Breeding Bird Populations and Habitat Conditions in Riparian Areas along the Madison and Missouri Rivers, Montana

2004-2017

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EXECUTIVE SUMMARY

Long-term assessments of the distribution and abundance of populations are central to evaluating the potential effects of human activities on wildlife. Since 2004, the University of Montana (UM), with funding from Northwestern Energy (formerly PPL Montana) and the Bureau of Land Management (BLM), has monitored bird populations and riparian vegetation on over 500 miles of the Madison and Missouri Rivers. This program meets Northwestern Energy's Federal Energy Regulatory Commission (FERC) license requirements for hydroelectric operations on the river system by:

1. Monitoring main stem bird distributions and population trends as an indicator of wildlife habitat conditions,
2. Identifying critical wildlife habitats based on analysis of bird habitat use, and
3. Measuring bird and vegetative responses to management actions to evaluate project benefits for wildlife.

This report summarizes analyses of bird population and vegetation trends across five annual surveys between 2004 and 2017, and documents conditions at important management areas within the Upper Missouri Breaks National Monument since 2015. To date, our monitoring efforts have resulted in 1,638 point-count surveys and detection of 30,094 individual birds of 127 species during standardized point-count surveys. We also observed additional bird species outside the standardized survey period, bringing the total number of species observed to 155, which represents 58% of species known to breed in Montana. The majority of species we observed were associated with riparian or wetland environments, including 24 Montana Species of Concern (MTSOC) and 29 U.S. Fish and Wildlife Birds of Management Concern. For 38 of those bird species, sample sizes were sufficient to generate precise annual estimates of density with the use of distance sampling methods.

Highlights of our findings include:

- Declining trends for many riparian obligate and dependent bird species, especially on the Madison River.
- Increasing densities of the Yellow-breasted Chat, a riparian obligate primarily found in the UMRB.
- No evidence that overall riparian species richness has changed.
- No Black-billed Cuckoos found in 2017, down from 5 occupied sites on UMRB in 2015.
- Significant differences in riparian species densities across ownership and management designation in the UMRB.
- Declining shrub and willow (*Salix* spp.) cover, especially on the Madison.
- Declining large cottonwood (Populus spp.) tree and snag density system-wide, but increasing small cottonwood trees, especially on the Missouri River.
- Livestock grazing intensity continued to decline markedly system-wide.
- No evidence of system-wide change in non-native Russian Olive (*Elaeagnus angustifolia*), density or invasive weed cover.

We found statistically significant declines in densities of 13 bird species and increases in densities of five species across time. Patterns we observed largely correspond to long-term trends documented across the region based on the North American Breeding Bird Survey. Such similarities suggest the drivers of

population declines along the river system are likely operating across large spatial scales. We measured significant changes in riparian vegetation conditions since 2004, which are likely influencing habitat suitability for bird populations. Those changes include aging cottonwood forests, declining shrub cover, and loss of snags. We also documented baseline conditions and located important breeding areas for riparian bird species, including several bird species of concern, in the Upper Missouri River Breaks National Monument (UMRB).

This program provides a direct measure of the status of wildlife within riparian areas across a large stretch of the Madison and Missouri Rivers, and is currently the only monitoring effort targeting riparian birds in Montana. Our findings are consistent with declines first observed in 2015. However, these results should still be viewed cautiously, since inferences are based on estimates from only five years since 2004. Future monitoring will build on this dataset, providing a more complete picture of the patterns and drivers of trends in wildlife populations.

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BACKGROUND

Riparian systems serve essential ecological functions and provide habitats for a disproportionately large number of plants and animals resulting in the highest known diversities of breeding birds in the western United States (Naiman and DeCamps 1997). Despite their limited spatial extent, riparian areas provide nesting habitats for the majority of Montana's bird species, including nearly half of the listed Species of Concern in Montana. Because riparian areas are highly productive and often occur at low elevations, they are also highly impacted by human activities, such as agricultural and urban development, alteration of hydrologic functions due to irrigation and water diversion, and invasion by non-native species (Johnson 1992, Ringold et al. 2008).

Yellow-breasted Chat singing from mature cottonwood, Missouri River Breaks.

Despite the importance of riparian areas to wildlife and major threats to populations and their habitats, there is little information on the status and trends of bird species that depend on riparian areas in Montana. Starting in 2004, the University of Montana, with support from Northwestern Energy (formerly PPL Montana) and the Bureau of Land Management (BLM), began monitoring bird populations along the Madison and Missouri Rivers, which encompass one of Montana's largest river corridors. This program meets Northwestern Energy's Federal Energy Regulatory Commission (FERC) license requirements for hydroelectric operations on the river system by monitoring system-wide bird distributions and population trends as an indicator of habitat conditions for wildlife. Additionally, this program serves to identify important habitat attributes for wildlife based on analysis of bird habitat use, measure bird and vegetative responses to management, and inform future management priorities within the region.

Preliminary analyses of bird population trends through 2012 showed significant declines for over half of the species considered (Noson & Smucker 2013). Given those alarming patterns, the Northwestern Energy Wildlife Technical Advisory Committee recommended a thorough re-analysis of bird population data following an additional year of monitoring in 2015. Moreover, they also requested an assessment of trends in riparian habitat conditions, and an evaluation of program design to determine the sample effort required to monitor population trends in this system. In 2015, we found continued measurable declines in abundance of 11 species. We also documented significant changes in riparian vegetation conditions, which are likely influencing habitat suitability for bird populations.

In 2017, we completed a fifth year of surveys of breeding birds and vegetation at established long-term monitoring locations. We also continued partner-supported bird monitoring within the Upper Missouri River Breaks (UMRB) designed to address science needs of the Missouri Breaks Riparian Group, a public and private partnership aimed at restoring cottonwood forest and improving wildlife habitat along the Upper Missouri River. This monitoring is designed to dovetail with long-term monitoring already in place in the UMRB to evaluate the effectiveness of restoration projects funded in part by the Northwestern Energy Wildlife TAC, and locate high-priority areas for future efforts within the UMRB.

Objectives

1. Complete a fifth survey of bird communities along the Madison and Missouri Rivers at sites that have been monitored since 2004, and assess the status and trends of riparian bird populations based on survey data gathered during five years between 2004 and 2017.
2. Complete a fifth survey of vegetation conditions at bird monitoring sites, and evaluate trends in riparian habitat conditions based on vegetation data gathered during four years between 2004 and 2015.
3. Collect, analyze, and summarize second year of breeding bird and vegetation data in important management areas within the main stem riparian habitats of the Upper Missouri River Breaks National Monument.

Objective 1: Riparian Bird Population Status & Trends

Methods

Monitoring Area & Design

In 2004, long-term monitoring locations were established along the Madison and upper Missouri Rivers in Montana between Varney Bridge (south of Ennis) to Fred Robinson Bridge (James Kipp Recreation Area; Fig. 1). The river was stratified into three geographical sections: the Madison River (MAD), the Missouri River between Three Forks and Great Falls (MIS), and the Upper Missouri River Breaks (BRK). To select areas for long-term monitoring, patches of riparian vegetation along the river corridor were first delineated, and then a random sample of those patches were selected as sample sites within each section. Survey points were established within each selected site by overlaying a 150 x 150 m grid (see Fletcher et al. 2005 for details). In total, 55 riparian sites were selected, which included a total of 223 monitoring points. The number of points per site ranged from 2 to 8 depending on area of the site, with an average of 4.1 (± 0.08 SE) points per site.

In 2015, we increased sampling effort within the Upper Missouri Breaks National Monument by adding 24 additional riparian sites, which included 74 sampling points. We also expanded the monitoring area upstream to the headwaters of the Madison River near Hebgen Lake (HEB) by adding 4 new riparian sites, which included 16 sampling points. The sampled area covers over 500 miles of the river corridor and includes a mix of public and private lands (Fig.1).

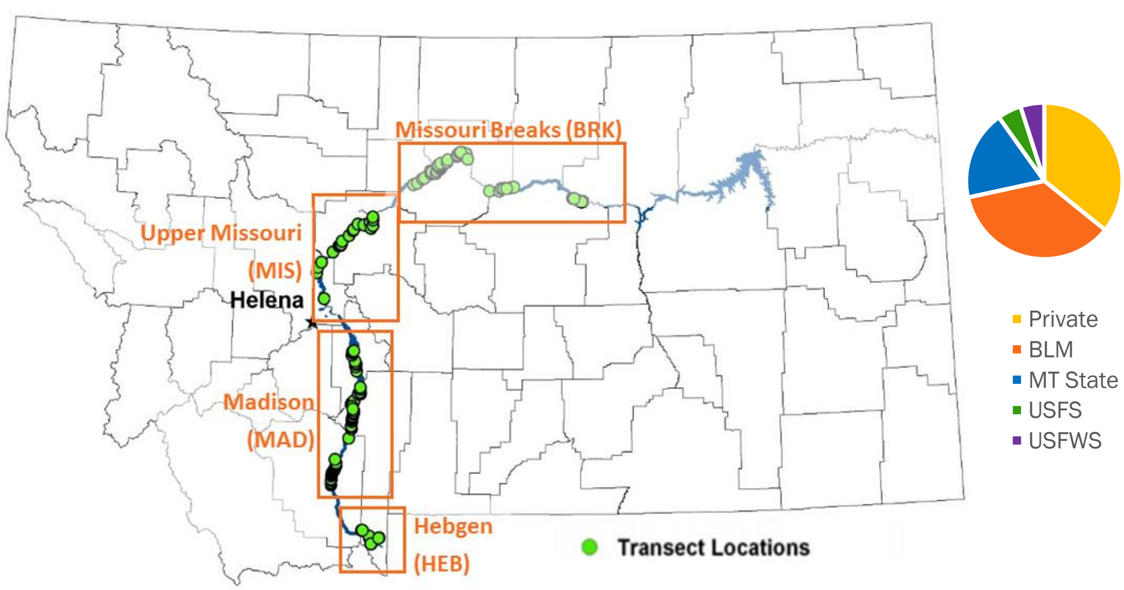
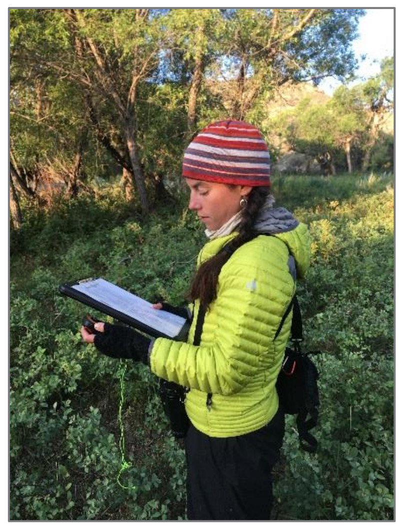


Figure 1. Location of long-term bird monitoring and ownership of selected riparian sites on Madison River, Upper Missouri River, Missouri River Breaks, and Hebgen Lake, Montana.

Ecological monitoring is built on a foundation of repeatedly measuring resources over time so that the presence, magnitude, and direction of trends can be detected in sufficient time to make informed management decisions (Thompson et al. 1998, Pollock et al 2002). In 2015 we conducted a review of bird observations gathered since 2004 which indicated that the current monitoring effort (e.g., 1 visit to 223 sample points) is sufficient to generate precise estimates of densities of many common and uncommon species of breeding landbirds in riparian areas along the Madison and Missouri Rivers of Montana. Based on tradeoffs between sampling frequency and power to detect population changes, we recommended sampling bird communities in this system every other year to most effectively monitor populations. Nonetheless, greater sampling effort would be required to obtain more precise estimates for some uncommon and many rare species, which tend to be of greater management and conservation concern.

Bird Surveys

We used standard 10-minute point-counts and distance sampling to survey birds at all long-term monitoring points (Hutto et al. 1986, Buckland et al. 2001). We surveyed birds between sunrise and 5 hours after sunrise but not at times when wind velocity was high (≥ 20 km/hr) or during consistent precipitation. During surveys, observers recorded all birds seen or heard within a 50-m radius, how each individual was detected (song, visual, or call), sex of individuals, and estimated distances to birds from the center point. All distances were estimated to the nearest meter using a laser rangefinder. Species not observed within 50 m of points during surveys were also noted for the purpose of occupancy estimation.



In addition, we recorded all species detected incidentally outside of standard point-count surveys and while traveling between points. Those data were not used for density estimation, but provide information on presence, species richness, and distribution of bird species not well surveyed during standard point counts, including rare species and species of conservation concern.

Analysis

Density Estimation

We used distance-sampling methods to estimate densities of various bird populations and species groups (e.g., riparian-obligate species). Such methods use frequency histograms of distance data to model a detection function that estimates detection probability and adjusts density estimates for spatial and temporal variation in detection probability. Distance sampling is based on the concept that the probability of detecting a focal object (e.g. a bird) decreases with increasing distance from the observer and also may vary with a variety of spatial, temporal, or survey-related factors (Buckland et al. 2001).

We computed density estimates (no. of birds/ha.) of species and species groups at three spatial scales: patch, river section, and study area. Spatiotemporal replication within patches was sufficient to generate precise annual estimates of density for species encountered at least 50 times across the monitoring period,. We evaluated trends of those encountered >80 times. Histograms of distance data of all species we considered were of suitable shape to fit detection functions. To compute estimates, we used the MRDS library in R (Laake et al. 2017, R Development Core Team 2016).

To estimate densities, we fit both simple detection functions with no covariates and more complex functions with covariates (Marques et al. 2007). Here, we consider both spatial and temporal covariates, and assume potential variation in detectability due to vegetation or other factors were linked to those factors. As covariates, we considered time-of-day (min. after local sunrise), time-of-year (Julian day), year, and river section (Madison, Upper Missouri, and Missouri Breaks). We fit models with all possible additive combinations of those covariates and used Akaike information criterion adjusted for small sample sizes (AIC_c) to rank models. To select final models, we assessed the shapes of detection functions, precision of parameter estimates, and goodness-of-fit of highly ranked models, and selected the best overall model for each species (Thomas et al. 2010). We considered uniform, half-normal (HN) and hazard-rate (HR) detection functions for models without covariates, and HN and HR functions for models with covariates. When fitting HN and HR functions, we considered models with up to 2 cosine or simple polynomial adjustment terms, and for uniform functions considered up to 2 hermite polynomial terms. We grouped data in 5 m bins, which in all cases effectively smoothed histograms. We did not right truncate encounter data because the small fixed radius used during counts (50 m) did not produce long-tailed distributions.

