	SOSA	1	0.001	1	0.001	0.034	1
Upland Sandpiper	UPSA	1	0.001	1	0.001	0.034	1
Broad-winged Hawk	BWHA	1	0.001	1	0.001	0.034	1
Bald Eagle@	BAEA	1	0.001	1	0.001	0.034	1
Black-billed Cuckoo	BBCU	1	0.001	1	0.001	0.034	1
Belted Kingfisher	BEKI	1	0.001	1	0.001	0.034	1
Pileated Woodpecker	PIWO	1	0.001	1	0.001	0.034	1
unid. Empidonax	UNEM	1	0.001	1	0.001	0.034	1
Summer Tanager	SUTA	1	0.001	1	0.001	0.034	1
Yellow-throated Vireo	YTVI	1	0.001	1	0.001	0.034	1
unid. Solitary Vireo complex	SOVI	1	0.001	1	0.001	0.034	1
Nashville Warbler	NAWA	1	0.001	1	0.001	0.034	1
Myrtle Warbler	MYWA	1	0.001	1	0.001	0.034	1
Yellow-rumped Warbler	YRWA	1	0.001	1	0.001	0.034	1
Yellow-throated Warbler	YTWA	1	0.001	1	0.001	0.034	1
Kentucky Warbler	KEWA	1	0.001	1	0.001	0.034	1
Carolina Wren	CARW	1	0.001	1	0.001	0.034	1
Tufted Titmouse	ETTI	1	0.001	1	0.001	0.034	1
Carolina Chickadee	CACH	1	0.001	1	0.001	0.034	1
Ruby-crowned Kinglet	RCKI	1	0.001	1	0.001	0.034	1

@ Federally Threatened (Bald Eagle).
△ Missouri State Rare list.
◇ Missouri State Watch list.

Appendix C. Summarization of counts, ordered from most abundant to least abundant, for 673 surveys conducted in early successional floodplain forest sites along the lower Missouri River between 2002–2004.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Indigo Bunting	INBU	567	0.842	2,108	3.132	2.460	15
Northern Cardinal	NOCA	407	0.605	716	1.064	1.276	12
American Goldfinch	AMGO	247	0.367	715	1.062	2.056	20
Baltimore Oriole	BAOR	333	0.495	637	0.947	1.389	12
Common Yellowthroat	COYE	341	0.507	636	0.945	1.383	14
Brown-headed Cowbird	BHCO	280	0.416	607	0.902	1.495	12
Yellow-billed Cuckoo	YBCU	314	0.467	551	0.819	1.096	8
American Crow	AMCR	249	0.370	510	0.758	1.213	6
Red-winged Blackbird	RWBL	84	0.125	443	0.658	3.855	70
Blue Jay	BLJA	226	0.336	418	0.621	1.159	8
Black-capped Chickadee	BCCH	202	0.300	353	0.525	0.973	7
Black-crested Titmouse	BCTI	215	0.319	342	0.508	0.918	7
Blue-gray Gnatcatcher	BGGN	180	0.267	338	0.502	0.945	4
Red-eyed Vireo	REVI	219	0.325	323	0.480	0.816	5
Yellow-breasted Chat	YBCH	205	0.305	308	0.458	0.848	5
Warbling Vireo	WAVI	178	0.264	297	0.441	0.913	7
Yellow-rumped Warbler	YRWA	51	0.076	253	0.376	2.274	40
Rose-breasted Grosbeak*	RBGR	123	0.183	216	0.321	1.098	20
House Wren	HOWR	104	0.155	187	0.278	0.782	6
Downy Woodpecker	DOWO	153	0.227	181	0.269	0.580	7
Canada Goose	CAGO	39	0.058	178	0.264	1.726	25
Red-bellied Woodpecker	RBWO	153	0.227	178	0.264	0.530	3
Mourning Dove	MODO	137	0.204	169	0.251	0.552	4
Cliff Swallow	CLSW	40	0.059	141	0.210	1.145	18

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.

Appendix C. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Red-headed Woodpecker	RHWO	89	0.132	140	0.208	0.712	9
Gray Catbird	GRCA	117	0.174	138	0.205	0.494	4
Northern Bobwhite	NOBO	79	0.117	125	0.186	0.663	10
Eastern Wood-Pewee	EWPE	102	0.152	121	0.180	0.455	3
Cedar Waxwing	CWAX	21	0.031	118	0.175	1.199	16
Wood Thrush	WOTH	78	0.116	110	0.163	0.526	5
Bell's Vireo*◇	BEVI	59	0.088	103	0.153	0.571	5
Tree Swallow	TRES	14	0.021	100	0.149	1.725	35
Carolina Wren	CARW	65	0.097	84	0.125	0.436	4
Great Crested Flycatcher	GCFL	64	0.095	80	0.119	0.409	4
Yellow Warbler	YWAR	48	0.071	70	0.104	0.417	3
Wild Turkey	WITU	53	0.079	64	0.095	0.353	3
Orchard Oriole	OROR	37	0.055	59	0.088	0.469	8
Northern (Yellow-shafted) Flicker	NOFL	45	0.067	59	0.088	0.374	4
Common Grackle	COGR	22	0.033	56	0.083	0.604	8
American Redstart	AMRE	37	0.055	53	0.079	0.417	7
Song Sparrow	SOSP	39	0.058	50	0.074	0.332	3
Tennessee Warbler	TEWA	35	0.052	49	0.073	0.365	4
Brown Thrasher	BRTH	40	0.059	47	0.070	0.293	2
Barn Swallow	BARS	23	0.034	46	0.068	0.406	4
Field Sparrow	FISP	23	0.034	46	0.068	0.474	8
Fish Crow	FICR	21	0.031	43	0.064	0.405	4
Eastern Towhee	EATO	23	0.034	39	0.058	0.371	5
Northern Parula	NOPA	30	0.045	37	0.055	0.275	3
Dickcissel	DICK	13	0.019	28	0.042	0.351	5

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.
◇ Missouri State Watch list.

Appendix C. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
White-breasted Nuthatch	WBNU	22	0.033	27	0.040	0.238	3
Turkey Vulture	TUVU	8	0.012	25	0.037	0.598	15
Willow Flycatcher	WIFL	16	0.024	24	0.036	0.253	3
White-throated Sparrow	WTSP	11	0.016	24	0.036	0.302	4
Prothonotary Warbler	PROW	15	0.022	22	0.033	0.260	4
White-eyed Vireo	WEVI	18	0.027	21	0.031	0.198	2
Eastern Kingbird	EAKI	14	0.021	19	0.028	0.213	3
Acadian Flycatcher	ACFL	14	0.021	17	0.025	0.183	2
Ovenbird	OVEN	12	0.018	17	0.025	0.220	4
Wood Duck	WODU	6	0.009	17	0.025	0.315	6
American Robin	AMRO	5	0.007	16	0.024	0.377	9
Lark Sparrow	LASP	10	0.015	16	0.024	0.224	4
Pileated Woodpecker	PIWO	16	0.024	16	0.024	0.152	1
Eastern Bluebird	EABL	11	0.016	15	0.022	0.184	2
Kentucky Warbler	KEWA	15	0.022	15	0.022	0.148	1
Philadelphia Vireo	PHVI	12	0.018	15	0.022	0.175	2
Ruby-throated Hummingbird	RTHU	13	0.019	15	0.022	0.167	2
Summer Tanager	SUTA	15	0.022	15	0.022	0.148	1
Least Flycatcher	LEFL	13	0.019	14	0.021	0.153	2
Yellow-throated Vireo	YTVI	14	0.021	14	0.021	0.143	1
Alder Flycatcher	ALFL	9	0.013	12	0.018	0.163	2
Palm Warbler	PAWA	9	0.013	11	0.016	0.149	2
American Woodcock	AMWO	3	0.004	9	0.013	0.228	5
Black-and-white Warbler	BAWW	8	0.012	8	0.012	0.108	1
Carolina Chickadee	CACH	5	0.007	8	0.012	0.172	4

[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.

