DISTRIBUTION OF BIRDS IN RELATION TO VEGETATION STRUCTURE AND LAND USE ALONG THE MISSOURI AND MADISON RIVER CORRIDORS:
FINAL REPORT

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Executive Summary: *Riparian habitats comprise an extremely small physical area (<1%) of the western United States. Although riparian systems are restricted in area, these areas harbor a wide diversity of birds and other wildlife. We investigated vegetation and land use associations of breeding birds along the Madison and Upper Missouri Rivers from 2002-2005. Understanding how these factors influence avian populations will help in implementing habitat restoration and conservation strategies focused on the river system.*

In 2002, we began establishing long-term avian monitoring techniques along this river system using two different survey techniques: point-count surveys focused on landbirds using habitat adjacent to the river system, and river surveys focused on species that are typically poorly detected with point-count techniques (e.g., waterbirds and waterfowl). We also began compiling and synthesizing existing information on riparian birds and have developed a database consisting of over 300 peer-reviewed articles, technical reports, theses, and dissertations on riparian birds.

In 2003, we continued to establish and initiate bird surveys at 310 point counts, accumulating over 6000 bird observations of 128 different species. Vegetation types at point counts were diverse along the river system, not only including riparian forest habitat but also commonly including grassland, sagebrush, and conifer forest habitats. Abundance and bird species richness (number of species) tended to be higher for riparian forest habitats than other habitats. The most common species using forest riparian habitats included Yellow Warbler, House Wren, and Least Flycatcher, whereas some rare species included Black-billed Cuckoo, Red-eyed Vireo, American Redstart, and Ovenbird. During the river surveys, we accumulated over 6300 bird observations of 58 species along 672 km of river. Common species included American White Pelican, Spotted Sandpiper, and Canada Goose, whereas rare species included Long-billed Curlew, Marbled Godwit, and American Avocet.

We continued river surveys in 2004, using two different approaches for determining the accuracy of the survey method. Overall, we accumulated over 15,000 detections of birds during the river surveys. Detection probabilities for different species were estimated and varied widely among species (64-96%). We related distribution patterns to recreation activity along the river. Avian species richness shows strong associations to different types of recreational activity in this river system, where richness declined with increasing boat activity.

During the 2004-2005 breeding seasons, we did more intensive surveys of breeding birds at 105 randomly selected riparian forest patches (223 point count locations) between Hebgen Dam and Fred Robinson Bridge. At each location we also measured a variety of vegetation attributes (e.g., canopy height and cover, subcanopy density, species cover, etc.), including information on exotic species cover and cattle grazing intensity. We accumulated over 8500 detections of 95 species using riparian forest areas. Some species showed distinct geographic patterns of abundance (e.g., Red-naped Sapsuckers) and bird community composition was distinct in riparian areas between the Madison River and the Wild-and Scenic portion of the Missouri. Based on the National Wetlands Inventory (NWI) Geographic Information System (GIS) coverage completed so far (from Great Falls to Fred Robinson Bridge) by the Bureau of Land Management, we determined if bird communities and vegetation structure were distinct among land cover classifications. Although there was some weak evidence for distinct

vegetation structure and bird communities, there was much variation in some categories, potentially making GIS-based approaches (in the absence of other information) limited. Our predefined vegetation type classifications did a better job than NWI classifications for discriminating bird communities, but much variation still existed. We developed models to estimate the influence of local vegetation structure, local disturbance, patch structure, and landscape disturbance on bird density, occurrence, and species richness (# of bird species). Overall, individual species were correlated with many factors, but landscape factors were correlated with species distribution less frequently than more local measures. For some species and for species richness, correlations varied by region, suggesting that recommendations for one region may not be applicable to other areas along the river.

During 2003-2004, we also monitored nest success and physiological condition (refueling rates) of birds using riparian areas that differed in sub-canopy vegetation structure. We documented over 560 nesting attempts made by 20 open-cup nesting species. The most common nesting species were Yellow Warbler, American Robin and Least Flycatcher. Nest success across all plots and all species was 29%, with success being significantly higher on dense plots than on sparse plots. Similar to patterns of nest success, estimates of refueling rates by migrant songbirds appeared to increase with sub-canopy vegetation structure. Overall, patterns of nest success and refueling rates were not correlated with bird abundance, suggesting that information on abundance alone might not provide an adequate measure of habitat quality.

Once NWI GIS layers are completed for the river system, GIS-based analyses on how local and landscape factors can influence bird distributions should be conducted. Given that information, it will be important to revisit habitat models to determine what factors best explain species distribution, whether GIS-only models can adequately predict bird distributions. GIS-based analyses can be used to develop maps of predicted distributions for riparian areas across the entire river system. Results thus far suggest that managing local habitat structure will be critical for maintaining bird diversity, but the key habitat components differ by region. Together, these results will help in understanding and predicting the influences of land use and disturbance on bird communities, monitoring relative success of habitat restoration, and can be used in planning for restoration and conservation strategies.

Background

Riparian habitats in the western United States comprise an extremely small physical area, amounting to less than 1% of the West (Knopf et al. 1988), yet as much as 90-95% of cottonwood-willow riparian habitats have been lost in the West (Johnson and Carothers 1981). Although riparian systems are restricted in area, these areas harbor a wide diversity of birds, as well as other plants and animals (Mosconi and Hutto 1982, Bock and Strong 1990, Saab et al. 1995). In fact, these areas have been referred to as the “aorta of an ecosystem” (Wilson 1979).

Although riparian areas contain a high diversity of wildlife, these systems have been severely stressed by a variety of anthropogenic factors, including river damming and changes in hydrology, deforestation and habitat loss, human recreation, grazing, and other disturbances (Johnson 1992, Rood and Mahony 1995, Scott et al. 1997, Miller et al. 2003, Scott et al. 2003, Sweeney et al. 2004). These anthropogenic stressors can have negative effects on wildlife populations (Mosconi and Hutto 1982, Dobkin et al. 1998, Fletcher et al. 1999, Rottenborn 1999, Miller et al. 2003, Scott et al. 2003). For example, as human development increased in riparian areas of Colorado, riparian areas tended have fewer native trees and shrubs, and these areas supported fewer species of breeding birds (Miller et al. 2003). Likewise, Scott et al. (2003) found that bird diversity was negatively correlated with grazing intensity along the Upper Missouri River in Montana (see also Dobkin et al. 1998, Krueper et al. 2003).

We investigated factors that influence distributions, reproduction, and physiological condition of birds using the Madison and Upper Missouri River system. Understanding how these factors influence avian populations will help in implementing habitat restoration and conservation strategies focused on the river system. We had the following objectives:

1) Synthesize known research information dealing with birds of the Missouri system;
2) Establish a long-term monitoring plan that incorporates sampling along the river corridor
3) Identify a meaningful series of vegetation types for the purposes of sampling design and habitat-relationships modeling;
4) Determine bird distribution relative to vegetation type, human settlement, and human recreational activity; and
5) Estimate nest success and physiological condition of landbird species that occur in association with disturbance.

Methods

Synthesis of existing literature. We conducted literature searches and compiled a database of relevant information regarding riparian birds and the Upper Missouri and Madison Rivers. In addition, we summarized information regarding known management issues for key bird species, based on their relative abundance and their Partners in Flight and U.S. Fish and Wildlife Service designations, which are distributed along the Madison and Upper Missouri Rivers (see Appendix 1). Summaries for key species were based on relevant research and monitoring of birds in the western United States.

Long-term monitoring plan. In 2002-2003, we established point count transects along the Madison and Upper Missouri Rivers, between the confluence of the Madison and just east of Fred Robinson Bridge along the Missouri (Fig. 1, Appendix 2). We divided the river into approximately 20-km sections, and randomly picked a transect location, given the constraints that the location must be accessible and we had to be granted landowner permission. Each transect consisted of 10 point count stations, spaced approximately 300 m apart (Fig. 1; Hutto and Young 2002). This design was used to be consistent with the Landbird Monitoring Program in the north-central Rocky Mountains, which is a long-term monitoring program intended to provide information on population trends and habitat relationships of a large suite of bird species (Hutto and Young 2002).

In 2003, we surveyed birds at these long-term transects to provide an anchor for future monitoring and trend analyses. We used a standard point-count protocol (Hutto et al. 1986). We visited each point count once between May 25-July 10, 2003. Surveys were conducted between sunrise and 5 hours after sunrise and were not conducted during high wind velocities (≥ 20 km/hr) or during precipitation. During surveys, observers recorded all birds seen or heard, including how individuals were detected (song, visual, or call), sex of individuals, and distances of birds from the center point. Distances (m) to birds were estimated using a rangefinder.

In addition to land-based point count techniques, we also developed and initiated methods to survey and monitor river birds (i.e., waterbirds and raptors actively using the river for foraging and/or breeding). We surveyed river bird communities along the Madison and Upper Missouri rivers by canoe, between 20 May-10 July, 2003-2004 (Fig. 2). Two observers floated the river in a single canoe, recording all non-passerine birds (passerines were more effectively sampled using point count surveys described above) seen using the river or flying above the river. For each detection, we recorded the species, sex, and location along the river (in water, on island, left or right bank of river, or in flight). We also recorded all nests observed of herons, raptors, and swallow nesting colonies. All observations were recorded with a Global Positioning System.

To help determine the accuracy of the boat-based river survey, we used a simultaneous double survey approach in 2004 (Magnusson et al. 1978, Graham and Bell 1989). Double surveys are a general technique where two observers independently sample the same area for species of interest. Double surveys consisted of two simultaneous surveys, where two canoes (2 observers/canoe) independently surveyed areas. Detection probabilities were estimated by considering the approach as a closed-population mark-recapture model (Magnusson et al. 1978, Graham and Bell 1989). We also determined how observer, group size, river width, and survey speed influenced detection probabilities for common species.

In 2003, we surveyed river birds from Reynold’s Pass (just downstream of Quake Lake) through Fred Robinson Bridge. Between these two extents, the only areas we did not survey included a short stretch below Ennis Lake, Canyon Ferry, upper Hauser Lake, and the Great Falls metropolitan area (Fig. 2). In 2004, we divided the entire stretch of river into 23 18-40 km segments, based on available public access locations to the river. From these 23 segments, we randomly selected 14 segments for surveys (stratified geographically), and double surveys were conducted on a random sample of 6 of the 14 segments surveyed. In 2003, we surveyed each area once, in 2004 we surveyed each area twice.

Meaningful vegetation types. For vegetation types to be meaningful for understanding bird communities, vegetation types should reflect birds that use the areas. To determine meaningful vegetation types relevant to bird communities, we used the following approaches. First, at each point count station, we classified vegetation based on the dominant species (Appendix 3). Second, we classified point count locations based on the National Wetlands Inventory (NWI) geographic information system (GIS) recently developed for part of the river system, using the primary category for the point count area (within 50 m of the center point). Third, we made detailed measurements of vegetation structure and composition at point counts (see below). We then used data on bird abundance at point counts to determine if vegetation classifications (both our classifications and NWI classifications) contained distinct bird communities using Multivariate Analysis of Variance (MANOVA), linear discriminant analysis, and non-metric multidimensional scaling (a non-parametric ordination technique).

Bird distribution in relation to vegetation, recreation, and land use. To estimate bird distribution in relative to vegetation and land use, we focused on birds breeding in forested riparian habitats between Hebgen Dam and Fred Robinson Bridge. We established point count stations along the Madison and Upper Missouri Rivers, between Hebgen Dam on the Madison and just east of Fred Robinson Bridge along the Missouri in 2004-2005 (Fig. 1, Appendix 4). To select patches, we stratified the river into three geographical sections: the Madison River, the Missouri between Three Forks and Great Falls ("Upper Missouri" hereafter), and between Great Falls and Fred Robinson Bridge ("Lower Missouri" hereafter). Within each geographical section, we randomly selected 35 deciduous riparian patches for surveying, based on digital orthophoto quarter quadrangle images (DOQQ). The only constraints on the site-selection process was that sites were at least 50 m wide, sites were separated by > 400 m (based on semivariogram analyses on 2003 data), and landowners granted us permission to survey birds on their property. We used a 50-m width criterion to facilitate site identification on DOQQ maps. For each patch selected, we overlaid a 150m x 150 m grid, parallel to the main axis of the riparian patch, with a potential point count location in the center of each grid cell. We sampled all potential point locations within each patch (1-8 points/patch). For each point count, we surveyed birds within 50-m of the point count center twice between 25 May-10 July. Two observers surveyed each point, with each observer surveying the point once.

At each point-count station, we measured vegetation after one of the two bird surveys. Vegetation was measured at 4 sampling locations within the point-count area: one at the center of the count and three at locations 25 m from the center, at 0°, 120°, and 240°. At each sampling location we measured vegetation composition and structure for two plots: 5-m and 11.3-m radii. Within the 5 m plot, we estimated shrub cover (by species), cottonwood sapling cover (by species), ground cover structure, and exotic species cover (by species), based on overlapping ocular percentages. Ground cover categories included woody, grass, forb, standing dead vegetation, litter, bare ground. Horizontal cover was estimated using a cover board (2 × 0.5 m), where we counted the percentage of squares covered at four height categories (0-0.5, 0.5-1, etc.) in four cardinal directions, 5 m from the cover board (Nudds 1977). We used the number of cow pies within each 5 m plot as an index for grazing intensity (Beever et al. 2003). Within the 11.3 m plot, we counted the total number of trees (by species) and snags by size, based on three dbh categories: small (8-23 cm), medium (23-38 cm), and large (>38 cm). We measured tree height (using a clinometer), and shrub height (shrubs > 1 m) at each location. We estimated canopy cover by averaging 4 densiometer readings (one in each cardinal direction). From these measurements, we estimated a variety of metrics related to vegetation structure and diversity. Many of these measurements were highly correlated, so we subjected variables to a Principal Component Analysis (PCA; Table 1) with varimax rotation on the correlation matrix to capture the variation measured in vegetation and determine what variables were explaining this variation. PCA is a data reduction technique that results in new independent (or uncorrelated) variables (factors or principal components) that are linear combinations of raw variables and capture most of the variation in the data set.

Land use in and around riparian sites was quantified using GIS. Using DOQQ photographs, we measured patch size (in hectares), and patch width (the widest distance orthogonal to the river for each patch) for each site. We consider these measures as indices of potential impacts from habitat fragmentation. Within 1-km of the center of each site, we measured road density (m/km^2) and the distance to nearest development as indices of development pressure. Finally, we measured the distance to the nearest campground as an index of recreational pressure on birds using riparian patches.

From Great Falls to Fred Robinson Bridge (approximately one third of the study area), we further estimated land cover using the MTSILC3 (Montana Satellite Imagery Land Cover Classification, 3rd generation) 30-m resolution layer developed by the Spatial Analysis Lab at the University of Montana. We focused on this area because it is currently the only portion of the study area where the National Wetland Inventory (NWI) GIS layer is completed. The NWI layer is an important layer for land cover analysis in riparian systems because other layers typically have poor classification of riparian habitats (see below). For these analyses, land cover categories included: human development, agriculture, grassland, sagebrush, shrub, riparian forest, deciduous (aspen), conifer, water, and rock (talus).

Using these local, patch, and landscape measures, we developed models to predict species occurrence, density, and species richness. Because we only had NWI layers for one third of the river system, we did not include this information. However, we do provide an example of how NWI layers could be included into the modeling process to help provide important information for land managers. For species with >100 detections, we modeled bird density using linear regression (see below for how density was estimated). For species with >10 detections but <100, we modeled species occurrence using logistic regression. For species richness (number of species detected/point), we used Poisson regression. For modeling bird density, we estimated density for each species per patch and considered the patch as the sampling unit (*n* = 105). For modeling species occurrence and species richness, we considered each point count location as a sampling unit (*n* = 223), but considered points within patches as correlated repeated measures (Johnson and Igl 2001). To predict species density, occurrence, and species richness, we compared the following general models:

Model	Number of variables	Interpretation
1) Local vegetation	3-4	Vegetation structure, based on PC1-3, PC5 (Table 1) drives habitat use. PC5 (snags) was only included in models for cavity nesters.
2) Non-linear local vegetation	6-7	Same as model #1, but relationship is non-linear to account for common patterns of species reacting to moderate amounts of vegetation structure (e.g., a Gaussian response). This was accomplished by adding quadratic terms to model #1.
3) Local disturbance	3	Local disturbance, based on PC4, PC6-7, drives habitat use.
4) Patch	2	Patch size and/or width drive habitat use.
5) Landscape disturbance	7	Landscape disturbance (road density, distance to campgrounds, distance to development) drives habitat use.
6) Local vegetation + local disturbance	6-7	Local habitat gradients (both natural vegetation and disturbance) drive habitat use.
7) Local disturbance + landscape disturbance	10	Both local and landscape disturbances influence habitat use.

8) Patch + geographic	4	Patch size and/or width drive habitat use and there is a geographic effect based on differences in regional abundance of species.
9) Patch × geographic	8	Patch size and/or width drive habitat use, but these effects differ by geographic section of the study area.
10) Local vegetation + patch	5-6	Both local vegetation and patch structure influence habitat use.
11) Local vegetation + geographic	5-6	Local vegetation drives habitat use and there is a geographic effect based on differences in regional abundance of species.
12) Local vegetation × geographic	11-12	Local vegetation influences habitat use, but these effects differ by geographic section of the study area.
13) Local veg + local dist + patch + landscape + geographic	17	All of the above are important predictors of habitat use. This is the global model.

We compared these models using a model-selection criterion, Akaike's Information Criterion (adjusted for sample size, AICc; Burnham and Anderson 1998). AICc weighs the likelihood of a statistical model, such as linear regression, given the data while discounting the value of a model for increased complexity (number of parameters), thus providing an objective measure of parsimony when comparing habitat use models. We present results based on the most parsimonious model investigated (i.e., model with the lowest AICc).

Finally, we also investigated the potential influence of different types of recreational activity on river birds in the study area. During river-based surveys, we marked locations with a GPS of all birds detected and all recreational activity. We broadly classified recreational activity into three forms: anglers, non-motorized boats (e.g., canoes), and motorized boats. We then used similar regression approaches as above to estimate the influence of recreational activity on river bird habitat use and species richness.

Nest success and physiological condition. While surveys provide important information on the distribution and abundance of birds, presence in a habitat does not necessarily imply suitability of that habitat for sustaining healthy populations (Van Horne 1983). Therefore, it is important to consider other measures, such as density of nesting pairs and their reproductive performance, when assessing the quality of habitat for breeding birds. Riparian habitats are known to support greater bird diversity and abundance than any other forest type (Mosconi and Hutto 1982, Knopf et al. 1988, Saab et al. 1995). The fact that riparian areas are extremely limited in extent makes it even more important to identify factors that contribute to maximizing the quality of these habitats for breeding birds.

Along the Wild and Scenic section of the Missouri River, bird species richness and the abundances of 17 species, including five species of concern, were positively correlated with the structural complexity of riparian vegetation, particularly the density and diversity of understory vegetation (Scott et al. 2003). To further examine how understory vegetation influences the quality of riparian areas for birds, we assessed breeding bird abundance and nest success at nine study plots within mature cottonwood riparian habitat along the Madison and upper Missouri rivers.

All possible study sites were initially characterized by visual assessment on the ground or while floating between Varney Bridge on the Madison River and Canyon Ferry Reservoir. Study sites were then selected based on accessibility, landowner permission, and vegetation density to represent a gradient of dense, moderate, and sparse understory vegetation. In 2003 and 2004, we conducted nest searching and monitoring of nests following Martin and Geupel (1993) and estimated nest survival (Mayfield 1961, 1975) and success of breeding bird pairs at each study site. Because understory-dependent species appear to be most sensitive to loss of structural complexity within riparian habitat (Scott et al. 2003), we focused nest searching efforts on species nesting in the shrub and sub-canopy layers. To verify initial classification of plot types and assess how density of vegetation within mature cottonwood stands may influence bird abundance and reproductive performance, we measured vegetation variables around nests of two common nesting species and around random points at each site.

In addition to being important breeding areas for birds, riparian habitat patches also provide stopover sites for birds needing to replenish their fuel supplies during migration (Skagen et al. 1998). Differences in vegetation structure and composition within riparian habitats may affect the quality and availability of food resources for migrant birds, as well as their vulnerability to predation. Recent studies have found that ratios of circulating blood plasma metabolites, particularly triglycerides, can be used to estimate the rates at which birds are able to accumulate fat (Schaub and Jenni 2001, Guglielmo et al. 2002). To assess whether the density of understory vegetation influences the refueling performance of migrant birds using cottonwood riparian habitat, we used mist nets to capture migrant birds at six intensive study sites during late summer and early autumn of 2003. We estimated rates of mass change (i.e. fat deposition or refueling rate) at each study site by comparing triglyceride levels in blood collected from migrant Wilson's warblers.

Results and Discussion

Objective 1) Synthesis of literature

We developed a database of riparian bird literature, focusing on the western region of the United State but also including relevant information from other regions. We have currently gathered over 300 references from peer-reviewed articles, technical reports, theses, and dissertations. We synthesized this information into a species-based framework. Based on references gathered from research and monitoring in the western United States, we compiled a summary of important characteristics of species (Table 2) and known responses to management issues (Table 3). We are currently in the process of making this information available to the general public over the internet (www.avianscience.org).

Objective 2) Long-term monitoring plan

Landbird approach. We developed a long-term monitoring plan and established monitoring routes throughout the river system. Point count survey locations are noted in Appendix 1. In 2003, we modeled our sampling approach after the Northern Region Landbird Monitoring Program (Hutto and Young 2002). When applying this approach to river bird communities, three salient issues emerged: 1) spacing points 300 m apart tended to miss important, albeit small, riparian areas, 2) conducting 10 points/transect was difficult in some areas because of problems in access, such as river crossings, slowed sampling, and 3) in riparian areas, detection profiles as a function of distance from the center point fell off markedly after 50 m (Fig. 3). In the future we recommend reducing distances between adjacent points to 150 m (see 2004 below), which is warranted (in terms of statistical independence) if point count radii are fixed at 50 m, and reducing transects to 8 points/transect.

In 2004-2005, our point counts were focused in randomly selected forest riparian patches along the river system. For these counts, we sampled each point twice during the breeding season and we constrained count radii to 50 m (based on Fig. 3). Overall, one sampling visit only picked up approximately 70% of the species detected across both visits (Fig. 4). In addition, detection profiles declined with distance to individuals for many species, even within 50 m (e.g., Fig. 5).

To accurately sample diverse riparian communities, more than one visit is important for estimating species richness and detecting less-common species, which was also recommended by Dobkin and Rich (1998) for western riparian systems. Furthermore, detection probabilities need to be addressed for point counts. There are a variety of ways to deal with detection probabilities (Nichols et al. 2000, Buckland et al. 2001, Farnsworth et al. 2002), each of which makes certain assumptions. Distance sampling approaches or removal models are two approaches that only require some ancillary data that can easily be recorded with conventional point counts; these methods need to be tested to assess their utility. Distance sampling only requires that distances to individuals be recorded, whereas removal models require that detections be recorded based on time intervals within point counts.

To address detection probabilities in riparian patches, we used a removal model that incorporated distance and observer effects to estimate detection probabilities for species in which we recorded > 100 detections (Table 4). This approach simultaneously addresses multiple sources of bias that can occur when surveying birds, including the singing frequency of different species, observer bias, and distance-related detection issues. To use this approach, we divided our 10-minute counts into 4-equal time intervals (0-2.5 minutes, 2.5-5 minutes, etc.). Using equal time intervals, with a minimum of 3 intervals, allows analysis with conventional mark-recapture programs. We used Program MARK (White and Burnham 1999) to estimate detection probabilities with covariates including observer identity and distance to detections (see Farnsworth et al. 2002, Moore et al. 2004 for details). Based on these analyses, detection probabilities for most of the species we investigated were influenced by both observer and distance to individuals (Table 4). For example, detection probabilities of yellow warblers declined with increasing distance to individuals, but this pattern differed for each observer (Fig. 5).

Given that observers can and do vary in detecting species, long-term monitoring approaches should address detectability issues when estimating long-term population trends. This is critical because typically long-term monitoring plans involve many different observers, and inevitably some observers will be better than others at detecting birds. Intensive training helps address this issue, but in our study, we initially trained observers for 1.5-2 weeks prior to the commencement of surveys, and marked observer effects were still apparent. Our approach to estimating detection probabilities could be a viable and cost-effective way to provide more rigor and stronger inference in long-term monitoring for riparian birds.

Waterbird approach. We used a boat-based approach to survey waterbirds along the river system. Overall, one sampling visit only picked up approximately 59% of the species detected across both visits (Fig. 4). Detection probabilities of species, estimated using the double survey approach, for each observer ranged from 57-89%, and combined detection probabilities (the likelihood of at least one observer detecting an individual) were consistently high (88% across all species; Table 5). Detection probabilities across species were positively correlated with body mass (Fig. 6). Detection probabilities for some species were influenced by observer, whether species were in groups or alone, and river conditions, with groups being more detectable and individuals in slow-flowing and wide sections of river being more detectable (Fig. 7).

Because of the temporal variability in species detection (Fig. 4) and the lower detection probabilities for small-bodied birds (Fig. 6), we recommend that at least two visits should occur for future monitoring of water birds and that counts should be adjusted by estimating detection probabilities. Double surveys can be conducted on a subset of surveys, and can efficiently estimate detection probabilities for water birds. To do so, double surveys should be done on a random subset and this subset should cover the entire habitat gradient surveyed. For example, density estimates using data collected only from observer 1 were similar to estimates from both observers (Table 6).

Objective 3) Meaningful vegetation types

Based on habitat characteristics measured at long-term point count monitoring plots, we developed a series of vegetation types that help describe the overall structure of vegetation along the Missouri system, focusing primarily on riparian vegetation types (Appendix 4). We have identified two series of vegetation types: 1) a fine-resolution and 2) a course-resolution vegetation series. Although the fine-resolution vegetation types provide more detailed information, we will focus on the course-resolution vegetation types for most analyses to attain satisfactory sample sizes within each category.

We evaluated NWI coverages using two approaches. First we determined if NWI layers were better at delineating riparian habitat than other existing coverages. We compared NWI layers to the SILC III coverage. Overall, SILC III consistently overestimated riparian coverage; that is, SILC often classified areas as riparian forest when in fact the areas were not forest (Fig. 8-9). NWI layers did consistently identify riparian forest along the river system.

Based on the current NWI coverage, which samples one third of the river (from Great Falls to Fred Robinson Bridge), we determined if local vegetation measurements and bird communities could discriminate among NWI land cover categories, which would suggest that these categories provide meaningful classifications for understanding and predicting habitat and bird communities along the river system. Overall, our detailed vegetation measurements could discriminate among land cover (Fig. 10a); however, one common category, deciduous forest, showed much variation in vegetation structure. An analysis to determine if bird communities were distinct among categories was statistically significant (Fig. 10b), but patterns were less strong than for vegetation structure. Overall, one land cover category, deciduous forest, showed the entire gradient in bird community variation.

We repeated analyses for the vegetation types we identified, listed in Appendix 3. As expected, these vegetation categories were more distinct in terms of overall vegetation structure ($P < 0.001$) and bird communities ($P < 0.001$). This is not unexpected, because these categories were made while visiting sites and are more refined than course NWI categories. Nonetheless, implementation of using these categories would require managers or biologists to visit areas, and this type of information may not be used for interpolation across broad spatial areas using GIS.