Trend Estimation

To estimate temporal trends in densities of each species and species group, and assess whether trends varied spatially among river sections, we used linear mixed-effects model (LMEM) of the following form:

$$y_{ijt} = (\beta_0 + b_{0i}) + \beta_1 x_{it} + \beta_2 x_{jt} + \beta_3 (x_{it} \times x_{jt}) + \varepsilon_{it}, \quad \varepsilon_{ijt} \sim N(0, \sigma_j^2) \quad \text{(eq. 1)}$$

where β_0 is an intercept for the population, b_{0i} is a vector of random intercepts for each patch, β_1 is a trend parameter for a fixed year effect, x_{it} indicates the year of each observation for the i^{th} patch centered at 0, β_2 estimates a fixed river section effect, x_{jt} indicates the river section of each observation for the j^{th} section, β_3 estimates an interaction term or whether the effect of year varies among sections, ε_{ijt} is an error term that has a normal distribution with a mean of zero and variance σ_j^2, which measures observation variance within each section, and y_{ijt} are estimates of density from each patch in each section and year. We log transformed density estimates before modeling to normalize distributions and so that parameter estimates equaled the relative or percent change in density per year.

We used the random effects and residual variance structures noted above after first assessing candidate models with other plausible structures and ranking them based on AIC_c. To assess variation in intercepts among river sections, for example, we assessed the efficacy of replacing b_{0i} in with a vector of random intercepts for section (b_{0j}) and a vector of random intercepts for patches nested within sections ($b_{0j(i)}$). To assess a simpler structure for observation error, we also assessed models that estimated one variance across all years. To assess covariance in observation error, we considered first-order autoregressive and compound symmetric structures. We used restricted maximum likelihood when assessing models with different random effects and variance structures and maximum likelihood to estimate fixed effects. We fit all models with the *nlme* library in R.

In addition to species-specific analyses, we also estimated spatiotemporal trends in densities of three species groups: riparian-dependent and riparian-obligate species (Rich 2002, as listed in Appendix A), and all bird species combined. Density estimates for species groups were based on sums of relevant estimates from MRDS. We categorized riparian-dependent as 60-90% of breeding restricted to riparian areas and riparian-obligate as >90% of breeding restricted to riparian areas throughout their range (Rich 2002). It is important to note that this is a conservative definition, since many species associated with deciduous forests, such as the Least Flycatcher, are found throughout forests in eastern North America, but are entirely restricted to riparian areas within Montana. We excluded raptor and waterfowl species from these analyses because they are not effectively surveyed with point-count methods. Additionally, we did not assess trends of 5 species with <80 detections. We estimated densities at the scale of each riparian patch in each year, and used those estimates to assess trends across time and space with the LMEM procedure described above. In estimating densities of all species and species groups, we fit simple detection functions with no covariates and detection functions with river section and year fit as nominal potential covariates of detection probability.

Comparison with Regional Trends

To evaluate whether observed trends within the study area correspond to those at larger spatial scales throughout the western U.S., we compared our findings with results of the North American Breeding Bird Survey (BBS). BBS has monitored the status and trends of bird population in North America with the help of qualified volunteers for over forty years (Sauer et al 2017; http://www.mbr-pwrc.usgs.gov/bbs/specl14.html).

Species Richness

The richness or number of species in a given area at a given time is a useful metric for monitoring biodiversity dynamics (Gotelli and Colwell 2001). Regardless, because all species are not detected perfectly during surveys, species that are present but undetected during sampling could bias estimates of species richness. Thus, to estimate species richness ($\widehat{N}$), we used observed species abundance distributions based on data we gathered during point counts and a bias-corrected version of the Chao 1 estimator (Chao 1984, Gotelli and Colwell 2011). The Chao1 estimator represents a universally valid lower bound of species richness that can be applied to any species abundance distribution and any sample size. In general, estimated lower bounds are close to species asymptotic richness if sample sizes are sufficiently large; a rough guideline for sufficiency is when the proportion of species detected once is <50% of the sample, which was the case with our dataset at 92% of samples at the patch level.

The bias-corrected version of the Chao 1 estimator is as follows:

$$\widehat{N} = N_{obs} + \frac{f_1 (f_1 - 1)}{2(f_2 + 1)} \quad \text{(eq. 2)}$$

where N_{obs} is the number of species observed, f_1 is the number of species observed once, and f_2 is the number of species observed twice in the sample.

We used point-count data from all points within each riparian patch to compute richness at the scale of patches. We considered data from 2004 and 2008, when points were visited twice, as separate samples of patches rather than summing detections across visits. To assess trends in richness across time, we used the same LMEM approach described above. In addition to assessing trends in richness of all species combined, we also considered riparian-dependent and riparian-obligate species. We also computed species richness for the entire study area based on the Chao 1 estimator and 95% confidence intervals with use of Estimates software (Colwell 2013).

Results

Survey Effort and Detections

We completed 1,638 point-count surveys across five years of monitoring (Table 1). Survey effort was highest in 2004 and 2008 when points were visited two times per year. One patch was not sampled in 2012 and 2017, but otherwise we sampled each patch at least once during each year. Twenty-seven additional patches were added in 2015 and re-sampled in 2017. Data from these new patches are included in estimates of total densities (e.g., Table 2) but not trends (e.g., Table 3).

Across all surveys, we recorded 30,094 individual birds and 127 species during standardized point-count surveys. We also observed additional bird species outside the standardized survey period or at distances >50 m, bringing the total number of species observed to 155, which represents 58% of species known to breed in Montana. The majority of species we observed were associated with riparian or wetland environments, including 21 riparian-obligate (>90% of breeding restricted to riparian areas) and 22 riparian-dependent (60-90% of breeding restricted to riparian areas) species, and 24 species associated with wetlands such as waterfowl and other water birds (Rich 2002). We observed numerous species of conservation concern, including 24 Montana Species of Concern (MTSOC) and 29 U.S. Fish and Wildlife Birds of Management Concern (see Appendix A for complete list; Rosenberg et al. 2016, USFWS 2011).

Table 1. Annual sampling effort by sample patch for birds on the Madison and Missouri Rivers in Montana 2004-2017. Total effort includes repeated visits to sample points.

Year	Patches (no.)	Total Effort
2004	55	445 [a]
2008	55	412 [a]
2012	54	210
2015	82 [b]	295[b]
2017	81 [b]	276[b]

[a] Points were surveyed two times in 2004 and 2008, and once in 2012, 2015, and 2017.
[b] Total includes 28 new sample patches and 90 points established in 2015, which were included in annual estimates, but not in trend analyses.

Population Status

We obtained estimates of density for 38 breeding bird species that we encountered at least 50 times during point counts. Together these species comprise approximately 25% of the breeding bird community observed in the system. The majority of these species are associated with riparian environments during the breeding season including 8 riparian-obligate and 14 riparian-dependent species (Rich 2002). Density estimates for each river section are presented in Table 2.

Yellow Warbler was the most abundant species in the region with densities that averaged 9.49 birds per ha across years, followed by House Wren at 6.29 birds per ha. In contrast, abundance of some species were low, such as the Ovenbird and Red-eyed Vireo with densities that averaged 0.04-0.10 birds per ha.

Densities of most species varied spatially, with significant differences among at least one river section for 25 of the 38 species we considered ($P < 0.05$; Table 3). For example, we estimated 3.26 Gray Catbirds per ha along the upper Missouri River, 2.59 per ha along the Madison, but only 0.46 per ha in the Missouri Breaks. In contrast, densities of Yellow-breasted Chat were higher in the Missouri Breaks than farther upstream (0.64 per ha versus 0.13 per ha). The only species we evaluated that occurred in higher densities on Hebgen Lake than any river section was the Common Yellowthroat, a riparian obligate that prefers wetlands with low vegetation. We estimated 0.52 Common Yellowthroat per ha on Hebgen Lake, slightly higher than on the Missouri Breaks with 0.49 birds per ha, and substantially higher than the other river sections where densities ranged from 0.04-0.05 per ha.

Average densities of all 107 bird species combined (excluding 12 species of raptors) were significantly higher along the Madison and Upper Missouri Rivers than the Missouri Breaks or Hebgen Lake. Similarly, densities of riparian-obligate species combined were also higher on average along the Madison and Upper Missouri (Fig. 5).

Table 2. Density estimates and degree of dependency on riparian environments (e.g. obligate, dependent, or generalist) of breeding bird species encountered along the Madison and Missouri Rivers, Montana. Encounters (*n*), estimated density per ha (*D*), and coefficients of variation (CV%) were pooled across all four survey years from 2004-2017.

				Hebgen Lake		Madison		Upper Missouri		Missouri Breaks	
Common Name	***n***	***D***	**CV (%)**	***n***	***D***	***n***	***D***	***n***	***D***	***n***	***D***
Obligate											
Common Yellowthroat	264	0.23	11.8	12	0.54	23	0.05	16	0.04	213	0.49
Gray Catbird	788	1.84	7.6	0	-	278	2.59	398	3.26	112	0.46
Ovenbird	50	0.04	36.6	0	-	0	-	3	0.01	47	0.07
Red-winged Blackbird	312	0.47	21.4	0	-	184	1.20	65	0.46	63	0.23
Song Sparrow	641	0.85	9.6	21	1.10	325	2.05	230	0.97	65	0.13
Willow Flycatcher	122	0.16	19.1	5	0.33	55	0.24	60	0.30	2	0.01
Yellow Warbler	4716	9.49	4.0	59	4.80	1392	15.41	1771	11.19	1494	5.00
Yellow-breasted Chat	309	0.34	16.4	0	-	10	0.13	10	0.13	289	0.64
Dependent											
American Goldfinch	979	1.86	9.3	1	0.09	274	2.24	365	2.05	339	1.44
Black-capped Chickadee	405	1.40	27.7	2	0.23	106	1.29	173	1.87	124	0.86
Black-headed Grosbeak	268	0.35	14.0	4	0.16	82	0.81	124	0.34	58	0.09
Bullock's Oriole	649	1.04	9.6	0	0.00	181	1.47	182	0.71	286	1.07
Cliff Swallow	101	1.64	50.8	1	0.22	62	4.30	12	0.92	26	1.18
Eastern Kingbird	488	0.63	8.5	0	0.00	127	0.66	164	0.53	197	0.69
House Wren	3305	6.29	4.2	2	0.21	708	6.62	1099	6.81	1496	6.54
Lazuli Bunting	128	0.18	17.7	0	-	8	0.04	19	0.08	101	0.36
Least Flycatcher	1507	2.43	6.5	0	-	384	2.99	532	2.92	591	1.65
Red-eyed Vireo	71	0.10	24.3	0	-	5	0.03	7	0.15	59	0.02
Red-naped Sapsucker	89	0.19	20.3	2	0.24	60	0.43	23	0.18	4	0.03
Tree Swallow	1195	4.05	8.2	4	0.24	397	5.90	586	6.95	208	1.01
Warbling Vireo	232	0.21	11.1	2	0.10	100	0.31	70	0.23	60	0.11
Western Wood-Pewee	797	0.76	5.5	0	-	185	0.61	317	1.02	295	0.70

Table 2.Continued

Common Name	*n*	*D*	CV (%)	Hebgen Lake		Madison		Upper Missouri		Missouri Breaks	
				n	*D*	*n*	*D*	*n*	*D*	*n*	*D*
Generalist											
American Robin	1461	2.10	6.7	3	0.12	420	3.00	539	2.49	499	1.32
Black-billed Magpie	163	0.52	17.0	1	0.03	55	0.17	68	0.20	39	0.08
Brewer's Blackbird	56	0.12	38.7	0	-	14	0.10	13	0.08	29	0.20
Brown-headed Cowbird	1049	1.72	7.7	6	0.24	456	3.35	435	2.18	152	0.60
Cedar Waxwing	583	2.08	10.0	3	0.40	130	1.55	262	3.64	188	1.44
Clay-colored Sparrow	78	0.19	19.7	0	0.24	14	0.39	56	0.17	8	0.06
Common Grackle	218	0.76	18.9	0	-	112	1.59	32	0.39	74	0.70
Common Nighthawk	61	0.11	27.3	0	-	12	0.07	20	0.11	29	0.20
Downy Woodpecker	231	0.45	11.8	0	-	24	0.36	97	0.58	110	0.35
European Starling	1249	2.40	9.0	0	-	368	2.72	477	2.70	404	2.14
House Finch	106	0.13	24.7	0	-	25	0.15	73	0.24	8	0.02
Mourning Dove	1130	1.02	5.4	0	-	196	0.64	413	1.07	521	1.14
Northern Flicker	470	0.44	7.7	0	-	86	0.31	136	0.42	248	0.48
Spotted Towhee	246	0.25	13.5	0	-	14	0.04	14	0.05	218	0.56
Western Kingbird	293	0.53	14.9	0	-	21	0.19	94	0.37	178	0.90
Western Tanager	64	0.16	34.6	0	-	58	0.71	5	0.05	1	0.00

Spatiotemporal Trends

Densities varied significantly ($P \leq 0.05$) over time across the river system for 17 of the 33 bird species we considered (Table 3). Note that although we obtained estimates of densities of Common Nighthawk, Red-eyed Vireo, Ovenbird, Clay-colored Sparrow, and Western Tanager, no trend estimates are reported given uncertainty associated with low sample sizes (e.g., <80 encounters across all years).

Bullock's Oriole perched in a cottonwood on the Madison River.

Densities of 13 bird species declined across time (Fig. 2). This total included four species not found to be declining in 2015 (Cliff Swallow, Brown-headed Cowbird, Bullock's Oriole, and Common Grackle; Noson & Flesch 2015). Declining species included riparian obligate species such as the Song Sparrow and Gray Catbird, as well as more widespread, generalist species such as Mourning Dove and House Finch. Six declining species nest in riparian shrubs (e.g. American Goldfinch, Gray Catbird, Song Sparrow, Willow Flycatcher, and Yellow Warbler) and two are cavity nesters in large snags (e.g., Red-naped Sapsucker and Downy Woodpecker). The average annual trend for declining species was -1.7 ± 0.3%, and ranged from -0.7 ± 0.3% per year for House Finch to -4.4 ± 0.6% per year for American Goldfinch (Table 4).