Appendix C. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Great Blue Heron	GBHE	4	0.006	8	0.012	0.181	4
Ruby-crowned Kinglet	RCKI	5	0.007	8	0.012	0.154	3
Swainson's Thrush	SWTH	6	0.009	8	0.012	0.133	2
European Starling	EUST	4	0.006	7	0.010	0.149	3
Suspect counts (probably RPHE)	RPHA^	6	0.009	7	0.010	0.115	2
Red-tailed Hawk	RTHA	7	0.010	7	0.010	0.102	1
Blue Grosbeak	BGBK	6	0.009	6	0.009	0.094	1
Blackpoll Warbler	BPLW	6	0.009	6	0.009	0.094	1
Blue-winged Warbler	BWWA	5	0.007	6	0.009	0.109	2
Chimney Swift	CHSW	3	0.004	6	0.009	0.144	3
Hairy Woodpecker	HAWO	6	0.009	6	0.009	0.094	1
Lincoln's Sparrow	LISP	3	0.004	6	0.009	0.144	3
Scarlet Tanager	SCTA	6	0.009	6	0.009	0.094	1
Worm-eating Warbler	WEWA	4	0.006	6	0.009	0.122	2
Nashville Warbler	NAWA	4	0.006	5	0.007	0.102	2
Savannah Sparrow	SAVS	4	0.006	5	0.007	0.102	2
unid. Solitary Vireo complex	SOVI	5	0.007	5	0.007	0.086	1
Blue-headed Vireo	BHVI	4	0.006	4	0.006	0.077	1
Eastern Phoebe	EAPH	4	0.006	4	0.006	0.077	1
Northern Rough-winged Swallow	RWSW	2	0.003	4	0.006	0.122	3
Swamp Sparrow	SWSP	3	0.004	4	0.006	0.094	2
Bewick's Wren	BEWR	2	0.003	3	0.004	0.086	2
Chestnut-sided Warbler	CSWA	2	0.003	3	0.004	0.086	2
Magnolia Warbler	MAGW	2	0.003	3	0.004	0.086	2
Vesper Sparrow	VESP	2	0.003	3	0.004	0.086	2

[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.
^ This species may be Red-necked Phalarope, Wilson's Phalarope, or, more likely, Ring-necked Pheasant, or some combination.

Appendix C. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Western Meadowlark	WEME	3	0.004	3	0.004	0.067	1
Wilson's Warbler	WIWA	2	0.003	3	0.004	0.086	2
Black-billed Cuckoo	BBCU	2	0.003	2	0.003	0.054	1
Broad-winged Hawk	BWHA	2	0.003	2	0.003	0.054	1
Cerulean Warbler[*◇]	CERW	2	0.003	2	0.003	0.054	1
Chipping Sparrow	CHSP	2	0.003	2	0.003	0.054	1
Green Heron	GRHE	2	0.003	2	0.003	0.054	1
Grasshopper Sparrow	GRSP	2	0.003	2	0.003	0.054	1
Mallard	MALL	1	0.001	2	0.003	0.077	2
Marsh Wren	MAWR	2	0.003	2	0.003	0.054	1
Purple Martin	PUMA	1	0.001	2	0.003	0.077	2
Bay-breasted Warbler	BBWA	1	0.001	1	0.001	0.039	1
Belted Kingfisher	BEKI	1	0.001	1	0.001	0.039	1
Black-throated Green Warbler	BTNW	1	0.001	1	0.001	0.039	1
Eastern Meadowlark	EAME	1	0.001	1	0.001	0.039	1
Greater Yellowlegs	GRYE	1	0.001	1	0.001	0.039	1
Golden-winged Warbler	GWWA	1	0.001	1	0.001	0.039	1
Lapland Longspur	LALO	1	0.001	1	0.001	0.039	1
Least Bittern[◇]	LEBI	1	0.001	1	0.001	0.039	1
Orange-crowned Warbler	OCWA	1	0.001	1	0.001	0.039	1
Peregrine Falcon	PEFA	1	0.001	1	0.001	0.039	1
Prairie Warbler	PRAW	1	0.001	1	0.001	0.039	1
Sedge Wren	SEWR	1	0.001	1	0.001	0.039	1
unid. Empidonax	UNEM	1	0.001	1	0.001	0.039	1
Veery	VEER	1	0.001	1	0.001	0.039	1
Yellow-throated Warbler	YTWA	1	0.001	1	0.001	0.039	1

[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.
[◇] Missouri State Watch list.

Appendix D. Summarization of counts from 864 surveys conducted in mature forest sites along the lower Missouri River between 2002–2004.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
House Wren	HOWR	419	0.485	1,166	1.350	1.839	10
Northern Cardinal	NOCA	537	0.622	1,035	1.198	1.416	12
Indigo Bunting	INBU	428	0.495	1,017	1.177	1.561	11
Red-bellied Woodpecker	RBWO	588	0.681	921	1.066	1.045	10
Blue-gray Gnatcatcher	BGGN	275	0.318	717	0.830	1.498	10
Black-crested Titmouse	BCTI	390	0.451	683	0.791	1.121	6
Common Yellowthroat	COYE	382	0.442	667	0.772	1.101	6
Baltimore (Northern) Oriole	BAOR	351	0.406	635	0.735	1.170	7
Red-headed Woodpecker	RHWO	344	0.398	626	0.725	1.291	13
Blue Jay	BLJA	328	0.380	613	0.709	1.341	14
American Redstart	AMRE	313	0.362	613	0.709	1.317	12
Red-eyed Vireo	REVI	356	0.412	601	0.696	1.021	5
Rose-breasted Grosbeak*	RBGR	288	0.333	569	0.659	1.379	17
Warbling Vireo	WAVI	282	0.326	528	0.611	1.176	11
Brown-headed Cowbird	BHCO	249	0.288	515	0.596	1.214	11
Eastern Wood-Pewee	EWPE	352	0.407	499	0.578	0.813	5
Wood Thrush	WOTH	294	0.340	493	0.571	0.959	6
American Crow	AMCR	210	0.243	461	0.534	1.241	15
Black-capped Chickadee	BCCH	283	0.328	444	0.514	0.903	8
Yellow-billed Cuckoo	YBCU	271	0.314	409	0.473	0.861	6
Great Crested Flycatcher	GCFL	258	0.299	374	0.433	0.795	5
Prothonotary Warbler	PROW	240	0.278	370	0.428	0.814	5
Downy Woodpecker	DOWO	294	0.340	364	0.421	0.669	5
Gray Catbird	GRCA	247	0.286	360	0.417	0.814	9
White-breasted Nuthatch	WBNU	245	0.284	350	0.405	0.773	7

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.

Appendix D. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Mourning Dove	MODO	222	0.257	334	0.387	0.808	7
American Goldfinch	AMGO	125	0.145	273	0.316	1.023	11
American Robin	AMRO	155	0.179	261	0.302	0.755	5
Northern Parula	NOPA	204	0.236	258	0.299	0.612	5
Tennessee Warbler	TEWA	113	0.131	234	0.271	0.875	7
Northern (Yellow-shafted) Flicker	NOFL	155	0.179	215	0.249	0.599	4
Carolina Wren	CARW	147	0.170	203	0.235	0.612	6
Red-winged Blackbird	RWBL	52	0.060	201	0.233	1.628	30
Eastern Towhee	EATO	125	0.145	192	0.222	0.625	5
Acadian Flycatcher	ACFL	139	0.161	186	0.215	0.545	4
Yellow Warbler	YWAR	109	0.126	171	0.198	0.600	5
European Starling	EUST	48	0.056	160	0.185	1.545	35
Yellow-breasted Chat	YBCH	86	0.100	121	0.140	0.510	5
White-throated Sparrow	WTSP	32	0.037	113	0.131	0.908	18
Cedar Waxwing	CWAX	21	0.024	111	0.128	1.146	25
Yellow-rumped Warbler	YRWA	43	0.050	102	0.118	0.620	8
Yellow-throated Vireo	YTVI	87	0.101	100	0.116	0.367	3
Fish Crow	FICR	55	0.064	92	0.106	0.489	5
Common Grackle	COGR	23	0.027	85	0.098	1.126	30
Canada Goose	CAGO	26	0.030	83	0.096	0.623	10
Wood Duck	WODU	36	0.042	81	0.094	0.522	8
Great Blue Heron	GBHE	32	0.037	78	0.090	0.643	9
Kentucky Warbler	KEWA	65	0.075	77	0.089	0.330	2
Orchard Oriole	OROR	50	0.058	77	0.089	0.394	3
Black-and-white Warbler	BAWW	58	0.067	68	0.079	0.317	3

[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.

Appendix D. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Blackpoll Warbler	BPLW	51	0.059	68	0.079	0.368	5
Myrtle Warbler	MYWA	17	0.020	67	0.078	0.817	20
Pileated Woodpecker	PIWO	54	0.062	61	0.071	0.290	3
Tree Swallow	TRES	32	0.037	60	0.069	0.397	4
Wild Turkey	WITU	26	0.030	58	0.067	0.769	16
Least Flycatcher	LEFL	43	0.050	56	0.065	0.309	3
Chimney Swift	CHSW	17	0.020	56	0.065	0.505	6
Ruby-crowned Kinglet	RCKI	19	0.022	52	0.060	0.615	13
Turkey Vulture	TUVU	32	0.037	49	0.057	0.334	4
Franklin's Gull	FRGU	2	0.002	41	0.047	1.361	40
Swainson's Thrush	SWTH	34	0.039	41	0.047	0.262	4
Ruby-throated Hummingbird	RTHU	33	0.038	38	0.044	0.232	2
Ovenbird	OVEN	29	0.034	37	0.043	0.258	4
Eastern Bluebird	EABL	28	0.032	37	0.043	0.249	2
Song Sparrow	SOSP	25	0.029	34	0.039	0.256	4
Summer Tanager	SUTA	26	0.030	34	0.039	0.252	3
Magnolia Warbler	MAGW	17	0.020	31	0.036	0.285	5
Northern Bobwhite	NOBO	24	0.028	31	0.036	0.226	2
Cerulean Warbler[*◇]	CERW	29	0.034	30	0.035	0.189	2
Carolina Chickadee	CACH	15	0.017	29	0.034	0.305	6
Brown Thrasher	BRTH	28	0.032	29	0.034	0.187	2
Chestnut-sided Warbler	CSWA	15	0.017	29	0.034	0.289	5
Nashville Warbler	NAWA	23	0.027	28	0.032	0.213	3
White-eyed Vireo	WEVI	24	0.028	27	0.031	0.193	2
Suspect counts (probably RPHE)	RPHA^	21	0.024	27	0.031	0.216	3

[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.
[◇] Missouri State Watch list. ^ This species may be Red-necked Phalarope, Wilson's Phalarope, or Ring-necked Pheasant.