GIS layers need to identify key vegetation components of riparian forests to better understand and predict habitat and wildlife conditions across broad spatial scales. The current NWI layer is useful for delineating riparian habitat relative to other existing GIS layers, and we recommend finishing this layer for the entire river system. However, we need to continue refining GIS layers based on aerial photographs and remote sensing to be able better understand local variation in vegetation structure.

Objective 4) Bird distribution in relation to habitat and recreation.

The long-term monitoring transects in 2003 covered all vegetation types along the river system, from agriculture to cottonwood riparian habitat (Fig. 11). When comparing among vegetation types, both the number of species and the relative abundance of most species were greater in riparian forest vegetation (willow, cottonwood) than other vegetation types (Figs. 12, 13). The rank abundance of the most common species also varied among vegetation types (Table 7). However, because many of these points contained >1 vegetation type, a more formal analysis controlling for the proportion of each vegetation type within points needs to be conducted when NWI GIS layers are completed for the entire river system. Such an analysis would greatly increase our ability to predict changes in bird communities with changes in habitat from restoration or other activities.

During the 2004-2005 breeding seasons, we focused on rigorously examining how vegetation, recreation, and other anthropogenic activity (e.g., cattle grazing) influences bird communities by integrating GIS information, riparian-based bird surveys, and detailed habitat measurements.

Overall, variation in local habitat was explained by 7 independent structural vegetation and disturbance gradients, based on the PCA (Table 1). Four gradients explained vegetation structure (PC1-3, PC5), whereas three gradients of local disturbance were evident (PC4, PC6-7; Table 1). The gradients derived from the PCA made biological sense. We interpret PC1 as a gradient of small tree cover, which was driven by mountain alder and water birch along the river. We interpret PC2 as a shrub cover and diversity gradient, which was driven by the cover of willow shrubs (*Salix* spp.) along the river. For PC3, canopy cover, canopy height, and the number of large trees loaded highly, and this gradient was driven by the presence of large cottonwoods along the river. We interpret PC4 to reflect exotic species cover and diversity, which was driven by common exotic forbs along the river, including leafy spurge (*Euphorbia esula*), hound's tongue (*Cynoglossum officinale*), and Canada thistle (*Cirsium arvense*). PC5 was interpreted as a gradient in medium to large snags. For PC6, conifer trees and tree diversity loaded high, which was driven by the presence of junipers (which in turn, increased tree diversity). Finally, PC7 was clearly a gradient in grazing intensity, independent of other vegetation structural variables.

Vegetation structure varied geographically along the river system (Fig. 14-15). For example, dominant cottonwood species differed geographically, with narrowleaf cottonwoods dominating canopy cover until just past the Gates of the Mountains, where narrowleafs were replaced by plains cottonwoods (Fig. 14). There was also an interesting geographic pattern in willow shrubs (*Salix* spp. not including the peach-leaf willow, which was characterized as a tree), where very few willow shrubs occurred in the portion of the river dominated by plains cottonwood, but willow shrubs were common throughout the region dominated by narrowleaf cottonwood (Fig. 14). A formal analysis of vegetation structure and geographic section showed that, overall, vegetation structure among sections were distinct (Fig. 17).

One land use practice that showed strong correlations with vegetation structure was the relative cattle grazing intensity (Fig. 16a). Grazing appears to set an upper limit on sub-canopy/shrub cover; that is, when grazing is absent, areas may or may not have a strong sub-canopy component, which is likely based on factors such as geomorphology and succession history. However, with grazing present, sub-canopy growth and development is likely impaired, effectively setting an upper bound on cover. We also observed similar patterns with exotic species cover (based on the PCA; Table 1), where shrub cover declined with increasing exotic species cover (Fig. 16b).

Avian communities also exhibited geographic differences along the river system. While community composition was distinct among geographic sections (Fig. 17), species richness and total abundance of birds did not show strong patterns geographically (Fig. 18). Some shrub-nesting species, such as the Song Sparrow (Fig. 19) and Willow Flycatcher, showed geographic patterns that reflected geographic patterns in shrub cover (Fig. 15). Brown-headed Cowbirds tended to be more abundant along the Madison River, whereas some cavity nesters, such as the House Wren and European Starling, tended to be more abundant further downstream (Fig. 20).

We developed models to predict the likelihood of occurrence, species density, and species richness as a function local vegetation structure, grazing intensity, riparian patch size, and landscape structure. Overall, local vegetation measures tended to explain bird density more often than bird occurrence, whereas larger-scale measures more frequently explained bird occurrence (Tables 8-9, Fig. 21a). Cushman and McGarigal (2004) also recently noted a similar pattern with avian communities in forested regions of Oregon.

When we look at the correlations of species occurrence and density (Tables 10-11), what is immediately apparent is that different species showed both positive and negative correlations with vegetation, patch attributes and landscape context. For vegetation structure, these correlations make sense in terms of the nesting requirements and foraging strategies of each species. For example, a number of species were positively correlated with shrub cover/diversity, and these species typically nest in shrubs, whereas those species that were negatively correlated with shrub cover typically nest in the canopy and are aerial foragers.

The influence of patch and landscape structure were more variable, and tended to occur less frequently in models (Fig. 21c). For landscape disturbances, both distance to campgrounds and road density did not enter into any models for bird occurrence or density. Patch structure more commonly entered into models, but often these effects were mixed, by which we mean that effects were different in different regions. For example, Spotted Towhees exhibited strong correlations with patch width along the Madison river (see also Rottenborn 1999), but no pattern along the Lower Missouri River (Fig. 22).

Geographic effects were also very apparent in the best model to explain species richness (Fig. 23). Based on this model, species richness exhibited a strong positive correlation with shrub cover and diversity along the lower Missouri River—a pattern that had been documented before in that region by Mike Scott and colleagues (Scott et al. 2003). However, species richness showed strong negative correlations with shrub cover and diversity just approximately 200 kilometers upstream along the Madison River. These different effects are likely driven by the fact that different vegetation structure is likely limiting in different regions. Along the Madison, willow shrub cover is plentiful (Fig. 15), yet large cottonwood stands are less common (narrowleaf cottonwoods tend to be smaller and provide less canopy cover than plains cottonwoods), whereas along the lower Missouri, shrub cover is more rare and large plains cottonwood stands dominate the deciduous riparian patches.

While these models are useful for understanding factors influencing habitat use by breeding birds, it would be valuable to provide links between habitat-relationship models and GIS databases. This could be possible once the NWI layer is completed for the entire river system. As an example of this potential approach, we modeled the relative abundance (birds/point) of Least Flycatchers between Great Falls and Fred Robinson Bridge. We only used information for this area because this is the only area where GIS layers are complete. Overall, a landscape only model was sufficient in modeling Least Flycatcher abundance (based on AICc), and within the candidate landscape variables, the most parsimonious model only included the amount of riparian habitat in the landscape (Fig. 24). From this model, we can predict the abundance of flycatchers in riparian habitats throughout this part of the river system, by linking the abundance model to NWI/SILC maps of the river (Fig. 25). Interestingly, using data from the entire river system suggested that local vegetation was the best predictor of flycatcher density (Table 8); however, in this analysis GIS-based information was relatively crude.

Such predictive maps will be an extremely valuable resource to managers, conservationists, and bird enthusiasts. Once the NWI GIS layer is completed for the entire river system, we can determine if such layers are sufficient for predicting species distributions. Predictive maps like these can be made available to the public over the internet. These maps could be used to evaluate potential restoration and conservation options, delineate areas of conservation concern, and determine where avian "hotspots" likely occur (areas with high diversity or abundance of key species).

To estimate the influence of recreational activity on birds, we focused on whether and how activity influences river birds by recording all locations of activity during our boat-based river bird surveys. Recreational activity ranged from anglers walking along the river's edge, to motorboats traveling down the center of the river. During these surveys, densities of some bird species and bird groups tended differ in the presence and absence of recreational activity (Fig. 26). For example, ducks (as a group) and some shorebirds occurred in lower densities in the presence of boating activity, whereas Canada Goose occurred in higher densities. Avian species richness changed dramatically as a function of recreational activity. Overall, 42% of the variation in species richness could be explained by the frequency of angler and boats along the river ($P < 0.008$ for both factors). The direction of these effects differed, with increases in angler activity (along shores; not in boats) being correlated with slight increases in species richness, whereas increase in boat activity was strongly correlated with declines in species richness (Fig. 27). While this information provides an important guide in understanding the effects of recreation on river bird distribution, we are currently beginning analyses to estimate the spatial extent of these effects (using spatial statistics; Rossi et al. 1992, Dale et al. 2002), which should be useful in attempts to mitigate the ever increasing recreational use of the river system.

Objective 5) Nest success and physiological condition of landbird species

Nest Success. During the 2003 and 2004 breeding seasons we documented over 560 nesting attempts made by 20 open-cup nesting species on the nine intensive study sites (see Appendix 6 for study site locations). The three most common nesting species were Yellow Warbler, American Robin and Least Flycatcher, for which we documented 208, 91 and 74 nesting attempts, respectively. We were able to determine the fates of 516 nests. Proportional nest success across all plots and all species was 44% (136 of 307) in 2003 and 50% (104 of 209) in 2004. Across years, plots consisting of sparse vegetation had the lowest proportional nest success (39%; 80 of 207), while moderate (47%; 43 of 92) and dense (54%; 117 of 217) plots had successively higher proportional nest success.

The large number of Yellow Warbler nests for which we were able to determine nest fate ($n = 200$) facilitated calculation of Mayfield estimates of nest survival rates for this species for each of the three plot types (Table 12; Fig. 28). Across all plots 45.5% of the Yellow Warbler nests for which fate was determined, produced at least one Yellow Warbler fledgling. Mayfield estimates of survival probabilities for these Yellow Warbler nests were significantly higher on plots with dense vegetation compared to plots with sparse vegetation ($p = 0.006$), while plots with moderately dense vegetation had intermediate nest survival. Proportional nest success for Least Flycatchers was also significantly higher on plots with dense versus sparse vegetation ($p < 0.001$; 62% and 22%, respectively). For American Robin nests, overall proportional success was 49% and did not differ significantly across plot type. These results provide considerable evidence that, by influencing nest success, the vegetative characteristics of cottonwood riparian habitat can significantly influence the quality of these habitats for breeding songbirds.

Physiological Condition during Fall Migration. Blood Plasma Triglyceride levels indicated that refueling rates for Wilson's Warblers (*Wilsonia pusilla;* $n = 105$) increased as vegetation density increased ($P = 0.06$; Fig. 29). Triglyceride levels were also positively correlated with minutes since sunrise, reflecting the ability of migrants to begin accumulating fat stores following pre-dawn arrival at riparian stopover sites and initiation of foraging activity. In addition, 16 species were captured during the fall migratory period that were not detected on the intensive plots during the summer breeding season (Table 13). Six of these species were not detected at any of 310 point count stations surveyed during 2003 or 2004. Many of the species shown in Table 12 breed in coniferous upland habitats but use riparian areas as travel corridors during migration. Thus, the diversity of wildlife using riparian habitats may be much greater when we consider the entire annual cycle instead of simply the wildlife breeding period (summer).

Conclusions and recommendations

Our research and monitoring of avian populations along the Madison and Upper Missouri Rivers have provided an important, and much needed, baseline for management and conservation issues for wildlife populations in Montana. While this information should be generally useful for targeting important issues related to riparian conservation, we specifically recommend the following:

1. *Riparian forests as an 'aorta' of river ecosystems*. Overall, the abundance and diversity of birds was greater in cottonwood and willow riparian forests than other vegetation types along the river system, which is consistent with other investigations (e.g., Mosconi and Hutto 1982, Bock and Strong 1990, Saab et al. 1995). These habitats should receive priority for management along the Madison and Missouri Rivers, because of the wildlife they harbor and the important ecosystem services they provide.

2. *Local habitat structure as a priority for management*. Our bird habitat models suggest that landscape stressors are less influential than more local stressors for breeding and migrating bird populations (see also Scott et al. 2003). Based on that conclusion, some tools may have limited efficiency as conservation strategies, such as some GIS-based tools. We need to work toward integrating more local information into the conservation tools that are widely applicable. GIS-based tools might be too coarse to provide the local information necessary to reliably predict issues for bird conservation in this system. Nonetheless, GIS-tools are increasingly incorporated into decision-making and can provide an effective means for evaluating management option, and our habitat models did not include a reliable GIS layer (e.g., NWI) in the analysis because no layers have been completed for the entire river system. This issue should be addressed in the future (see below). For example, using the NWI layer completed for the Lower Missouri section, least flycatcher distribution was most reliably predicted with GIS layers; however, models using data across the entire river (without detailed GIS data) suggested that local vegetation best explained flycatcher distribution. Based on results presented here, different species respond to local vegetation in different ways (based primarily on foraging and nest-site preferences; Tables 10-11). Nonetheless, managing for increased vegetation complexity in the sub-canopy and canopy layers will likely have positive impacts on birds and other taxa.

3. *Understand and incorporate regional effects into management*. For some species and for avian species richness, different patterns emerged in habitat models in different regions. For example, we found strong positive correlations between species richness and shrub cover along the Wild-and-Scenic portion of the Missouri, similar to recent work by Mike Scott and colleagues (Scott et al. 2003). However, just approximately 200

km upstream, we found the opposite pattern: species richness declined with increasing shrub cover on the Madison River. These patterns likely reflect that there are different limiting factors in different regions (e.g., Fig. 15). It is important to recognize that patterns observed on some stretches of the river system may not be applicable to other areas. We suggest that when data are lacking for an area, that managers use information cautiously in their decisions and that attempts are made to collect relevant data for those areas of interest.

4. *Recreation, particularly boating, may influence river bird habitat use*. Our river-based surveys suggest that some species of birds, and bird species richness, may be impacted by recreation. To reliably mitigate this issue, we need to determine how much local habitat can potentially explain the patterns we found (Fig. 26-27). By partitioning the effect of local habitat and recreation, we could then predict how different strategies for managing for recreation may influence wildlife communities along the river system.

This project should also serve as a springboard to better manage the river system. With relatively little effort, these data and results could go much farther in providing managers with accurate and important decision support tools. Future efforts should consider:

1. *Continue long-term monitoring.* Our riparian and river-based surveys can provide an important anchor for identifying and understanding population trends of this diverse bird community. Because we have already established a rigorous and defendable protocol (e.g., Fletcher and Hutto 2006), continuing to implement these surveys should require less effort than the initial establishment of the project. Four technicians (2 for river surveys and 2 for land-based surveys) hired for approximately 3 months could complete breeding surveys and enter data into appropriate databases. Long-term monitoring will provide an invaluable tool for managers to identify whether species decline or increase in relation to with ongoing landscape change. Such information will be even more powerful if included as part of a state-wide partnership for bird monitoring (http://avianscience.dbs.umt.edu/research_coordinated.htm).

2. *Integrate NWI GIS layers into habitat models*. Once NWI GIS layers are completed for the river system, GIS-based analyses on how local and landscape factors can influence bird distributions for riparian and river habitats should be conducted. Such an analysis will allow us to better conclude if indeed local habitat should be the priority for management (see above). Given that information, it will be important to revisit habitat models to determine what factors best explain species distribution, and whether GIS-only models can adequately predict bird distributions. GIS-based analyses can be used to develop maps of predicted distributions for riparian areas across the entire river system. Such predictive maps, if reliable, will provide important deliverables to land managers for identifying “hotspot” areas for conservation. We anticipate that it once layers are completed, it would take one skilled technician approximately 1 year to refine models and provide them in a format usable to managers.

3. *Validate habitat models.* Once NWI GIS layers are integrated into species-environment models, these models should be validated to better insure the accuracy and

reliability of using such models in management strategies. Model validation could be easily implemented along the river system by surveying new sites for birds and determining whether species-environment models adequately predicted observed distributions (see Fielding and Bell 1997). We anticipated that this could be done with 1-2 field seasons with 2 technicians, which could complement long-term monitoring efforts.

4. *Use models as a tool for understanding management alternatives*. Habitat models can be used for interpreting the potential implications of different restoration and land management scenarios. By working with land managers, we can estimate how different land use approaches may influence bird diversity, and we can forecast the influence of potential landscape change on animal diversity. Such an effort would require a technician to develop GIS-based tools that could be made available over the internet.

5. *Determine the utility of birds as indicators.* There has been a recent call that birds can be used as indicators of riparian health (Bryce et al. 2002, Rich 2002 Sorace et al. 2002; see Niemi and McDonald 2004 for a general critique). If so, bird surveys in riparian areas could provide a rapid and informative method to identify and understand riparian condition across broad spatial scales. However, this potential needs to be determined and confronted with other possible indicators (e.g., butterflies, amphibians) to best inform managers. Recent work at the Avian Science Center suggests that birds may be reliable indicators in other systems in Montana (http://avianscience.dbs.umt.edu/research_riparian_indicators.htm).

6. *Determine when habitat use is an appropriate indicator for the dynamics of wildlife populations*. Biologists often assume that if an animal occupies and uses a habitat that it is suitable habitat for management and conservation of the population (Van Horne 1983, Bock and Jones 2004). However, our data on the Yellow Warbler suggest that this may not be the case in riparian habitats along the Madison River. Yellow Warbler abundance did not differ with sub-canopy structure, but their reproductive success did (Fig. 28). It would be very informative to know if this is generally the case for other species and in other areas along the river system. In particular, little is known about the population dynamics of birds along the Missouri Breaks, an area of much conservation attention (Bovee and Scott 2002, Scott and Auble 2002, Shafroth et al. 2002, Scott et al. 2003). Determining when habitat use is a useful surrogate for understanding the viability of populations will be critical for using habitat use models (described above) in management and conservation decisions. To address this issue along the Missouri Breaks, it would require a more intensive effort of approximately 4-6 technicians for 2 field seasons.

7. *Develop a website for disseminating information on the riparian birds of the Missouri and Madison Rivers*. Making this information available to managers and the public will be important for education and outreach efforts related to riparian areas in the western United States. We are beginning such an initiative at the Avian Science Center, (http://www.avianscience.org/), but much more will need to be done to get this valuable information into the hands of people that could use it to inform management decisions

and private land use. This effort could easily be coupled with #4 above with 1-2 technicians in approximately one year.

In conclusion, our efforts to establish avian monitoring have provided much insight into avian communities along the Madison and Missouri Rivers in Montana. These results should help guide management in this river system. However, much more could be done with this baseline effort to help provide useful and robust tools for managers. Furthermore, we recommend that managers limit extrapolating our results to other river systems in Montana and elsewhere, based on the amount of geographic variation we observed within the Madison and Missouri Rivers.

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Table 1. Major environmental gradients of vegetation structure, diversity, and grazing intensity described by a Principal Components Analysis. Variables with high scores explain most of the variation; similar values on the same principal component suggest high correlations among variables. PC scores > 0.4 are bolded.

	PC1	PC2	PC3	PC4	PC5	PC6	PC7
Eigenvalue	2.74	2.27	2.16	1.56	1.24	1.07	0.94
Proportion explained	0.17	0.14	0.14	0.10	0.08	0.07	0.06
Cumulative explained	0.17	0.31	0.45	0.55	0.62	0.69	0.75
Shrub cover	-0.16	**0.87**	-0.03	-0.19	0.07	0.04	-0.12
Shrub diversity	0.00	**0.78**	-0.01	-0.12	0.05	0.14	0.26
Horizontal cover	0.00	**0.79**	-0.21	0.12	-0.07	0.06	-0.33
Canopy cover	0.38	0.20	**0.78**	0.06	-0.08	-0.02	-0.11
Canopy height	0.00	-0.29	**0.80**	-0.10	0.04	0.03	0.06
Deciduous trees (8-23 cm)	**0.83**	-0.06	0.04	-0.04	-0.20	0.03	-0.13
Deciduous trees (34-38 cm)	**0.85**	-0.12	0.12	0.00	0.06	0.05	0.02
Deciduous trees (>38 cm)	-0.18	-0.09	**0.80**	-0.15	0.30	-0.01	0.10
Conifer trees	-0.03	0.13	-0.06	-0.18	0.18	**0.81**	-0.20
Tree diversity	0.03	0.10	0.10	0.33	-0.12	**0.70**	0.27
Snags (8-23 cm)	**0.74**	0.02	-0.10	0.05	0.27	-0.10	0.07
Snags (34-38 cm)	0.24	0.03	-0.02	0.01	**0.82**	-0.06	0.01
Snags (>38 cm)	-0.18	0.03	0.32	0.03	**0.68**	0.20	0.05
Exotic cover	0.04	-0.24	-0.07	**0.77**	-0.15	-0.07	-0.14
Exotic diversity	-0.04	0.03	-0.09	**0.83**	0.18	0.09	0.09
Grazing intensity	-0.04	-0.08	0.03	-0.02	0.04	-0.01	**0.89**
Interpretation	*Small trees*	*Shrub*	*Canopy*	*Exotics*	*Snags*	*Conifer*	*Grazing*

Table 2. Life-history characteristics of bird species using the Madison and Missouri Rivers, Montana. Species list includes all species from Appendix 1 and all species for which we modeled bird-habitat relationships (Tables 7, 8).

Species	Migration guild	Nest type	Nest location	Nest height	Cowbird host?	Foraging strategy	Diet
American goldfinch	short	open	shrub	>5m	common	foliage	seeds
American kestrel	short	secondary cavity	cavity	>5m	non	aerial	carnivore
American redstart	long	open	shrub	<5m	common	foliage	insects
American robin	short	open	tree	<5m	non	ground	omnivore
American white pelican	long	open	wetland	<2.5m	non	surface dip	fish
Bald eagle	short	open	tree	>5m	non	soaring	fish
Black-billed cuckoo	resident	open	tree	>5m	non	ground	omnivore
Black-billed magpie	resident	covered	shrub	>2.5m	non	ground	omnivore
Black-capped chickadee	resident	secondary cavity	cavity	>2.5m	rare	bark	insects
Black-headed grosbeak	long	open	shrub	<5m	rare	foliage	insects
Brown-headed cowbird	short	N/A	parasite	N/A	non	ground	omnivore
Bullock's oriole	long	open	tree	>5m	rare	foliage	insects
Caspian tern	long	open	ground	<2.5m	non	high diver	fish
Cedar waxwing	short	open	tree	>5m	rare	foliage	fruit
Common grackle	short	open	tree	>5m	rare	ground	omnivore
Common yellowthroat	long	open	shrub	<2.5m	common	foliage	insects
Downy woodpecker	resident	primary cavity	cavity	>5m	non	bark	insects
Eastern kingbird	long	open	tree	>5m	common	aerial	insects
European starling	short	secondary cavity	tree	>5m	non	ground	insects
Forster's tern	long	open	floating on water	<2.5m	non	high diver	fish
Franklin's gull	long	open	floating on water	<2.5m	non	ground	insects
Golden eagle	short	open	cliff	>5m	non	soaring	sm. mammals
Gray catbird	long	open	shrub	<2.5m	rare	ground	omnivore
House finch	short	open	tree	>5m	rare	ground	seeds
House wren	long	secondary cavity	cavity	<5m	rare	ground	insects
Killdeer	long	open	ground	<2.5m	non	ground	insects
Lazuli bunting	long	open	shrub	<2.5m	common	ground	omnivore
Long-billed curlew	short	open	ground	<2.5m	non	probes below surface	insects
Least flycatcher	long	open	tree/shrub	<10m	rare	hover glean	insects
Least tern	long	open	ground	<2.5m	non	high diver	fish
Marbled godwit	short	open	ground	<2.5m	non	probes below surface	aquatic inverts
Mourning dove	short	open	tree	<15m	rare	ground	seed
Ovenbird	long	covered	ground	<2.5m	common	ground	insects
Northern flicker	short	primary cavity	cavity	>5m	non	ground	insects
Red-eyed vireo	long	open	tree	>5m	common	hover glean	insects

Table 2. *Continued.*

Species	Migration guild	Nest type	Nest location	Nest height	Cowbird host?	Foraging strategy	Diet
Red-naped sapsucker	short	primary cavity	cavity	>5m	non	bark	omnivore
Ring-necked pheasant	resident	open	ground	<2.5m	non	ground	omnivore
Red-winged blackbird	short	open	reeds	<2.5m	common	ground	insects
Song sparrow	short	open	ground	<2.5m	common	ground	omnivore
Sharp-shinned hawk	short	open	tree	>5m	non	aerial pursuit	birds
Spotted towhee	short	open	ground/shrub	<2.5m	common	ground	insects
Swainson's hawk	short	open	ground	<2.5m	common	ground	aquatic
Tree swallow	short	secondary cavity	cavity	>5m	non	aerial	insects
Trumpeter swan	resident	open	ground	<2.5m	non	surface dip	aquatic plants
Veery	long	open	ground	<2.5m	common	ground	omnivore
Warbling vireo	long	open	shrub	>5m	common	foliage	insects
Western kingbird	long	open	tree	>5m	rare	hawk	insects
Western wood-pewee	long	open	tree	>5m	common	aerial	insects
Willow flycatcher	long	open	shrub	<2.5m	common	aerial	insects
Wilson's phalarope	long	open	ground	<2.5m	non	surface dip	aquatic inverts
Yellow-billed cuckoo	long	open	shrub	<2.5m	non	foliage	insects
Yellow -breasted chat	long	open	shrub	<2.5m	common	foliage	insects
Yellow-headed blackbird	long	open	reeds	<2.5m	non	ground	insects
Yellow warbler	long	open	shrub	<2.5m	common	foliage	insects

Compiled from: Ehrlich et al. (1988), Rich (2002), Tewksbury et al. (2002), Poole (2005).