We found no evidence of trends in densities of 14 of the 38 bird species considered across the broader monitoring region (Fig. 3). For five of those species, however, we found trends in densities within one or more river sections as indicated by significant time by section interactions (e.g., Western Wood-Pewee, Willow Flycatcher, Black-billed Magpie, European Starling, and Yellow Warbler). Densities of Willow Flycatcher, an obligate riparian species, for example, declined along the Madison River, but increased along the upper Missouri River (Table 3, Appendix B).

Densities of five bird species increased across time, including two riparian obligate species, Yellow-breasted Chat and Red-winged Blackbird, two riparian-dependent species, House Wren and Black-capped Chickadee (both cavity nesting species that use small snags), and the generalist American Robin (Fig. 4). Trends of two species found to be increasing after 2015, Least Flycatcher and Yellow Warbler, were no longer detectable (Noson & Flesch 2015). The average annual trend for increasing species was 1.8 ± 0.6% per year, and ranged from 0.7 ± 0.3% for Yellow-breasted Chat to 4.2 ± 0.4% per year for House Wren (Table 4).

Densities of all species combined increased significantly across time (F = 1.48, P = 0.23). This change was driven by increases in densities of the most common riparian-dependent species and small increases in densities of riparian-obligate species, whereas generalists declined. There was little evidence that temporal trends in densities of species groups varied spatially (Fig. 5).

Table 3. Results from linear mixed-effects model test for year, section, and year x section interaction of bird species densities in riparian patches on the Madison and Missouri Rivers, Montana 2004-2017. Significant trends and Western BBS trends classified as Decline, Increase, or Varied.

Common Name	Year		Section		Year*Section		Trend	Western BBS (1966-2015)
	F	*P*	*F*	*P*	*F*	*P*		
Obligate								
Common Yellowthroat	0.06	0.802	10.21	<0.001	1.85	0.160	-	Increase
Gray Catbird	13.79	<0.001	28.43	<0.001	4.77	0.009	Decline	Increase
Red-winged Blackbird	10.62	0.001	15.27	0.000	7.96	<0.001	Increase	-
Song Sparrow	22.73	<0.001	48.59	<0.001	17.09	<0.001	Decline	Decline
Willow Flycatcher	0.85	0.358	3.24	0.047	10.50	<0.001	Varied	Decline
Yellow Warbler	1.47	0.226	81.19	<0.001	6.01	0.003	Varied	Decline
Yellow-breasted Chat	5.25	0.023	20.35	<0.001	2.18	0.115	Increase	Increase
Dependent								
American Goldfinch	53.41	<0.001	0.08	0.925	0.82	0.441	Decline	Decline
Black-capped Chickadee	21.32	<0.001	5.11	0.009	5.92	0.003	Increase	Decline
Black-headed Grosbeak	0.17	0.684	16.07	<0.001	2.43	0.090	-	Increase
Bullock's Oriole	5.19	0.024	3.06	0.055	1.05	0.351	Decline	Decline
Cliff Swallow	7.47	0.007	2.10	0.133	2.61	0.076	Decline	Decline
House Wren	121.28	<0.001	0.01	0.993	0.63	0.535	Increase	Increase
Lazuli Bunting	2.06	0.152	14.44	<0.001	0.80	0.450	-	-
Least Flycatcher	3.26	0.072	1.33	0.273	0.50	0.607	-	-
Tree Swallow	2.12	0.147	37.37	<0.001	0.18	0.838	-	Decline
Warbling Vireo	13.86	<0.001	2.04	0.140	7.41	0.001	Decline	Increase
Western Wood-Pewee	0.59	0.443	2.46	0.095	9.46	<0.001	Varied	Decline
Generalist								
American Robin	4.51	0.035	19.73	<0.001	0.14	0.869	Increase	-
Black-billed Magpie	0.93	0.337	2.07	0.136	6.30	0.002	Varied	-
Brown-headed Cowbird	10.01	0.002	35.36	<0.001	0.64	0.530	Decline	Decline
Cedar Waxwing	6.96	0.009	5.47	0.007	2.23	0.111	Increase	-
Common Grackle	11.63	0.001	9.91	<0.001	2.30	0.103	Decline	Decline
Downy Woodpecker	4.51	0.035	4.38	0.018	0.06	0.940	Decline	Decline
European Starling	0.11	0.736	1.19	0.314	4.67	0.010	Varied	-
House Finch	6.83	0.010	7.06	0.002	0.57	0.564	Decline	Decline
Mourning Dove	38.65	<0.001	10.41	<0.001	0.96	0.384	Decline	Decline
Northern Flicker	2.37	0.126	1.31	0.278	1.44	0.240	-	Decline
Spotted Towhee	0.00	0.948	19.06	<0.001	0.67	0.512	-	-
Western Kingbird	0.14	0.704	5.53	0.007	0.55	0.579	-	-

Table 4. Estimates of river system-wide annual trends (%) in bird species densities based on linear mixed effects models in which year was fit as the only fixed effect (e.g., without year x section interactions).

Common Name	Est.	SE	t	P
Obligate				
Common Yellowthroat	0.00	0.206	0.02	0.984
Gray Catbird	-1.88*	0.514	-3.65	<0.001
Ovenbird	-0.10	0.073	-1.37	0.174
Red-winged Blackbird	1.09*	0.348	3.15	0.002
Song Sparrow	-1.41*	0.380	-3.72	<0.001
Willow Flycatcher	-0.14	0.239	-0.57	0.570
Yellow Warbler	0.13	0.305	0.43	0.669
Yellow-breasted Chat	0.68*	0.291	2.33	0.021
Dependent				
American Goldfinch	-4.36*	0.594	-7.33	<0.001
Black-capped Chickadee	2.02*	0.476	4.25	<0.001
Black-headed Grosbeak	-0.12	0.325	-0.38	0.708
Bullock's Oriole	-1.04*	0.468	-2.22	0.027
Cliff Swallow	-2.39*	0.935	-2.56	0.011
Eastern Kingbird	-0.71	0.436	-1.63	0.105
House Wren	4.22*	0.382	11.03	<0.001
Lazuli Bunting	0.34	0.236	1.44	0.150
Least Flycatcher	-0.65	0.376	-1.72	0.087
Red-eyed Vireo	-0.08	0.176	-0.46	0.646
Red-naped Sapsucker	-0.75*	0.393	-1.92	0.056
Tree Swallow	1.01	0.744	1.36	0.176
Warbling Vireo	-0.85*	0.273	-3.11	0.002
Western Wood-Pewee	-0.27	0.378	-0.70	0.484
Generalist				
American Robin	0.97*	0.467	2.08	0.039
Black-billed Magpie	-0.23	0.233	-0.98	0.327
Brown-headed Cowbird	-1.57*	0.486	-3.22	0.001
Cedar Waxwing	-1.93*	0.739	-2.61	0.010
Clay-colored Sparrow	-1.12*	0.387	-2.90	0.004
Common Grackle	-2.30*	0.727	-3.17	0.002
Common Nighthawk	-0.16	0.217	-0.72	0.473
Downy Woodpecker	-1.05*	0.503	-2.09	0.038
European Starling	0.22	0.759	0.29	0.773
House Finch	-0.74*	0.290	-2.57	0.011
Mourning Dove	-2.43*	0.384	-6.33	<0.001
Northern Flicker	-0.52	0.334	-1.57	0.118
Spotted Towhee	0.00	0.195	-0.01	0.991
Western Kingbird	0.19	0.423	0.46	0.648
Western Tanager	-0.11	0.181	-0.62	0.534

* Significant (P<0.05) linear trend

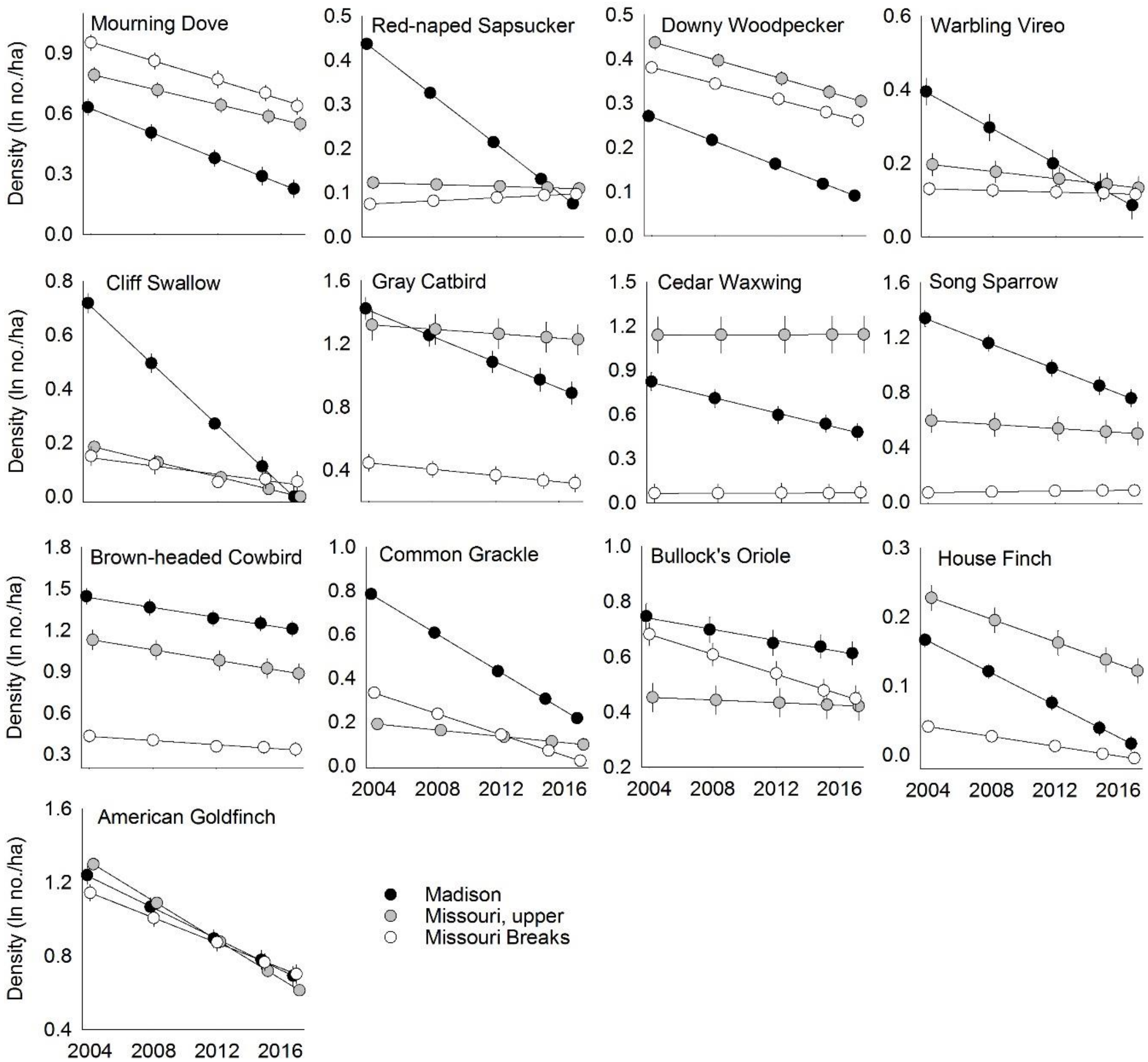


Figure 2. Spatiotemporal variation in densities (ln no./ha.) of 13 bird species with decreasing population trends along three sections of the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time. Note: scale of Y-axis varies among species.

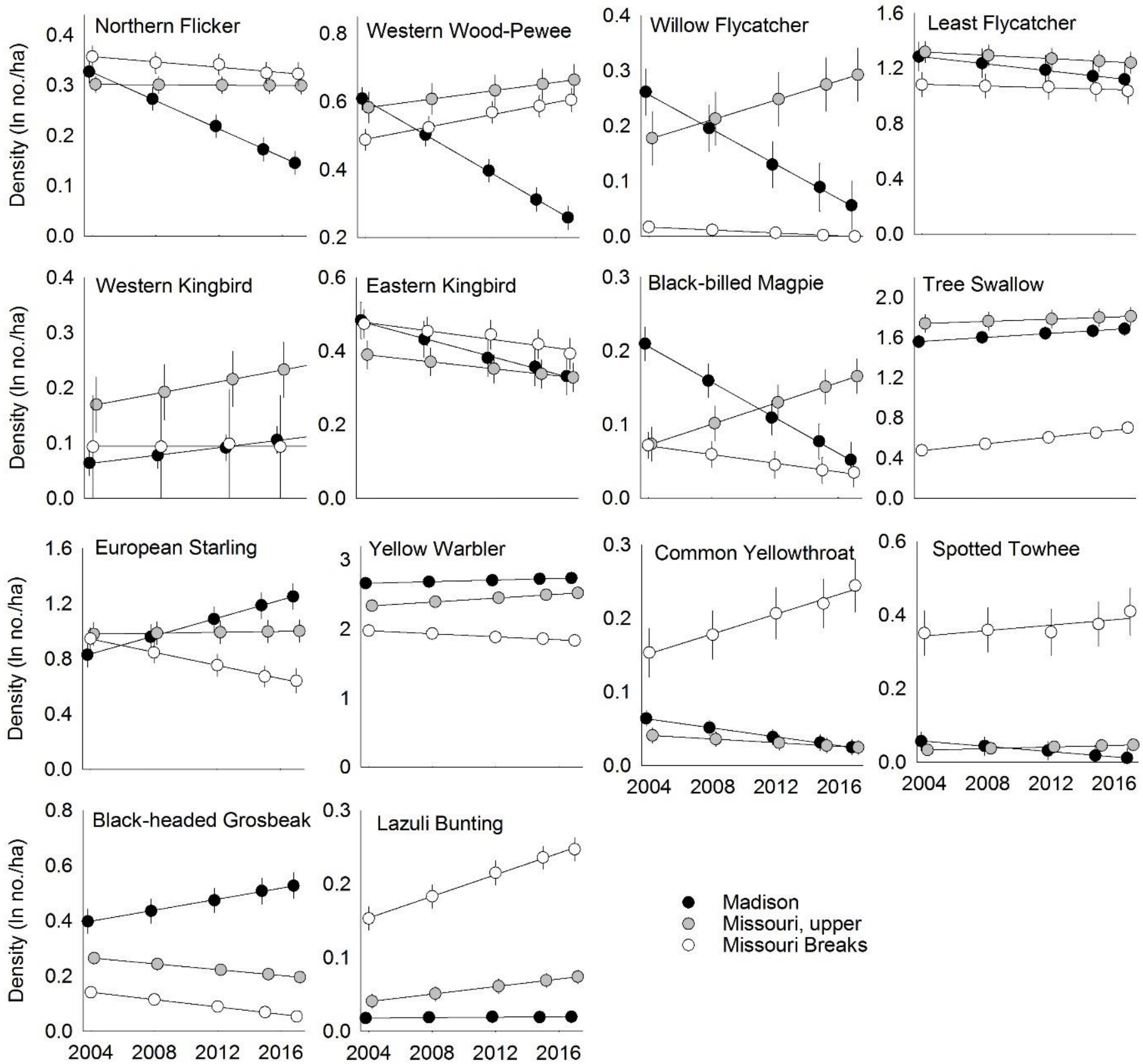


Figure 3. Spatiotemporal variation in densities (ln no./ha.) of 14 bird species with regionally variable or stable trends in populations across three sections of the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time. Note: scale of Y-axis varies among species.