Appendix D. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Red-shouldered Hawk◇	RSHA	20	0.023	26	0.030	0.213	3
Barred Owl	BAOW	19	0.022	26	0.030	0.229	4
Scarlet Tanager	SCTA	18	0.021	24	0.028	0.224	4
Hairy Woodpecker	HAWO	19	0.022	23	0.027	0.188	2
Philadelphia Vireo	PHVI	15	0.017	20	0.023	0.185	2
Red-tailed Hawk	RTHA	15	0.017	17	0.020	0.155	2
unid. Solitary Vireo complex	SOVI	16	0.019	17	0.020	0.147	2
Tufted Titmouse	ETTI	14	0.016	16	0.019	0.151	2
Eastern Kingbird	EAKI	11	0.013	16	0.019	0.179	3
Eastern Phoebe	EAPH	12	0.014	14	0.016	0.144	2
Blue-winged Warbler	BWWA	13	0.015	14	0.016	0.135	2
Northern Waterthrush	NOWA	9	0.010	14	0.016	0.166	2
Yellow-throated Warbler	YTWA	12	0.014	13	0.015	0.131	2
Lincoln's Sparrow	LISP	7	0.008	12	0.014	0.180	4
Sedge Wren	SEWR	9	0.010	12	0.014	0.144	2
Alder Flycatcher	ALFL	9	0.010	10	0.012	0.117	2
Dickcissel	DICK	9	0.010	10	0.012	0.117	2
Wilson's Warbler	WIWA	5	0.006	8	0.009	0.127	2
Blackburnian Warbler	BLBW	4	0.005	7	0.008	0.132	3
Killdeer	KILL	6	0.007	7	0.008	0.102	2
Orange-crowned Warbler	OCWA	5	0.006	7	0.008	0.122	3
Golden-winged Warbler	GWWA	7	0.008	7	0.008	0.090	1
Northern Rough-winged Swallow	RWSW	2	0.002	7	0.008	0.207	6
Louisiana Waterthrush	LOWA	7	0.008	7	0.008	0.090	1
Black-billed Cuckoo	BBCU	5	0.006	6	0.007	0.096	2

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.
◇ Missouri State Watch list.

Appendix D. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Green-winged Teal	AGWT	1	0.001	5	0.006	0.17	5
Mallard	MALL	2	0.002	5	0.006	0.14	4
Belted Kingfisher	BEKI	5	0.006	5	0.006	0.076	1
Black-throated Green Warbler	BTNW	5	0.006	5	0.006	0.076	1
Swamp Sparrow	SWSP	3	0.003	5	0.006	0.113	3
Purple Martin	PUMA	2	0.002	4	0.005	0.096	2
Worm-eating Warbler	WEWA	4	0.005	4	0.005	0.068	1
Cliff Swallow	CLSW	2	0.002	4	0.005	0.108	3
Veery	VEER	4	0.005	4	0.005	0.068	1
Blue-headed Vireo	BHVI	4	0.005	4	0.005	0.068	1
Blue-winged Teal	BWTE	1	0.001	3	0.003	0.102	3
Willow Flycatcher	WIFL	3	0.003	3	0.003	0.059	1
Palm Warbler	PAWA	3	0.003	3	0.003	0.059	1
Mourning Warbler	MOWA	2	0.002	2	0.002	0.048	1
Cooper's Hawk△	COHA	2	0.002	2	0.002	0.048	1
Mottled Duck	MODU	1	0.001	2	0.002	0.068	2
Broad-winged Hawk	BWHA	2	0.002	2	0.002	0.048	1
Bay-breasted Warbler	BBWA	1	0.001	2	0.002	0.068	2
Sandhill Crane	SACR	1	0.001	2	0.002	0.068	2
Sharp-shinned Hawk	SSHA	2	0.002	2	0.002	0.048	1
Eastern Meadowlark	EAME	2	0.002	2	0.002	0.048	1
Great Horned Owl	GHOW	1	0.001	1	0.001	0.034	1
Marsh Wren	MAWR	1	0.001	1	0.001	0.034	1
Savannah Sparrow	SAVS	1	0.001	1	0.001	0.034	1
Chipping Sparrow	CHSP	1	0.001	1	0.001	0.034	1

* Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
# Upper Mississippi River / Great Lakes Joint Venture focal species.
△ Missouri State Rare list.

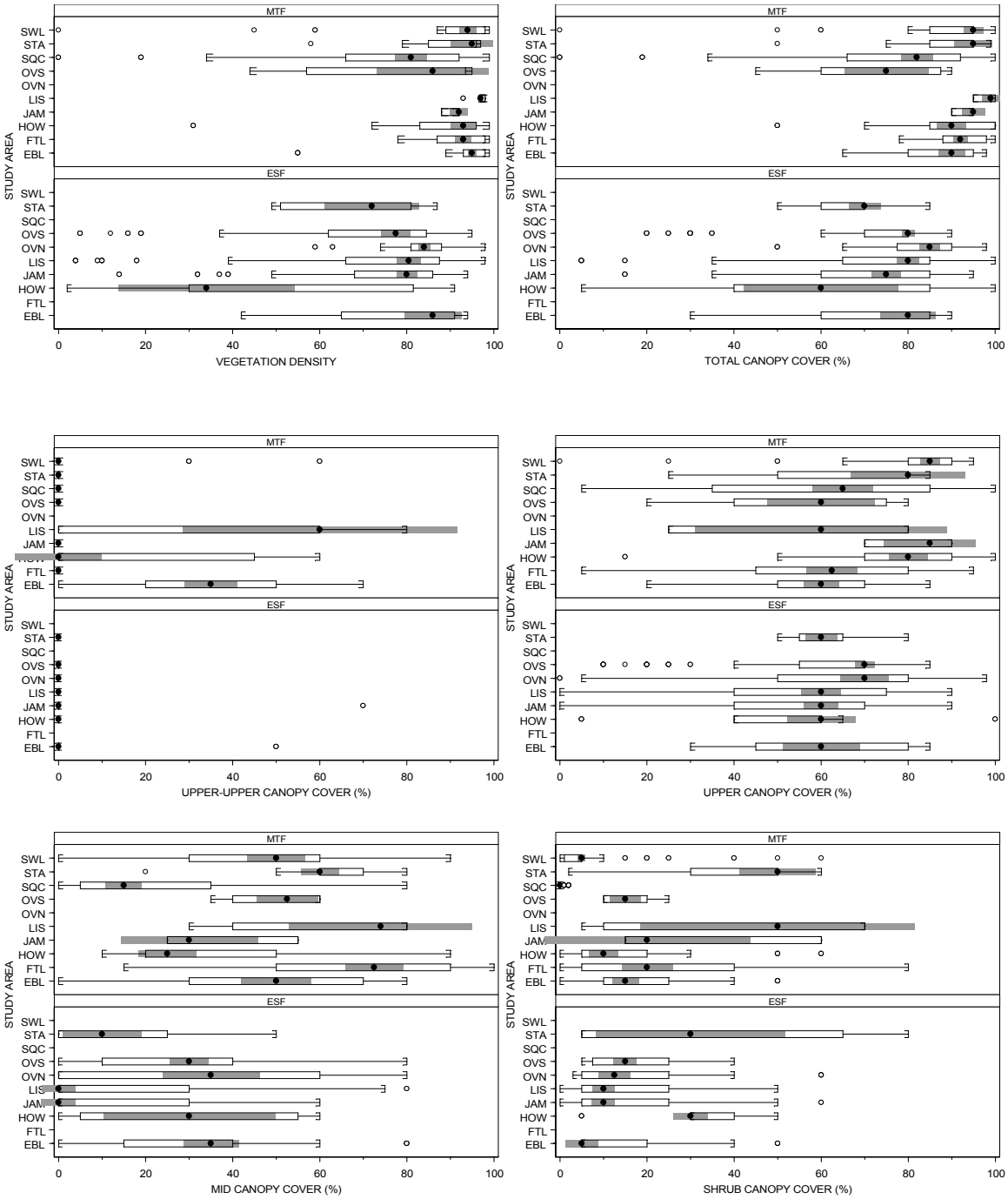
Appendix D. Continued.