Table 3. Population trends and conservation issues for species using the Madison and Missouri Rivers, Montana. Species list includes all species from Appendix 1 and all species for which we modeled bird-habitat relationships (Tables 7, 8). Population trends taken from the North American Breeding Bird Survey (http://www.mbr-pwrc.usgs.gov/bbs/). Conservation summary based on reported responses (abundance and/or reproductive performance; POS = positive, NEG = negative, MIXED = positive and negative responses) of species to habitat loss and fragmentation, development, grazing, and human activity.[a]

	BBS Trend (1966-2004)*			Reported responses to:			
Species	Montana	Western U.S.	Continent	Habitat loss / fragmentation	Development	Human activity	Grazing
American goldfinch	1.8	**-1.5**	0.0		POS		
American kestrel	-0.6	**-1.3**	-0.5		NEG		NEG
American redstart	**-5.3**	-1.4	-0.6	NEG			NEG
American robin	-0.3	0.2	**0.6**	POS	POS		MIXED
American white pelican	3.1†	2.0	2.6			NEG	
Bald eagle	22.5†	5.0	**6.1**		NEG	NEG	
Black-billed cuckoo	**-11.3**	**-6.0**	**-1.5**	NEG			
Black-billed magpie	-1.3	-0.2	-0.3	POS	NEG		
Black-capped chickadee	**2.3**	**-0.8**	**1.3**	NEG			
Black-headed grosbeak	**3.5**	0.7	0.7	NEG	POS		NEG
Brown-headed cowbird	1.2	**-1.1**	**-1.2**	POS	NEG		
Bullock's oriole	0.6	**-1.0**	**-0.9**	POS			NEG
Caspian tern	no info.	**4.3**	**3.3**			NEG	
Cedar waxwing	4.7†	0.3	**1.1**	NEG			
Common grackle	-0.4	0.0	**-1.2**		NEG		
Common yellowthroat	-2.7	0.8	**-0.4**				NEG
Downy woodpecker	0.4	0.3	0.0		NEG		NEG
Eastern kingbird	**2.1**	-0.8	**-0.9**				POS
European starling	0.8	**-1.7**	**-1.0**	POS	POS		
Forster's tern	-21.9†	-1.4	0.6				
Franklin's gull	-7.7†	9.6†	7.4†	NEG		NEG	
Golden eagle	4.1†	0.6	1.5			NEG	NEG
Gray catbird	**2.6**	**2.3**	-0.1	NEG			NEG
House finch	**14.5†**	-0.6	1.2		POS		
House wren	2.2	0.5	0.5	NEG	NEG		MIXED
Killdeer	**-3.9**	**-2.3**	**-0.5**		MIXED		
Lazuli bunting	-0.3	23.3†	22.7†				NEG
Long-billed curlew	-1.3	1.3	-1.6			NEG	POS

Table 3. *Continued.*

	BBS Trend (1966-2004)			Reported responses to:			
Species	Montana	Western U.S.	Continent	Habitat loss / fragmentation	Development	Human activity	Grazing
Least flycatcher	2.9	0.0	**-1.2**	NEG			NEG
Least tern	no info.	no info.	-1.2			NEG	
Marbled godwit	2.7†	-1.3	-1.0				
Mourning dove	-1	**-0.8**	-0.1				NEG
Ovenbird	1.7†	-0.7	**0.5**				NEG
Northern flicker	-1.3	**-0.9**	**-2.0**	NEG	MIXED		NEG
Red-eyed vireo	-1.1	-0.9	**1.3**	NEG			NEG
Red-naped sapsucker	3.6	0.1	0.5	NEG			
Ring-necked pheasant	0.3	**-1.4**	**-0.9**	POS			
Red-winged blackbird	**-1.8**	**-0.7**	**-1.0**	NEG	MIXED		POS
Song sparrow	0.7	**-0.9**	**-0.6**	MIXED			NEG
Sharp-shinned hawk	no info.	**8.7†**	3.7†				
Spotted towhee	2.8	0.0	0.2	NEG	NEG		
Swainson's hawk	2.0	0.0	-0.5				
Tree swallow	2.2	0.6	0.0				NEG
Trumpeter swan	no info.	no info.	no info.			NEG	
Veery	-4.7	0.0	**-1.4**				NEG
Warbling vireo	0.6	**1.1**	**1.1**	NEG	NEG		
Western kingbird	**4.4**	0.6	**0.5**	NEG	NEG		
Western wood-pewee	1.2	**-1.3**	**-1.2**		MIXED		
Willow flycatcher	-1.3	**-1.2**	-0.2	NEG	POS		
Wilson's phalarope	0.9	**1.7**	0.8	NEG			
Yellow-billed cuckoo	6.1†	-3.2†	**-1.7**	NEG			
Yellow -breasted chat	2.1	0.5	0.0		POS		NEG
Yellow-headed blackbird	0.0	0.8	0.9	NEG			
Yellow warbler	0.8	0.0	**0.3**	MIXED	MIXED		NEG

*Annual change in detections/route. Trends in bold are statistically significant at $P \leq 0.05$.

†Major deficiencies in BBS trend data, such that biological trends should not be inferred.

[a] Compiled from: Burger (1974), Martin (1981), Mosconi and Hutto (1982), Quinn (1984), Ehrlich et al. (1988), Faanes (1983), Quinn (1984), Finch (1989), Bock et al. (1992), Skagen and Knopf (1993), Dobkin (1994), Stevens et al. (1997), Dobkin and Rich (1998), Dobkin et al. (1998), Skagen et al. (1998), Tewksbury et al. (1998), Fletcher et al. (1999), Naugle et al. (1999), Rottenborn (1999), Saab (1999), Warner et al. (1999), Naugle et al. (2000), Rich (2002), Rodgers and Schwikert (2002), Tewksbury et al. (2002), Stanley and Knopf (2002), Fletcher and Koford (2003), Hennings and Edge (2003), Krueper et al. (2003), Scott et al. (2003), Miller et al. (2004), Poole (2005).

Table 4. Models used for estimating detection probabilities for species with >100 detections.

	Best model for estimating detection probability (based on AICc)**				
Species code*	*p*(.)	*p*(obs)	*p*(dist)	*p*(obs + dist)	*p*(obs × dist)
AMGO	X				
AMRO			X		
BCCH	X				
BHCO	X				
BUOR			X		
CEDW	X				
EAKI					X
EUST					X
GRCA			X		
HOWR					X
LEFL					X
MODO			X		
NOFL	X				
SOSP					X
TRES	X				
WAVI					X
WEWP	X				
YWAR					X

*see Appendix 1 for species codes

***p*(.) = constant detection probability, *p*(obs) = observer differences, *p*(dist) = detection changes with distance, etc.

Table 5. Capture histories and estimated detection probabilities ($\hat{p}$) for species (all species where x_{11} >10) and species groups (e.g., ducks) for river birds using double surveys along the Madison and Missouri rivers, Montana, 2004 (Fletcher and Hutto, *in press*).

	Capture history[a]				Observer 1		Observer 2		Combined	
Species/group	x_{10}	x_{01}	x_{11}	r	$\hat{p}_1$	SE($\hat{p}_1$)	$\hat{p}_2$	SE($\hat{p}_2$)	$\hat{p}_t$	SE($\hat{p}_t$)
American White Pelican	6	9	56	71	0.889	0.030	0.889	0.030	0.988	0.007
Double-crested Cormorant	8	6	12	26	0.667	0.111	0.600	0.110	0.867	0.067
Great Blue Heron	6	9	14	29	0.609	0.102	0.700	0.102	0.883	0.058
Canada Goose	4	8	30	42	0.789	0.066	0.882	0.055	0.975	0.014
Mallard	11	10	24	45	0.706	0.078	0.686	0.078	0.908	0.039
Common Merganser	4	16	30	50	0.674	0.078	0.892	0.054	0.965	0.022
Killdeer	28	29	54	111	0.655	0.043	0.655	0.043	0.881	0.030
Spotted Sandpiper	96	100	129	325	0.572	0.034	0.574	0.033	0.817	0.024
Species groups:										
Ducks	32	45	99	176	0.662	0.039	0.733	0.038	0.910	0.017
Raptors	9	5	17	31	0.773	0.089	0.654	0.093	0.921	0.042
Total	198	225	398	821	0.639	0.019	0.668	0.019	0.880	0.011

For species with ≥50 detections (r), covariates were included in the modeling process using information-theoretic approaches that included covariates into the estimation process (observer, group size, river condition).

[a] x_{10} = number of detections where the first observer detects an individual but the second observer does not. x_{01} = number of detections where the first observer does not detect an individual that the second observer does. x_{11} = number of detections where both observers detect the same individual. $r = x_{11} + x_{01} + x_{10}$, or the total number of detections.

Table 6. Density estimates ($\hat{D}$; individuals/ha) for birds based on data from observer 1, observer 2, and using both observers for double surveys along the Madison and Missouri Rivers, Montana, 2004.

Species/group	Observer 1		Observer 2		Combined	
	$\hat{D}_1$ (SE)	95% CI	$\hat{D}_2$ (SE)	95% CI	$\hat{D}$ (SE)	95% CI
American White Pelican	0.305 (0.050)	0.275-0.547	0.256 (0.042)	0.231-0.463	0.277 (0.047)	0.274-0.580
Double-crested Cormorant	0.043 (0.015)	0.031-0.107	0.050 (0.016)	0.035-0.110	0.042 (0.015)	0.037-0.136
Great Blue Heron	0.041 (0.008)	0.031-0.064	0.021 (0.005)	0.017-0.040	0.029 (0.006)	0.026-0.063
Canada Goose	0.543 (0.089)	0.458-0.867	0.320 (0.063)	0.286-0.641	0.396 (0.074)	0.386-0.894
Mallard	0.051 (0.008)	0.042-0.075	0.051 (0.008)	0.042-0.074	0.049 (0.008)	0.045-0.094
Common Merganser	0.107 (0.016)	0.087-0.153	0.049 (0.010)	0.044-0.104	0.068 (0.013)	0.065-0.152
Killdeer	0.121 (0.012)	0.103-0.153	0.100 (0.010)	0.086-0.126	0.109 (0.012)	0.099-0.154
Spotted Sandpiper	0.362 (0.028)	0.316-0.427	0.297 (0.023)	0.260-0.350	0.322 (0.027)	0.289-0.402
Species groups:						
Ducks	0.857 (0.138)	0.686-1.269	0.540 (0.095)	0.441-0.861	0.579 (0.109)	0.531-1.188
Raptors	0.023 (0.006)	0.019-0.049	0.029 (0.006)	0.022-0.048	0.025 (0.005)	0.023-0.058

Detection probabilities were based on the best covariate model to explain detection probability. For species with <50 total detections, baseline detection probabilities were used (not including covariates).

Table 7. The 10 most frequently observed species for each vegetation type encountered during point count transect surveys in 2003 (see Appendix 3 for vegetation type descriptions and Appendix 5 for species codes).

Grassland	Sagebrush	Shrub	Conifer	Willow	Cottonwood w/ subcanopy	Cottonwood without subcanopy	Mixed riparian
1) RWBL	WEME	SPTO	MOCH	YWAR	YWAR	YWAR	YWAR
2) SAVS	SPTO	YWAR	AUWA	SOSP	HOWR	HOWR	HOWR
3) CCSP	BRSP	GRCA	AMRO	BHCO	MODO	WEWP	AMRO
4) EAKI	SAVS	BHCO	YWAR	HOWR	AMRO	LEFL	BHCO
5) WEME	COYE	LAZB	DEJU	AMRO	WEWP	MODO	SOSP
6) BHCO	BHCO	LASP	DUFL	LEFL	EUST	EUST	LEFL
7) AMRO	VESP	SOSP	SPTO	GRCA	LEFL	AMRO	GRCA
8) COYE	AMRO	AMRO	BHCO	RWBL	CEDW	BUOR	WEWP
9) YWAR	CCSP	COYE	WCSP	AMGO	BHCO	AMGO	EAKI
10) SPTO	CEDW	ROWR	MODO	COYE	BUOR	BHCO	CEDW

Table 8. Model-selection summary (based on Akaike's Information Criterion) for linear regression models explaining bird density in deciduous riparian patches for species with >100 detections, 2004-2005. The most parsimonious model to explain bird density (model with the lowest AICc) is denoted with an **X**.

Species	Model**												
code*	1	2	3	4	5	6	7	8	9	10	11	12	13
AMGO			**X**										
AMRO				**X**									
BCCH			**X**										
BHCO										**X**			
BUOR											**X**		
CEDW											**X**		
EAKI			**X**										
EUST										**X**			
GRCA						**X**							
HOWR		**X**											
LEFL	**X**												
MODO											**X**		
NOFL			**X**										
SOSP											**X**		
TRES			**X**										
WAVI								**X**					
WEWP											**X**		
YWAR				**X**									

*See Appendix 2 for species names.

** Model 1 = local vegetation.
Model 2 = non-linear local vegetation.
Model 3 = local disturbance.
Model 4 = patch structure.
Model 5 = landscape disturbance.
Model 6 = local vegetation + local disturbance.
Model 7 = local disturbance + landscape disturbance.
Model 8 = patch structure + geographic section.
Model 9 = patch structure × geographic section.
Model 10 = local vegetation + geographic section.
Model 11 = local vegetation × geographic section.
Model 12 = local vegetation + patch structure.
Model 13 = global model (vegetation + local disturbance + patch structure + landscape disturbance + geographic section).

Table 9. Model-selection summary (Akaike's information criterion) for logistic and Poisson regression models explaining bird occurrence and avian species richness, 2004-2005. The most parsimonious model (model with the lowest AICc) is denoted with an **X**.

Species	Model**												
code*	1	2	3	4	5	6	7	8	9	10	11	12	13
AMKE										**X**			
AMRE				**X**									
BBMA								**X**					
BHGR				**X**									
COGR									**X**				
COYE									**X**				
DOWO										**X**			
HOFI								**X**					
LAZB							**X**						
REVI												**X**	
RNSA										**X**			
RPHE					**X**								
RWBL									**X**				
SPTO									**X**				
VEER						**X**							
WEKI										**X**			
WIFL												**X**	
YBCH										**X**			
Species richness											**X**		

*See Appendix 2 for species names.

** Model 1 = local vegetation.
Model 2 = non-linear local vegetation.
Model 3 = local disturbance.
Model 4 = patch structure.
Model 5 = landscape disturbance.
Model 6 = local vegetation + local disturbance.
Model 7 = local disturbance + landscape disturbance.
Model 8 = patch structure + geographic section.
Model 9 = patch structure × geographic section.
Model 10 = local vegetation + geographic section.
Model 11 = local vegetation × geographic section.
Model 12 = local vegetation + patch structure.
Model 13 = global model (vegetation + local disturbance + patch structure + landscape disturbance + geographic section).

Table 10. Correlations of bird density with local vegetation, local disturbance, patch structure, landscape disturbance, and geography, 2004-2005. Correlations are based on the best linear regression model to explain bird density (see Table 6). Most correlated variable denoted in bold.

	Local vegetation				Local disturbance			Patch structure		Landscape disturbance			
Species code*	Small trees	Shrub cover	Canopy cover	Snags	Exotic cover	Conifer	Grazing	Area	Width	Camp-ing	Devel-opment	Road density	Geographic section
AMGO					POS								
AMRO													
BCCH					POS								
BHCO		POS	NEG						NEG				
BUOR	NEG	NEG											Fewest in UM**
CEDW	NEG	POS	NEG										Increased downstream
EAKI					POS	NEG	POS						
EUST	NEG	NEG	POS						NEG				
GRCA		POS	NEG				NEG						
HOWR													
LEFL	POS		POS										
MODO			POS										Increased downstream
NOFL						POS							
SOSP		POS	NEG										Decreased downstream
TRES						POS							
WAVI													Increased downstream
WEWP		NEG	POS										
YWAR									NEG				Decreased downstream

*See Appendix 2 for species names.
**UM = Upper Missouri section, between Three Forks and Great Falls, MT.

Table 11. Correlations of bird occurrence and avian species richness with local vegetation, local disturbance, patch structure, landscape disturbance, and geography, 2004-2005. Correlations are based on the best logistic or Poisson regression model to explain occurrence or richness (see Table 7). Most correlated variable denoted in bold.

	Local vegetation				Local disturbance			Patch structure		Landscape disturbance			
Species Code*	Small trees	Shrub cover	Canopy cover	Snags	Exotic cover	Conifer	Grazing	Area	Width	Camp-ing	Devel-opment	Road density	Geographic section
AMKE													
AMRE									POS				
BBMA													
BHGR								POS					
COGR								NEG†					Decrease downstream
COYE						NEG					NEG		
DOWO			POS										Most in UM**
HOFI									POS				Most in UM**
LAZB											NEG		
REVI			POS						POS				
RNSA	POS		POS	POS									Decrease downstream
RPHE											POS		
RWBL									NEG†				Increase downstream
SPTO								POS†	NEG†				Increase downstream
VEER			POS		NEG		POS						
WEKI			POS										
WIFL		POS	NEG					NEG					
YBCH	POS	POS	NEG										Increase downstream
Species richness		POS†	POS†	POS†									

*See Appendix 2 for species names.

**UM = Upper Missouri section, between Three Forks and Great Falls, MT.

†Interaction with geographic section. That is, the relationship differed among geographic sections.

Table 12. Nest success and cowbird parasitism rates for Yellow Warbler nests for all plot types based on density of vegetation.

Study Site Type	# Nests	Proportional Nest Success	# Exposure Days	Nest Survival Rate (Standard Error)[1]	Parasitism rate (Standard Error)
Sparse (n = 4)	83	0.36	849	0.1996 (0.0083)	0.46 (0.03)
Moderate (n = 2)	36	0.39	385.5	0.2301 (0.0118)	0.27 (0.14)
Dense (n = 3)	81	0.58	1037.5	0.4347 (0.0078)	0.25 (0.03)
	N=200	0.455	N=2272	0.2926 (0.0045)	0.35 (0.06)

[1] Nest survival rate derived from Mayfield estimate of daily survival probability raised by the number of days in the nesting period; e.g. 25 days for Yellow Warblers. Standard errors are for daily survival rates.

Table 13. Species captured during fall migration banding on intensive plots that were not observed on these areas during the breeding season, 2003.

Species	Species Code	Species	Species Code
Cassin’s (Solitary) vireo	CAVI*	MacGillivray's warbler	MGWA*
Golden-crowned kinglet	GCKI*	Nashville warbler	NAWA*
Ruby-crowned kinglet	RCKI	Orange-crowned warbler	OCWA
Townsend's solitaire	TOSO	Ovenbird	OVEN
Hermit thrush	HETH*	Chipping sparrow	CHSP
Townsend's warbler	TOWA*	White-crowned sparrow	WCSP
Audubon's warbler	AUWA	Lincoln's sparrow	LISP
Wilson's warbler	WIWA	Spotted towhee	SPTO

*Species not detected on long-term point-count transects surveyed during 2003

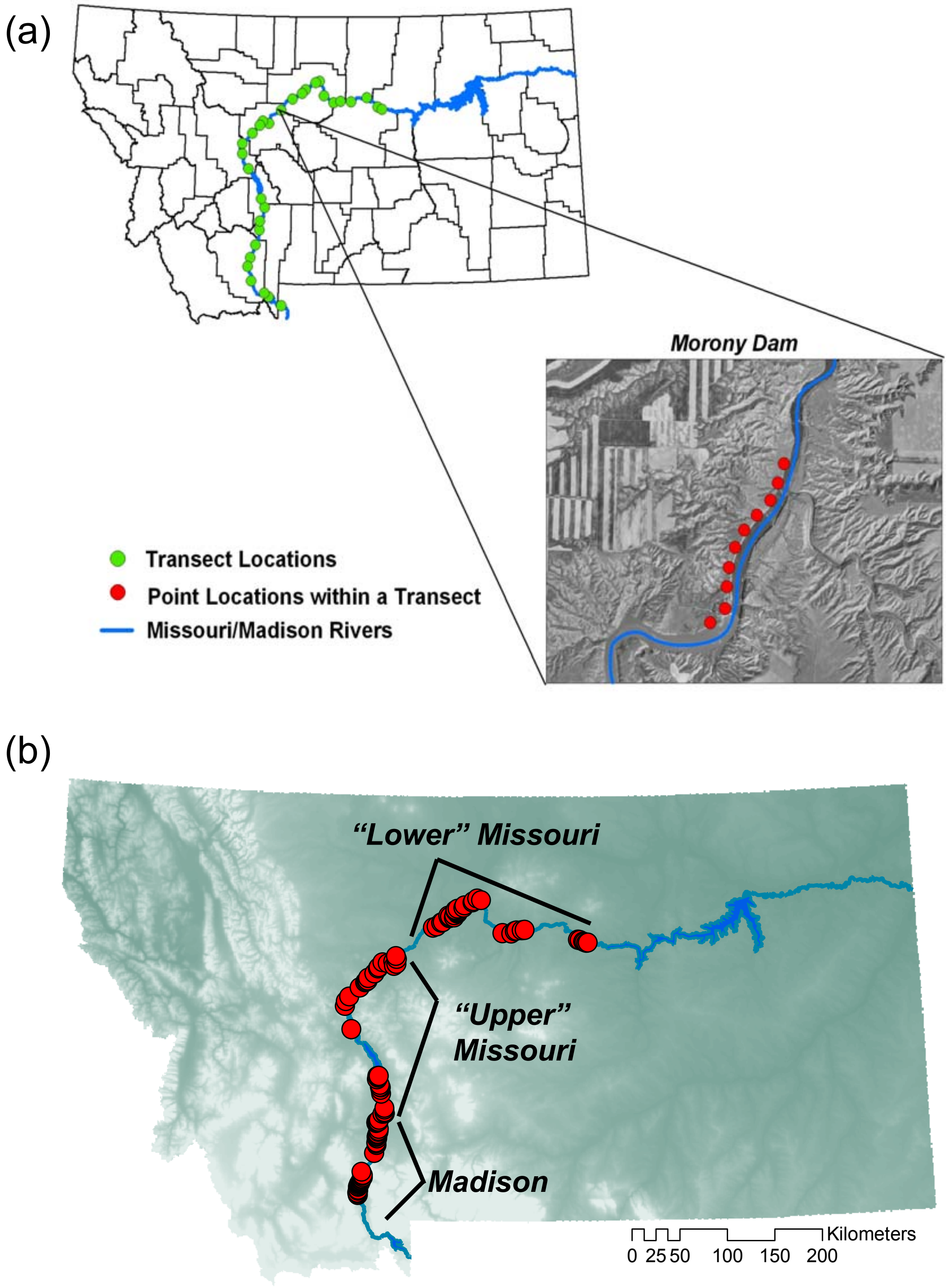


Fig. 1. Point-count locations established in (a) 2003 (n = 31 transects, 310 points) and (b) 2004-2005 (n = 105 sites, 223 points)for long-term avian monitoring along the Upper Missouri and Madison Rivers, Montana. The aerial photo shows an example of a transect near Morony Dam, downstream of Great Falls, Montana. In 2004-2005, we selected sites within three geographic strata: the Madison, the "Upper" Missouri, and the "Lower" Missouri.

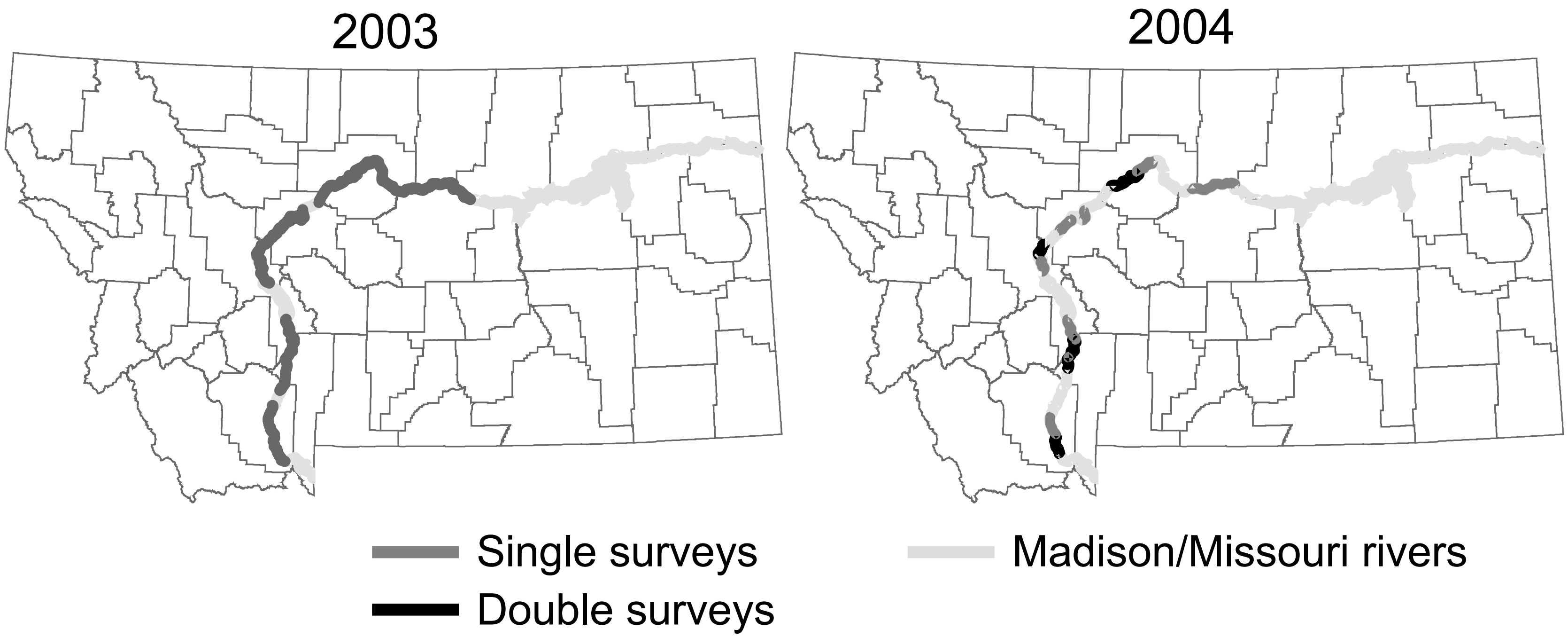


Fig. 2. River survey locations used in 2003 and 2004 for establishing long-term avian monitoring along the Upper Missouri and Madison Rivers, Montana. In 2003, we surveyed each location once. In 2004, we surveyed each location twice, and we conducted double surveys (2 simultaneous surveys) on a subset (6 of 14 stretches) of the locations to estimate detection probabilities of different species.

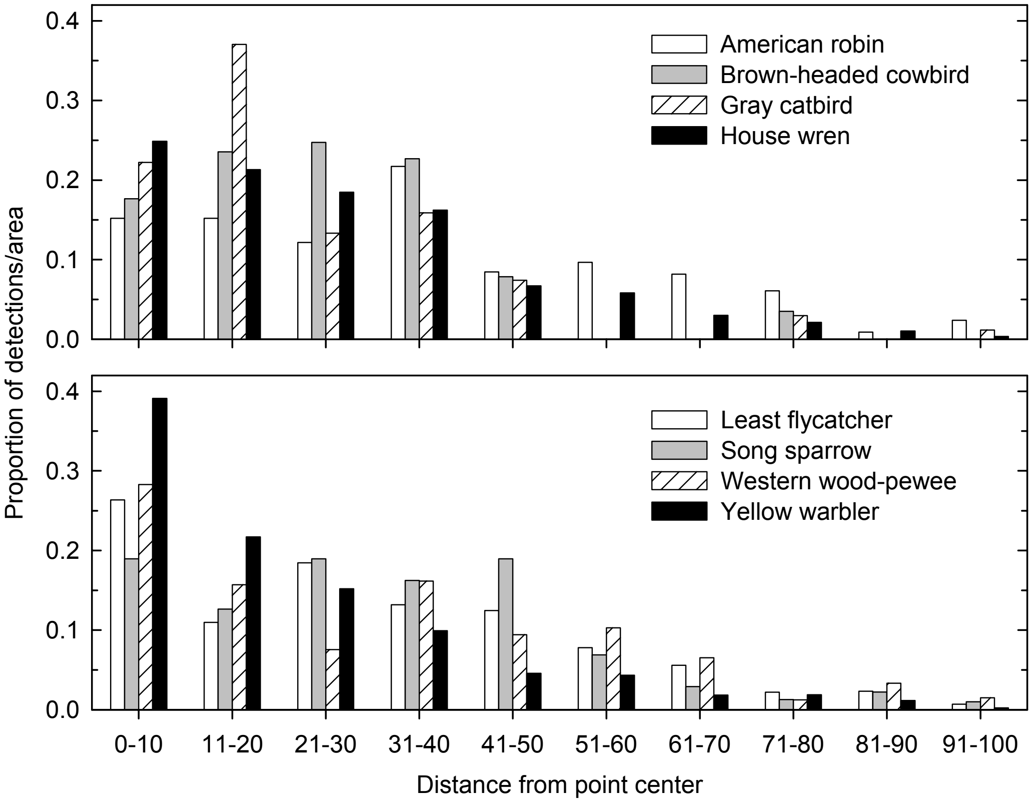


Fig. 3. Point count detection profiles for common species in riparian areas, 2003.