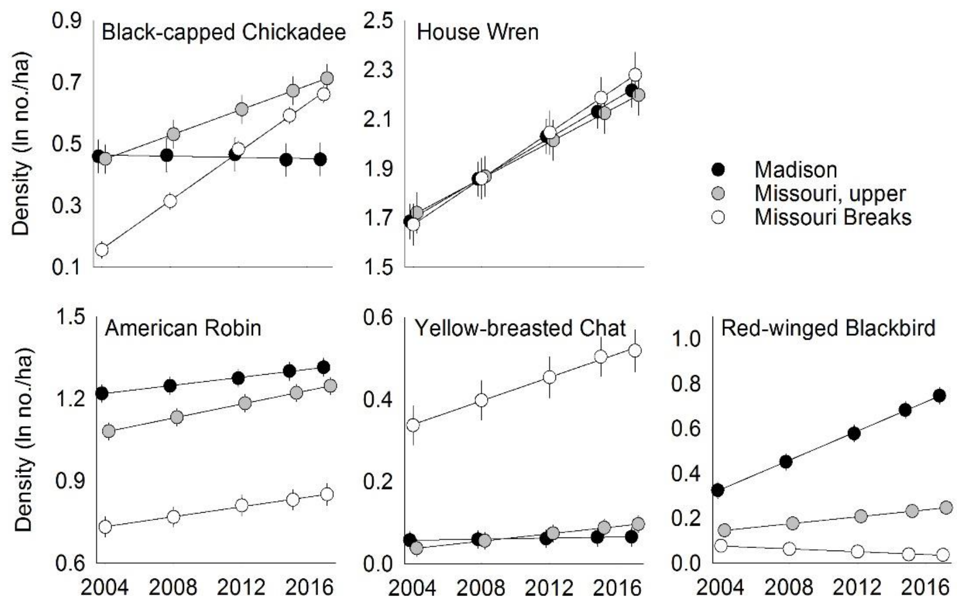


Figure 4. Spatiotemporal variation in densities (ln no./ha.) of five bird species with increasing population trends along three sections of the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time. Note: scale of Y-axis varies among species.

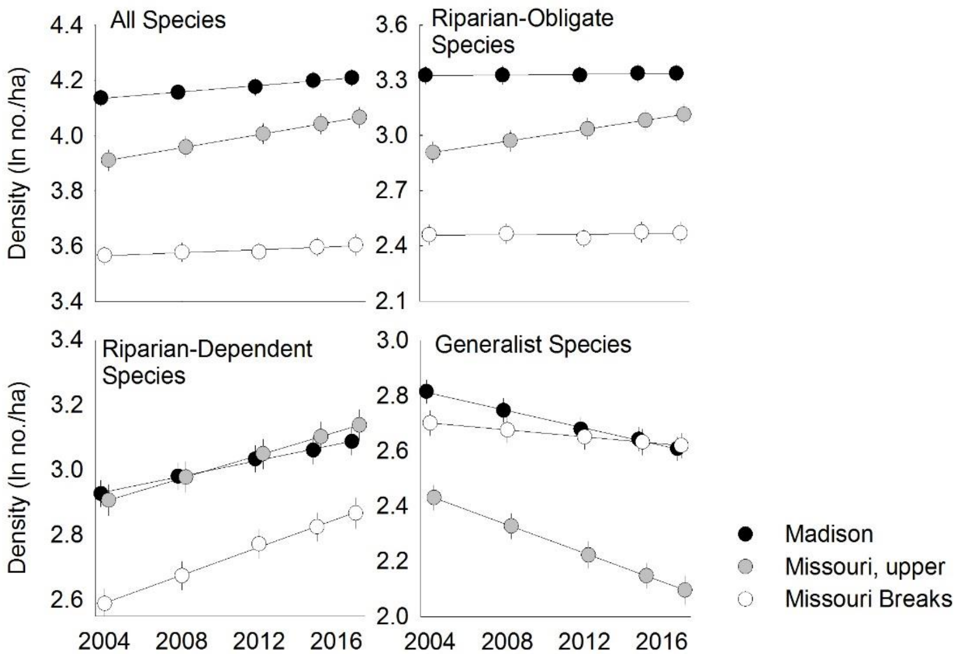


Figure 5. Spatiotemporal variation in densities (ln no./ha.) of three bird species groups and all species combined along three sections of the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time**.** Note: scale of Y-axis varies among groups.

Comparison with Regional Trends

Of the 33 bird species we considered, BBS analyses showed that 14 declined and six increased significantly across the western United States since 1966 (Table 3). The majority of species (64%) for which our results indicated population declines along the Madison and Missouri Rivers also showed significant declines across broader spatial and temporal scales based on BBS analyses.

There were also important differences between trends we observed in the study area and long-term trends based on BBS data. For example, two species with negative trends in the monitoring area have increased significantly across the west since 1966 according to BBS, including Red-naped Sapsucker and Gray Catbird. Additionally, one species with an increasing trend in our study area, the Black-capped Chickadee, declined according to BBS.

Species Richness

At the scale of riparian patches, estimated species richness of all species combined ranged from 5.5 to 88 across all years of study. Estimated richness of all species combined was higher on average along the Madison River (25.3 ± 0.9) than along the upper Missouri (22.9 ± 0.5) or Missouri Breaks (23.4 ± 0.8; $F_{2,375} = 2.89$, $P = 0.057$, ANOVA). Despite spatial variation in species richness, there was no evidence that richness of any species group or of all species combined varied across time ($P \geq 0.36$, LMEM) or that the presence or magnitude of temporal trends in richness varied among river sections ($P \geq 0.13$; for year × section interaction, Fig. 6). Based on the observed abundance distribution and the 101 species we detected during point counts at long-term monitoring sites across time, we estimate that 127 species were present in these riparian areas during the study period. Based on the observed abundance distribution and the 127 species we detected during point counts across the entire study area across time, we estimate that 135 species were present during the study period.

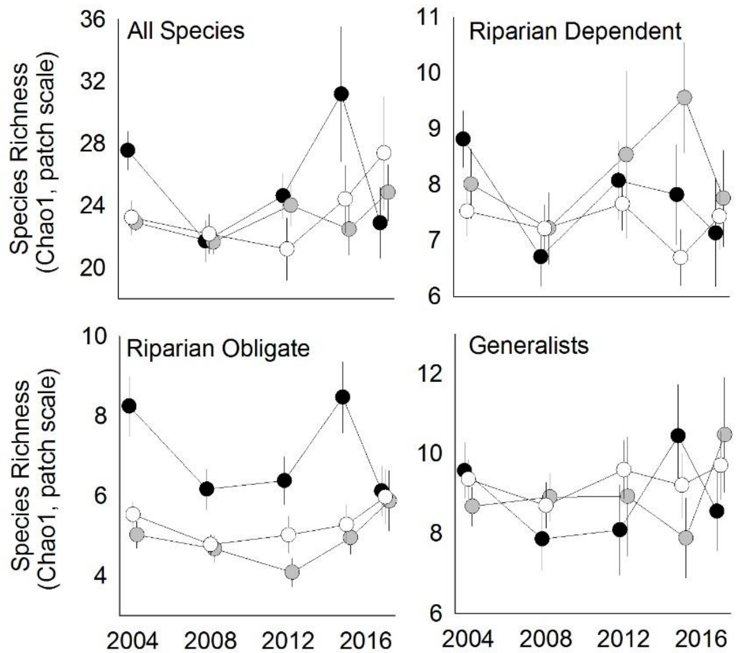


Figure 6. Spatiotemporal variation in estimated species richness of three bird species groups and all species combined along three sections of the Madison and Missouri Rivers, Montana 2004-2017. Points are estimates (± SE) based on the Chao1 estimator**.**

Objective 2: Trends in Riparian Habitat Conditions

Methods

Study Area & Design

See Objective 1, “Study Area & Design”.

Vegetation

At each point-count station, we measured vegetation within four sub-plots, one that was centered at points and three that were located 25 meters from the center point at directions of 0°, 120°, and 240° (adapted from Martin et al. 1997). Within each sub-plot, we measured vegetation composition and structure at two scales: 5-m radius and 11.3-m radius circular plots.

Within each 5-m radius circular plot, we recorded ocular estimates of shrub species cover, shrub height, species cover of saplings (trees <8 cm diameter at breast height; DBH) and of non-native herbaceous species, and ground cover. We estimated grazing intensity based on the density of cow feces, which we classified as none, low, moderate, or high. Starting in 2012, we also measured sapling density of cottonwoods (*Populus* spp.) and of Russian Olive (*Elaeagnus angustifolia*) to monitor cottonwood recruitment and the spread of non-native Russian Olive.

Within each 11.3-m radius circular plot, we measured density of each tree species and of snags in three size classes: small (8-23 cm DBH), medium (23-38 cm DBH), and large (>38 cm DBH), and considered all woody plants with stems ≥8 cm DBH as trees. We measured tree canopy height using a clinometer.

Analysis

We combined several vegetation variables for analysis. We grouped all species of willow (*Salix* spp.) and cottonwood (*Populus* spp.). We calculated dominance of each individual tree species by multiplying basal area (m^2) of each size class by density (no./ha). We calculated maximum canopy height (m), as the height of the tallest canopy layer by combining shrub and tree height measures to generate a single continuous measure of vegetation height. We combined estimates of all species of herbaceous weed cover (%) into total weed cover.

To estimate trends in the structure and composition of vegetation and other habitat conditions (e.g., grazing), we considered a subset of variables (Appendix C2) and used the same modeling procedure described above for bird populations (see Objective 1, Analysis). That procedure involved using linear mixed-effects models with site-level random effects, and fitting year by river section interaction terms to evaluate spatial variation in trends (see eq. 1 above).

Results

Survey Effort

We completed 1,015 vegetation surveys at 55 patches across five years of monitoring (Table 5). One site was not sampled due to access issues in 2012, but otherwise we sampled all patches at least once during each monitoring year.

Table 5. Annual sampling effort for vegetation on the Madison and Missouri Rivers in Montana 2004-2017. Total effort is number of sample points with ≥3 vegetation plots recorded.

Year	Patches (no.)	Points (no.)
2004	55	223
2008	55	199
2012	54	197
2015	55	204
2017	54	192

Riparian Habitat Conditions

We recorded 11 tree species across the river system (Appendix C). Narrowleaf Cottonwood (*Populus angustifolia*) and Plains Cottonwood (*Populus deltoids*) were the most common trees, and occurred at 76% and 53% of sites, respectively (Appendix C). Density of all cottonwood species combined were significantly higher on the Missouri River than the Madison River (Section P <0.005; Appendix D).

We encountered 13 shrub species (or species groups), including seven species associated with wetland areas (facultative wetland plants, Lichvar 2014, Appendix C). Common Snowberry (*Symphoricarpus albus*) was the most common shrub and occurred at 96% of sites, followed by willow (*Salix* spp.), at 87% of sites. Willow cover was higher on the Madison than the Missouri (Section $F = 12.11$, $P < 0.001$; Appendix D). We rarely encountered upland shrub communities, but 14% of sites contained sagebrush (*Artemesia* spp.).

We found invasive species of weeds at virtually all sites, representing 21 species or species groups (Appendix C). Canada Thistle (*Cirsium arvense*) was the most common weed and occurred at 89% of sites, followed by Common Hound's Tongue (*Cynoglossum officinale*) and Leafy Spurge (*Euphorbia esula*) at 74% and 58% of sites, respectively. Two tree species known to invade riparian habitats, Rocky Mountain Juniper (*Juniperus scopulorum*) and non-native Russian Olive (*Elaeagnus angustifolia*), occurred at 44% and 22% of sites, respectively. We observed significantly higher juniper densities on the Upper Missouri than the Madison, and few on the Missouri Breaks (Section $F = 5.52$, $P = 0.007$; Appendix D). For more details on vegetation distributions across the river system, see Noson & Flesch 2015.

Rocky Mountain Juniper in the Upper Missouri (left) and Russian Olive in the Missouri Breaks (right)

Trends in Riparian Conditions

We continued to observe significant changes in the vegetation structure and composition in riparian areas along the Madison and Missouri rivers since 2004 (Table 6). Large-diameter (>38 cm) cottonwood (*Populus* spp.) trees showed significant declines, while small (8 -23 cm) cottonwood trees increased, particularly on the Missouri River (Fig.7).

We also observed a significant decline in densities of both small and large snags (Table 6). When monitoring began in 2004, densities of large snags were significantly lower on the Madison than the Missouri River, but by 2015, they were similar across the river system, and it now appears that while large snags continue to increase slightly on the Madison, they are deteriorating on the Missouri (Fig. 8).

Rocky Mountain Juniper, an invasive woody species in riparian areas in the west, continued to increase in dominance. However, dominance of Russian Olive, another woody invasive that was found to be increasing in 2015, did not vary systematically across time (Fig.9). Sample sizes for Green Ash and Box

Elder, which occur only locally along the Missouri Breaks, were too low to reliably evaluate change in dominance across time.