Common Name	Acronym	Total Occurrences	Proportion Of Occurrence	Total Birds Counted	Mean Count Per Visit	Standard Deviation Per Visit	Maximum Observed
Gray-cheeked Thrush	GCTH	1	0.001	1	0.001	0.034	1
Cape May Warbler	CMWA	1	0.001	1	0.001	0.034	1
Bewick's Wren	BEWR	1	0.001	1	0.001	0.034	1
Mississippi Kite	MIKI	1	0.001	1	0.001	0.034	1
Lark Sparrow	LASP	1	0.001	1	0.001	0.034	1
Red-breasted Nuthatch	RBNU	1	0.001	1	0.001	0.034	1
Hooded Warbler	HOWA	1	0.001	1	0.001	0.034	1
Virginia Rail	VIRA	1	0.001	1	0.001	0.034	1
White-crowned Sparrow	WCSP	1	0.001	1	0.001	0.034	1
House Finch	HOFI	1	0.001	1	0.001	0.034	1
Harris's Sparrow	HASP	1	0.001	1	0.001	0.034	1
Green Heron	GRHE	1	0.001	1	0.001	0.034	1
unid. Empidonax	UNEM	1	0.001	1	0.001	0.034	1
Double-crested Cormorant	DCCO	1	0.001	1	0.001	0.034	1
Whip-poor-will	WPWI	1	0.001	1	0.001	0.034	1

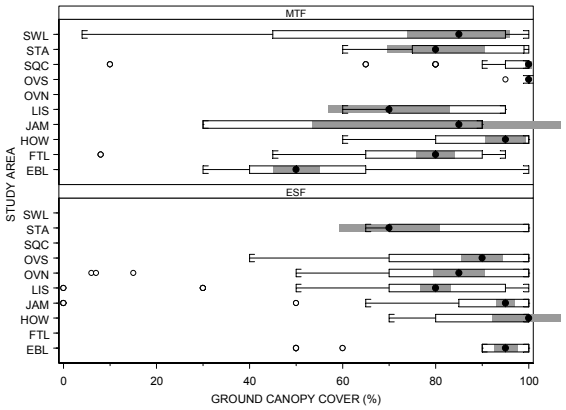
[*] Neotropical migratory landbird species of conservation concern and USFWS Region 3 resource conservation priority.
[#] Upper Mississippi River / Great Lakes Joint Venture focal species.

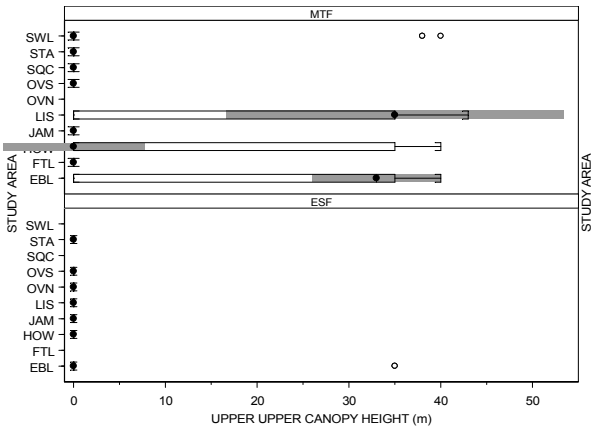
Appendix E. Box plots of cover type-specific vegetation characteristics for 10 study areas along the lower Missouri River, 2002–2004. The limits of the box denote the 25th and 75th quartiles, whereas the whiskers extend to 1.5 × the interquartile range. The 95% confidence bounds of the mean are provided in gray (if the intervals on the boxes do not overlap, the study area responses significantly differ). ESF = early successional forest, MTF = mature forest, and WTP = wet prairie. See Table 1 for study area acronyms.

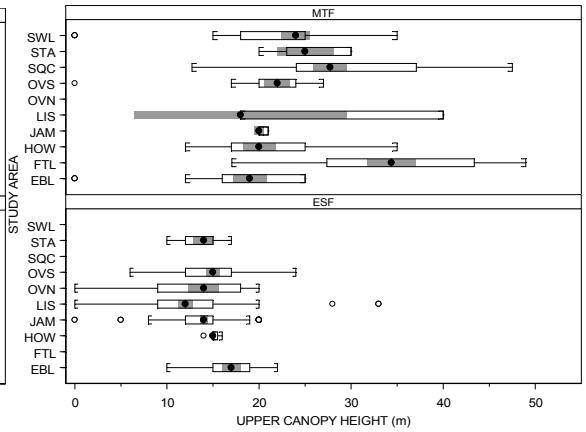
FOREST

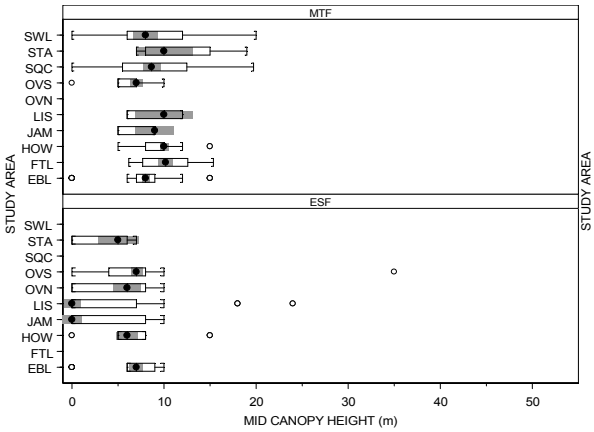


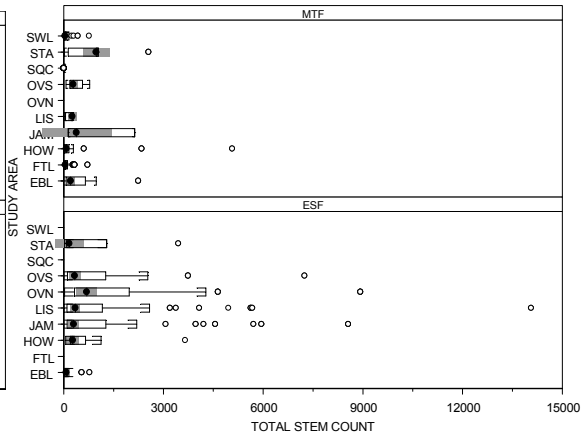
Appendix E. Continued.