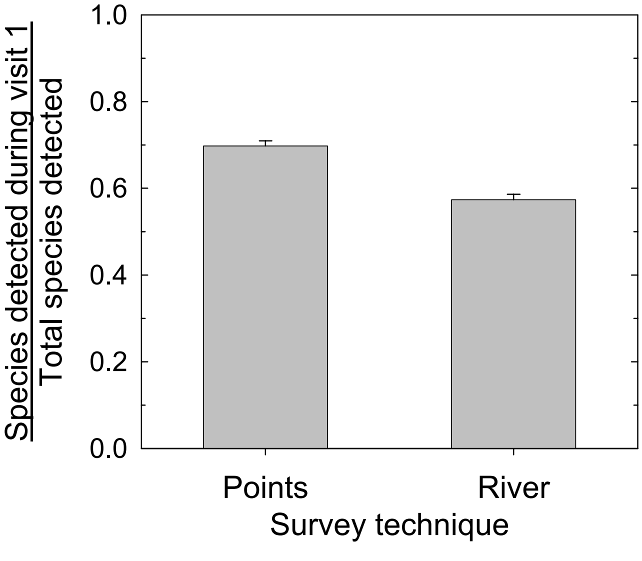


Fig. 4. The percent of species detected during the first visit relative to the total detected during two visits for each monitoring technique, 2004.

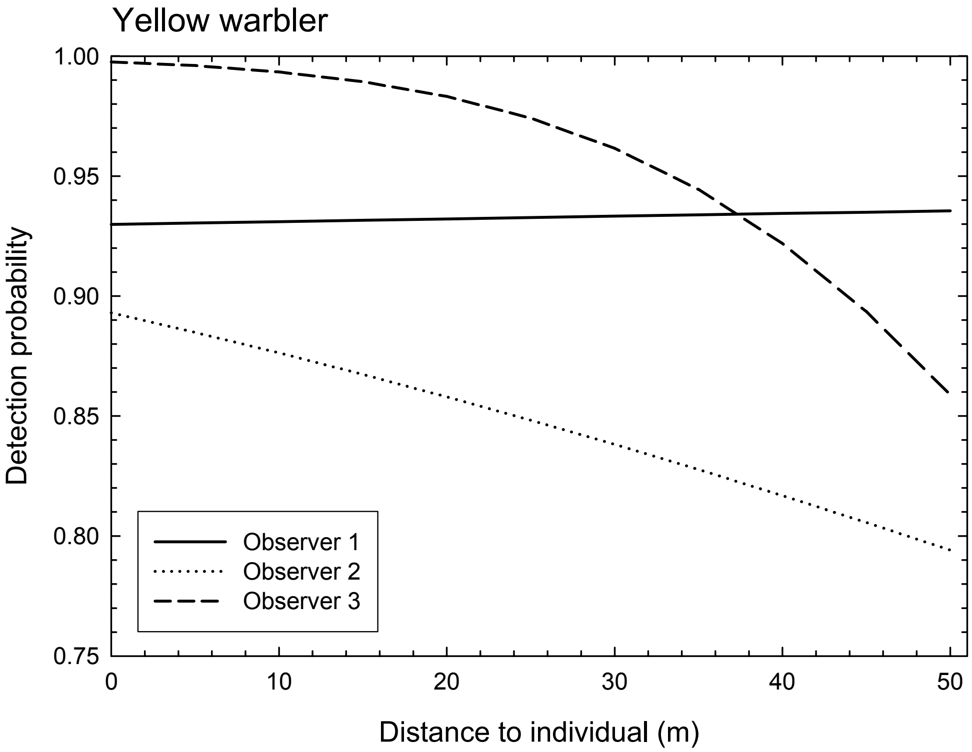


Fig. 5. An example of detection probabilities from riparian point counts for the Yellow Warbler, 2004-2005. The best model to explain detection probability included both observer effects and distances to individuals (p(obs × dist); Table 2).

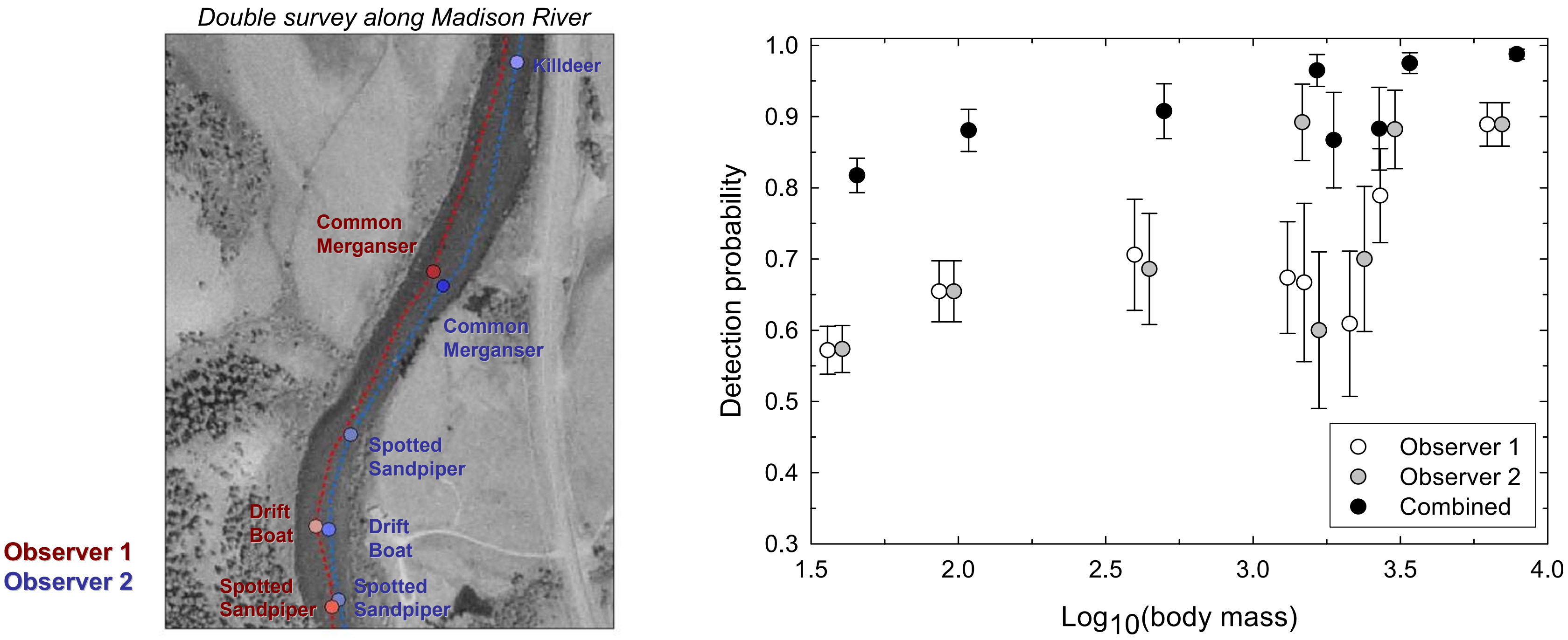


Fig. 6. Example of double surveys for river birds and estimated detection probabilities as a function of bird body mass for each observer and both observers combined from double surveys along the Madison and Upper Missouri Rivers, Montana, 2004. Body mass values among observer categories were offset slightly (± 0.05 $\log_{10}$(body mass)) to reduce overlap and increase figure clarity. Body mass values were taken from Dunning (1993).

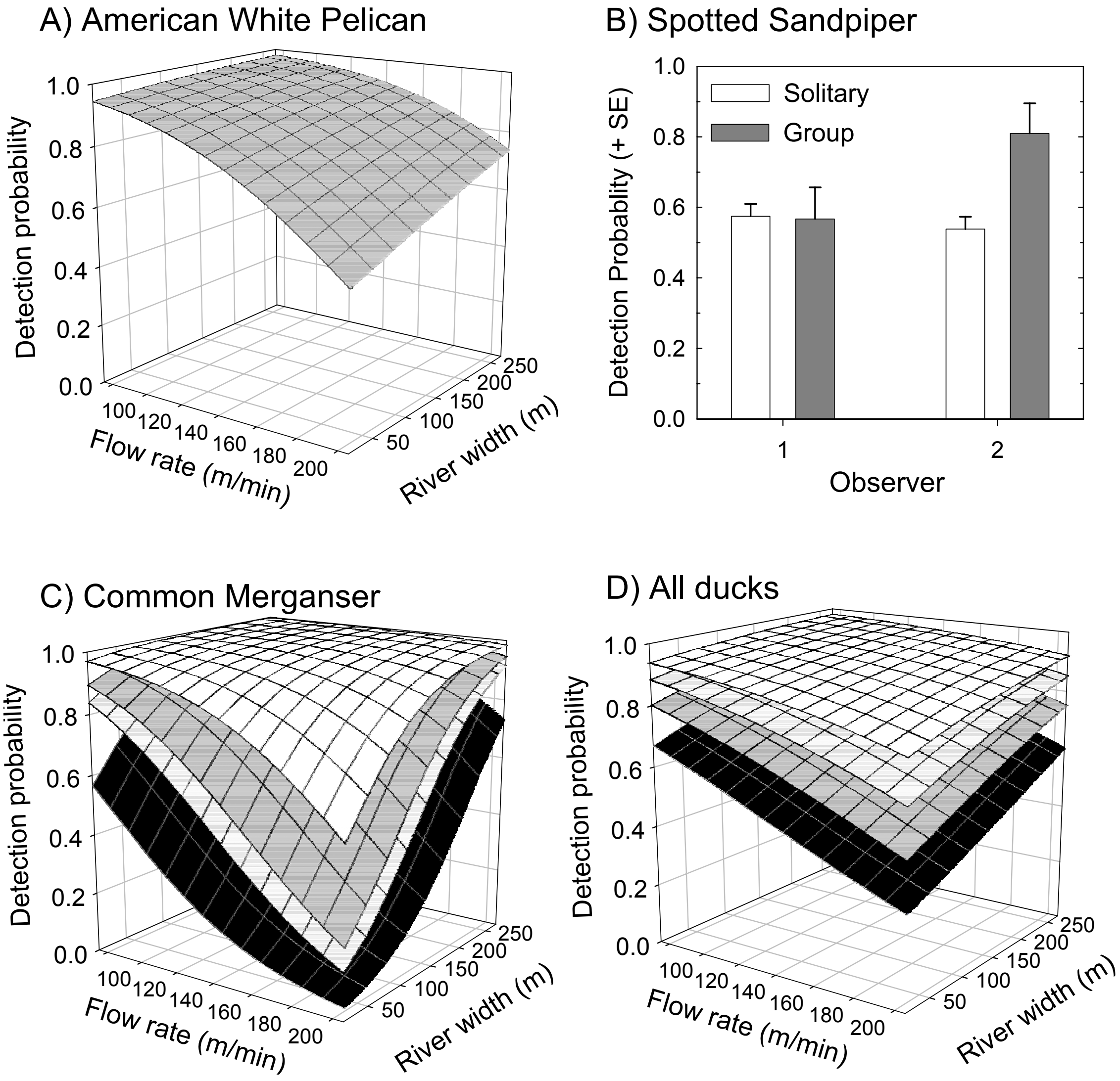


Fig. 7. Examples of how detection probabilities of river birds can be influenced by observer, group size, and river condition (river flow rate and river width), based on double surveys along the Madison and Upper Missouri rivers, Montana, 2004. Only species and species groups where covariates were included in the best model (based on AICc) are included. For panels C-D, black surface denotes observer 1 and detections of solitary individuals, dark grey surface denotes observer 1 and group detections, light grey surface denotes observer 2 and detections of solitary individuals, and white surface denotes observer 2 and group detections.

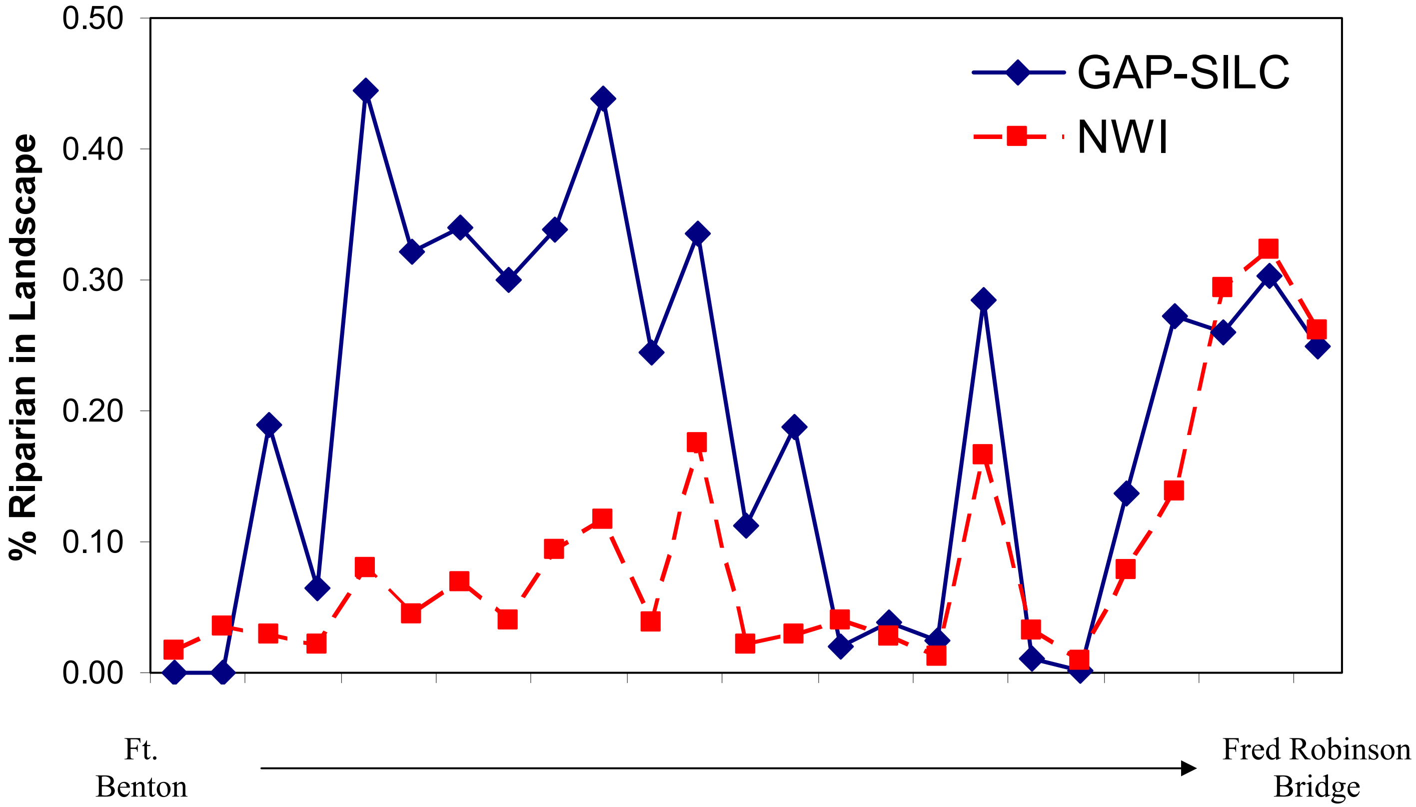


Fig. 8. Riparian forest discrimination based on two GIS layers, the National Wetlands Inventory (NWI) and the Montana GAP-SILCIII layer.

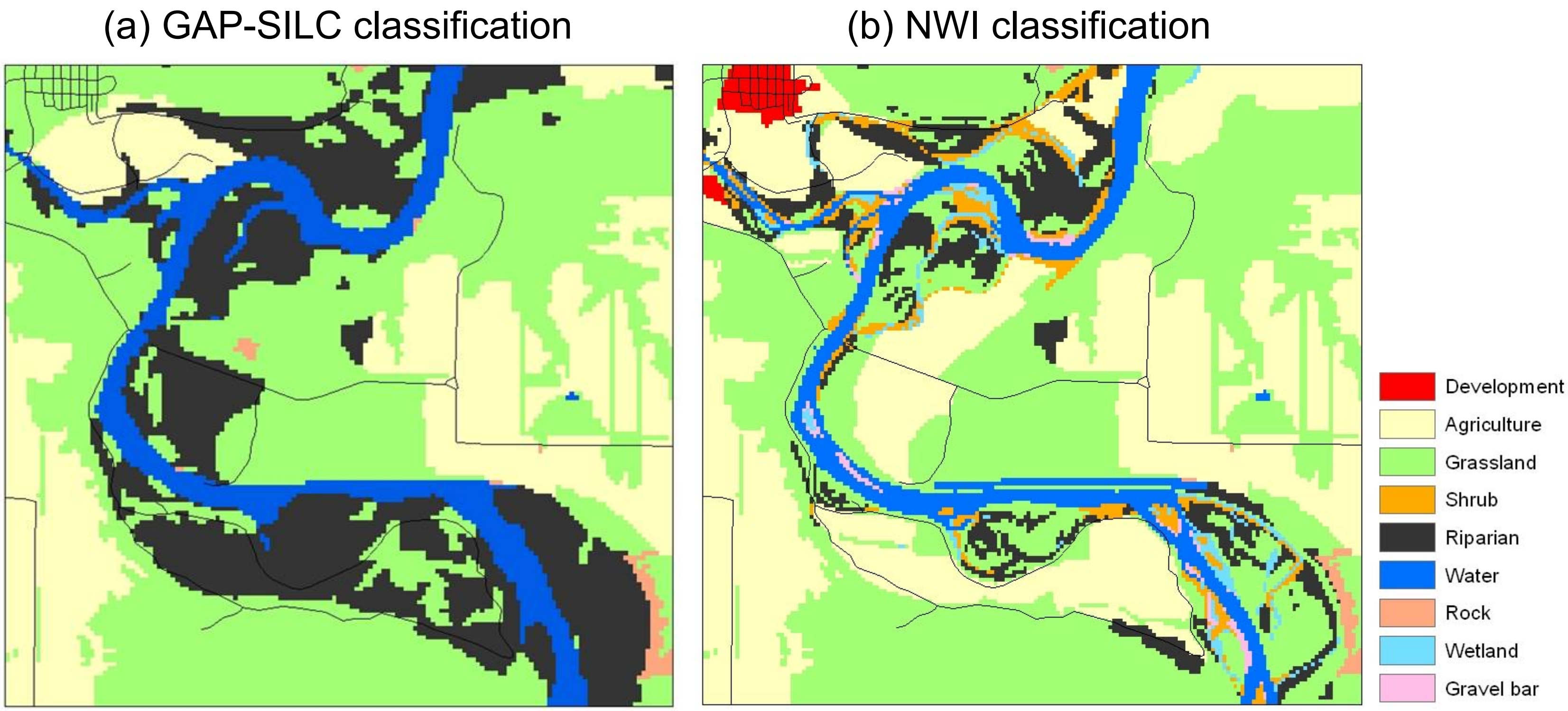


Fig. 9. An example of differences in riparian forest discrimination based on the (a) GAP-SILCIII Montana GIS layer and (b) the National Wetlands Inventory (NWI) GIS layer near Loma, MT.

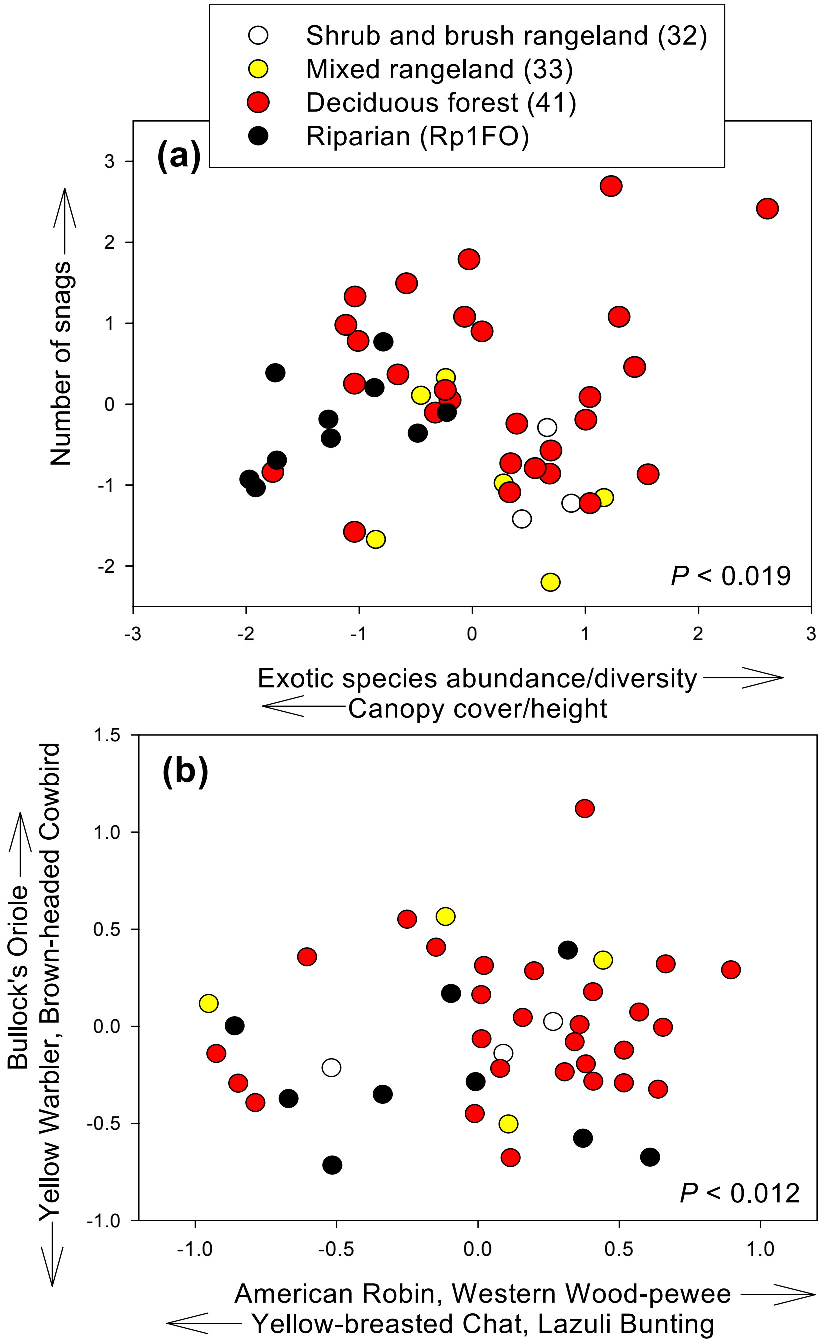


Fig. 10. (a) Local vegetation measurements (from 2004) can broadly discriminate among NWI land cover categories, based on a discriminant analysis. However, some categories (e.g., deciduous forest) contain much variation in vegetation structure. (b) Bird communities were statistically different among categories, based on a Multiple Response Permutation Procedure (MRPP) analysis. But, again, categories contained much variation and differences are less than for vegetation.

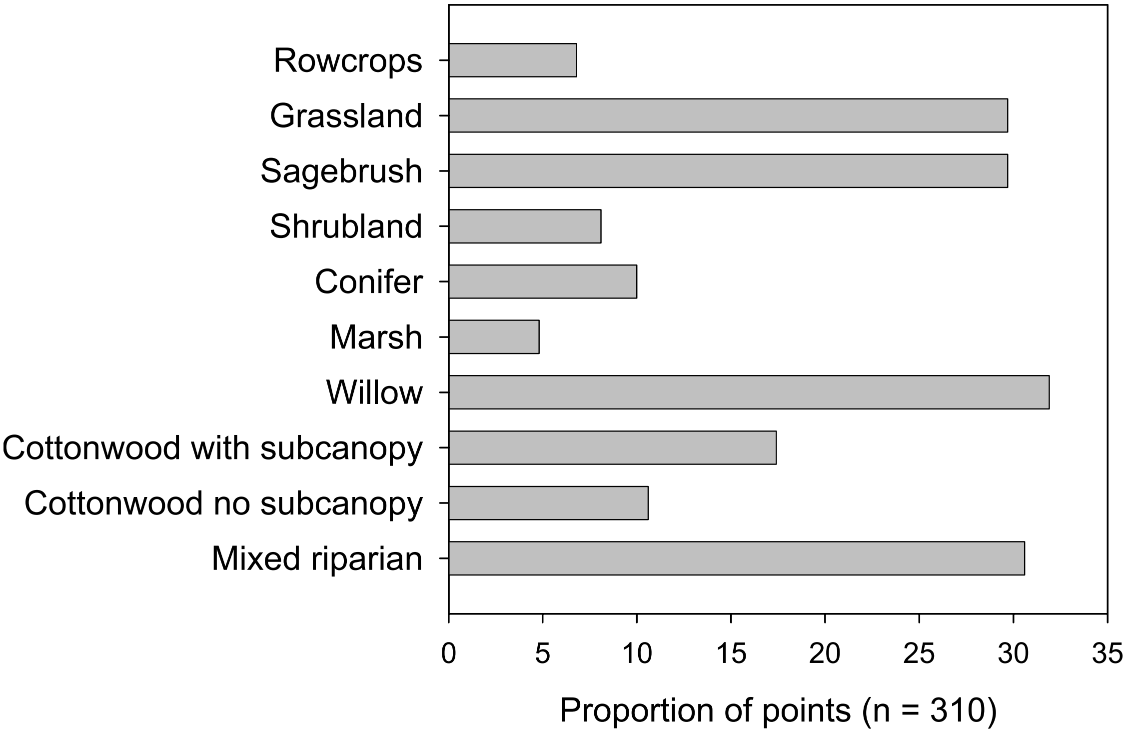


Fig. 11. Vegetation types observed at point count locations based on transects from 2003 (see Appendix 3 for vegetation type descriptions). Note that point locations could consist of > 1 vegetation type, so proportions do not sum to 100.