Total shrub cover declined significantly across the river system (Fig. 10). Cover of willow species declined by 2.4 ± 0.7% per year on average, and there was strong evidence declines were steepest on the Madison and upper Missouri River (Time x Section $F = 6.68$, $P = 0.001$). There no evidence of a temporal trend in cover of cottonwood saplings either across the study area or in various river sections (Fig. 10, Table XX). However, we found evidence that maximum canopy height continued to decline across time (by 2.2 ± 0.3% per year), suggesting losses of taller trees and shrubs across the river system (Fig. 11).

Trends in two measures of human impact, grazing and herbaceous weed cover, showed disparate trends over time (Fig. 11). Intensity of livestock grazing continued to decline markedly across the river system matching trends from 2015. We found no evidence of a system-wide trend in total herbaceous weed cover, although cover declined significantly along the upper Missouri River (Time x Section $F = 4.66$, $P = 0.010$).

Table 6. Estimates of river system-wide annual trends (%) in vegetation measures based on linear mixed effects models in which year was fit as the only fixed effect (e.g., without year x section interactions). Note: estimates are annual percent change.

Vegetation Measures	Est.	SE	*t*	*P*
Small *Populus* spp. density (per ha)	3.398*	1.011	3.360	0.001
Medium *Populus* spp. density (per ha)	1.249	1.000	1.249	0.212
Large *Populus* spp. density (per ha)	-3.006*	0.963	-3.122	0.002
Populus spp. dominance	-0.845	0.556	-1.522	0.128
Russian Olive dominance	0.007	0.083	0.086	0.932
Juniper dominance	0.584*	0.194	3.009	0.003
Small snag density (per ha)	-3.123*	0.762	-4.099	<0.001
Medium snag density (per ha)	-0.972	0.740	-1.313	0.189
Large tree density (per ha)	-1.505*	0.670	-2.248	0.025
Total snag dominance	-0.864*	0.329	-2.628	0.009
Total shrub cover (%)	-5.203*	0.592	-8.793	<0.001
Salix spp. cover (%)	-2.441*	0.674	-3.621	<0.001
Populus spp. sapling cover (%)	-0.224*	0.294	-0.762	0.446
Max. canopy height (m)	-2.240*	0.283	-7.917	<0.001
Index of Grazing Intensity	-2.034*	0.253	-8.038	<0.001
Total weed cover (%)	-0.343	0.578	-0.593	0.553

* Significant (P<0.05) linear trend

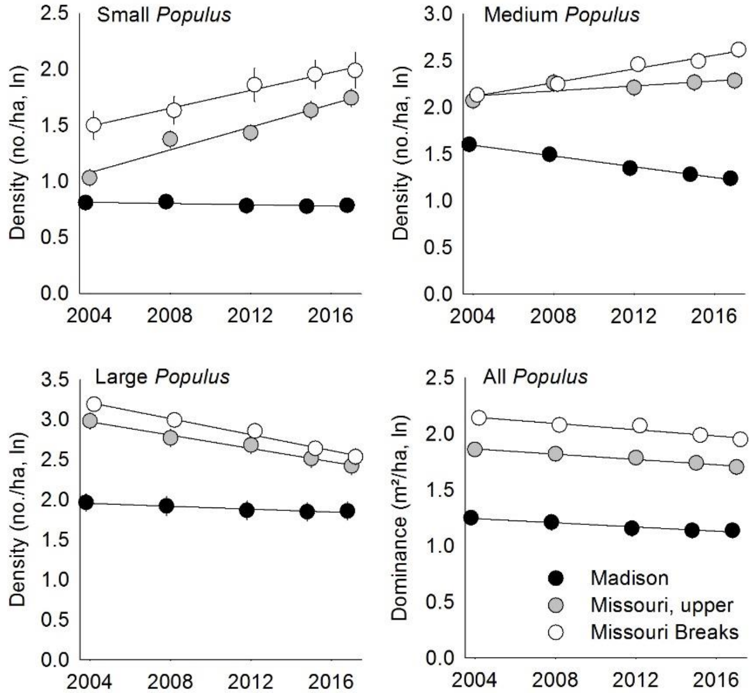


Figure 7. Trends in cottonwood (Populus spp.) tree density (ln no./ha.) for 3 size classes (small=8-23 cm DBH, med=23-38 cm DBH, and large=>38 cm DBH), and total cottonwood tree dominance (ln m²/ha.) across time along the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time.

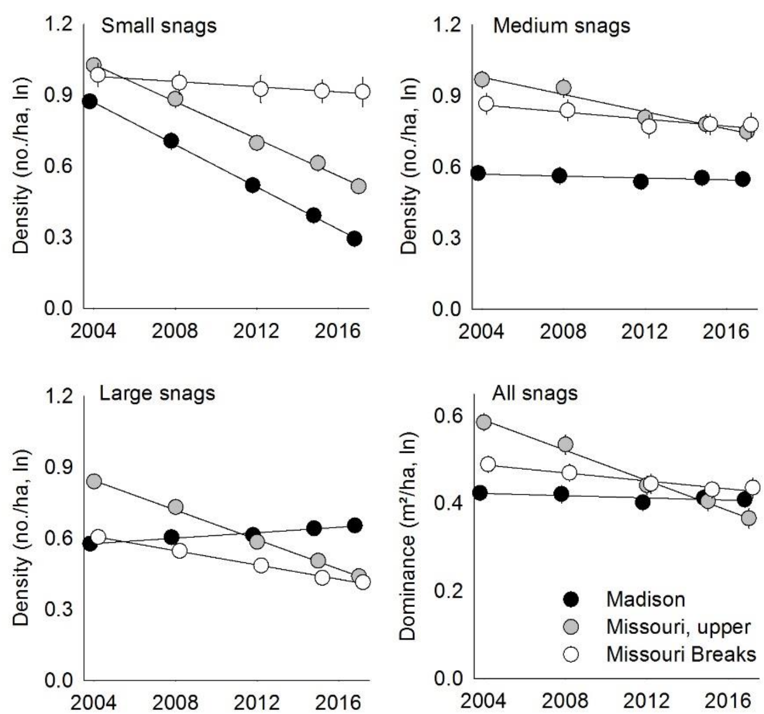


Figure 8. Trends in snag density (ln no./ha.) for 3 size classes (small=8-23 cm DBH, med=23-38 cm DBH, and large=>38 cm DBH), and total snag dominance (ln m²/ha.) across time along the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time.

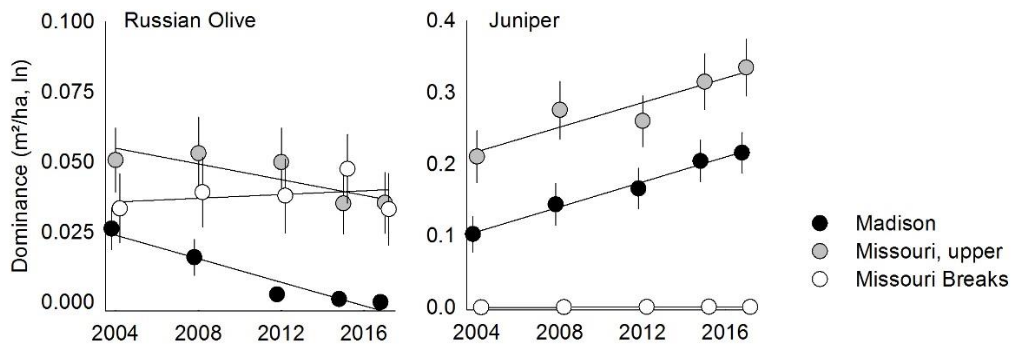


Figure 9. Trends in invasive woody species dominance (ln m²/ha.) across time for Russian Olive and Rocky Mountain Juniper along the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time.

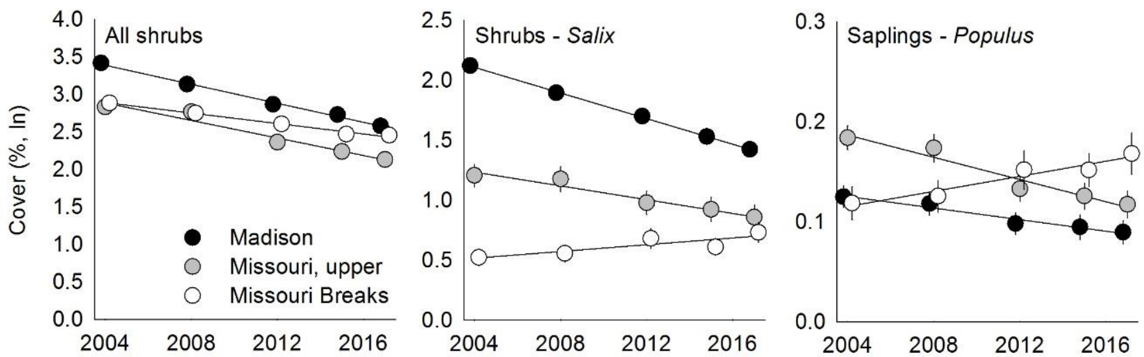


Figure 10. Trends in cover (ln %) across time for all shrubs, *Salix* spp. shrubs, and *Populus* spp. saplings, along the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time.

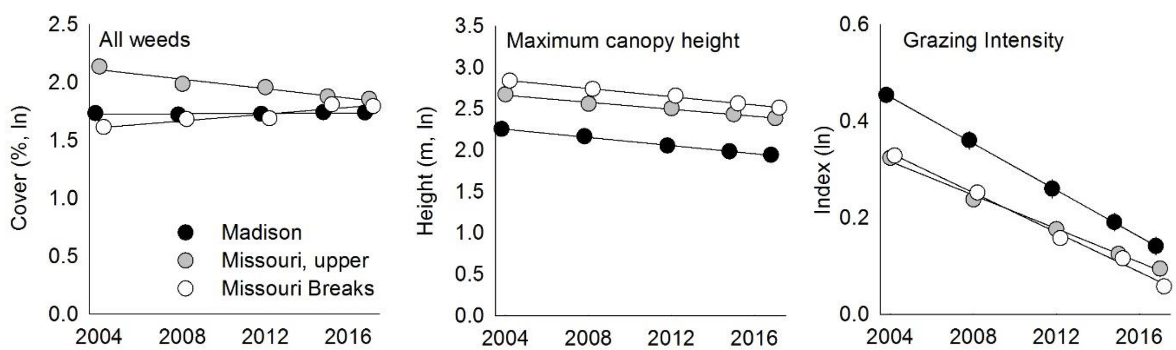


Figure 11. Trends across time for total weed cover (ln %), maximum canopy height (ln m.), and grazing intensity (ln index) along the Madison and Missouri Rivers, Montana 2004-2017. Estimates are predictions (± SE) from linear mixed-effects models that estimated trends across time.

Objective 3: Bird Populations in Upper Missouri Breaks

Methods

Study Area & Design

The Upper Missouri River Breaks National Monument (UMRB), covers about 375,000 acres of BLM-administered public land in central Montana, and encompasses the 149-mile Upper Missouri National Wild and Scenic River designated for its scenic qualities, historic significance, and wildlife resources. Constrained side-valley sandstone and shale badlands and frequent ice-drive disturbance confine riparian forests to relatively small patches along elevated flood deposits (Hansen 1989). Flood control measures, including dams and levees, have reduced the frequency of large flood events along the river, reducing establishment opportunities for cottonwoods along the river (Bovee & Scott 2002), and contributing to the invasion of non-native plants.

A public and private partnership in the UMRB, which includes the BLM and the Friends of the Upper Missouri Breaks National Monument, is working to restore cottonwood forest and improve wildlife habitat through targeted restoration projects and improved management practices. Several of these projects have received funding through the Northwestern Energy Wildlife TAC.

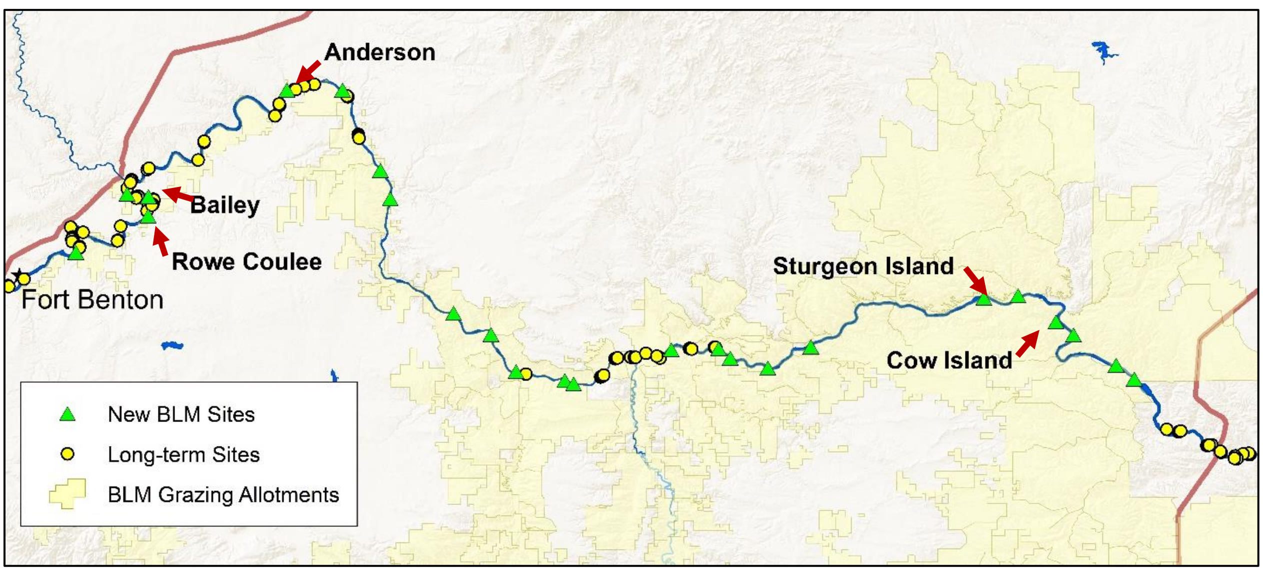


Figure 12. Location of existing long-term monitoring sites, and new sites established in riparian areas within the Upper Missouri River Breaks National Monument, including 5 restoration project areas (Rowe Coulee, Bailey, Sturgeon Island, and Cow Island).