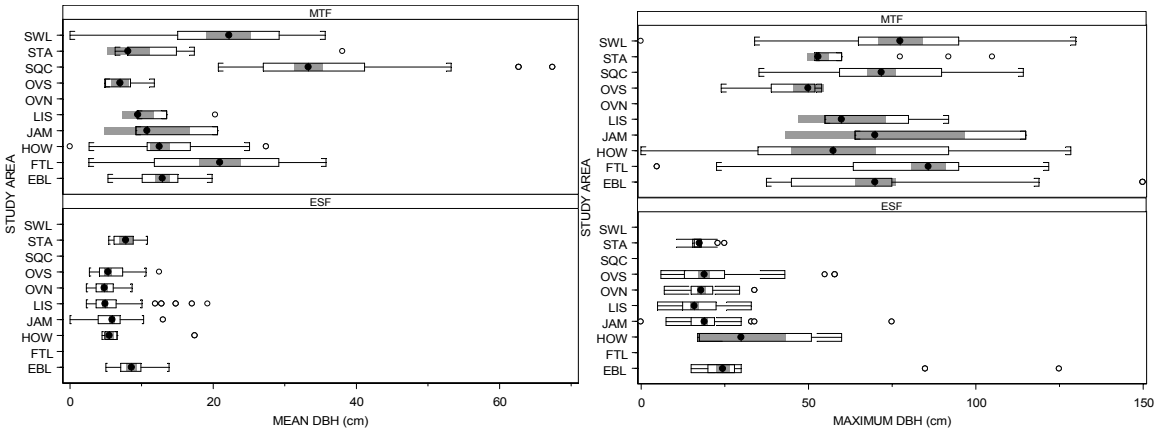




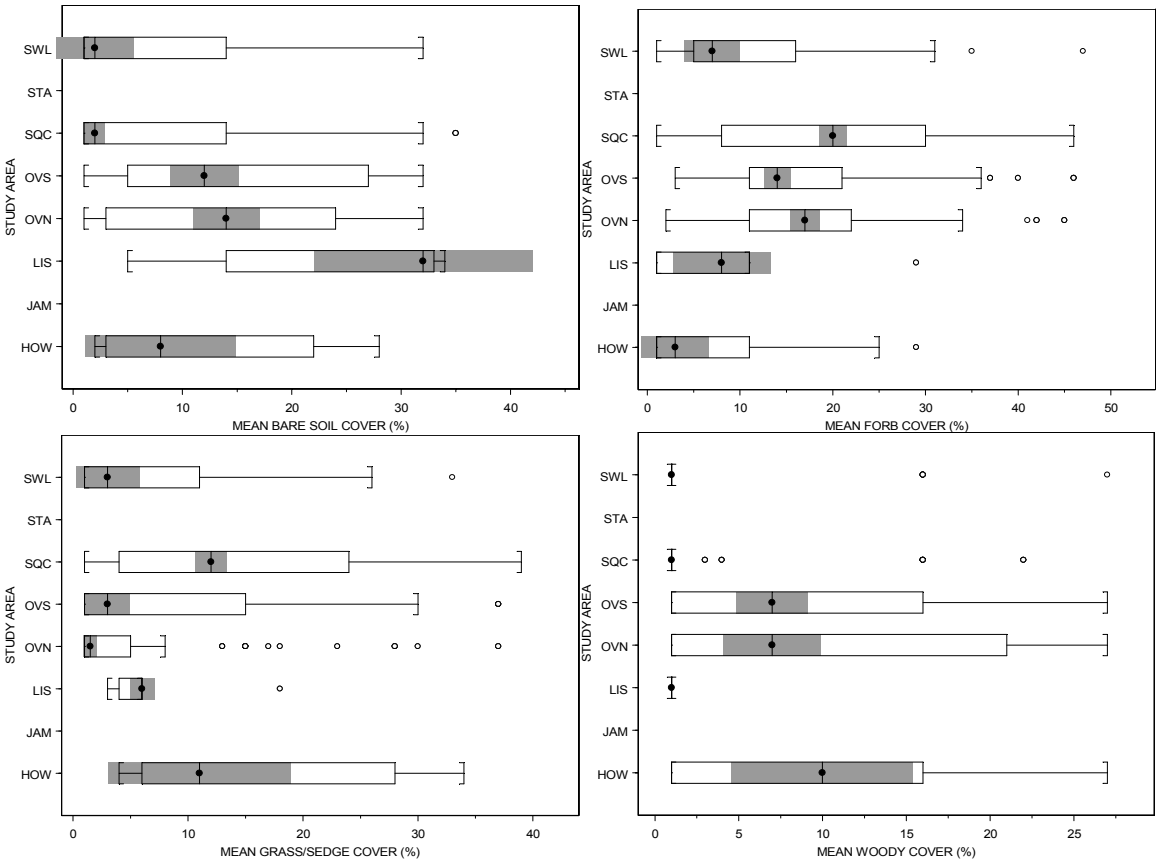




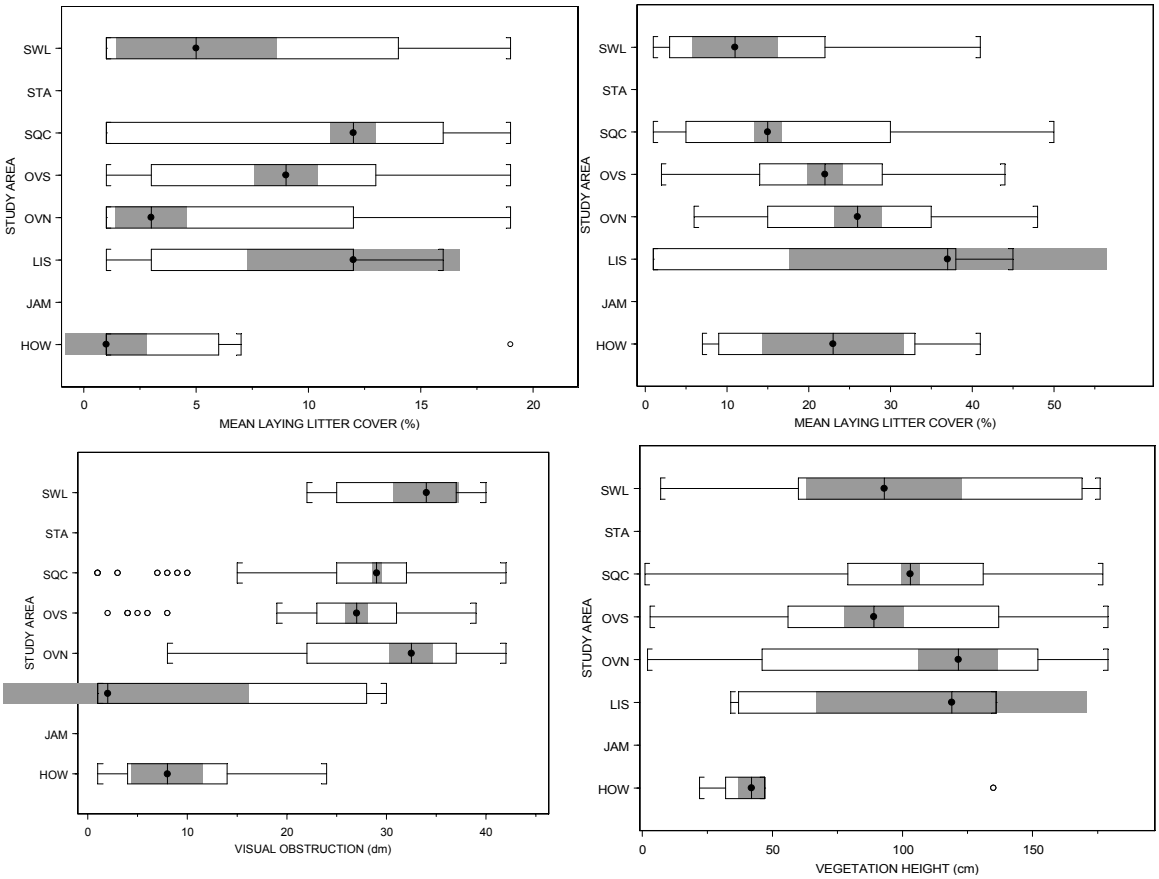
Appendix E. Continued.



WET PRAIRIE



Appendix E. Continued.



Appendix F. Pair-wise comparisons of study area differences in avian community composition. The number of permutations is the number out of 999 exceeding the Global *R*. See Table 1 for study area acronyms.

Pair-wise Comparisons	*R*	Significance level (*P*)	No. of Permutations
EBL, FTL	0.268	0.001	0
EBL, HOW	0.241	0.001	0
EBL, JAM	0.197	0.001	0
EBL, LIS	0.170	0.001	0
EBL, OVN	0.338	0.001	0
EBL, OVS	0.325	0.001	0
EBL, SQC	0.607	0.001	0
EBL, STA	0.034	0.205	204
EBL, SWL	0.163	0.001	0
FTL, HOW	0.334	0.001	0
FTL, JAM	0.395	0.001	0
FTL, LIS	0.390	0.001	0
FTL, OVN	0.557	0.001	0
FTL, OVS	0.508	0.001	0
FTL, SQC	0.628	0.001	0
FTL, STA	0.354	0.001	0
FTL, SWL	0.422	0.001	0
HOW, JAM	0.289	0.001	0
HOW, LIS	0.335	0.001	0
HOW, OVN	0.359	0.001	0
HOW, OVS	0.299	0.001	0
HOW, SQC	0.536	0.001	0
HOW, STA	0.138	0.004	3
HOW, SWL	0.224	0.001	0
JAM, LIS	0.024	0.001	0
JAM, OVN	0.283	0.001	0
JAM, OVS	0.215	0.001	0
JAM, SQC	0.581	0.001	0
JAM, STA	0.059	0.132	131
JAM, SWL	0.298	0.001	0
LIS, OVN	0.297	0.001	0
LIS, OVS	0.252	0.001	0
LIS, SQC	0.634	0.001	0
LIS, STA	0.061	0.099	98
LIS, SWL	0.282	0.001	0
OVN, OVS	0.050	0.001	0
OVN, SQC	0.291	0.001	0
OVN, STA	0.251	0.001	0
OVN, SWL	0.215	0.001	0

Appendix F. Continued.

Pair-wise Comparisons	*R*	Significance level (*P*)	No. of Permutations
OVS, SQC	0.347	0.001	0
OVS, STA	0.243	0.001	0
OVS, SWL	0.250	0.001	0
SQC, STA	0.584	0.001	0
SQC, SWL	0.422	0.001	0
STA, SWL	0.077	0.022	21

Appendix G. Indicator species (denoted by 4-letter acronym) sorted by cover type (wet floodplain prairie, WTP; early successional floodplain forest, ESF; and mature forest, MTF) and significance level for birds surveyed at 10 study locations along the lower Missouri River between 2002–2004. The observed indicator value represents the degree of concordance with the indicator cover type; the randomized mean and standard deviation are from 1,000 Monte Carlo permutations of the data. Species acronyms are listed in Appendices B, C, and D.

Species	Cover Type	Observed Indicator Value (%)	Randomized Mean (%)	SD	*p*
RTHA	WTP	72.3	46.9	11.4	0.011
TRES	WTP	89.0	64.4	15.8	0.013
NOHA	WTP	100.0	30.5	15.6	0.015
BOBO	WTP	100.0	31.0	15.8	0.015
NSTS	WTP	85.7	34.5	17.3	0.028
NRWS	WTP	76.9	34.6	15.9	0.034
DICK	WTP	82.8	43.1	18.6	0.037
SAVS	WTP	76.0	38.6	17.7	0.048
MALL	WTP	94.6	56.9	19.6	0.054
BWHA	WTP	76.9	35.4	17.1	0.054
KILL	WTP	78.2	47.5	18.6	0.057
EAKI	WTP	74.0	51.4	14.1	0.057
EAME	WTP	73.4	44.5	17.4	0.069
BARS	WTP	72.6	43.1	16.7	0.069
EUST	WTP	89.9	57.1	19.0	0.075
RWBL	WTP	85.5	64.9	14.4	0.080
WODU	WTP	81.4	51.4	17.6	0.087
CHSP	WTP	67.8	36.2	17.5	0.089
SWSP	WTP	74.1	44.8	16.7	0.106
COYE	WTP	63.1	52.2	8.7	0.115
RNPH	WTP	93.5	62.9	19.7	0.120
AMRO	WTP	87.3	61.8	18.8	0.123
TUVU	WTP	64.9	48.3	14.0	0.139
HOLA	WTP	60.0	34.6	17.6	0.141
WTSP	WTP	50.0	43.2	6.0	0.142
OROR	WTP	71.9	60.1	11.0	0.146
PBGR	WTP	50.0	26.5	10.1	0.149
DCCO	WTP	50.0	26.5	10.1	0.149
AWPE	WTP	50.0	26.5	10.1	0.149
MODU	WTP	50.0	26.5	10.1	0.149
NSHO	WTP	50.0	26.5	10.1	0.149

Appendix G. Continued.