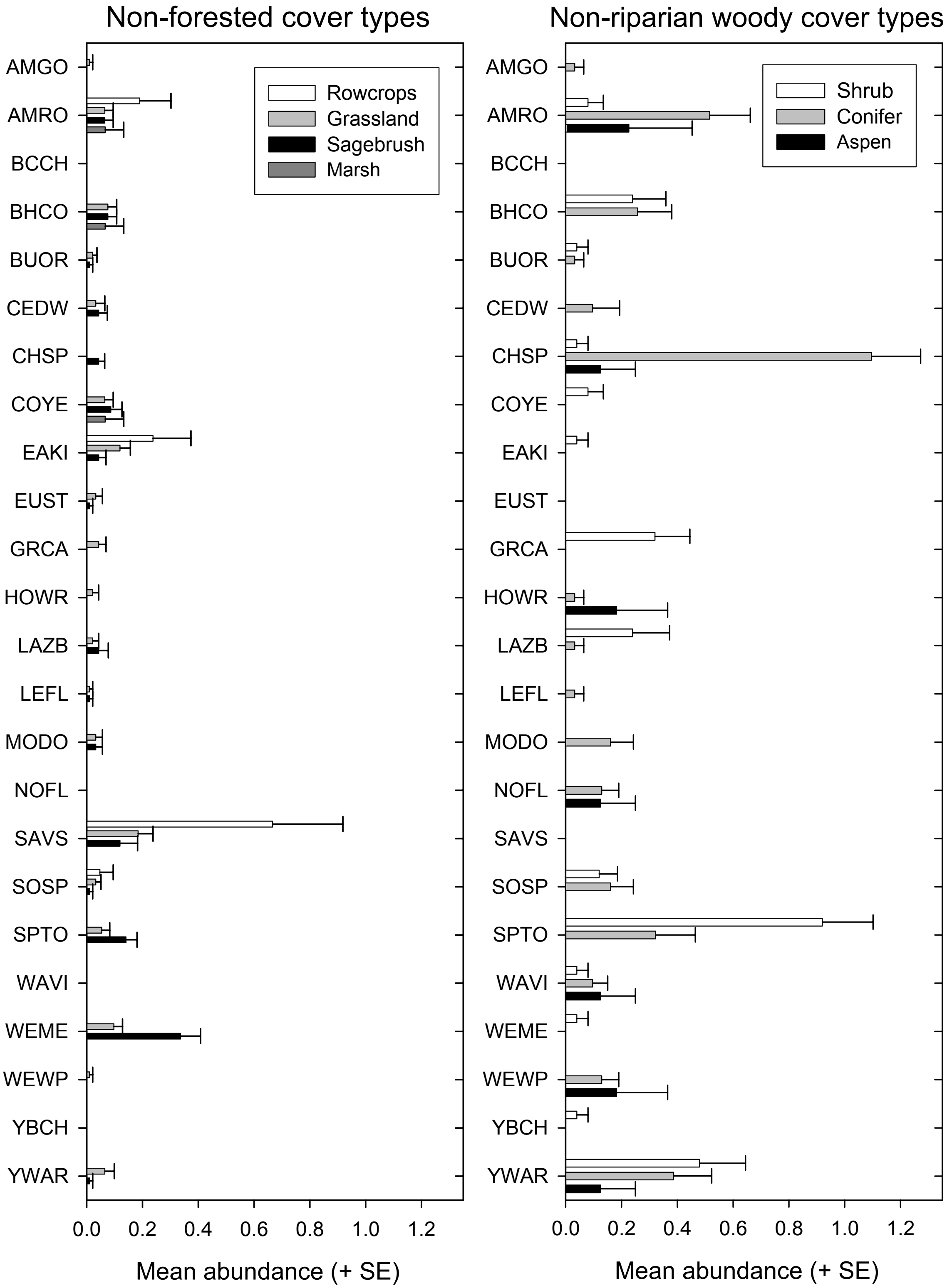


Fig. 12. Relative abundance of common species (number of detections/point) for each non-riparian course-resolution vegetation type based on point-count transects conducted in 2003 (see Appendix 3 for vegetation type descriptions and Appendix 5 for species codes).

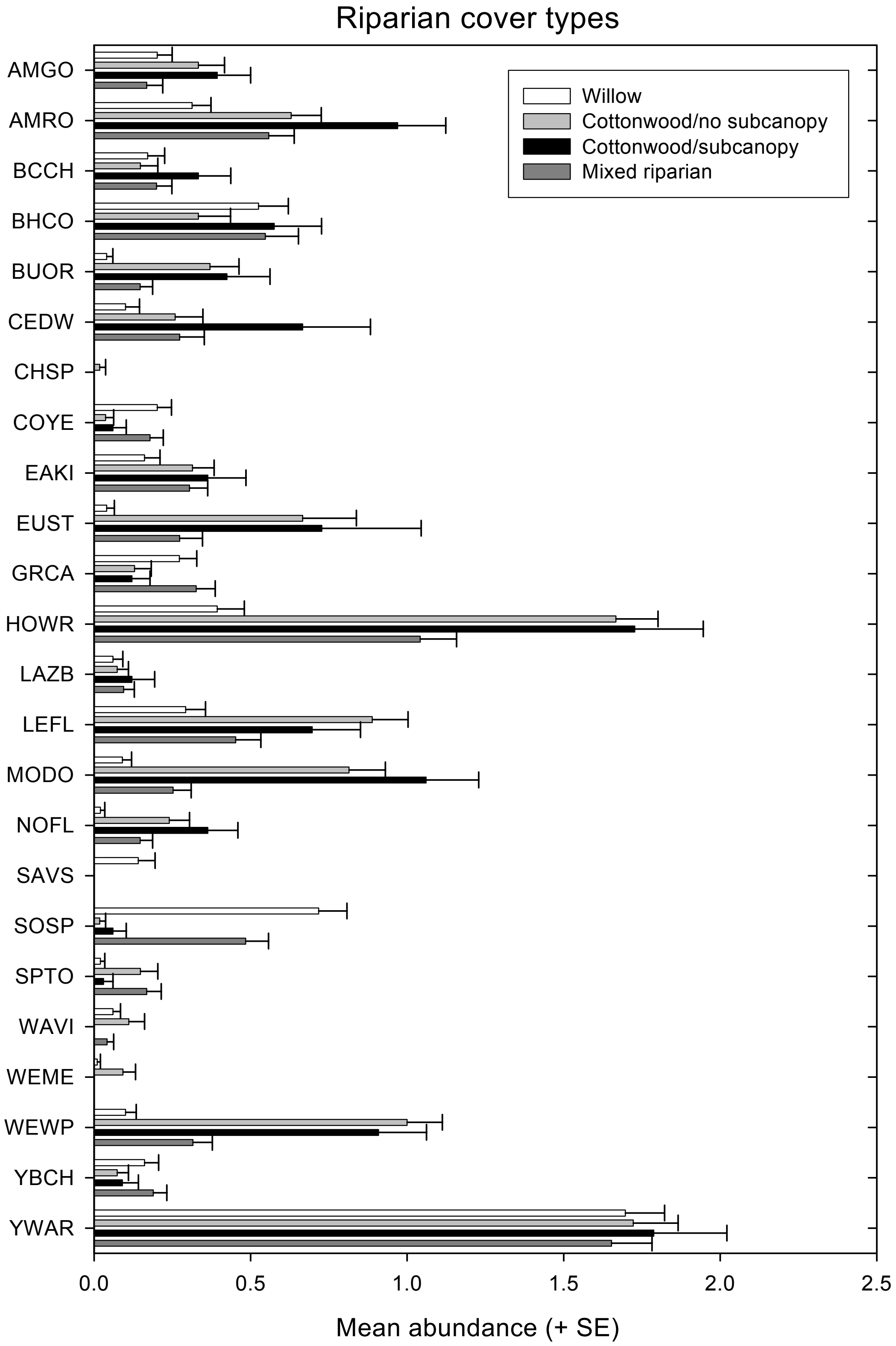


Fig. 13. Relative abundance of common species (number of detections/point) for each riparian course-resolution vegetation type based on point-count transects conducted in 2003 (see Appendix 3 for vegetation type descriptions and Appendix 5 for species codes).

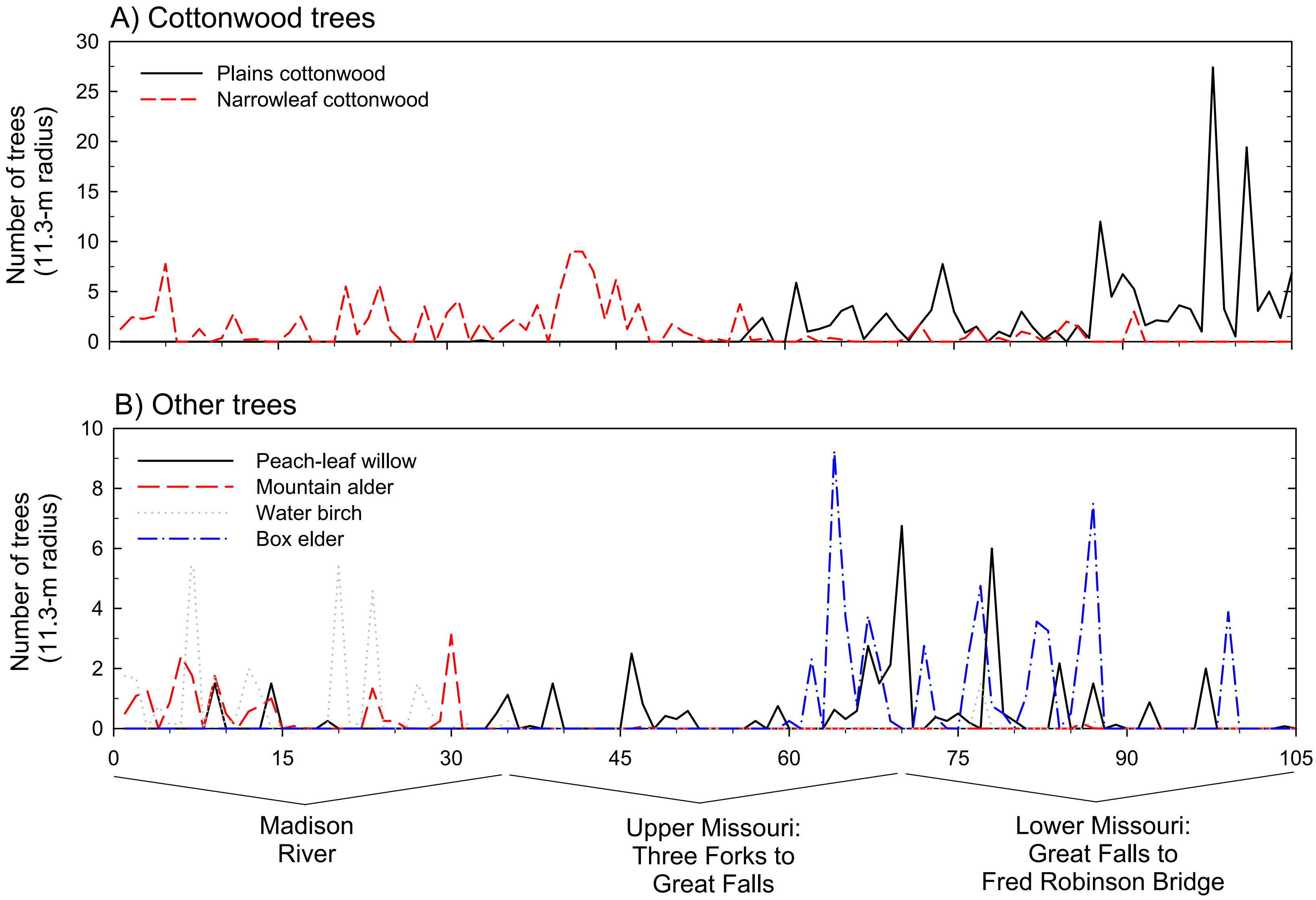


Fig. 14. Geographic patterns in the tree community sampled in riparian patches, 2004-2005. (A) Number of cottonwood trees and (B) other common trees as a function of patch location along the river.

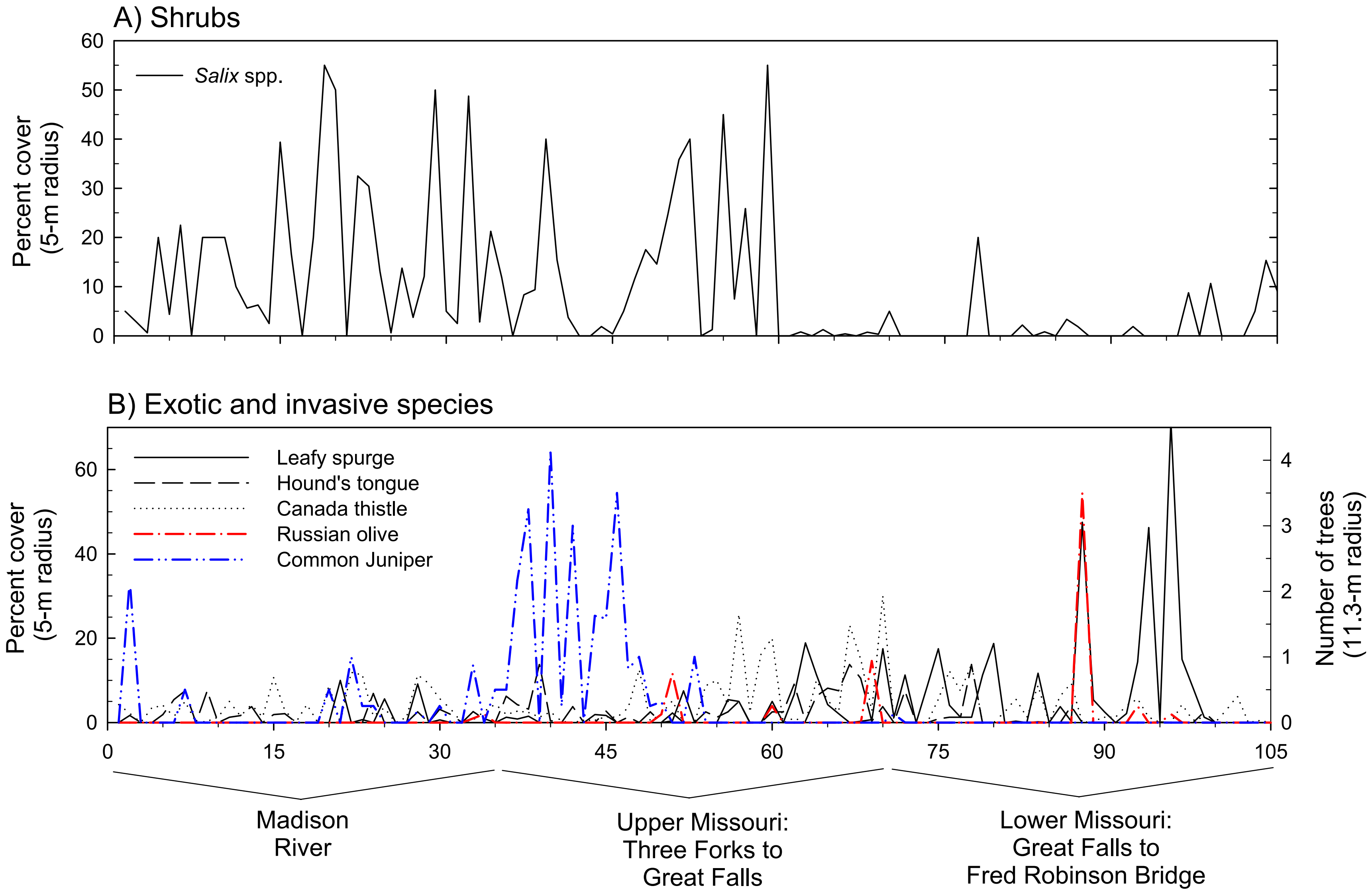
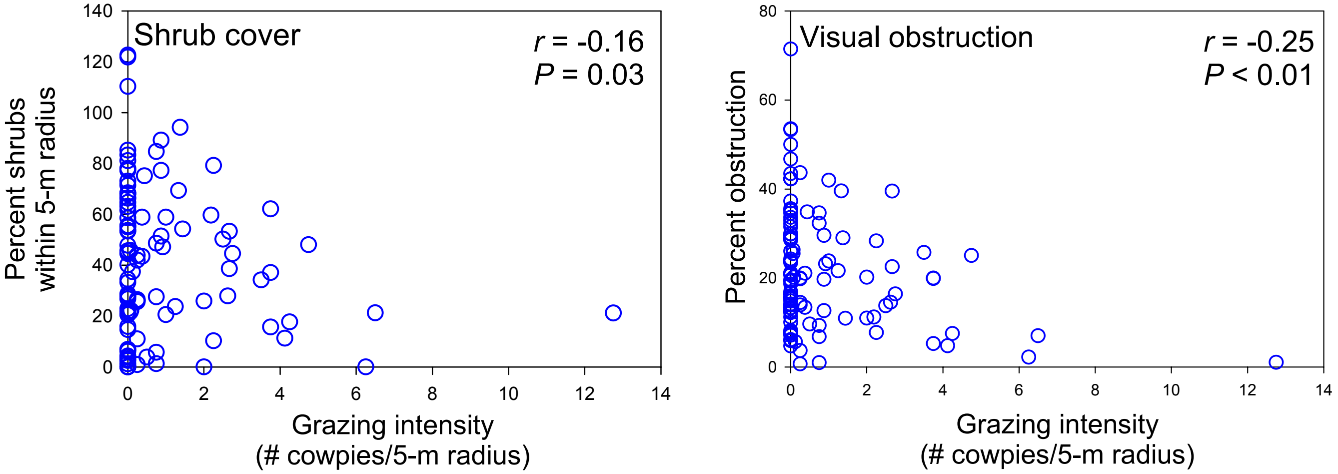


Fig. 15. Geographic patterns in vegetation sampled in riparian patches, 2004-2005. (A) Percent willow cover (*Salix* spp.), and (B) cover of exotic and invasive species as a function of patch location along the river.

(a) Grazing intensity and the sub-canopy



(b) Exotic species cover and the sub-canopy

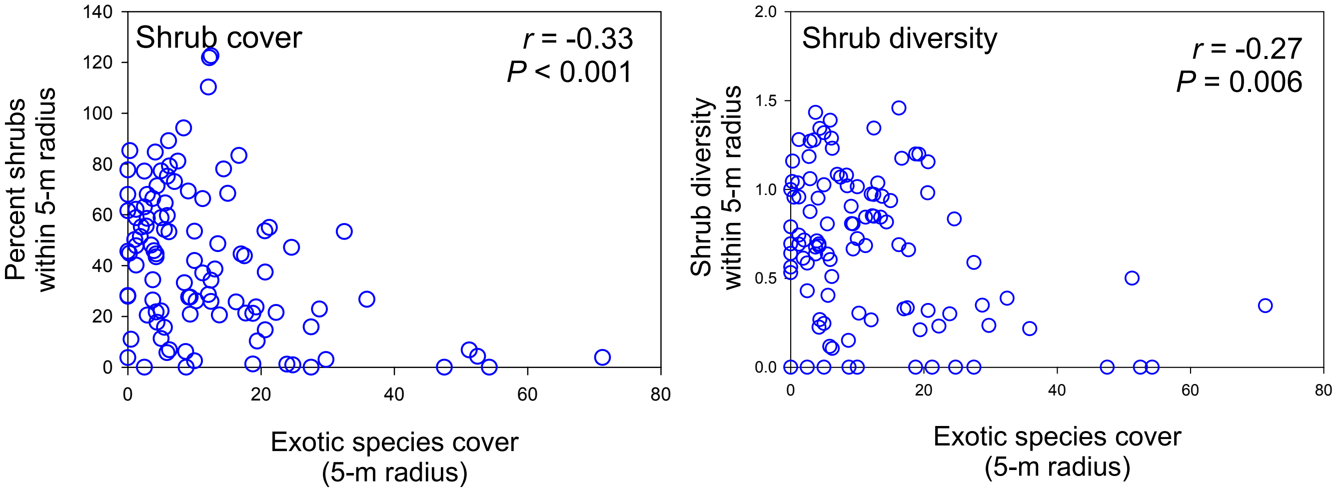


Fig. 16. Correlation between (a) grazing intensity (# cow pies/5-m radius) and (b) exotic species cover with measures of sub-canopy structure, 2004-2005.

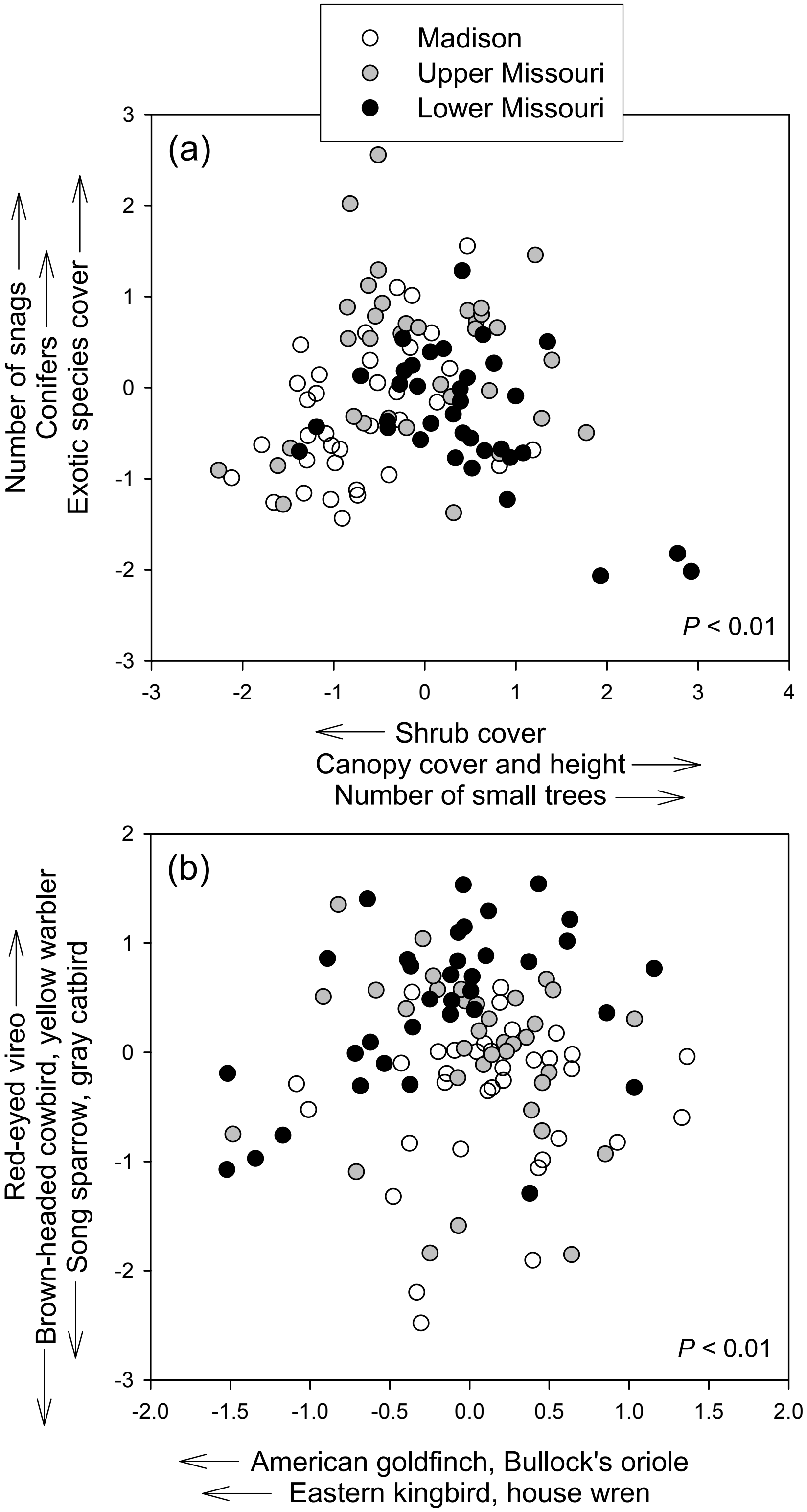


Fig. 17. Geographic sections of the study area contain distinct (A) vegetation and (B) bird communities, with the main differences being between the Madison and Lower Missouri sections, 2004-2005. Analysis same as in Fig. 10.

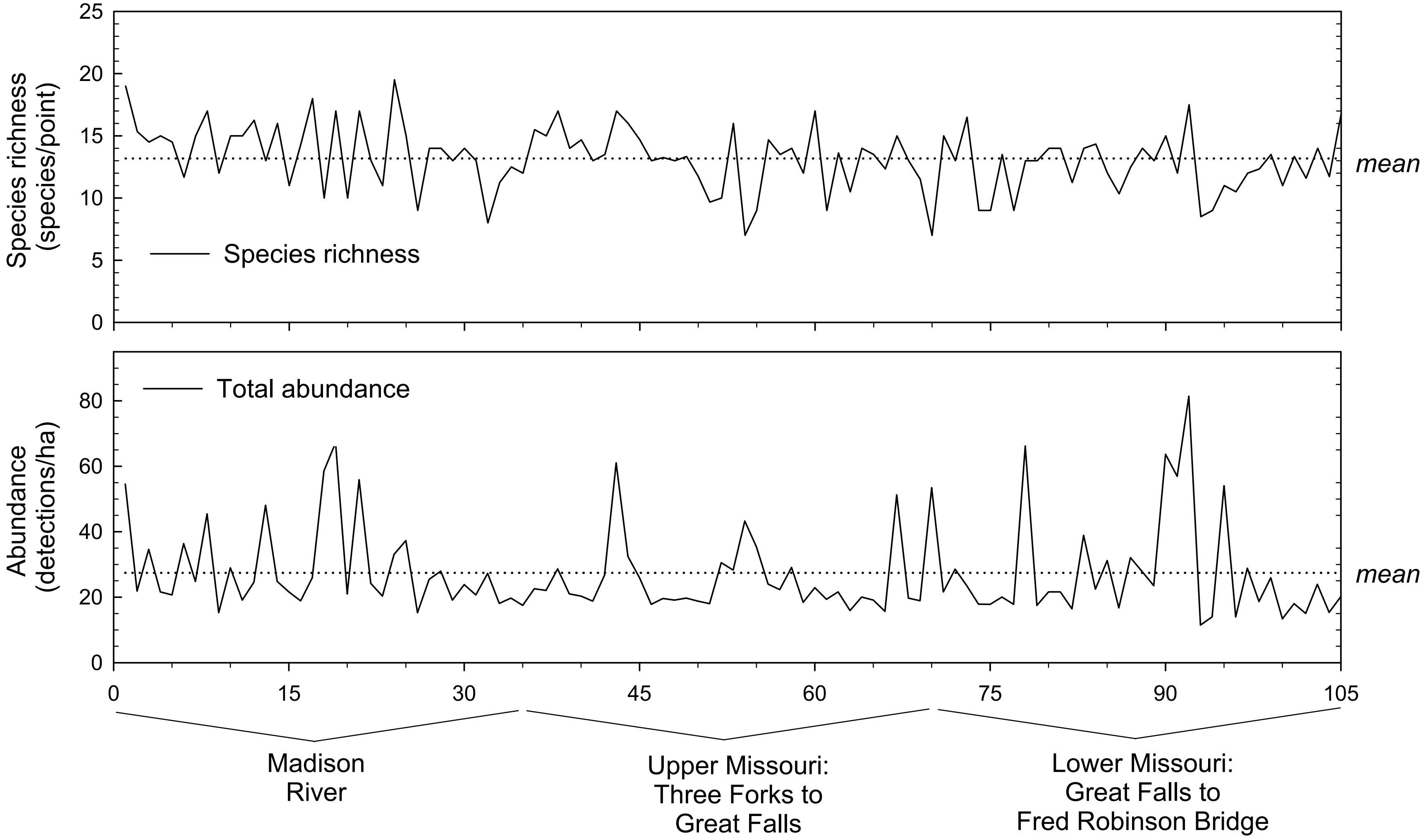
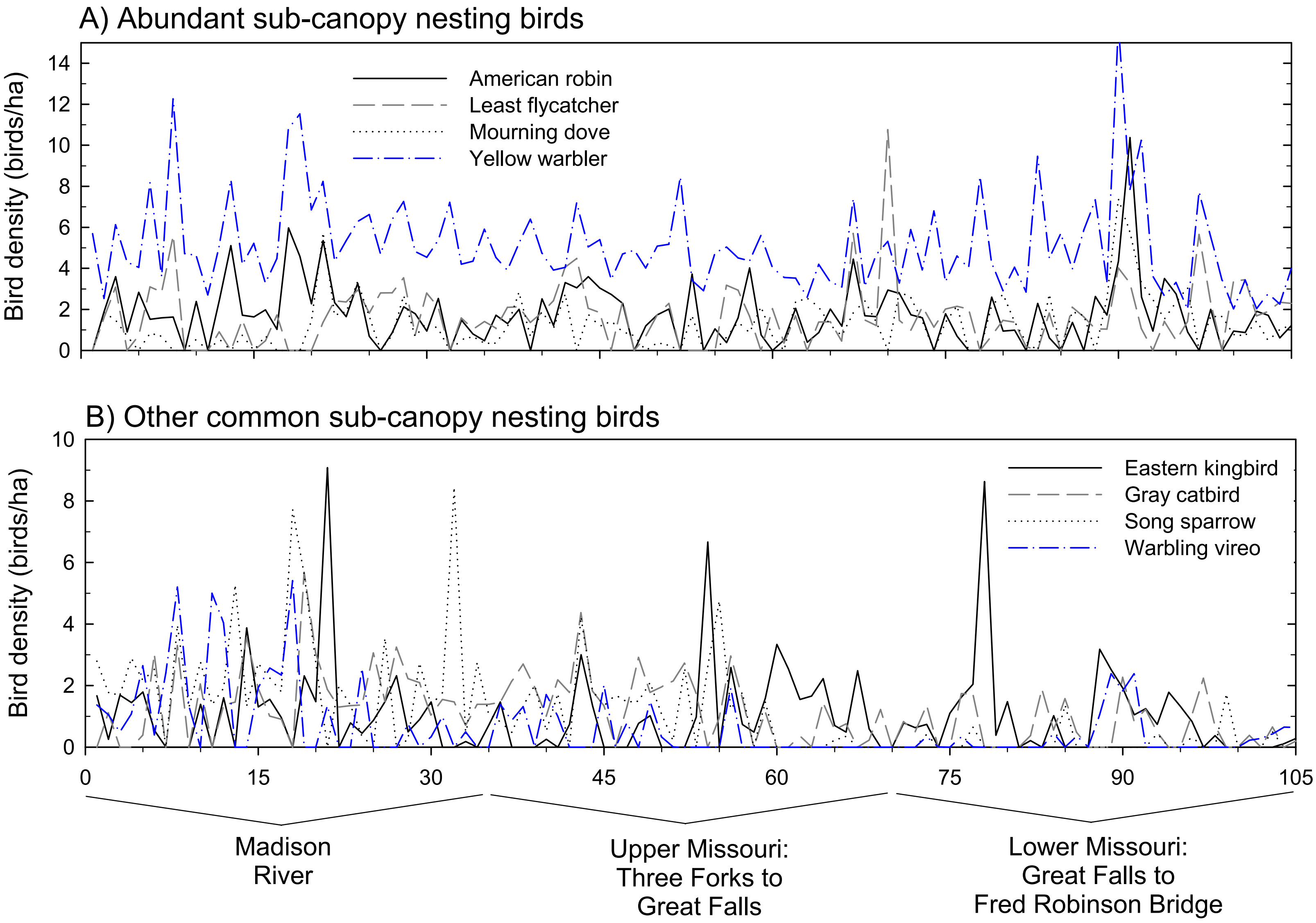