We supplemented long-term monitoring already in place in the UMRB (31 sites, 74 points) with additional sampling to better evaluate management practices and locate areas of high priority for future projects within the UMRB (Fig. 12). Monitoring points were added at five new restoration project areas (e.g. Rowe Coulee, Bailey, Anderson, Sturgeon, and Cow Island), as well as 19 additional areas on BLM-administered lands, including existing exclosures and recreation sites (Table 7). Note that project areas and exclosures are in some cases located at recreation sites (e.g. The Wall and Wood Bottom).

Bird Surveys

We conducted standard point count surveys for all birds detected at monitoring points (see Objective 1 methods section for more details).

We followed point count surveys with 5 minutes of playbacks targeting Yellow-billed and Black-billed Cuckoos based on Montana Natural Heritage protocols for these species. Surveys were timed to coincide with peak detectability in late June- late July. Because detectability of these secretive species is low, we attempted to repeat sampling for as many locations as possible as time permitted. Calls were broadcast at the beginning of each minute.

Vegetation

At each bird monitoring points surveyed for birds, we also measured vegetation at four sampling locations (see Objective 2 methods section for more details).

Analysis

We will evaluate biological outcomes of restoration projects by BLM and partners in the UMRB relative to BLM grazing management by collecting baseline information prior to installation of exclosures installed to fence out livestock, and tracking changes over time using a Before-After-Control-Impact (BACI) study design (Schwarz 1998).

If restoration has immediate effects on bird community composition, then we expect: 1) control and treatment sites to be most similar before restoration, and 2) post-restoration control and treated sites to differ significantly. If there is no effect then we expect no pattern of significance. We will use a generalized linear mixed model (GLMM) with site included as random effect to account for site-to-site variation.

Results

Songbirds

We documented 2,134 birds representing 79 species across all sites within the UMRB in 2017. We found that riparian species densities varied significantly across ownership and management designation (Fig. 13). Mean density of obligate species was highest on private lands (F-test $P = 0.024$), while dependent species were highest on other BLM lands (F-test $P = 0.024$). Recreation sites had lower density of riparian obligate species than any other management area.

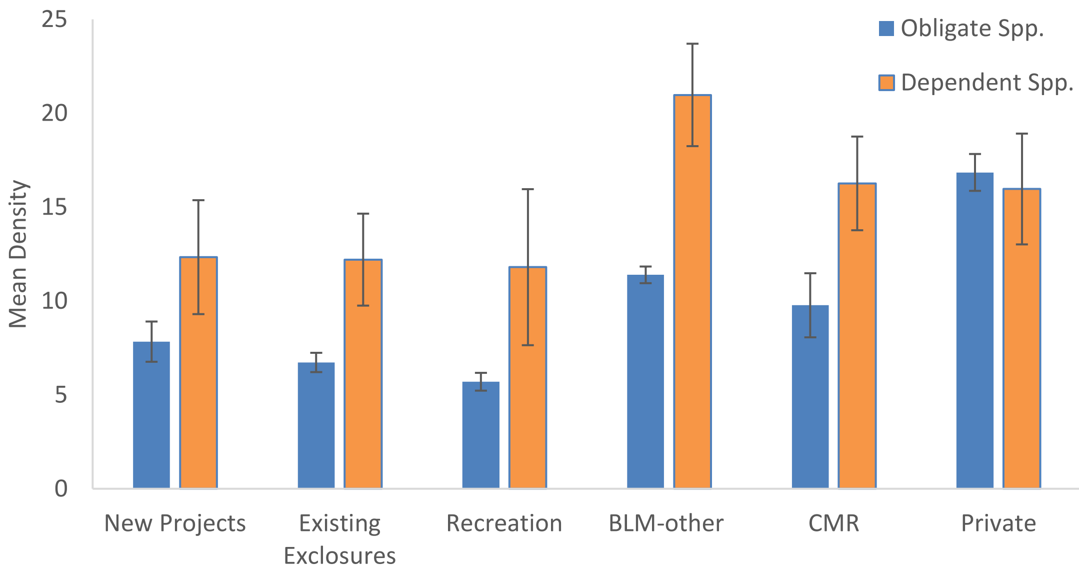


Figure 13. Mean bird density of riparian obligate species (blue) and riparian dependent species (orange) observed in riparian areas along the Upper Missouri River Breaks in 2015 and 2017. Error bars represent ±SE.

Densities of riparian species also varied among selected management sites within the Upper Missouri Breaks (Table 7). Overall, the highest density of all riparian species combined (28.7 birds/ha) was found at Rowe Coulee, a new project area on private and BLM land. We also found the highest density of Yellow-breasted Chats at this site. We measured the highest obligate species density (11.5 birds/ha) at Hideaway, a BLM recreation site. The lowest density of riparian species (7.5 birds/ha) was observed at Bailey, a new project area on private land consisting primarily of new cottonwood seedlings and low herbaceous wetlands. Evan's Bend retained relatively high overall riparian species densities across years (22.6 birds/ha), despite a sharp decline in obligate species density from 11.4 in 2015 to 1.2 birds/ha in 2017 following wildfire.

Table 7. Mean density of five riparian obligate species occurring in the Upper Missouri Breaks, and total riparian obligate and dependent species densities in selected management areas including new projects, existing exclosures, and recreation sites, 2015 and 2017.

	Common Yellowthroat	Gray Catbird	Ovenbird	Yellow Warbler	Yellow-breasted Chat	Obligate Spp.	Dependent Spp.	Total Riparian Spp.
New Projects								
Anderson[a]	0.1	0.4	-	4.1	-	6.9	18.4	25.4
Bailey	2.1	-	-	1.6	0.3	4.9	2.7	7.5
Cow Island	1.6	0.4	-	4.2	1.4	8.3	9.0	17.4
Rowe Coulee	0.9	0.8	-	2.4	2.7	10.1	18.7	28.7
Sturgeon Island	1.7	-	-	2.9	0.8	6.8	6.5	13.3
Existing Exclosures								
Demars	1.9	-	-	3.1	0.9	6.8	6.7	13.5
Ford Bottom	0.6	-	-	1.2	-	5.0	2.5	7.6
Hagadone	0.8	-	-	2.1	1.0	3.9	10.8	14.7
Ironcity	0.3	1.6	-	2.9	0.3	6.4	10.1	16.5
Little Sandy	0.3	-	-	6.2	-	6.5	19.5	26.0
Monro Island	-	-	-	1.8	-	8.4	7.1	15.4
Pablo	1.2	-	-	3.3	-	6.7	12.5	19.2
The Wall	0.9	-	-	3.3	-	5.1	15.9	21.1
Wagonbed	1.0	-	-	7.6	0.4	8.9	16.6	25.6
Wood Bottom[a]	0.6	0.4	-	5.6	0.9	8.0	18.3	26.3
Woodhawk	1.0	-	-	3.5	0.5	6.9	8.1	14.9
Recreation								
Dark Butte	-	-	-	-	-	1.1	7.7	8.7
Eagle Creek	-	-	0.2	2.6	-	5.7	9.5	15.2
Evans Bend	0.2	-	-	4.4	0.9	6.3	16.3	22.6
Gist Ranch	0.4	-	-	1.8	0.5	4.4	14.0	18.4
Hideaway	1.6	0.8	-	4.1	2.4	11.5	11.9	23.4
Mcgarry Bar	1.7	0.8	-	2.7	-	7.2	3.4	10.6
Murray Dugout	0.2	-	-	5.0	0.2	6.1	15.9	22.0
Slaughter River	-	-	-	3.0	0.4	3.4	15.9	19.2

[a] No exclosure in place, but grazing access is restricted.

Common Yellowthroats were found in low densities at most sites, but were not observed at three recreation sites and one exclosure. This species prefers low, dense riparian vegetation, and is often found on wetland fringes. Their highest density was at Bailey, the new project area with otherwise low densities of riparian species. Gray Catbirds, a shrub nesting species showing population declines across the river system (see Objective 1 Results), were found in low densities at three of the five new project areas, but only two existing exclosures and two recreation sites. We found the highest density of Gray Catbirds at Iron City an existing BLM exclosure. Yellow Warblers, the most abundant and widespread obligate species in this river section, was found at all sites except Dark Butte. We found the highest density of this riparian shrub nesting species (7.6 birds/ha) at Wagonbed, an existing exclosure on Montana state land. The only Ovenbird (Montana Potential Species of Concern, S4B) found in the selected management areas was at Eagle Creek recreation site.

Targeted Surveys for Cuckoo Species

We conducted targeted surveys for Yellow and Black-billed Cuckoos at 42 riparian sites that contained sufficient habitat to warrant surveys (e.g. >1 ha cottonwood forest).

In 2017, we detected no Black-billed or Yellow-billed Cuckoos within the Upper Missouri Breaks. In 2015 we observed Black-billed Cuckoos in 5 locations, as shown in Figure 14. All observations were at the upstream end of the UMRB, near the Fort Benton-Ulm area, or at the far downstream end of the UMRB near the Charles M. Russell National Wildlife Refuge (CMR) boundary. The majority of observations were located on BLM-administered lands, including two recreation areas (Evans Bend and Hideaway). One individual was detected at Wood Bottom in an area where livestock are restricted. We also observed a bird within the new Rowe Coulee exclosure, which contains a mix of private and BLM land. A single individual was detected in a large cottonwood patch within the Charles M. Russell National Wildlife Refuge.

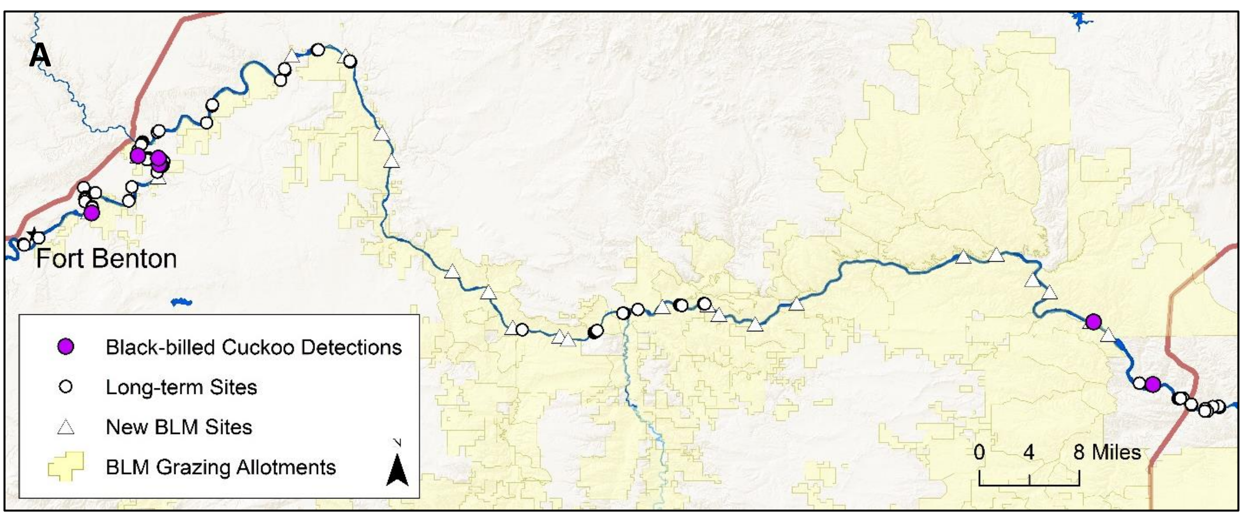


Figure 14. Locations of Black-billed Cuckoos detected during playback surveys of the Upper Missouri River Breaks in 2015.

Habitat Conditions

We found that shrub cover and cottonwood tree density varied significantly across ownership and management designations in the UMRB (F-test $P = 0.012$ and $P = 0.002$, respectively; Fig. 15). Total shrub cover was was 13.5 ± 4.4% higher in new project areas and existing exclosures than private land. Total density of cottonwood trees was lower in new project areas and existing exclosures (26.6 ± 5.1 and 34.5 ± 6.2 trees/ha, respectively) compared to BLM, CMR, and private land where densities ranged from 80.3-126.3 trees/ha. We documented 17 invasive plant species or groups. Leafy Spurge (*Euphorbia esula*) and Thistle species (*Cirsium* spp.) were the most commonly found within the UMRB. We measured no significant differences in total cover across management designations, but infestations varied among selected management areas (Table 8). The highest invasive weed cover (21.6%) was found at Evans Bend, a recreation site that burned in 2016. Hideaway, a recreation site located downstream near the CMR boundary, had the lowest weed cover (1.8%).

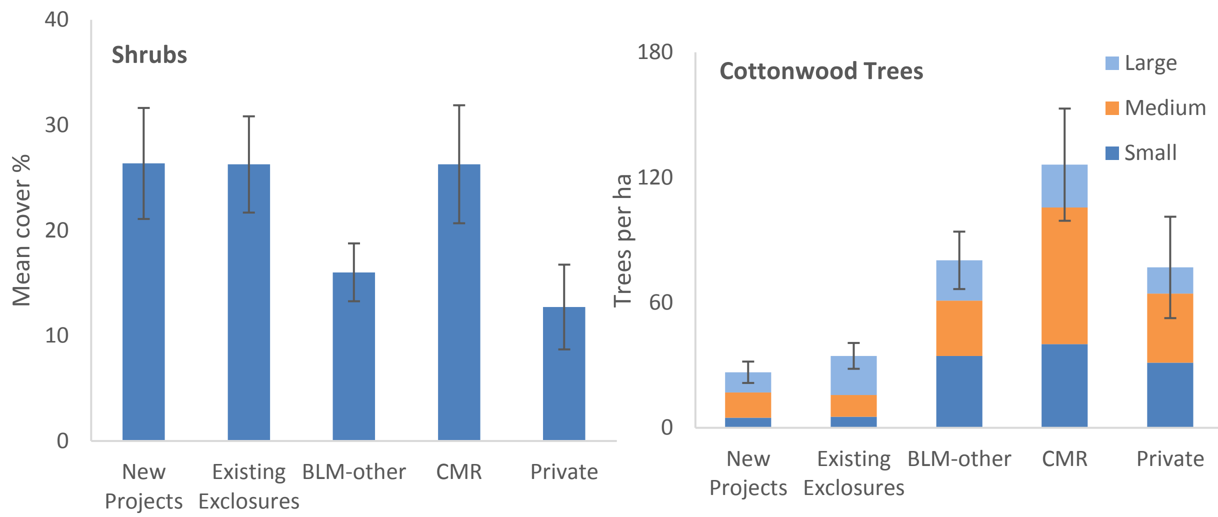


Figure 15. Mean shrub cover (left) and cottonwood tree density (right) across five categories of land management and ownership in the Upper Missouri River Breaks, 2017. Error bars represent ± SE.