Species	Cover Type	Observed Indicator Value (%)	Randomized Mean (%)	SD	*p*
NOPI	WTP	50.0	26.5	10.1	0.149
LSGO	WTP	50.0	26.5	10.1	0.149
AMBI	WTP	50.0	26.5	10.1	0.149
SACR	WTP	50.0	26.5	10.1	0.149
VIRA	WTP	50.0	26.5	10.1	0.149
COSN	WTP	50.0	26.5	10.1	0.149
UPSA	WTP	50.0	26.5	10.1	0.149
RPHE	WTP	50.0	26.5	10.1	0.149
SSHA	WTP	50.0	26.5	10.1	0.149
BAEA	WTP	50.0	26.5	10.1	0.149
YHBL	WTP	50.0	26.5	10.1	0.149
GTGR	WTP	50.0	26.5	10.1	0.149
HOFI	WTP	50.0	26.5	10.1	0.149
LCSP	WTP	50.0	26.5	10.1	0.149
HASP	WTP	50.0	26.5	10.1	0.149
BANS	WTP	50.0	26.5	10.1	0.149
CMWA	WTP	50.0	26.5	10.1	0.149
HOWA	WTP	50.0	26.5	10.1	0.149
TUTM	WTP	50.0	26.5	10.1	0.149
GRHE	WTP	61.2	38.2	16.3	0.162
COGR	WTP	53.2	45.5	7.7	0.169
RUBL	WTP	50.0	27.5	11.1	0.190
GBHE	WTP	59.5	51.4	10.5	0.203
Empidonax Spp.	WTP	41.7	30.0	15.4	0.207
YWAR	WTP	65.2	56.2	10.1	0.207
NOFL	WTP	59.2	49.0	10.6	0.209
EABL	WTP	66.3	51.3	14.0	0.213
BHCO	WTP	48.7	44.3	5.9	0.220
BRTH	WTP	53.1	47.5	7.8	0.231
EAPH	WTP	51.3	42.9	12.5	0.257
GRSP	WTP	51.9	40.7	19.3	0.257
ALFL	WTP	54.3	43.9	13.8	0.263
SORA	WTP	41.7	30.6	15.2	0.264
LEYE	WTP	45.5	30.9	15.5	0.264
HOWR	WTP	60.2	52.6	12.5	0.271
SWTH	WTP	49.8	46.1	8.3	0.288
MODO	WTP	58.7	51.1	11.4	0.294
WEME	WTP	40.0	37.3	18.5	0.327
MAWR	WTP	42.6	39.0	16.6	0.334
CLSW	WTP	54.8	48.3	19.6	0.339
BWTE	WTP	48.8	39.5	17.1	0.343

Appendix G. Continued.

Species	Cover Type	Observed Indicator Value (%)	Randomized Mean (%)	SD	*p*
SEWR	WTP	49.7	40.1	16.8	0.349
LISP	WTP	37.7	34.0	17.1	0.350
VESP	WTP	38.5	35.1	18.0	0.390
WAVI	WTP	48.8	48.2	7.8	0.436
FRGU	WTP	40.0	30.5	15.2	0.454
MOWA	WTP	35.7	29.9	15.1	0.466
BAOW	WTP	32.3	35.0	18.0	0.483
GRYE	WTP	33.3	34.1	16.9	0.491
AMWO	WTP	34.1	36.5	18.2	0.523
MYWA	WTP	33.3	30.2	15.9	0.547
RBWO	WTP	41.9	43.6	6.7	0.570
LEBI	WTP	33.3	30.5	15.7	0.621
BCNH	WTP	33.3	30.5	15.3	0.628
SOSP	WTP	49.9	54.5	12.9	0.648
FISP	WTP	29.6	39.2	18.4	0.708
WCSP	WTP	25.8	38.7	18.9	0.788
WIWA	WTP	23.8	33.9	15.7	0.828
CAGO	WTP	39.3	51.3	11.4	0.829
LEFL	WTP	32.4	47.9	14.7	0.849
HESP	WTP	24.6	35.2	18.3	0.850
RBGR	WTP	36.8	44.7	6.2	0.908
OCWA	WTP	16.1	35.1	17.6	0.929
HAWO	WTP	28.1	47.1	13.2	0.966
BEVI	ESF	86.1	44.1	16.7	0.013
YBCH	ESF	62.7	49.3	10.4	0.131
PAWA	ESF	67.8	42.1	17.9	0.132
INBU	ESF	50.3	44.2	5.7	0.141
AMCR	ESF	50.2	44.2	5.9	0.151
YBCU	ESF	50.7	44.7	5.9	0.160
BAOR	ESF	45.8	44.3	6.0	0.350
BEKI	ESF	39.5	38.4	16.6	0.425
BGGN	ESF	44.8	44.3	6.0	0.429
WIFL	ESF	41.7	44.0	14.7	0.488
SOSA	ESF	25.0	27.3	11.2	0.527
RODO	ESF	25.0	27.3	11.2	0.527
PEFA	ESF	25.0	27.3	11.2	0.527
PRAW	ESF	25.0	27.5	11.2	0.546
BCCH	ESF	41.3	42.3	4.7	0.558
NOBO	ESF	56.9	60.8	12.0	0.615
BLGR	ESF	34.1	38.9	18.1	0.642
VEER	ESF	20.8	31.9	16.5	0.642

Appendix G. Continued.

Species	Cover Type	Observed Indicator Value (%)	Randomized Mean (%)	SD	*P*
AMGO	ESF	43.1	46.4	7.1	0.644
WITU	ESF	43.1	48.5	9.4	0.671
NOCA	ESF	38.4	40.9	4.0	0.715
WEWA	ESF	27.8	36.9	17.2	0.761
CEDW	ESF	38.2	44.1	7.1	0.797
YRWA	ESF	32.9	45.2	8.0	0.946
LASP	ESF	15.2	41.2	19.9	0.952
BLJA	ESF	35.6	41.8	4.7	0.958
PUMA	ESF	17.9	37.3	17.1	1.000
BBWA	ESF	13.9	31.3	16.3	1.000
NOPA	MTF	73.3	44.5	8.4	0.001
PROW	MTF	84.0	47.3	11.4	0.003
CSWA	MTF	63.4	44.2	11.3	0.061
ACFL	MTF	81.1	56.2	15.3	0.062
SUTA	MTF	51.3	43.3	5.9	0.076
PIWO	MTF	67.1	47	13.6	0.100
AMRE	MTF	63.8	51.1	10.2	0.109
RSHA	MTF	60.0	36.8	17.6	0.122
BLBW	MTF	60.0	34	16.0	0.132
TUTI	MTF	45.8	41.5	4.3	0.140
KEWA	MTF	56.5	47.6	8.1	0.162
NOWA	MTF	52.7	36.1	17.1	0.177
TEWA	MTF	50.8	44.8	6.9	0.193
OVEN	MTF	51.3	44.5	8.3	0.222
FICR	MTF	55.9	45.3	14.9	0.240
RHWO	MTF	48.9	44.6	6.8	0.241
MAWA	MTF	53.3	44	14.4	0.256
REVI	MTF	46.9	43.6	5.5	0.257
BTGW	MTF	48.0	36	17.5	0.260
CERW	MTF	55.8	42.1	16.7	0.265
BLPW	MTF	47.4	43.3	7.1	0.270
GCFL	MTF	49.4	45.6	6.6	0.281
CACH	MTF	40.0	30.8	17.5	0.292
YTWA	MTF	42.4	38.6	19.0	0.297
WOTH	MTF	52.5	47.3	8.7	0.299
COHA	MTF	40.0	31.5	15.3	0.311
YTVI	MTF	62.5	53.8	12.2	0.324
BWWA	MTF	50.7	47.6	18.6	0.379
SCTA	MTF	42.4	43.7	18.7	0.404
NAWA	MTF	47.4	43.9	9.4	0.411
CARW	MTF	41.9	41.4	4.3	0.416

Appendix G. Continued.