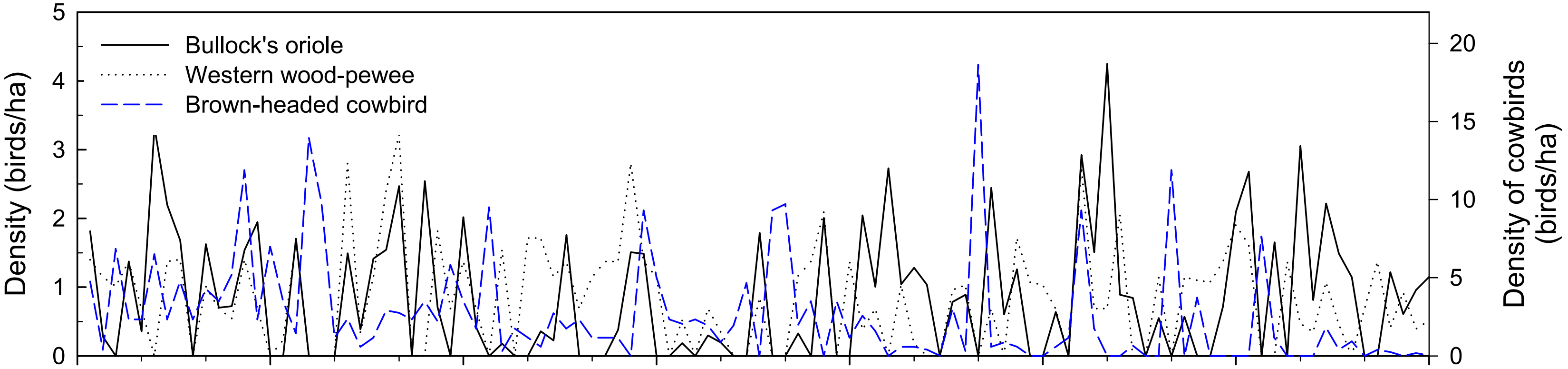
Fig. 18. Geographic patterns in avian species richness (species/point) and total abundance (detections/ha) in riparian patches, 2004-2005.


A) Abundant sub-canopy nesting birds

B) Other common sub-canopy nesting birds

Fig. 19. Geographic patterns in bird density (birds/ha) for relatively common species in riparian patches, 2004-2005. (A) Abundant sub-canopy nesters and (B) other common sub-canopy nesters.

A) Cowbirds and canopy-nesting birds



B) Cavity-nesting birds

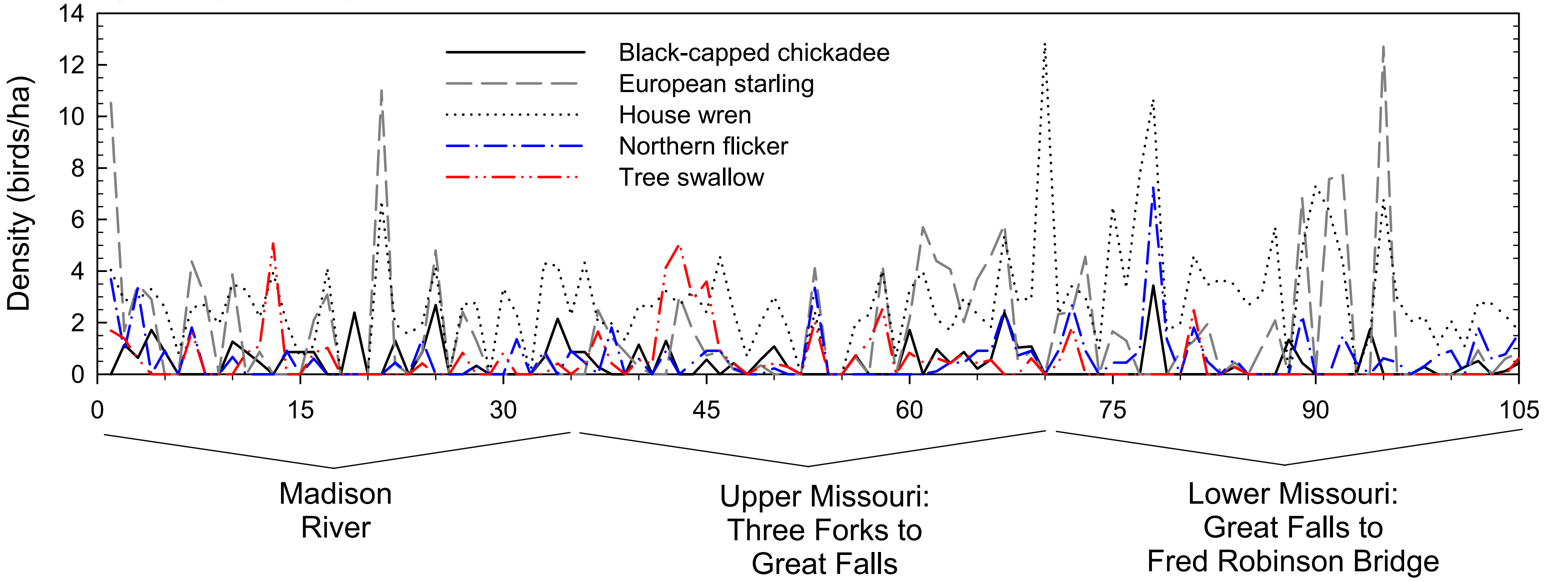


Fig. 20. Geographic patterns in bird density (birds/ha) for relatively common species in riparian patches, 2004-2005. (A) Canopy-nesters and brown-headed cowbirds and (B) cavity-nesting species.

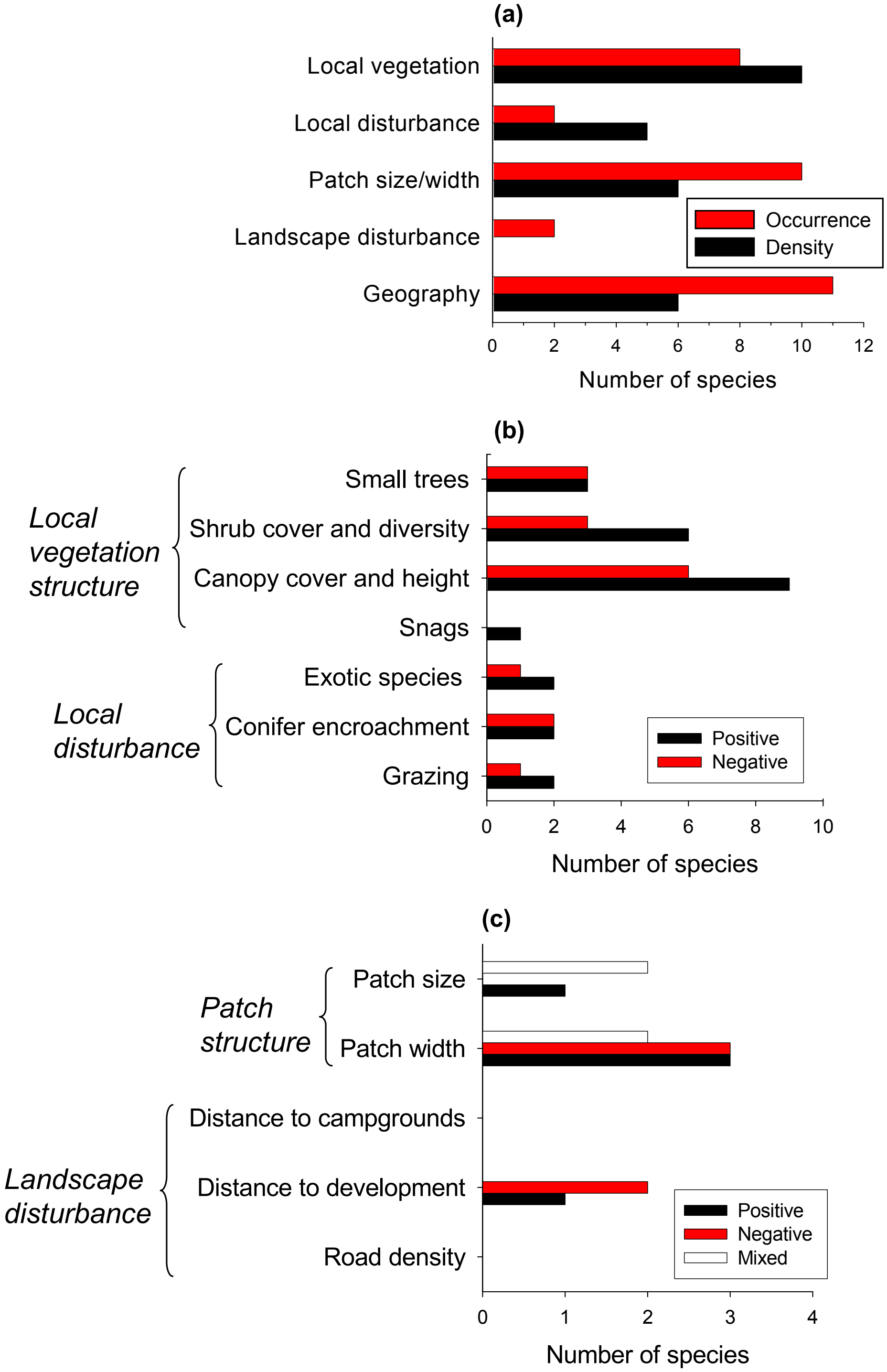


Fig. 21. Summary of factors influencing bird density and occurrence in riparian patches, 2004-2005. (A) Number of species in which the best model contained the general type of explanatory factor. (B) Number of species with positive and negative correlations with local vegetation and local disturbance factors. (C) Number of species with positive, negative, and mixed correlations with patch structure and landscape disturbance. A mixed correlation refers to a model where the correlation changed in different geographic regions.

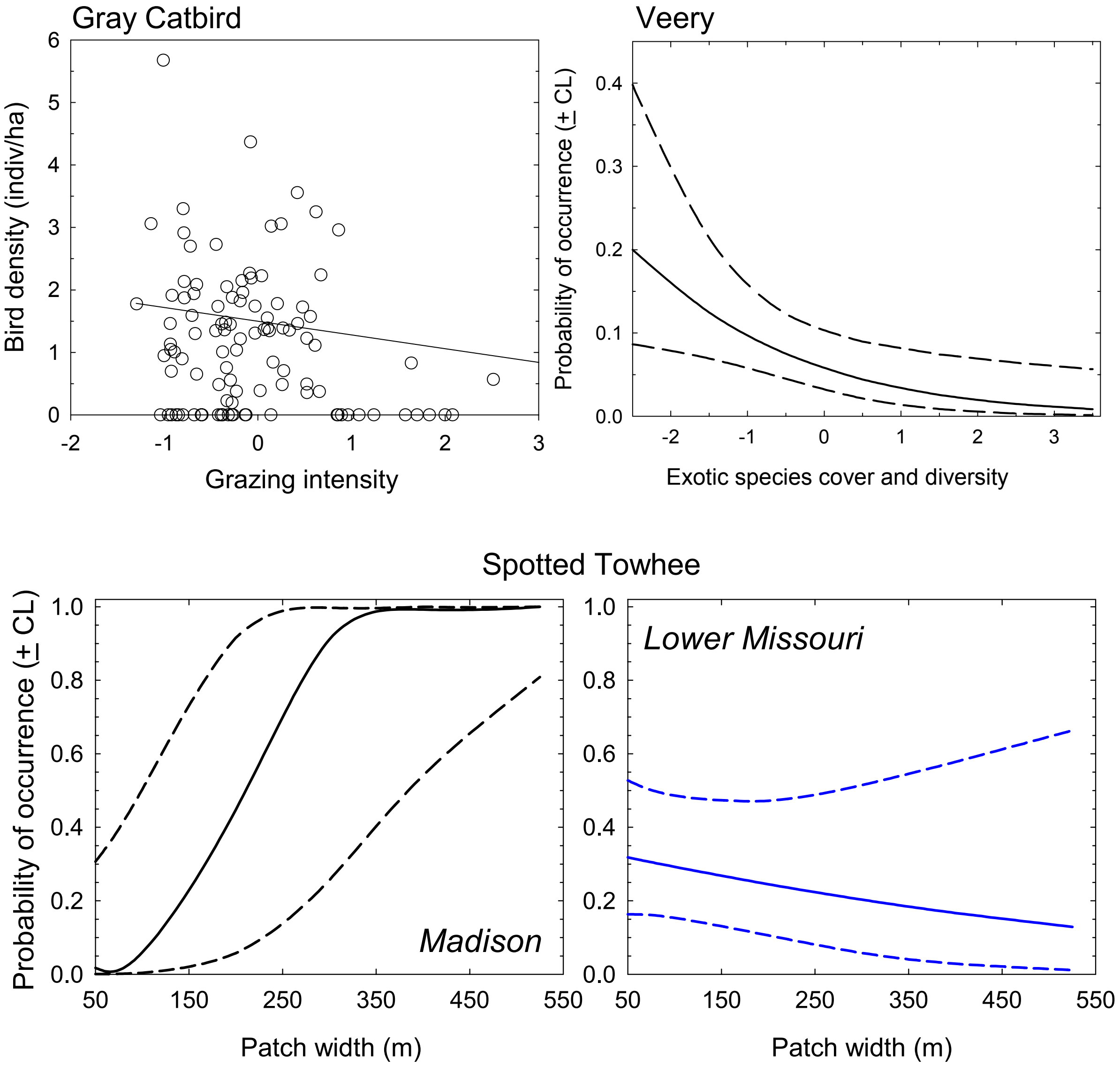
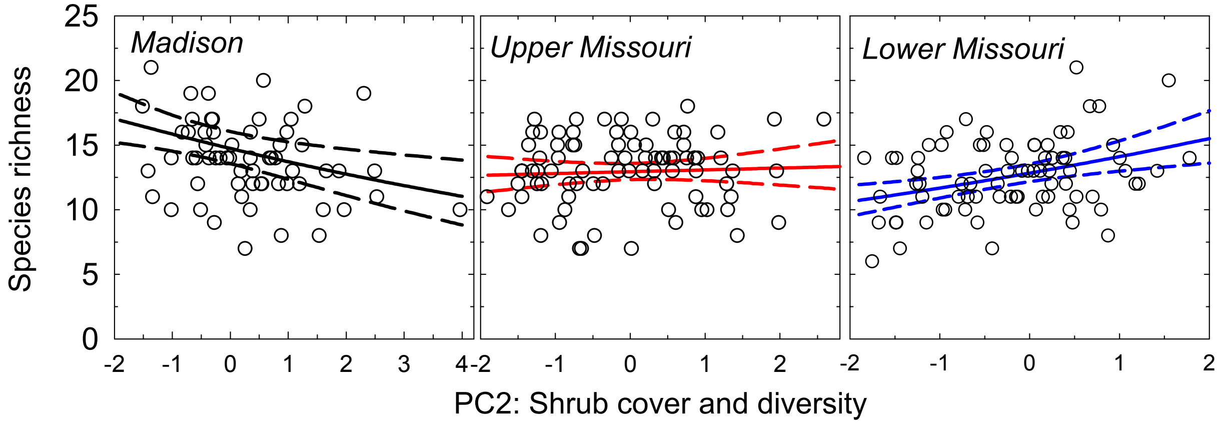
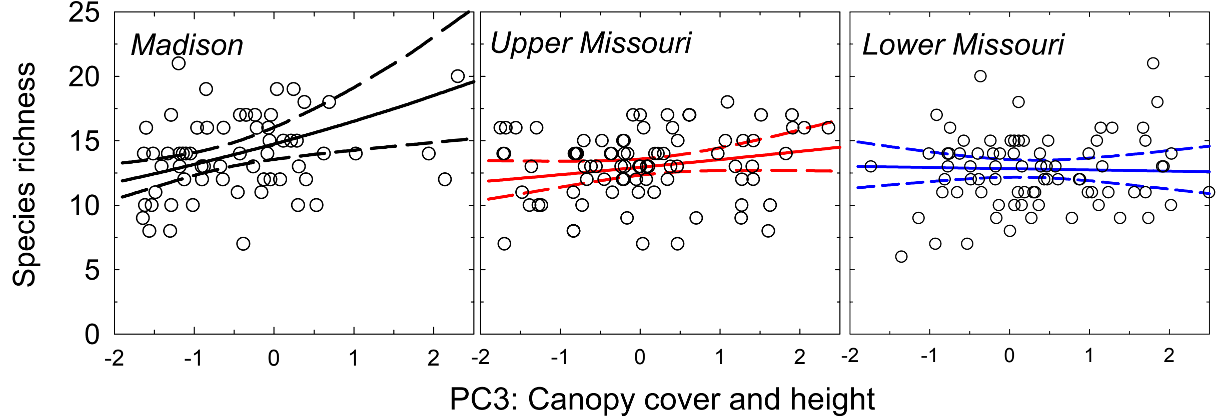


Fig. 22. Examples of correlates in models of bird density and occurrence along the Madison and Missouri Rivers, 2004-2005. The gray catbird showed a negative relationship in bird density with grazing intensity (exemplified by PC7; Table 1), and the Veery showed a negative relationship in occurrence with exotic cover (exemplified by PC4; Table 1). Spotted Towhee occurrence showed a relationship with riparian patch width, but the relationship differed in different geographic sections of the river system. Estimates (± 95% confidence limits) from the most parsimonious model to explain density and occurrence patterns (from Tables 6, 7), while controlling for other factors in the model.

(a) Shrub cover and diversity



(b) Canopy cover and height



(c) Snags

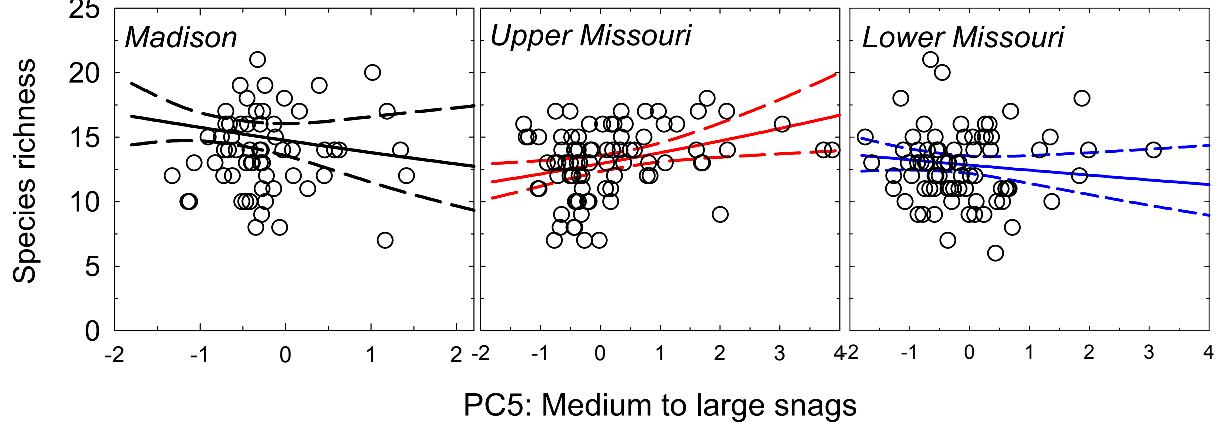


Fig. 23. Avian species richness (# species/point) showed strong geographic variation in correlations with vegetation structure, 2004-2005. Estimates (± 95% confidence limits) from the most parsimonious model to explain patterns of species richness (from Table 7), while controlling for other factors in the model.

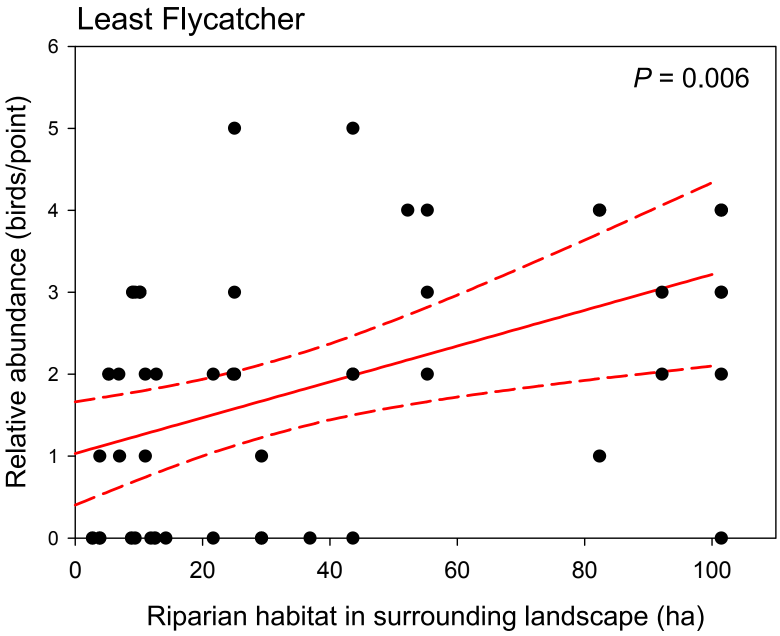


Fig. 24. Using the NWI database, the best model for describing least flycatcher relative abundance only included the amount of riparian habitat in the surrounding landscape (within 1-km).

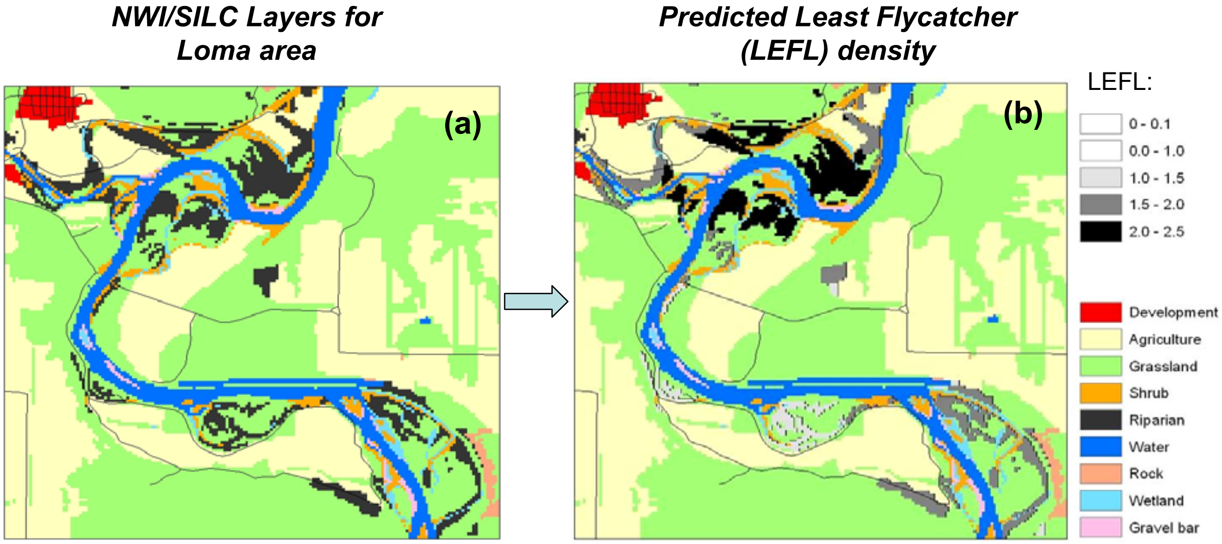


Fig. 25. An example of combining GIS layers (a) and habitat models (from Fig. 22) to generate a predictive bird abundance map for the least flycatcher (b).