Table 8. Vegetation measures in selected management areas including new projects, existing exclosures, and recreation sites in the Upper Missouri River Breaks, 2017.

	Shrub Cover (%)	Small Cottonwood (trees/ha)	Med. Cottonwood (trees/ha)	Large Cottonwood (trees/ha)	Leafy Spurge (%)	Thistle Spp. (%)	Total Invasive (%)
New Projects							
Anderson [a]	9.2	2.5	18.8	7.5	4.6	3.5	9.5
Bailey	15.5	-	-	-	5.4	1.4	7.7
Cow Island	23.3	26.6	31.3	15.6	3.0	0.3	3.3
Rowe Coulee	23.2	2.5	15.0	15.0	0.3	6.0	7.2
Sturgeon Island	44.7	-	-	0.8	3.8	0.7	5.1
Existing Exclosures							
Demars	54.1	-	-	20.8	0.4	9.1	10.5
Eagle Creek	12.9	2.1	45.8	8.3	4.2	-	4.3
Ford Bottom	52.0	-	-	50.0	12.0	0.5	19.0
Hagadone	71.0	-	-	46.9	0.6	-	3.0
Ironcity	50.8	-	-	15.6	3.1	3.8	11.4
Little Sandy	21.5	3.1	15.6	18.8	1.1	0.6	4.5
Monro	13.5	-	-	12.5	2.8	-	2.8
Pablo	14.6	-	6.3	12.5	-	2.5	2.5
The Wall	10.4	-	9.4	31.3	5.6	-	5.6
Wagonbed	15.1	-	15.6	40.6	2.1	1.3	5.9
Wood Bottom [a]	23.2	-	12.5	13.8	4.8	1.7	7.1
Woodhawk	15.1	25.0	10.4	14.6	2.6	0.2	6.1
Recreation Sites							
Dark Butte	11.9	2.1	17.4	27.8	2.4	-	2.4
Evans Bend	2.6	-	-	-	4.6	14.7	21.6
Gist Ranch	25.0	-	14.6	31.3	3.8	-	7.3
Hideaway	30.1	45.3	37.5	17.2	0.3	1.4	1.8
Mcgarry Bar	23.5	-	-	12.5	1.3	-	8.4
Murray Dugout	18.7	3.1	21.9	15.6	2.9	0.6	3.5
Slaughter River	25.0	-	-	12.5	-	-	3.1

[a] No exclosure in place, but grazing access is restricted.

CONCLUSIONS

Long-term assessments of the distribution and abundance of wildlife are central to evaluating the potential effects of anthropogenic stressors on animal populations and communities (Thompson et al 1998, Pollock et al. 2002). This program provides a direct measure of the status of riparian-dependent bird populations across an expansive (500 mile) stretch of the Madison and upper Missouri Rivers in Montana. Currently this effort is the only broad-scale monitoring program focused on riparian birds in Montana.

Ovenbird carrying food for nestlings at Eagle Creek recreation site, Missouri River.

Five years of monitoring data gathered between 2004 and 2017 for 33 bird species of management concern, continue to show measurable declines in populations of many riparian-obligate and riparian-dependent species. In contrast, increasing trends in abundance were largely restricted to the most common bird species. Following bird surveys in 2017, we documented 13 declining species, 5 increasing species, and an additional 5 species with significant trends on at least one river section. Collectively, these bird species represent approximately 25% of the breeding landbird community in the region. Although abundances of other populations likely also varied in this system since 2004, we were able to obtain relatively precise estimates of densities for these 33 species based on previous sampling effort and encounter rates. As sample sizes increase with continued monitoring in future years, the number of species that can be effectively monitored will also increase.

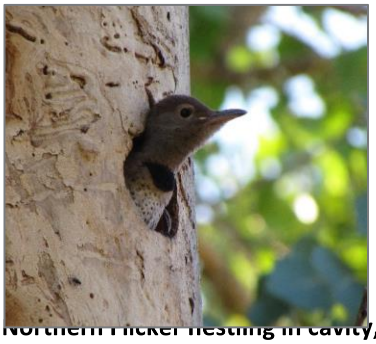
Populations that declined have a broad range of nesting, foraging, and other habitat requirements, and include riparian-obligate and riparian-dependent species such as shrub-dependent Song Sparrow, canopy dwelling Bullock's Oriole, and cavity-nesting Red-naped Sapsucker. Generalist species in decline included the Mourning Dove and Common Grackle. While both these generalist species are abundant and widespread, they also show declines throughout the west. According to the North American Breeding Bird Survey, Common Grackle populations declined by almost 2% per year since 1966, resulting in a cumulative decline of 58%.

Species that increased in abundance across time are all common in North America, and thus may not be as sensitive to changes in environmental conditions in this river system. Most are also among the most abundant species in the monitoring region (e.g., House Wren and American Robin; Appendix A). The Red-winged Blackbird, North America's most common breeding marsh bird, can breed in cattail-dominated wetlands associated with poor hydraulic conditions (Searcy & Yasukawa 1995). The only other riparian obligate species that increased significantly during the monitoring period was the Yellow-breasted Chat, a shrub nesting species found primarily in the Missouri Breaks that prefers riparian areas with dense shrub cover.

We found sometimes dramatic differences in trends among river sections we monitored, with many riparian species like the Willow Flycatcher and Red-naped Sapsucker declining more steeply along the

Madison River than the Missouri River. We also measured the largest increase of European Starlings on the Madison River, a species known to outcompete native cavity nesting species in riparian areas.

Our findings largely corresponded to long-term trends observed across the region by the North American Breeding Bird Survey (BBS) since 1966 (Sauer et al. 2017). Those similarities in trends suggest that at least some of the drivers of population declines in our system are likely operating at larger spatial scales. Nonetheless, our results also included several important differences from regional BBS trends. For example, we found significant population declines of Gray Catbird. This species is associated with high shrub densities that declined significantly across the river system since 2004. However, according to BBS, Gray Catbirds have increased in the western U.S. likely due to increases in shrub cover associated with fire and forest clearing in areas where catbird were historically rare (Smith et al 2011). Such differences show how large-scale monitoring of population trends, while critical for evaluating continental populations, may mask local changes in the status of populations of conservation concern.



Northern Flicker nesting in cavity, Madison River.

We also examined trends in densities of all bird species combined, and of riparian-obligate and riparian-dependent bird species, and of species richness. Those analyses indicated only stable or increasing trends across the river -system. While these findings might be interpreted as showing overall bird community stability, it is important to understand that changes in abundances of the most common species, such as House Wren, likely drove those patterns and may mask declines of many less abundant species.

Management Implications

Generating efficient management responses to observed changes in bird communities and environmental conditions depends on understanding factors that are driving trends. Therefore, an important next step will be to assess environmental conditions that explain spatiotemporal variation in densities of various bird populations in this system. We found significant changes in vegetation and other environmental conditions in riparian areas along the river since 2004, which are likely influencing habitat suitability for various bird populations (Fletcher & Hutto 2008). Such changes include aging cottonwood forests and declining shrub cover that may be linked to large-scale modifications of the river system and its floodplain over the past century for flood control, agriculture, and hydroelectric operations (Dixon et al. 2012). Other studies of riparian birds have found that bird communities are affected by land-use activities at multiple spatial scales, including local changes to vegetation structure associated with altered river flows and livestock grazing (Scott et al. 2003, Saab et al. 2005). Moreover, changes to surrounding landscapes due to agricultural conversion and urbanization can also influence populations at much more local scales (Tewksbury et al. 2002, Rodewald & Bakermans 2006). Finally, riparian bird populations are thought to be especially vulnerable to climate change, which can influence habitat conditions and given the sensitivity of riparian vegetation to climate-induced hydrologic changes (Huntley et al. 2006).

Our findings confirm the ability of this program to estimate biologically meaningful changes in densities of a relatively large number of breeding bird species, which include species that are common, uncommon, and of management and conservation interest. The majority of the early trends we observed in 2015 continued in 2017. Nevertheless, although our efforts spanned a period of over 10 years, trend estimates we report are based on surveys from only five years and thus should be viewed cautiously. This is because trends we report here could represent natural spatiotemporal variability in populations rather than deterministic changes in abundances. Continued monitoring will build on this dataset and provide more reliable assessments of population changes of wildlife and environmental conditions in riparian areas over time.

Upper Missouri River Breaks

We measured significant differences in riparian bird populations and habitat conditions across management designation and ownership in the Upper Missouri Breaks (UMRB). Our findings demonstrate that new project areas selected for restoration include important habitat for riparian bird species. Restoring these areas should benefit riparian bird populations, but continued monitoring is critical to provide science-based measures of project outcomes for wildlife. We also identified additional BLM-administered areas of importance for bird species of concern. The only Ovenbirds we observed outside of the Charles M. Russell National Wildlife Refuge (CMR) were at Eagle Creek, a BLM recreation site with an existing exclosure. Black-billed Cuckoos were only found within exclosures near Ulm at a popular public river access (Wood Bottom) and two BLM recreation sites: Evans Bend (which burned in 2016) and Hideaway. Ensuring habitat conditions are maintained with recreational use will be key to sustaining breeding populations in these areas. No Black-billed Cuckoos were detected in 2017, despite a similar field effort to 2015. Low numbers and detectability combined with apparent annual fluctuations in breeding of this species mean that regular monitoring will be critical to finding breeding locations and evaluating populations for this species.

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Appendix A. Total bird encounters, breeding habitat, and conservation status across long-term monitoring patches from 2004-2017.

Common Name	Abundance [a]	Breeding Habitat	MTSOC	USFWS
American Avocet	-	Water/Wetland		
American Crow	12			
American Goldfinch	1,083	Riparian Dependent		
American Kestrel	98			
American Redstart	34	Riparian Obligate		
American Robin	1,517			
American White Pelican	273	Water/Wetland	S3B	
American Wigeon	2	Water/Wetland		BMC
Bald Eagle	16	Riparian Obligate		BMC
Bank Swallow	102	Riparian Obligate		
Barn Swallow	8			
Belted Kingfisher	39	Riparian Obligate		
Black-billed Cuckoo	-	Riparian Dependent	S3B	BMC
Black-billed Magpie	176			
Black-capped Chickadee	423	Riparian Dependent		
Black-headed Grosbeak	272	Riparian Dependent		
Blackpoll Warbler	2			
Blue-winged Teal	2	Water/Wetland		
Brewer's Blackbird	85			
Brewer's Sparrow	14		S3B	BMC
Brown Creeper	1		S3	
Brown Thrasher	27	Riparian Dependent		
Brown-headed Cowbird	1,219			
Bufflehead	-	Water/Wetland		
Bullock's Oriole	686	Riparian Dependent		
California Gull	107			
Canada Goose	28	Water/Wetland		BMC
Caspian Tern	-	Water/Wetland	S2B	
Cassin's Vireo	2			
Cedar Waxwing	830			
Chipping Sparrow	18			
Clark's Nutcracker	-		S3	
Clay-colored Sparrow	80			
Cliff Swallow	443	Riparian Dependent		
Common Goldeneye	1	Water/Wetland		BMC

…continued next page.

Appendix A continued.

Common Name	Abundance [a]	Breeding Habitat	MTSOC	USFWS
Common Grackle	284			
Common Loon	-	Water/Wetland	S3B	
Common Merganser	53	Water/Wetland		
Common Nighthawk	84			
Common Poorwill	-		S4B	
Common Raven	15			
Common Yellowthroat	265	Riparian Obligate		
Cooper's Hawk	12			
Dark-eyed Junco	5			
Double-crested Cormorant	32	Water/Wetland		
Downy Woodpecker	234			
Dusky Flycatcher	6			
Eastern Kingbird	533	Riparian Dependent		
Eastern Screech-Owl	-	Riparian Obligate	S3S4	
Eurasian Collared-Dove	15			
European Starling	1,815			
Evening Grosbeak	11		S3	
Field Sparrow	4			
Fox Sparrow	5	Riparian Obligate		
Franklin's Gull	108	Water/Wetland	S3B	
Gadwall	6	Water/Wetland		BMC
Golden Eagle	-		S3	BMC
Grasshopper Sparrow	1			BMC
Gray Catbird	809	Riparian Obligate		
Great Blue Heron	51	Water/Wetland	S3	
Great Horned Owl	21			
Greater Yellowlegs	-	Water/Wetland		
Green-winged Teal	-	Water/Wetland		BMC
Hairy Woodpecker	34			
Hermit Thrush	-			
Hooded Merganser	3	Water/Wetland	S4	
House Finch	115			
House Sparrow	8			
House Wren	3,374	Riparian Dependent		
Killdeer	16	Water/Wetland		
Lark Sparrow	35			

…continued next page.

Appendix A continued.

Common Name	Abundance [a]	Breeding Habitat	MTSOC	USFWS
Lazuli Bunting	131	Riparian Dependent		
Least Flycatcher	1,530	Riparian Dependent		
Lesser Scaup	1	Water/Wetland		BMC
Lincoln's Sparrow	22	Riparian Obligate		
Long-billed Curlew	2		S3B	BMC
Long-eared Owl	1	Riparian Dependent		
MacGillivray's Warbler	7	Riparian Dependent		
Mallard	64	Water/Wetland		BMC
Marbled Godwit	10	Water/Wetland		BMC
Marsh Wren	44	Riparian Obligate		
Mountain Bluebird	8			
Mountain Chickadee	1			
Mourning Dove	1,202			
Northern Bobwhite	-			
Northern Flicker	490			
Northern Harrier	6			BMC
Northern Mockingbird	-			
Northern Rough-winged Swallow	167			
Northern Waterthrush	20	Riparian Obligate		
Olive-sided Flycatcher	-			BMC
Orange-crowned Warbler	-	Riparian Dependent		
Orchard Oriole	8	Riparian Obligate		
Osprey	18	Water/Wetland		
Ovenbird	50	Riparian Obligate	S4B	
Pileated Woodpecker	4		S3	
Pine Siskin	26			
Pinyon Jay	-		S3	BMC
Prairie Falcon	-			BMC
Red Crossbill	2			BMC
Red-breasted Nuthatch	12			
Red-eyed Vireo	71	Riparian Dependent		
Red-naped Sapsucker	92	Riparian Dependent		
Red-necked Phalarope	1	Water/Wetland		
Red-tailed Hawk	114			
Red-winged Blackbird	339	Riparian Obligate		
Ring-billed Gull	18	Water/Wetland		

…continued next page.