Species	Cover Type	Observed Indicator Value (%)	Randomized Mean (%)	SD	*P*
RCKI	MTF	51.1	50.8	13.1	0.449
BAWW	MTF	43.8	44.6	8.9	0.489
EATO	MTF	55.4	56.9	15.6	0.490
GWWA	MTF	33.9	35.8	18.6	0.509
PHVI	MTF	41.3	42.6	12.5	0.512
WBNU	MTF	45.9	46.9	8.6	0.532
SOVI	MTF	37.9	41.7	15.2	0.572
RTHU	MTF	41.1	46.5	13.6	0.587
BBCU	MTF	40.0	42.7	10.7	0.700
EAWP	MTF	39.9	44.2	7.0	0.702
CHSW	MTF	41.3	55.2	14.7	0.832
WEVI	MTF	32.5	49.8	19.6	0.850
DOWO	MTF	36.0	41.1	4.6	0.864
LOWA	MTF	20.0	38.2	16.3	0.946
BHVI	MTF	20.0	40.2	17.0	0.956
GRCA	MTF	35.2	42.1	4.7	0.961
GWTE	MTF	20.0	27.7	11.2	1.000
MIKI	MTF	20.0	27.5	11.2	1.000
GHOW	MTF	20.0	27.7	11.2	1.000
WPWI	MTF	20.0	27.2	10.8	1.000
LALO	MTF	20.0	27.2	10.8	1.000
BEWR	MTF	12.3	32.6	17.0	1.000
RBNU	MTF	20.0	27.2	10.8	1.000
GCTH	MTF	20.0	27.2	10.8	1.000

Supplement
Data Integrity

Land Cover Misclassification

Discrepancies in land cover designation existed between digitization of aerial photos, vegetation field surveys, and point count surveys. Taking the point count location OVS62 as an example, the habitat as determined during the annual point counts succeeded from wet prairie through early successional forest to mature forest in the span of 26 months; early successional forest was identified as the primary land cover during the bird point count survey history, coincident with the vegetation survey designation. Conversely, digitization of the aerial photos indicated the site was wet prairie (Fig. A1). We believe this latter classification was simply a result of observer error, as to our eye the habitat looks to be early successional forest (Fig. A2), birds observed from this location are emblematic of early successional forest habitat (e.g., Indigo Bunting, Northern Oriole), and vegetation survey data from two visits suggest that the location was forested (Table A2), with the predominant species being eastern cottonwood (DBH ranged from 4.6 to 9.5 cm) and sandbar willow (*Salix interior*) (mean DBH ≈ 4.6 cm), also emblematic of early successional forest habitat.

Problems such as exhibited by OVS62 were not uncommon and were of sufficient frequency as to make initial use of the dataset difficult. There were 421 separate survey points where bird point counts were conducted. Of these 421, 176 (39%) were not classified to habitat during vegetation surveys (WTP, ESF, MTF). Other discrepancies of note were:

- 6 out of 10 (10%) of study areas had at least one survey location that differed between *Habitat* (as determined by bird point count observers) and *Covertype* (as determined by aerial photo classification);
- 63 of 421 (15.0%) point count locations differed between *Habitat* and *Covertype*;
- 222 out of 2,409 (9.2%) of visits (point count location by date) differed between *Habitat* and *Covertype*;
- 2,738 out of 23,305 (11.8%) of point counts (point count location by date by bird species) differed in *Habitat* and *Covertype*.

There were also four point count locations which were classified to habitat and for which vegetation data was collected but in which no bird surveys were conducted (JAM40, JAM58, OVN29, OVN30).

We found 14 instances, each occurring on 29 or 30 June 2004, in which *Habitat* was recorded as a different cover type after a long series in a different cover type (either from ESF to MTF, or MTF to ESF).

Some changes over time that we noted undoubtedly correctly track changes in habitat. Others of the discrepancies exist simply because land cover was described by different observers within different time periods. Unfortunately, it is unclear which changes in habitat are real and which are in error. However, the classification based upon aerial photo interpretation (*Covertype*) appears to possess a correct classification rate of at least 90%, which is very good relative to other classifications of remotely sensed data.

Figure A1. Aerial photo and interpreted covertype classification for the example point count location, OVS62 (Point location 62 in Overton South Missouri Conservation Area).

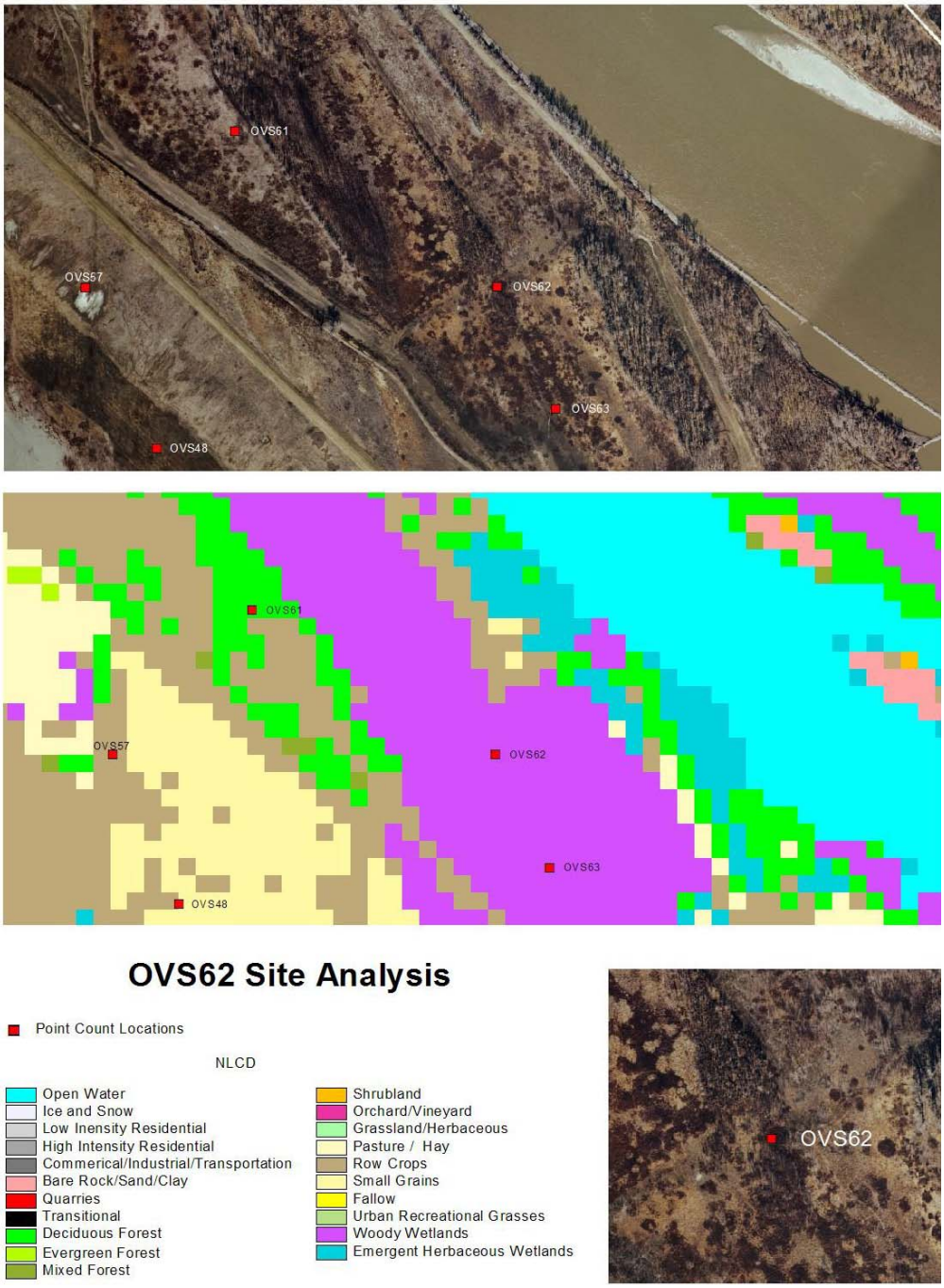


Figure A2. Expanded aerial photo of OVS62 (Point location 62 in Overton South Missouri Conservation Area).

Mis-estimation of Percent Canopy Closure

There were 96 out of 1,402 (6.8%) percent canopy closure readings (unique site, date, and canopy level) with <99% or >101% total canopy closure for a specific canopy level (e.g., Ground (5), Shrub (4), Mid (3), Upper (2), Upper-Upper (1)) and 45 out of 1,402 (3.21%) that had <95 % or >105% total canopy closure for a specific canopy level. These inconsistencies may be due to observer error.

Observation Records without Birds Observed

There were 546 out of 23,852 (2.29 %) point count observations that recorded zero birds observed for all six possible time/distance increments. These records within the point count table were deleted for this analysis.

Table A1. Discrepancy between land cover designation for three different efforts at land cover classification for OVS62, Overton South Missouri Conservation Area. Season is Migration (M) and Breeding (B); land covers are wet floodplain prairie (WTP), early successional floodplain forest (ESF), and mature forest (MTF).