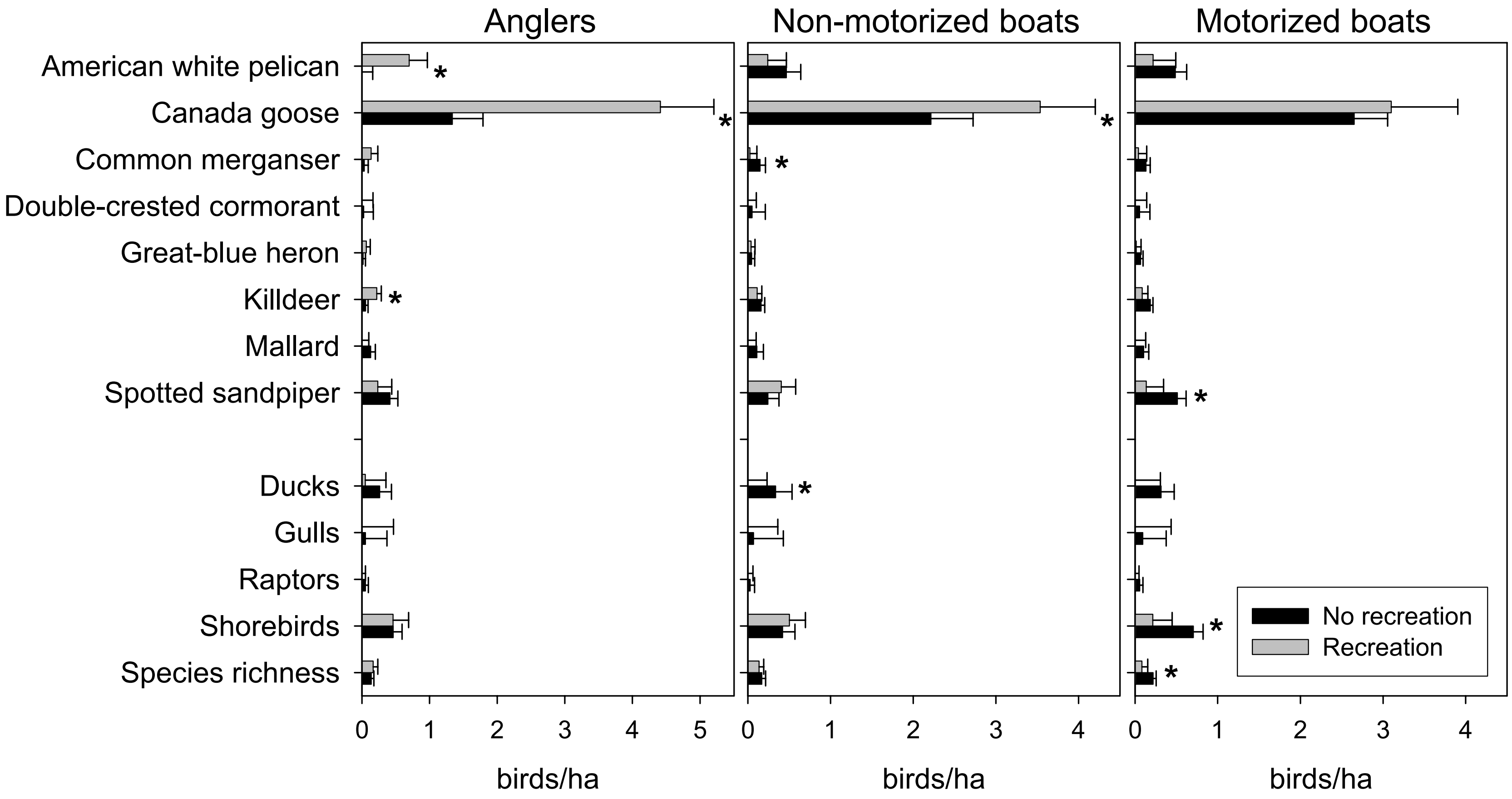


Fig. 26. Densities (birds/ha + SE) for species and species groups and avian species richness (species/ha) based on river surveys in the presence and absence of recreational activity, Madison and Missouri Rivers, 2004. *$P < 0.10$.

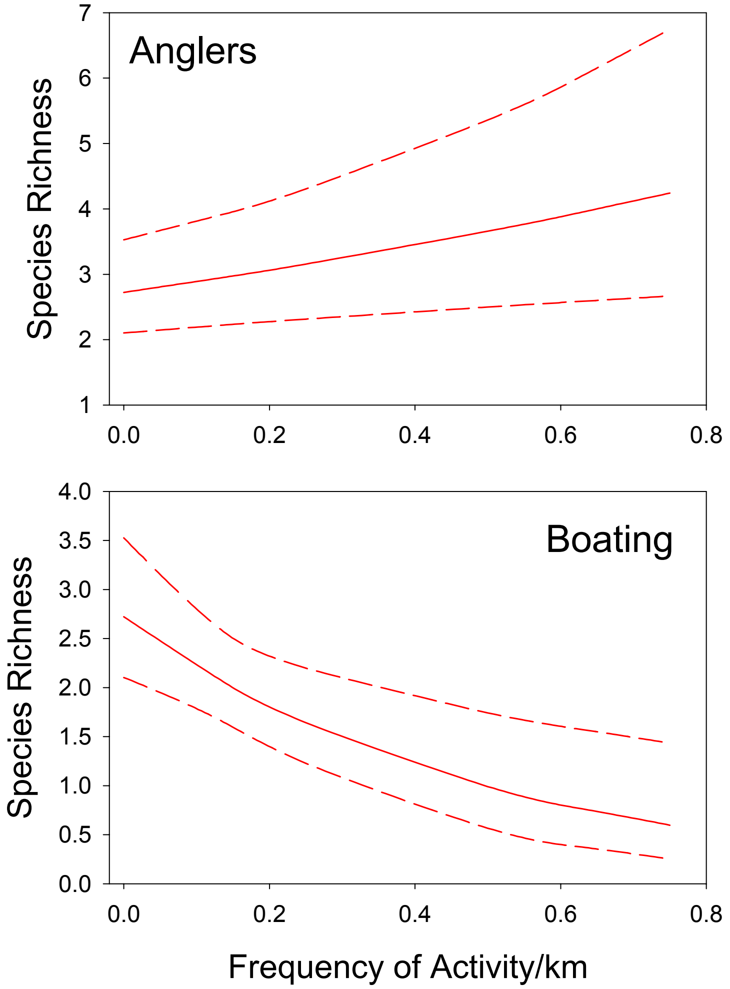


Fig. 27. Predicted avian species richness (log(species/km) ± 95% confidence limits) as a function of increasing recreational activity during river surveys, Madison and Missouri Rivers, 2004.

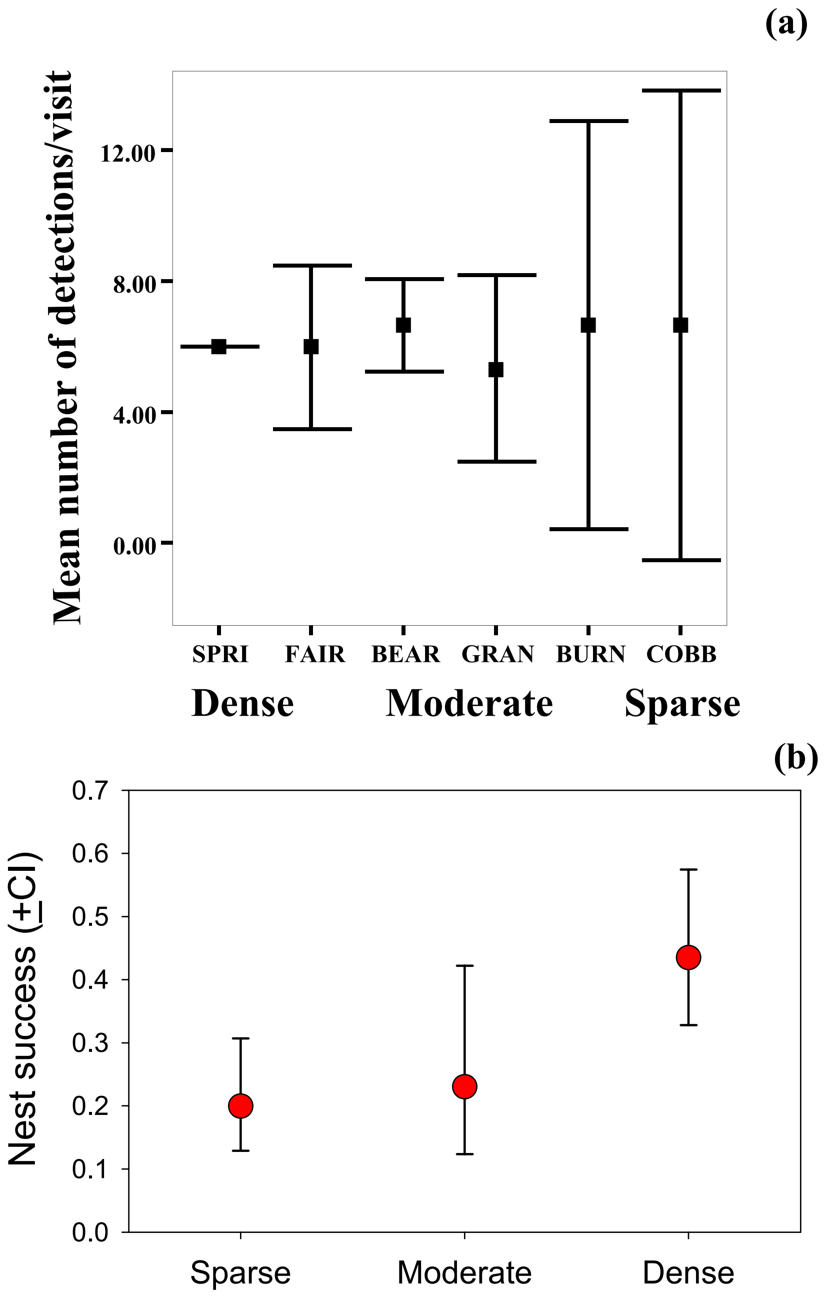


Fig. 28. (a) Relative abundance (detections/point) in 2003and (b) nesting success of Yellow Warblers in 2003-2004 as a function of subcanopy vegetation structure along the Madison and Missouri Rivers, Montana. Note that there is no correspondence between abundance and reproductive performance.

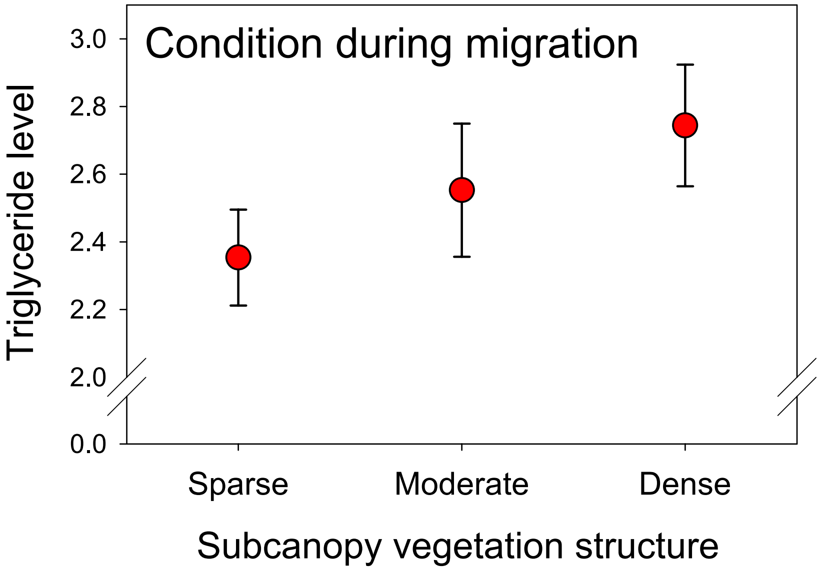


Fig. 29. Triglyceride levels of migrating Wilson's Warblers in fall 2003 as a function of subcanopy vegetation structure along the Madison and Missouri Rivers, Montana. Higher triglyceride reflects faster refueling rates. (Guglielmo et al. 2002). $P = 0.06$.

Appendix 1. Targeted avian species for literature syntheses. We targeted these species based on Partners in Flight (PIF) priority status, USFWS status, or if species were relatively common in riparian habitats along the Upper Missouri/Madison River system.

	Species	PIF Priority				Common
Species	Code	I	II	III	USFWS	riparian
American goldfinch	AMGO					X
American redstart	AMRE			X		
American robin	AMRO					X
American white pelican	AWPE			X		
Bald eagle	BAEA		X		X	
Black-billed cuckoo	BBCU		X			
Brown-headed cowbird	BHCO					X
Bullock's oriole	BUOR					X
Caspian tern	CATE		X			
Cedar waxwing	CEDW					X
Common yellowthroat	COYE					X
Downy woodpecker	DOWO			X		
Eastern kingbird	EAKI					X
European starling	EUST					X
Forster's tern	FOTE		X			
Franklin's gull	FRGU		X			
Golden eagle	GOEA				X	
Gray catbird	GRCA			X		
House wren	HOWR					X
Killdeer	KILL			X		
Lazuli bunting	LAZB		X			
Long-billed curlew	LBCU		X		X	
Least flycatcher	LEFL			X		
Least tern (interior)	LETE	X			X	
Marbled godwit	MAGO		X		X	
Mourning dove	MODO					X
Ovenbird	OVEN			X		
Red-eyed vireo	REVI		X			
Red-naped sapsucker	RNSA		X		X	
Red-winged blackbird	RWBL			X		
Song sparrow	SOSP			X		
Sharp-shinned hawk	SSHA			X		
Swainson's hawk	SWHA			X	X	
Trumpeter swan	TRUS	X				
Veery	VEER			X		
Warbling vireo	WAVI			X		
Western wood-pewee	WEWP					X
Willow flycatcher	WIFL		X			
Wilson's phalarope	WIPH			X	X	
Yellow-billed cuckoo	YBCU		X		X	
Yellow -breasted chat	YBCH					X
Yellow-headed blackbird	YHBL			X		
Yellow warbler	YWAR					X

Appendix 2. Point count locations for 2003 transects conducted across all habitat types.

Transect	Stretch	Pt	Latitude	Longitude	Transect	Stretch	Pt	Latitude	Longitude	Transect	Stretch	Pt	Latitude	Longitude
Yellowstone	MA	1	44.66471	-110.96495	Townsend	UM	1	46.27227	-111.49502	Black Bluff	LM	1	47.91273	-110.49709
Yellowstone	MA	2	44.66634	-110.96760	Townsend	UM	2	46.26981	-111.49489	Black Bluff	LM	2	47.91123	-110.49362
Yellowstone	MA	3	44.66821	-110.97005	Townsend	UM	3	46.26750	-111.49442	Black Bluff	LM	3	47.91019	-110.48995
Yellowstone	MA	4	44.66945	-110.97325	Townsend	UM	4	46.26634	-111.49134	Black Bluff	LM	4	47.90935	-110.48595
Yellowstone	MA	5	44.67023	-110.97675	Townsend	UM	5	46.26551	-111.48802	Black Bluff	LM	5	47.91005	-110.48202
Yellowstone	MA	6	44.67025	-110.98039	Townsend	UM	6	46.26354	-111.48492	Black Bluff	LM	6	47.91070	-110.47779
Yellowstone	MA	7	44.66890	-110.98360	Townsend	UM	7	46.26062	-111.48337	Black Bluff	LM	7	47.91037	-110.47323
Yellowstone	MA	8	44.66779	-110.98695	Townsend	UM	8	46.25833	-111.48486	Black Bluff	LM	8	47.91048	-110.46900
Yellowstone	MA	9	44.66677	-110.99059	Townsend	UM	9	46.25602	-111.48654	Black Bluff	LM	9	47.90853	-110.46562
Yellowstone	MA	10	44.66462	-110.99270	Townsend	UM	10	46.25441	-111.49009	Black Bluff	LM	10	47.90624	-110.46330
Hebgen Dam	MA	1	44.78566	-111.27684	Hauser	UM	1	46.71142	-111.80544	Coal Banks	LM	1	48.02360	-110.24183
Hebgen Dam	MA	2	44.78830	-111.27742	Hauser	UM	2	46.70894	-111.80581	Coal Banks	LM	2	48.02109	-110.24262
Hebgen Dam	MA	3	44.79058	-111.27598	Hauser	UM	3	46.70644	-111.80466	Coal Banks	LM	3	48.01841	-110.24330
Hebgen Dam	MA	4	44.79282	-111.27383	Hauser	UM	4	46.70414	-111.80283	Coal Banks	LM	4	48.01550	-110.24359
Hebgen Dam	MA	5	44.79460	-111.27085	Hauser	UM	5	46.70609	-111.80211	Coal Banks	LM	5	48.01308	-110.24331
Hebgen Dam	MA	6	44.79685	-111.26896	Hauser	UM	6	46.70420	-111.80281	Coal Banks	LM	6	48.01053	-110.24330
Hebgen Dam	MA	7	44.79939	-111.26766	Hauser	UM	7	46.70191	-111.80049	Coal Banks	LM	7	48.00768	-110.24356
Hebgen Dam	MA	8	44.80195	-111.26908	Hauser	UM	8	46.69960	-111.79870	Coal Banks	LM	8	48.00514	-110.24466
Hebgen Dam	MA	9	44.80437	-111.27029	Hauser	UM	9	46.69686	-111.79859	Coal Banks	LM	9	48.00272	-110.24638
Hebgen Dam	MA	10	44.78328	-111.27600	Hauser	UM	10	46.69473	-111.80111	Coal Banks	LM	10	48.00158	-110.24989
Quake Lake	MA	1	44.85380	-111.35438	Holter	UM	1	46.91654	-111.94375	ABN Ranch	LM	1	48.02945	-110.14601
Quake Lake	MA	2	44.85376	-111.35730	Holter	UM	2	46.91878	-111.94633	ABN Ranch	LM	2	48.03243	-110.14757
Quake Lake	MA	3	44.85340	-111.36108	Holter	UM	3	46.92103	-111.94817	ABN Ranch	LM	3	48.03455	-110.15052
Quake Lake	MA	4	44.85304	-111.36520	Holter	UM	4	46.92349	-111.94925	ABN Ranch	LM	4	48.03594	-110.15398
Quake Lake	MA	5	44.85248	-111.36926	Holter	UM	5	46.92581	-111.94948	ABN Ranch	LM	5	48.03693	-110.15777
Quake Lake	MA	6	44.85150	-111.37285	Holter	UM	6	46.92861	-111.94995	ABN Ranch	LM	6	48.03754	-110.16164
Quake Lake	MA	7	44.85279	-111.37661	Holter	UM	7	46.93143	-111.94942	ABN Ranch	LM	7	48.03846	-110.16561
Quake Lake	MA	8	44.85329	-111.38027	Holter	UM	8	46.93399	-111.94329	ABN Ranch	LM	8	48.03908	-110.16986
Quake Lake	MA	9	44.85363	-111.38405	Holter	UM	9	46.93634	-111.94835	ABN Ranch	LM	9	48.03878	-110.17384
Quake Lake	MA	10	44.85423	-111.38696	Holter	UM	10	46.93889	-111.94818	ABN Ranch	LM	10	48.03820	-110.17754
Wall Creek	MA	1	45.03674	-111.67688	Craig	UM	1	47.06836	-111.96210	Hole in Wall	LM	1	47.81928	-110.06290
Wall Creek	MA	2	45.03455	-111.67477	Craig	UM	2	47.07067	-111.96086	Hole in Wall	LM	2	47.81940	-110.05907
Wall Creek	MA	3	45.03175	-111.67307	Craig	UM	3	47.07315	-111.96017	Hole in Wall	LM	3	47.81945	-110.05477
Wall Creek	MA	4	45.02888	-111.67262	Craig	UM	4	47.07540	-111.95993	Hole in Wall	LM	4	47.81870	-110.05079
Wall Creek	MA	5	45.02701	-111.66968	Craig	UM	5	47.07809	-111.95991	Hole in Wall	LM	5	47.81757	-110.04705
Wall Creek	MA	6	45.02445	-111.66790	Craig	UM	6	47.08099	-111.95729	Hole in Wall	LM	6	47.81562	-110.04259
Wall Creek	MA	7	45.02202	-111.66634	Craig	UM	7	47.08344	-111.95554	Hole in Wall	LM	7	47.81531	-110.03795
Wall Creek	MA	8	45.01923	-111.66601	Craig	UM	8	47.08610	-111.95667	Hole in Wall	LM	8	47.81494	-110.03334
Wall Creek	MA	9	45.01670	-111.66467	Craig	UM	9	47.08873	-111.95759	Hole in Wall	LM	9	47.81419	-110.02978
Wall Creek	MA	10	45.01399	-111.66502	Craig	UM	10	47.08891	-111.95413	Hole in Wall	LM	10	47.81294	-110.02618
Varney Bridge	MA	1	45.23464	-111.75494	Pelican	UM	1	47.22695	-111.73541	Arrow Creek	LM	1	47.71059	-109.80837
Varney Bridge	MA	2	45.23737	-111.75664	Pelican	UM	2	47.22940	-111.73529	Arrow Creek	LM	2	47.71045	-109.81228
Varney Bridge	MA	3	45.24018	-111.75758	Pelican	UM	3	47.23278	-111.73571	Arrow Creek	LM	3	47.71089	-109.81624

Appendix 2, *continued*

Transect	Stretch	Pt	Latitude	Longitude	Transect	Stretch	Pt	Latitude	Longitude	Transect	Stretch	Pt	Latitude	Longitude
Varney Bridge	MA	4	45.24305	-111.75652	Pelican	UM	4	47.23564	-111.73417	Arrow Creek	LM	4	47.71219	-109.82017
Varney Bridge	MA	5	45.24586	-111.75746	Pelican	UM	5	47.23790	-111.73114	Arrow Creek	LM	5	47.71410	-109.82331
Varney Bridge	MA	6	45.24843	-111.75918	Pelican	UM	6	47.23823	-111.72660	Arrow Creek	LM	6	47.71524	-109.82668
Varney Bridge	MA	7	45.25148	-111.75998	Pelican	UM	7	47.23703	-111.72264	Arrow Creek	LM	7	47.71514	-109.83044
Varney Bridge	MA	8	45.25264	-111.76241	Pelican	UM	8	47.23710	-111.71919	Arrow Creek	LM	8	47.71358	-109.83383
Varney Bridge	MA	9	45.25606	-111.76381	Pelican	UM	9	47.23957	-111.72115	Arrow Creek	LM	9	47.71302	-109.83767
Varney Bridge	MA	10	45.25889	-111.76380	Pelican	UM	10	47.24172	-111.72243	Arrow Creek	LM	10	47.71332	-109.84191
Ennis	MA	1	45.37009	-111.70397	Voegles	UM	1	47.35775	-111.57636	Judith	LM	1	47.73403	-109.66584
Ennis	MA	2	45.37259	-111.70331	Voegles	UM	2	47.35937	-111.57086	Judith	LM	2	47.73397	-109.66154
Ennis	MA	3	45.37525	-111.70324	Voegles	UM	3	47.36002	-111.56658	Judith	LM	3	47.73396	-109.65754
Ennis	MA	4	45.37761	-111.70146	Voegles	UM	4	47.36077	-111.56262	Judith	LM	4	47.73360	-109.65336
Ennis	MA	5	45.37991	-111.69911	Voegles	UM	5	47.36306	-111.55945	Judith	LM	5	47.73389	-109.64935
Ennis	MA	6	45.38238	-111.69748	Voegles	UM	6	47.36567	-111.55780	Judith	LM	6	47.73456	-109.64539
Ennis	MA	7	45.38516	-111.69571	Voegles	UM	7	47.36818	-111.55785	Judith	LM	7	47.73633	-109.64200
Ennis	MA	8	45.38758	-111.69394	Voegles	UM	8	47.37099	-111.55902	Judith	LM	8	47.73733	-109.63831
Ennis	MA	9	45.39016	-111.69313	Voegles	UM	9	47.37343	-111.55813	Judith	LM	9	47.73734	-109.63447
Ennis	MA	10	45.39286	-111.69314	Voegles	UM	10	47.37604	-111.55662	Judith	LM	10	47.73709	-109.63028
Beartrap	MA	1	45.57528	-111.59368	Ulm	UM	1	47.43062	-111.50039	Little Dog Rapids	LM	1	47.73623	-109.39389
Beartrap	MA	2	45.57327	-111.59116	Ulm	UM	2	47.42996	-111.49712	Little Dog Rapids	LM	2	47.73449	-109.39699
Beartrap	MA	3	45.57170	-111.58836	Ulm	UM	3	47.42848	-111.49416	Little Dog Rapids	LM	3	47.73282	-109.40055
Beartrap	MA	4	45.56919	-111.58589	Ulm	UM	4	47.42660	-111.49170	Little Dog Rapids	LM	4	47.73188	-109.40425
Beartrap	MA	5	45.56641	-111.58637	Ulm	UM	5	47.42415	-111.48933	Little Dog Rapids	LM	5	47.72971	-109.40714
Beartrap	MA	6	45.56511	-111.59009	Ulm	UM	6	47.42178	-111.48809	Little Dog Rapids	LM	6	47.72800	-109.40941
Beartrap	MA	7	45.56460	-111.59326	Ulm	UM	7	47.41914	-111.48669	Little Dog Rapids	LM	7	47.72533	-109.41274
Beartrap	MA	8	45.56177	-111.59319	Ulm	UM	8	47.41645	-111.48583	Little Dog Rapids	LM	8	47.72449	-109.41651
Beartrap	MA	9	45.55901	-111.59471	Ulm	UM	9	47.41352	-111.48414	Little Dog Rapids	LM	9	47.72323	-109.42011
Beartrap	MA	10	45.55710	-111.59603	Ulm	UM	10	47.41262	-111.48029	Little Dog Rapids	LM	10	47.72200	-109.42379
Cobblestone	MA	1	45.80156	-111.50853	Big Bend	UM	1	47.39055	-111.33056	Bullwhacker	LM	1	47.79529	-109.04678
Cobblestone	MA	2	45.79927	-111.50654	Big Bend	UM	2	47.39069	-111.33422	Bullwhacker	LM	2	47.79432	-109.04236
Cobblestone	MA	3	45.79668	-111.50773	Big Bend	UM	3	47.39166	-111.33763	Bullwhacker	LM	3	47.79367	-109.03842
Cobblestone	MA	4	45.79509	-111.51087	Big Bend	UM	4	47.39308	-111.34074	Bullwhacker	LM	4	47.79380	-109.03437
Cobblestone	MA	5	45.79235	-111.51124	Big Bend	UM	5	47.39526	-111.34289	Bullwhacker	LM	5	47.79438	-109.03032
Cobblestone	MA	6	45.78948	-111.51067	Big Bend	UM	6	47.39743	-111.34455	Bullwhacker	LM	6	47.79543	-109.02653
Cobblestone	MA	7	45.78688	-111.51169	Big Bend	UM	7	47.40025	-111.34431	Bullwhacker	LM	7	47.79734	-109.02351
Cobblestone	MA	8	45.78420	-111.51304	Big Bend	UM	8	47.40297	-111.34390	Bullwhacker	LM	8	47.79961	-109.02118
Cobblestone	MA	9	45.78176	-111.51413	Big Bend	UM	9	47.40580	-111.34337	Bullwhacker	LM	9	47.80141	-109.01662
Cobblestone	MA	10	45.77916	-111.51570	Big Bend	UM	10	47.40842	-111.34322	Bullwhacker	LM	10	47.80209	-109.01128
Headwaters	UM	1	45.91825	-111.50458	Morony	LM	1	47.58032	-111.06490	Grand	LM	1	47.64875	-108.76074
Headwaters	UM	2	45.92071	-111.50297	Morony	LM	2	47.58227	-111.06181	Grand	LM	2	47.64982	-108.76470
Headwaters	UM	3	45.92331	-111.50193	Morony	LM	3	47.58525	-111.06146	Grand	LM	3	47.65048	-108.76850
Headwaters	UM	4	45.92588	-111.50282	Morony	LM	4	47.58786	-111.06109	Grand	LM	4	47.65085	-108.77273
Headwaters	UM	5	45.92832	-111.50475	Morony	LM	5	47.59062	-111.05988	Grand	LM	5	47.65143	-108.77691
Headwaters	UM	6	45.93061	-111.50611	Morony	LM	6	47.59301	-111.05798	Grand	LM	6	47.65314	-108.78028
Headwaters	UM	7	45.93224	-111.50299	Morony	LM	7	47.59507	-111.05528	Grand	LM	7	47.65542	-108.78272

Appendix 2, *continued*.