Season	Date	Habitat (Point Counts)	Covertype (Aerial Photos)	Habitat (Vegetation Survey)
M	22-Apr-02	WTP	WTP	ESF
M	29-Apr-03	ESF	WTP	ESF
B	21-May-03	ESF	WTP	ESF
B	09-Jun-03	ESF	WTP	ESF
M	30-Apr-04	ESF	WTP	ESF
B	15-May-04	ESF	WTP	ESF
B	28-May-04	ESF	WTP	ESF
B	28-Jun-04	ESF	WTP	ESF
B	28-Jun-04	MTF	WTP	ESF

Table A2. Vegetation data from the two visits to OVS62, Overton South Missouri Conservation Area.

Date	Total Canopy Closure %	Upper Canopy Closure %	Midstory Canopy Closure %	Shrub Canopy Closure %	Ground Cover Canopy Closure %	Ocular Canopy Height – Upper (m)
21-Jul-03	85	85	NA	10	95	12
24-Aug-04	90	70	45	30	100	14

Errant Coding of Species

There were several "Species" codes given to specific birds observed at each visit which did not match the species code used within the Bird Banding Laboratory (BBL) and/or the Breeding Bird Survey (BBS) bird list. It was decided to standardize the bird "Species" codes using the BBS list due to the availability of a large amount of ancillary taxonomic information (e.g., Species Name, Genus Name, Common Name, AOU number, etc.). Table A3 displays the original "Species" code from the observer's spreadsheet and the matching BBS Code used in the compiled data table. These changes were made based upon correspondence with Neal Young.

We also learned late in the analyses that there was likely a mis-coding for the bulk of the Ring-necked Pheasant sightings. Two hundred forty nine sightings were classified as RPHA, when they probably should have been classified as RPHE. RPHA is the code for Red-necked Phalarope. Unfortunately, there was a possibility the sightings were confounded with actual observations of Red-necked Phalaropes or possibly Wilson's Phalaropes. Because of this uncertainty, we decided to remove the specific analyses involving RPHA; we did not lump the RPHA sightings in with the RPHE sightings.

Table A3. Species codes and the number of observations associated with them which were rectified to correspond with the Breeding Bird Survey (BBS) species code.

Species	BBS Code	Common Name	Total Birds Obs.
AMPE	AWPE	American White Pelican	8
GWTE	AGWT	Green-winged Teal	5
BLWT	BWTE	Blue-winged Teal	2
LSGO	SNGO	Snow Goose	2
GTBH	GBHE	Great Blue Heron	8
SHCR	SACR	Sandhill Crane	2
RNPH	RPHA	Red-necked Phalarope*	369
RODO	ROPI	Rock Pigeon	17
RHCO	RHWO	Red-headed Woodpecker	1
RBW0	RBWO	Red-bellied Woodpecker	2
NOFL	YSFL	Yellow-shafted Flicker	250
EAWP	EWPE	Eastern Wood-Pewee	633
Empidonax	UNEM	unid. Empidonax	1
Empidonax sp.	UNEM	unid. Empidonax	2
RWBB	RWBL	Red-winged Blackbird	212
WMEA	WEME	Western Meadowlark	5
SASP	SAVS	Savannah Sparrow	2
SQVS	SAVS	Savannah Sparrow	1
LCSP	LESP	Le Conte's Sparrow	2
RGBR	RBGR	Rose-breasted Grosbeak	1
BLGR	BGBK	Blue Grosbeak	9
TRSW	TRES	Tree Swallow	22
BANS	BNKS	Bank Swallow	180
NRWS	RWSW	Northern Rough-winged Swallow	15
CEDW	CWAX	Cedar Waxwing	540
WHVI	WEVI	White-eyed Vireo	1
MAWA	MAGW	Magnolia Warbler	34
BLPW	BPLW	Blackpoll Warbler	74
BTGW	BTNW	Black-throated Green Warbler	6
TUTM	ETTI	Tufted Titmouse	17
TUTI	BCTI	Black-crested Titmouse	1070

* Red-necked Phalaropes may be incorrectly identified; the proper identification may be Wilson's Phalarope (*Phalaropus tricolor*) or Ring-necked Pheasant. Red-necked Phalaropes are uncommon late season migrants (mid-May to mid-June).

Redundant Observations

There were 11 out of 23,305 point count observance records that had a second completely identical record with respect to site, date, observer, time, species, and bird counts. The extra records were assumed for this analysis to be a duplicate entry error by the data recorder and the 11 duplicates were deleted from the point counts table. There were 39 out of 23,305 point count observance records that had a second identical record with respect to site, date, observer, xytime, and species but were not identical with respect to bird counts (time/distance categories and/or total birds). For this analysis the second record's bird count numbers for each count field were consolidated with the first record (Table A4).

Table A4. An example of consolidating duplicative bird count survey records.

Garid	Date	Time	<50_3	>50_3	<50_5	>50_5	Total Birds	Common Name
HOW8	29-Jun-04	613	0	0	2	0	2	Northern Cardinal
HOW8	29-Jun-04	613	2	0	0	0	2	Northern Cardinal

The resultant count consolidation becomes:

Garid	Date	Time	<50_3	>50_3	<50_5	>50_5	Total Birds	Common Name
HOW8	29-Jun-04	613	2	0	2	0	4	Northern Cardinal

If the time documented was not identical for records that were matching for site, date, species, and Observer and the time difference was less than or equal to 5 minutes from the minimum time but had different species counts (<50_3, >50_3, FLO_50_3, <50_5, >50_5, FLO_50_5, and Total_Birds), it was considered to be part of the same visit and the individual species counts were consolidated into one unique record. These changes were made based on the assumption that the observer errantly added an additional line for the species on their data sheet, resulting in the duplication. There were 10 out of 23,305 (0.043%) individual records that were affected and the 5 extra records were deleted (Table A5).

Errant Recording of Sample Time

The sample time was to be recorded when the 5-minute survey started, and at the end of the first three minutes, in order to differentiate the 0-3 minute columns and the 3-5 minutes column. In reality this was not done consistently for all observers and all sites. To correct this, a new field was created labeled "First_time" which depicts the minimum time documented for each unique (site, date, observer) combination as long (Table A6).

If the time documented was more than five minutes from the minimum time, it was considered as a separate visit. There were 16 out of the 2,411 (0.66%) total visits which occurred under this scenario. These 16 separate visits were added to the original database (Visits table as VisitID [2412 – 2427]) (Table A7).

Table A5. The 5 unique site/date combinations of consolidated records and the updated Total Birds Observed for those updated records.

Garid	Date	Observer	Time1	Time2	Common Name	Total Birds Observed
LIS53	27-May-03	SMC	712	715	Yellow-billed Cuckoo	1+1 = 2
LIS56	27-May-03	SMC	726	729	American Goldfinch	1+1 = 2
OVS94	04-Jun-03	NBY	732	735	Northern Cardinal	2+1 = 3
SWL1	13-May-03	SGP	850	853	Northern Cardinal	1+3 = 4
SWL8	24-Jun-03	SMC	654	657	American Redstart	2+3 = 5

Table A6. An example for observations made at Lisbon Bottoms, site 29 on April 30, 2002 in which the start time of the point count survey was recoded.

Garid	Date	Time	BBS Code	Total Birds Observed	First Time
LIS29	30-Apr-02	755	BHCO	3	7:55:00 AM
LIS29	30-Apr-02	755	INBU	1	7:55:00 AM
LIS29	30-Apr-02	755	REVI	1	7:55:00 AM
LIS29	30-Apr-02	755	WAVI	1	7:55:00 AM
LIS29	30-Apr-02	756	BGGN	2	7:55:00 AM
LIS29	30-Apr-02	757	CARW	1	7:55:00 AM
LIS29	30-Apr-02	758	NOCA	2	7:55:00 AM
LIS29	30-Apr-02	758	WEME	1	7:55:00 AM

Table A7. Sixteen visits added to the bird count survey database after rectifying the survey start time problem.

VisitID	Garid	Date	Observer	First Time
2412	EBL5	18-Apr-03	NBY	9:37:00 AM
2413	FTL27	29-Jun-04	PS	8:15:00 AM
2414	JAM15	03-Jun-04	SMC	9:24:00 AM
2415	JAM15	03-Jun-04	SMC	9:51:00 AM
2416	JAM17	03-Jun-04	NBY	7:40:00 AM
2417	JAM28	16-Jun-03	SMC	7:28:00 AM
2418	JAM3	03-May-02	NBY	8:04:00 AM
2419	JAM50	02-Jun-04	SMC	7:18:00 AM
2420	OVS62	28-Jun-04	SMC	8:49:00 AM
2421	OVS86	29-Apr-03	SGP	10:02:00 AM
2422	SQCM3	19-May-03	SA	8:30:00 AM
2423	SQCW10	22-May-03	SA	9:15:00 AM
2424	SQCW2	06-May-03	SA	9:38:00 AM
2425	SQCW27	07-May-04	FED	8:23:00 AM
2426	SQCW62	05-Jun-02	SA	9:15:00 AM
2427	STA4	05-Jun-03	SMC	7:31:00 AM

A DVD (1.7 GB) containing an electronic copy of this report,
the complete data set, and maps accompanies this report.