Transect	Stre-tch	Pt	Latitude	Longitude	Transect	Stre-tch	Pt	Latitude	Longitude	Transect	Stre-tch	Pt	Latitude	Longitude
Headwaters	UM	8	45.93114	-111.49975	Morony	LM	8	47.59713	-111.05241	Grand	LM	8	47.65812	-108.78431
Headwaters	UM	9	45.93300	-111.49659	Morony	LM	9	47.59953	-111.05095	Grand	LM	9	47.66031	-108.78640
Headwaters	UM	10	45.93578	-111.49411	Morony	LM	10	47.60216	-111.04972	Grand	LM	10	47.66276	-108.78801
Toston	UM	1	46.12167	-111.39889	Lennington	LM	1	47.75783	-110.81435	Kipp	LM	1	47.62536	-108.67959
Toston	UM	2	46.12374	-111.39657	Lennington	LM	2	47.75810	-110.81032	Kipp	LM	2	47.62332	-108.67761
Toston	UM	3	46.12633	-111.39537	Lennington	LM	3	47.75842	-110.80641	Kipp	LM	3	47.62084	-108.67586
Toston	UM	4	46.12883	-111.39660	Lennington	LM	4	47.75967	-110.80309	Kipp	LM	4	47.61875	-108.67188
Toston	UM	5	46.13111	-111.39822	Lennington	LM	5	47.76138	-110.79960	Kipp	LM	5	47.61825	-108.66786
Toston	UM	6	46.13350	-111.39993	Lennington	LM	6	47.76287	-110.79592	Kipp	LM	6	47.61898	-108.66357
Toston	UM	7	46.13551	-111.40226	Lennington	LM	7	47.76502	-110.79237	Kipp	LM	7	47.61981	-108.65943
Toston	UM	8	46.13727	-111.40480	Lennington	LM	8	47.76778	-110.78955	Kipp	LM	8	47.62080	-108.65578
Toston	UM	9	46.13813	-111.40837	Lennington	LM	9	47.77013	-110.78683	Kipp	LM	9	47.62068	-108.65166
Toston	UM	10	46.14019	-111.41165	Lennington	LM	10	47.77208	-110.78333	Kipp	LM	10	47.62001	-108.64755
					Evan's Bend	LM	1	47.84562	-110.58152					
					Evan's Bend	LM	2	47.84690	-110.57780					
					Evan's Bend	LM	3	47.84660	-110.57361					
					Evan's Bend	LM	4	47.84818	-110.57031					
					Evan's Bend	LM	5	47.85078	-110.56799					
					Evan's Bend	LM	6	47.85342	-110.56926					
					Evan's Bend	LM	7	47.85600	-110.57112					
					Evan's Bend	LM	8	47.85693	-110.57488					
					Evan's Bend	LM	9	47.85692	-110.57938					
					Evan's Bend	LM	10	47.85743	-110.58335					

Appendix 3. Vegetation cover type categories used in point count analyses.

Fine-resolution	Description	Course-resolution	Description
Urban	Areas of human development, including housing, roads, etc.	Urban	Areas of human development, including housing, roads, etc.
Irrigated cropland	Crops with irrigation (e.g., alfalfa)	Cropland	Irrigated and non-irrigated crops
Dry cropland	Crops without irrigation (e.g., barley)		
Native grassland	Grasslands dominated by native species (e.g., crested wheatgrass)	Grassland	Native and/or exotic dominated grasslands
Exotic grassland	Grasslands dominated by exotic species (e.g., leafy spurge)		
Big sagebrush	Shrubsteppe dominated by big sagebrush (*Artemisia tridentata*)	Sagebrush	Big sage or silver sage dominated areas
Silver sagebrush	Shrubsteppe dominated by silver sagebrush (*A. cana*)		
Shrub	Open areas dominated by shrubs (e.g., skunkbush, *Rhus trilobata*)	Shrub	Open areas dominated by shrubs (e.g., skunkbush)
Juniper woodland	Conifer forest dominated by juniper (*Juniperus* spp.)	Conifer	Coniferous forest, including doug-fir, ponderosa pine
Douglas-fir	Conifer forest dominated by *Pseudotsuga menziesii*		
Lodgepole pine	Conifer forest dominated by *Pinus contorta*		
Mixed conifer	No dominant conifer species		
Aspen	*Populus tremuloides* stands	Aspen	*Populus tremuloides* stands
Water	Riverside or open water habitat	Water	Riverside or open water habitat
Wet meadow	Sedge or rush dominated wet grasslands	Wet meadow	Sedge or rush dominated wet grasslands
Marsh	Emergent vegetation (e.g., *Typha* spp.)	Marsh	Sedges, emergent vegetation (e.g., *Typha* spp.)
Box elder			
Green ash			
Willow shrub	Open *Salix* spp. dominated areas	Willow	*Salix* spp. dominated areas
Willow flats	Expansive floodplain *Salix* spp. dominated areas		
Narrowleaf cottonwood with subcanopy	*P. angustifolia* with any shrub or subcanopy layers	Cottonwood with subcanopy	Plains cottonwood with subcanopy
Black cottonwood with subcanopy	*P. trichocarpa* with any shrub or subcanopy layers		
Plains cottonwood with subcanopy	*P. deltoides* with any shrub or subcanopy layers		
Young cottonwood with subcanopy			
Narrowleaf cottonwood without subcanopy	*P. angustifolia* without any shrub or subcanopy layers	Cottonwood without subcanopy	*P. deltoides* or *P. angustifolia* without any shrub or subcanopy layers
Black cottonwood without subcanopy	*P. trichocarpa* without any shrub or subcanopy layers		
Plains cottonwood without subcanopy	*P. deltoides* without any shrub or subcanopy layers		
Young cottonwood without subcanopy			
Mixed conifer-deciduous riparian	Deciduous riparian vegetation and confer trees with no dominant species	Mixed riparian	Riparian vegetation with no dominant species
Mixed deciduous riparian	Deciduous riparian vegetation with no dominant species		

Appendix 4. Point count locations for 2004-2005 sites in riparian forests (site 1 closest to Hebgen Dam, site 105 at Fred Robinson Bridge).

Site	Stretch	Pt	Latitude	Longitude	Site	Stretch	Pt	Latitude	Longitude	Site	Stretch	Pt	Latitude	Longitude
1	MA	1	45.22578	-111.75150	36	UM	1	45.93729	-111.49324	71	LM	1	47.76015	-110.80229
2	MA	1	45.23691	-111.75444	36	UM	2	45.93601	-111.49391	71	LM	2	47.75896	-110.80433
2	MA	2	45.23824	-111.75460	37	UM	1	45.99456	-111.44543	72	LM	1	47.77372	-110.75612
2	MA	3	45.23836	-111.75255	37	UM	2	45.99335	-111.44440	72	LM	2	47.77431	-110.75125
3	MA	1	45.24659	-111.75721	37	UM	3	45.99217	-111.44340	73	LM	1	47.80797	-110.69194
3	MA	2	45.24526	-111.75690	38	UM	1	45.99789	-111.41586	73	LM	2	47.80693	-110.69054
4	MA	1	45.26516	-111.75118	38	UM	2	45.99673	-111.41692	74	LM	1	47.81536	-110.66544
5	MA	1	45.27549	-111.75196	39	UM	1	46.00351	-111.41571	75	LM	1	47.85280	-110.57405
5	MA	2	45.27686	-111.75220	40	UM	1	46.01014	-111.42242	75	LM	2	47.85144	-110.57388
6	MA	1	45.30114	-111.75166	40	UM	2	46.01029	-111.42039	76	LM	1	47.86353	-110.58538
6	MA	2	45.30237	-111.75117	40	UM	3	46.00874	-111.42206	76	LM	3	47.86219	-110.58620
6	MA	3	45.30352	-111.75049	41	UM	1	46.03516	-111.42161	76	LM	4	47.86090	-110.58698
7	MA	1	45.31667	-111.74425	41	UM	2	46.03326	-111.42127	76	LM	5	47.85829	-110.58637
8	MA	1	45.32803	-111.74041	42	UM	1	46.05193	-111.42131	77	LM	1	47.87441	-110.58905
9	MA	1	45.33399	-111.73153	42	UM	2	46.05063	-111.42169	78	LM	1	47.86877	-110.56849
10	MA	1	45.34260	-111.72580	43	UM	1	46.18670	-111.47174	79	LM	1	47.86052	-110.51022
10	MA	2	45.34127	-111.72539	44	UM	1	46.22163	-111.48359	79	LM	2	47.85970	-110.51111
11	MA	1	45.34724	-111.72121	44	UM	2	46.22295	-111.48324	80	LM	1	47.87611	-110.50612
12	MA	1	45.35393	-111.71427	45	UM	1	46.24401	-111.47943	81	LM	1	47.89363	-110.46261
12	MA	2	45.35520	-111.71349	45	UM	2	46.24305	-111.47585	82	LM	1	47.90689	-110.45248
12	MA	3	45.35643	-111.71273	45	UM	3	46.24353	-111.47762	82	LM	2	47.90589	-110.45128
12	MA	4	45.35765	-111.71212	46	UM	1	46.25097	-111.49062	82	LM	3	47.90097	-110.45283
13	MA	1	45.36431	-111.70961	47	UM	1	46.26751	-111.49345	82	LM	4	47.90008	-110.45435
14	MA	1	45.37463	-111.70396	47	UM	2	46.26895	-111.49445	83	LM	1	47.90334	-110.46169
15	MA	1	45.38295	-111.70012	47	UM	3	46.27029	-111.49491	84	LM	1	47.90999	-110.47762
15	MA	2	45.38167	-111.70096	47	UM	4	46.27191	-111.49490	84	LM	2	47.90922	-110.48152
16	MA	1	45.39285	-111.69236	48	UM	1	46.32006	-111.53536	84	LM	3	47.90793	-110.48094
16	MA	2	45.39159	-111.69305	49	UM	1	46.33810	-111.52185	85	LM	1	47.91868	-110.49607
16	MA	3	45.39029	-111.69376	49	UM	2	46.33733	-111.52309	86	LM	1	47.92830	-110.48848
17	MA	1	45.40544	-111.69639	49	UM	3	46.33664	-111.52517	86	LM	2	47.92700	-110.48934
18	MA	1	45.41137	-111.69574	50	UM	1	46.35013	-111.52805	86	LM	3	47.92502	-110.49062
19	MA	1	45.44209	-111.70905	50	UM	2	46.34868	-111.52839	87	LM	1	47.93972	-110.46322
20	MA	1	45.62315	-111.54908	50	UM	3	46.34860	-111.53036	87	LM	2	47.94148	-110.46013
21	MA	1	45.70061	-111.51779	50	UM	4	46.34720	-111.53022	88	LM	1	47.95124	-110.37830
22	MA	1	45.71615	-111.52070	51	UM	1	46.35160	-111.51527	89	LM	1	47.97100	-110.36896
22	MA	2	45.71745	-111.52010	51	UM	2	46.35275	-111.51350	89	LM	2	47.97233	-110.36854
23	MA	1	45.72647	-111.51737	51	UM	3	46.35434	-111.51280	90	LM	1	48.00145	-110.25102
23	MA	2	45.72701	-111.51939	52	UM	1	46.78612	-111.90179	91	LM	1	48.01321	-110.24341
23	MA	3	45.72592	-111.52061	53	UM	1	47.00058	-112.00395	91	LM	2	48.01481	-110.24416
24	MA	1	45.76355	-111.51402	54	UM	1	47.04706	-111.99331	92	LM	1	48.03696	-110.18798
24	MA	2	45.76224	-111.51492	55	UM	1	47.09076	-111.94918	92	LM	2	48.03722	-110.18602
25	MA	1	45.77935	-111.51582	55	UM	2	47.09166	-111.94771	93	LM	1	48.02355	-110.12989
25	MA	2	45.77660	-111.51703	56	UM	1	47.17923	-111.80624	93	LM	2	48.02460	-110.13130

Appendix 4, continued.

Site	Stretch	Pt	Latitude	Longitude	Site	Stretch	Pt	Latitude	Longitude	Site	Stretch	Pt	Latitude	Longitude
26	MA	1	45.78623	-111.51248	56	UM	2	47.17897	-111.80834	94	LM	1	47.71450	-109.83088
27	MA	1	45.79645	-111.50875	56	UM	3	47.18147	-111.80676	95	LM	1	47.71149	-109.70693
28	MA	1	45.80859	-111.50555	57	UM	1	47.23254	-111.73285	95	LM	2	47.71216	-109.70510
28	MA	2	45.80722	-111.50602	57	UM	2	47.23117	-111.73318	95	LM	3	47.71298	-109.70343
28	MA	3	45.80477	-111.50723	58	UM	1	47.23638	-111.71549	95	LM	4	47.71384	-109.70187
29	MA	1	45.82637	-111.49764	58	UM	2	47.23702	-111.71368	96	LM	1	47.73383	-109.65549
30	MA	1	45.83590	-111.49603	59	UM	1	47.24647	-111.70368	96	LM	2	47.73392	-109.65754
30	MA	2	45.83530	-111.49816	60	UM	1	47.27211	-111.69566	97	LM	1	47.73825	-109.63177
31	MA	1	45.85463	-111.49461	61	UM	1	47.31950	-111.60871	98	LM	1	47.74374	-109.55980
31	MA	2	45.85316	-111.49536	61	UM	2	47.31816	-111.60868	98	LM	2	47.74340	-109.55780
32	MA	1	45.90599	-111.52627	62	UM	1	47.36963	-111.55906	98	LM	3	47.74304	-109.55584
33	MA	1	45.91598	-111.52526	62	UM	2	47.36826	-111.55904	99	LM	1	47.74494	-109.51635
33	MA	2	45.91495	-111.52658	62	UM	3	47.36686	-111.55899	99	LM	2	47.74510	-109.51843
33	MA	3	45.91387	-111.52797	62	UM	4	47.36542	-111.55893	100	LM	1	47.65086	-108.76899
33	MA	4	45.91201	-111.52783	62	UM	5	47.36404	-111.55888	101	LM	1	47.64796	-108.74959
34	MA	1	45.91666	-111.51618	62	UM	6	47.36252	-111.56088	101	LM	2	47.64847	-108.74776
34	MA	2	45.91570	-111.51485	62	UM	7	47.36079	-111.56283	101	LM	3	47.64898	-108.74587
35	MA	1	45.91996	-111.50354	62	UM	8	47.36071	-111.56488	102	LM	1	47.63242	-108.70282
					63	UM	1	47.37381	-111.55264	102	LM	2	47.63256	-108.70076
					63	UM	2	47.37395	-111.55060	102	LM	3	47.63271	-108.69864
					64	UM	1	47.42142	-111.50066	102	LM	4	47.63284	-108.69657
					64	UM	2	47.41891	-111.49883	102	LM	5	47.63299	-108.69453
					65	UM	1	47.41401	-111.42698	103	LM	1	47.62456	-108.67942
					65	UM	2	47.41398	-111.42522	103	LM	2	47.62564	-108.68031
					65	UM	3	47.41334	-111.42345	104	LM	1	47.61768	-108.65710
					65	UM	4	47.41266	-111.42161	104	LM	2	47.61754	-108.65501
					66	UM	1	47.43389	-111.35075	104	LM	3	47.61738	-108.65279
					66	UM	2	47.43242	-111.34659	104	LM	5	47.61888	-108.65467
					66	UM	3	47.43227	-111.34485	104	LM	6	47.61874	-108.65261
					67	UM	1	47.38885	-111.33704	104	LM	7	47.62041	-108.65639
					68	UM	1	47.40929	-111.30496	104	LM	8	47.62027	-108.65438
					68	UM	2	47.40887	-111.30690	105	LM	1	47.62172	-108.63146
					68	UM	3	47.40847	-111.30879	105	LM	2	47.62190	-108.63366
					68	UM	4	47.40803	-111.31064	105	LM	3	47.62272	-108.64312
					68	UM	5	47.40759	-111.31247	105	LM	4	47.62330	-108.63333
					69	UM	1	47.45716	-111.30759					
					69	UM	2	47.45622	-111.30618					
					69	UM	3	47.45529	-111.30477					
					69	UM	4	47.45432	-111.30343					
					70	UM	1	47.48229	-111.31320					

Appendix 5. Total bird detections during point counts and river surveys along the Madison and Missouri Rivers, 2003-2004. For point counts, flyovers were only included in the total for each species. In 2003, point counts were conducted in all habitat types, while in 2004 point counts were conducted only in riparian areas.

		Points					
	Species	2003		2004-2005		River surveys	
Species	Code	<50m	Total	<50m	Total	2003	2004
American avocet	AMAV	0	3	0	0	1	17
American coot	AMCO	0	0	0	0	1	35
American crow	AMCR	3	40	3	3	26	53
American goldfinch	AMGO	49	151	199	399	0	33
American kestrel	AMKE	10	25	16	22	20	0
American redstart	AMRE	6	9	19	19	0	0
American robin	AMRO	94	279	421	448	0	0
American wigeon	AMWI	0	5	0	0	24	57
American white pelican	AWPE	0	163	1	114	955	1581
Bald eagle	BAEA	1	16	1	6	32	68
Bank swallow	BANS	2	128	0	47	770	1835
Baltimore oriole	BAOR	1	1	0	0	0	0
Barn swallow	BARS	0	3	0	0	2	0
Black-billed cuckoo	BBCU	0	1	0	0	0	0
Black-billed magpie	BBMA	17	98	47	59	0	0
Black-capped chickadee	BCCH	25	71	109	109	0	0
Belted kingfisher	BEKI	2	8	8	16	28	50
Blue-winged teal	BWTE	0	0	0	0	0	89
Brown-headed cowbird	BHCO	113	258	321	409	0	0
Black-headed grosbeak	BHGR	13	26	74	78	0	0
Blackpoll warbler	BPWA	0	0	2	2	0	0
Bobolink	BOBO	1	7	0	0	0	0
Brewer's blackbird	BRBL	4	8	11	14	0	0
Brewer's sparrow	BRSP	9	12	0	0	0	0
Brown thrasher	BRTH	5	5	4	4	0	0
Bufflehead	BUFL	0	0	0	0	3	0
Bullock's oriole	BUOR	44	69	207	211	0	0
Canada goose	CAGO	0	71	0	11	956	2280
California gull	CAGU	0	70	0	24	191	129
Calliope hummingbird	CAHU	2	2	0	0	0	0
Canvasback	CANV	0	0	0	0	0	2
Canyon wren	CANW	0	5	0	0	1	0
Caspian tern	CATE	0	6	0	0	12	37
Clay-colored sparrow	CCSP	9	22	25	25	0	0
Cedar waxwing	CEDW	60	121	142	217	0	0
Chipping sparrow	CHSP	26	52	1	1	0	0
Cinnamon teal	CITE	0	0	0	0	13	24
Clark's grebe	CLGR	0	0	0	0	0	1
Cliff swallow	CLSW	1	150	0	73	1327	3074
Common goldeneye	COGO	0	4	0	0	3	1
Common grackle	COGR	5	26	50	83	0	0
Cooper's hawk	COHA	0	2	2	3	0	4
Common loon	COLO	0	0	0	0	1	1
Common merganser	COME	0	41	0	6	253	441
Common nighthawk	CONI	0	9	2	10	6	82
Common raven	CORA	3	37	1	7	27	54
Common snipe	COSN	1	6	0	0	0	1
Common yellowthroat	COYE	29	70	48	48	0	0
Double-crested cormorant	DCCO	0	107	0	14	164	548
Dark-eyed junco	DEJU	7	11	1	1	0	0
Downy woodpecker	DOWO	14	18	80	82	0	0
Dusky flycatcher	DUFL	6	11	0	0	0	0
Eared grebe	EAGR	0	0	0	0	1	0

Appendix 5. *Continued.*

		Points					
		2003		2004-2005		River surveys	
Species	Code	<50m	Total	<50m	Total	2003	2004
Eastern kingbird	EAKI	51	109	166	183	0	0
European starling	EUST	57	288	329	447	0	0
Field sparrow	FISP	2	6	0	0	0	0
Forster's tern	FOTE	0	1	0	0	1	3
Franklin's gull	FRGU	0	7	0	43	161	139
Gadwall	GADW	0	1	0	1	26	89
Great blue heron	GBHE	0	19	2	14	76	116
Great-horned owl	GHOW	5	6	13	13	0	3
Golden eagle	GOEA	0	0	0	0	6	21
Gray catbird	GRCA	57	86	256	258	0	0
Gray jay	GRJA	0	1	0	0	0	0
Greater yellowlegs	GRYE	0	0	0	0	0	8
Greater white-fronted goose	GWFG	0	0	0	0	0	1
Green-winged teal	GWTE	0	0	0	0	0	13
Hairy woodpecker	HAWO	3	11	7	7	0	0
House finch	HOFI	8	10	39	42	0	0
House sparrow	HOSP	0	0	3	3	0	0
Horned lark	HOLA	0	1	0	0	0	0
Hooded merganser	HOME	0	0	0	0	2	3
House wren	HOWR	187	336	832	832	0	0
Killdeer	KILL	5	40	3	9	156	372
Lark sparrow	LASP	10	32	8	8	0	0
Lazuli bunting	LAZB	22	36	25	25	0	0
Long-billed curlew	LBCU	0	1	0	0	2	1
Least flycatcher	LEFL	87	157	483	484	0	0
Least sandpiper	LESA	0	0	0	0	0	1
Lesser scaup	LESC	0	0	0	0	18	1
Lincoln's sparrow	LISP	4	7	0	0	0	0
Marbled godwit	MAGO	0	0	0	0	2	1
Mallard	MALL	7	45	0	20	314	660
Marsh wren	MAWR	2	2	5	5	0	0
MacGillivray's warbler	MGWA	0	0	1	1	0	0
Mountain bluebird	MOBL	1	2	1	1	0	0
Mountain chickadee	MOCH	13	29	0	0	0	0
Mourning dove	MODO	42	205	402	461	0	0
Northern flicker	NOFL	13	87	139	150	0	0
Northern harrier	NOHA	0	1	0	4	3	8
Northern pintail	NOPI	0	0	0	0	0	19
Northern shoveler	NOSH	0	1	0	0	0	16
Northern rough-winged swallow	NRWS	2	16	0	80	8	0
Northern waterthrush	NOWA	0	0	6	6	0	0
Orange-crowned warbler	OCWA	1	1	0	0	0	0
Olive-sided flycatcher	OSFL	0	5	0	0	0	0
Osprey	OSPR	0	10	0	9	49	86
Ovenbird	OVEN	2	8	18	18	0	0
Pileated woodpecker	PIWO	0	0	0	1	0	0
Pinyon jay	PIJA	1	4	0	0	0	0
Pine siskin	PISI	0	5	0	0	0	0
Prairie falcon	PRFA	0	0	0	0	2	1
Red-breasted nuthatch	RBNU	0	0	5	5	0	0
Ring-billed gull	RBGU	0	4	0	13	15	154
Ruby-crowned kinglet	RCKI	5	14	0	0	0	0
Redhead	REDH	0	2	0	0	0	0
Red-eyed vireo	REVI	6	9	20	20	0	0
Red-naped sapsucker	RNSA	5	8	29	30	0	0
Rock dove	RODO	2	31	0	4	66	348
Rock wren	ROWR	3	52	0	0	1	0
Ring-necked pheasant	RPHE	0	52	13	13	0	2

Appendix 5. *Continued.*

		Points					
		2003		2004-2005		River surveys	
Species	Code	<50m	Total	<50m	Total	2003	2004
Red-tailed hawk	RTHA	2	28	12	29	79	102
Red-winged blackbird	RWBL	45	148	48	65	0	0
Ruddy duck	RUDU	0	0	0	0	0	1
Sandhill crane	SACR	0	14	6	10	0	17
Say's phoebe	SAPH	0	1	0	0	0	0
Savannah sparrow	SAVS	32	65	3	3	0	0
Sora	SORA	1	1	0	0	0	0
Song sparrow	SOSP	66	157	242	242	0	0
Spotted sandpiper	SPSA	4	74	3	4	399	1137
Spotted towhee	SPTO	39	96	58	60	0	0
Sharp-shinned hawk	SSHA	2	2	2	5	1	0
Swainson's hawk	SWHA	0	3	0	0	4	9
Swainson's thrush	SWTH	1	6	0	0	0	0
Townsend's solitare	TOSO	0	2	0	0	0	0
Tree swallow	TRES	15	156	121	490	47	0
Trumpeter swan	TRUS	0	1	0	0	1	2
Turkey vulture	TUVU	0	1	0	0	22	55
Unknown buteo (hawk)	UNHA	0	0	0	0	0	15
Unknown corvid	UNCO	0	0	0	0	0	3
Unknown duck	UNDU	0	0	0	0	15	65
Unknown eagle	UNEA	0	0	0	0	0	1
Unknown falcon	UNFA	0	0	0	0	0	2
Unknown flycatcher (*Empidonax* spp.)	UNEM	2	2	1	1	0	0
Unknown gull	UNGU	0	6	0	20	0	1119
Unknown hummingbird	UNHU	0	2	0	0	0	0
Unknown species	UNKN	3	3	1	1	0	3
Unknown tern	UNTE	0	2	0	0	0	3
Unknown yellowlegs	UNYE	0	0	0	0	1	0
Veery	VEER	1	1	26	26	0	0
Vesper sparrow	VESP	6	40	1	1	0	0
Violet-green swallow	VGSW	2	56	0	4	21	135
Warbling vireo	WAVI	11	36	102	104	0	0
White-breasted nuthatch	WBNU	1	7	5	5	0	0
White-crowned sparrow	WCSP	15	40	2	2	0	0
Western grebe	WEGR	0	5	0	0	11	40
Western kingbird	WEKI	15	37	60	64	0	0
Western meadowlark	WEME	9	191	3	3	0	0
Western screech owl	WESO	0	0	1	1	0	0
Western tanager	WETA	2	2	6	6	0	0
Western wood-pewee	WEWP	64	167	244	245	0	0
White-throated sparrow	WTSP	0	0	1	1	0	0
White-throated swift	WTSW	0	11	0	4	8	273
Willet	WILL	0	0	0	0	0	4
Willow flycatcher	WIFL	9	29	49	49	0	0
Wild turkey	WITU	0	1	0	0	0	0
Wilson's phalarope	WIPH	0	0	0	0	2	5
Wilson's warbler	WIWA	0	1	3	3	0	0
Wood duck	WODU	0	2	0	0	9	89
Yellow warbler	YWAR	320	592	1290	1297	0	0
Yellow-breasted chat	YBCH	17	67	61	61	0	0
Yellow-headed blackbird	YHBL	2	11	0	0	12	0
Yellow-rumped warbler	YRWA	13	28	9	9	0	0
Total species		**83**	**124**	**77**	**95**	**55**	**62**
Total observations		**1864**	**6069**	**6960**	**8590**	**6361**	**15643**

Appendix 6. Study area locations for breeding biology and migratory monitoring 2003-2004, Madison and Missouri Rivers, Montana. Coordinates in UTM Montana State Plane projection.

Site	Breeding/ migration	Year monitored	River	Vegetation type	Easting	Northing
Granger Island	Both	2003	Madison	Moderate	423156	112343
Spring Creek	Both	2003-2004	Madison	Dense	422835	113604
Breeding	2004		Madison	Sparse	423208	114215
Alton	Breeding	2004	Madison	Sparse	423157	114816
Burnt Tree	Both	2003	Madison	Sparse	424083	121096
Bear Rapids	Both	2003	Madison	Moderate	424723	122739
Rattlesnake	Breeding	2004	Madison	Dense	443348	169349
Cobblestone	Both	2003-2004	Madison	Sparse	443808	173762
Fairweather	Both	2003	Missouri	Dense	451250	200408