Appendix A continued.

Common Name	Abundance [a]	Breeding Habitat	MTSOC	USFWS
Ring-necked Duck	-			BMC
Ring-necked Pheasant	41			
Rock Pigeon	43			
Rock Wren	-			
Rose-breasted Grosbeak	-			
Ruby-crowned Kinglet	-			
Ruffed Grouse	-			
Rufous Hummingbird	-		S4B	BMC
Sandhill Crane	14	Water/Wetland		BMC
Savannah Sparrow	15			
Say's Phoebe	1			
Sharp-shinned Hawk	2			
Short-eared Owl	-		S4	BMC
Song Sparrow	648	Riparian Obligate		
Sora	2	Water/Wetland		BMC
Spotted Sandpiper	43	Water/Wetland		
Spotted Towhee	249			
Swainson's Hawk	8	Riparian Dependent		BMC
Swainson's Thrush	30	Riparian Dependent		
Townsend's Warbler	1			
Tree Swallow	1,817	Riparian Dependent		
Trumpeter Swan	-	Water/Wetland	S3	BMC
Turkey Vulture	4			
Veery	37	Riparian Obligate	S3B	
Vesper Sparrow	1			
Violet-green Swallow	221			
Warbling Vireo	233	Riparian Dependent		
Western Kingbird	358			
Western Meadowlark	46			
Western Screech-Owl	1	Riparian Obligate	S3S4	
Western Tanager	86			
Western Wood-Pewee	805	Riparian Dependent		
White-breasted Nuthatch	8			
White-crowned Sparrow	30			
White-faced Ibis	-	Water/Wetland	S3B	
White-throated Sparrow	1			
White-throated Swift	27			
Wild Turkey	2			

Appendix A continued.

Common Name	Abundance [a]	Breeding Habitat	MTSOC	USFWS
Willet	-	Water/Wetland		
Willow Flycatcher	123	Riparian Obligate		BMC
Wilson's Snipe	5	Water/Wetland		BMC
Wilson's Warbler	6	Riparian Obligate		
Wood Duck	1	Water/Wetland		BMC
Yellow Warbler	4,805	Riparian Obligate		
Yellow-breasted Chat	310	Riparian Obligate		
Yellow-headed Blackbird	9	Water/Wetland		
Yellow-rumped Warbler	40			
Yellow-throated Vireo	1	Riparian Dependent		

[a] No abundance reported for species detected outside of 50 m survey distance or 10 minute survey period.
[b] MTSOC- Montana Species of Concern, S1-high risk, S2-very limited, S3-Potential risk, S4-rare or potentially declining (Montana Animal Species of Concern Report 2016)
[c] USFWS- U.S. Fish and Wildlife Service, BMC- Birds of Management Concern (U.S. Fish and Wildlife Service 2011)

Appendix B. Estimates of trends in bird species density based on linear-mixed effects model with Section and Year x Section interaction terms. *Note*: estimates are only shown for species with significant ($P < 0.05$) Year x Section interaction, ANOVA.

	Year			Section						Year x Section					
				Missouri Breaks			Missouri, upper			Year x Missouri Breaks			Year x Missouri, upper		
Species	Est.	SE	*p*	Est.	SE	*p*	Est.	SE	*p*	Est.	SE	*p*	Est.	SE	*p*
American Goldfinch	-0.034	0.011	0.001	0.034	0.106	0.751	0.024	0.101	0.814	-0.009	0.015	0.564	-0.018	0.014	0.202
American Robin	0.009	0.008	0.271	0.472	0.089	<0.001	0.376	0.085	<0.001	-0.002	0.012	0.856	0.004	0.011	0.738
Black-capped Chickadee	0.040	0.008	<0.001	0.027	0.105	0.797	0.156	0.101	0.127	-0.039	0.011	0.001	-0.020	0.011	0.069
Brown-headed Cowbird	-0.008	0.009	0.381	0.922	0.119	<0.001	0.616	0.114	<0.001	-0.012	0.012	0.316	-0.011	0.012	0.341
Bullock's Oriole	-0.019	0.008	0.025	0.111	0.097	0.259	-0.114	0.093	0.228	0.006	0.012	0.586	0.016	0.011	0.153
Cedar Waxwing	-0.034	0.013	0.009	-0.039	0.178	0.826	0.480	0.170	0.007	0.005	0.018	0.772	0.034	0.017	0.053
Clay-colored Sparrow	-0.002	0.006	0.806	0.218	0.041	<0.001	0.084	0.040	0.039	-0.027	0.009	0.004	-0.005	0.009	0.602
Cliff Swallow	-0.008	0.016	0.630	0.148	0.086	0.092	-0.048	0.083	0.565	-0.048	0.023	0.037	-0.006	0.022	0.770
Common Grackle	-0.024	0.012	0.055	0.309	0.078	<0.001	-0.023	0.074	0.757	-0.020	0.018	0.262	0.017	0.017	0.324
Downy Woodpecker	-0.009	0.009	0.305	-0.141	0.068	0.042	0.049	0.065	0.449	-0.004	0.013	0.738	-0.001	0.012	0.935
Gray Catbird	-0.010	0.009	0.249	0.750	0.137	<0.001	0.897	0.132	<0.001	-0.032	0.013	0.013	0.003	0.012	0.795
House Finch	-0.004	0.005	0.480	0.070	0.043	0.106	0.154	0.041	<0.001	-0.008	0.007	0.289	-0.005	0.007	0.514
House Wren	0.047	0.007	<0.001	-0.013	0.133	0.920	-0.024	0.127	0.852	-0.004	0.010	0.706	-0.010	0.009	0.273
Mourning Dove	-0.023	0.007	0.001	-0.385	0.083	<0.001	-0.133	0.080	0.104	-0.009	0.010	0.367	0.004	0.009	0.660
Red-naped Sapsucker	0.003	0.006	0.642	0.220	0.043	<0.001	0.096	0.041	0.023	-0.031	0.009	0.001	-0.004	0.009	0.649
Red-winged Blackbird	-0.003	0.006	0.586	0.498	0.076	<0.001	0.149	0.072	0.044	0.035	0.009	<0.001	0.011	0.009	0.191
Song Sparrow	0.001	0.006	0.812	0.937	0.106	<0.001	0.463	0.102	<0.001	-0.047	0.009	<0.001	-0.009	0.008	0.284
Warbling Vireo	-0.001	0.005	0.808	0.098	0.056	0.086	0.039	0.054	0.473	-0.023	0.007	<0.001	-0.004	0.006	0.547
Yellow-breasted Chat	0.015	0.005	0.003	-0.384	0.067	<0.001	-0.375	0.064	<0.001	-0.015	0.007	0.046	-0.011	0.007	0.128

[a] Madison River set as reference section.

Appendix C. Plant species encountered during riparian vegetation surveys from 2004-2017.

Common Name	Genus Species	Wetland Status[a]
Trees (>8cm DBH)		
Box Elder	*Acer negundo*	
Mountain Alder	*Alnus incana.*	FACW
Water Birch	*Betula occidentalis*	FACW
Russian Olive	*Elaeagnus angustifolia*	
Green Ash	*Fraxinus pennsylvanica*	FACW
Rocky Mountain Juniper	*Juniperus scopulorum*	
Narrowleaf Cottonwood	*Populus angustifolia*	FACW
Black Cottonwood	*Populus balsamifera*	FACW
Plains Cottonwood	*Populus deltoides*	FAC
Choke Cherry	*Prunus viginiana*	FACU
Willow spp.	*Salix spp.*	FACW
Shrubs & Saplings (<8cm DBH)		
Box Elder	*Acer negundo*	FAC
Mountain Alder	*Alnus incana.*	FACW
Serviceberry	*Amelanchier alnifolia*	FACU
Silver sagebrush	*Artemesia cana*	FACU
Big Sagebrush	*Artemisia tridentata*	
Water Birch	*Betula occidentalis*	FACW
Red-osier Dogwood	*Cornus sericea*	FACW
Russian Olive	*Elaeagnus angustifolia*	
Green Ash	*Fraxinus pennsylvanica*	FACW
Rocky Mountain Juniper	*Juniperus scopulorum*	
Common Juniper	*Juniperus communis*	
Narrowleaf Cottonwood	*Populus angustifolia*	FACW
Black Cottonwood	*Populus balsamifera*	FACW
Plains Cottonwood	*Populus deltoides*	FAC
Choke Cherry	*Prunus viginiana*	FACU
Skunkbush Sumac	*Rhus trilobata*	FAC
Currant spp.	*Ribes spp.*	FAC
Rose spp.	*Rosa spp.*	FACU
Willow spp.	*Salix spp.*	FACW
Buffaloberry	*Shepherdia canendensis*	FACU
Common Snowberry	*Symphoricarpus albus*	FACU
Non-native & Invasive Herbaceous		
Yellow mustard	*Brassica* spp.	
Cheat grass	*Bromus tectorum*	
Shepherd's Purse	*Capsella bursa-pastoris*	
Hoary Cress Whitetop	*Cardaria draba*	
Knapweed species	*Centaurea* spp.	
Canada Thistle	*Cirsium arvense*	
Thistle spp.	*Cirsium* spp.	

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Appendix C continued.

Common Name	Genus Species	Wetland Status[a]
Common Hound's Tongue	*Cynoglossum officinale*	
Leafy Spurge	*Euphorbia esula*	
Bedstraw	*Galium* spp.	
Pepperweed	*Lepidium latifolium*	
Dalmation Toadflax	*Linaria dalmatica*	
Common Toadflax	*Linaria vulgaris*	
Reed Canary Grass	*Phalaris arundinacea*	
Sulfur Cinquefoil	*Potentilla recta*	
Tall Buttercup	*Ranunculus acris*	
Sowthistle	*Sonchus arvensis*	
Dandelion	*Taraxacum officinale*	
Common Tansy	*Tanacetum vulgare*	
Field Pennycress	*Thlaspi arvense*	
Common Mullein	*Verbascum Thapsus*	

[a] National Wetland Plant List: OBL-Obligate wetland (almost always occurs in wetlands), FACW-Facultative Wetland (Usually occur in wetlands), FAC-Facultative (Occur in wetlands and non-wetlands), FACU-Facultative upland (Usually occur in non-wetlands, Lichvar 2014

Appendix D1. Results from linear mixed-effects model testing for effects of Year, Section, and Year × Section interaction of vegetation measures in riparian habitats on the Madison and Missouri Rivers, Montana 2004-2017.

	Time		Section		Time x Section	
Vegetation Measures	***F***	***P***	***F***	***P***	***F***	***P***
Small *Populus* spp. density (per ha)	11.33	0.001	6.42	0.003	2.76	0.064
Medium *Populus* spp. density (per ha)	1.45	0.229	7.77	0.001	2.47	0.085
Large *Populus* spp. density (per ha)	10.11	0.002	4.99	0.010	2.16	0.116
Populus spp. dominance	2.40	0.122	10.98	<0.001	0.27	0.764
Russian Olive dominance	0.01	0.938	0.85	0.432	0.48	0.621
Rocky Mountain Juniper dominance	9.10	0.003	5.52	0.007	2.05	0.129
Small snag density (per ha)	16.88	<0.001	3.76	0.030	2.57	0.077
Medium snag density (per ha)	1.73	0.189	2.32	0.108	0.58	0.558
Large snag density (per ha)	5.07	0.025	1.04	0.361	2.73	0.066
Total snag dominance	6.97	0.008	0.40	0.671	2.62	0.073
Populus spp. sapling cover (%)	0.59	0.444	0.78	0.465	0.85	0.427
Salix spp. shrub cover (%)	13.72	<0.001	12.11	<0.001	6.68	0.001
Total shrub cover (%)	77.77	<0.001	2.38	0.103	1.41	0.244
Max. canopy height (m)	62.88	<0.001	17.97	<0.001	0.22	0.804
Total weed cover (%)	0.35	0.554	0.63	0.538	4.66	0.010
Index of Grazing Intensity	64.15	<0.001	1.28	0.286	0.56	0.570

Appendix D2. Estimates of trends in vegetation measures based on linear-mixed effects model with Section and Year x Section interaction terms.

	Year			Section [a]						Year*Section					
				Missouri Breaks			Missouri, upper			Year*Missouri Breaks			Year*Missouri, upper		
Vegetation Measures	**Est.**	**SE**	***p***	**Est.**	**SE**	***p***	**Est.**	**SE**	***p***	**Est.**	**SE**	***p***	**Est.**	**SE**	***p***
Small *Populus* density (per ha)	0.041	0.018	0.022	-1.155	0.328	0.001	-0.382	0.308	0.220	-0.044	0.026	0.093	0.013	0.024	0.580
Med. *Populus* density (per ha)	0.033	0.018	0.063	-1.036	0.288	0.001	-0.110	0.270	0.686	-0.055	0.026	0.033	-0.013	0.024	0.571
Large *Populus* density (per ha)	-0.050	0.017	0.003	-0.910	0.339	0.010	-0.048	0.319	0.882	0.050	0.025	0.044	0.013	0.023	0.557
Populus dominance	-0.014	0.010	0.159	-0.871	0.197	0.000	-0.204	0.185	0.277	0.011	0.014	0.465	0.006	0.013	0.667
Russian Olive dominance	0.001	0.001	0.391	-0.044	0.039	0.262	-0.008	0.037	0.831	-0.002	0.002	0.397	-0.002	0.002	0.392
Juniper dominance	0.000	0.003	0.983	0.169	0.094	0.079	0.304	0.089	0.001	0.009	0.005	0.080	0.008	0.005	0.077
Small snag density (per ha)	-0.006	0.013	0.645	-0.433	0.167	0.012	-0.230	0.156	0.147	-0.041	0.020	0.039	-0.034	0.018	0.064
Medium snag density (per ha)	-0.008	0.013	0.550	-0.298	0.169	0.084	0.015	0.158	0.927	0.008	0.019	0.657	-0.011	0.018	0.535
Large snag density (per ha)	-0.016	0.012	0.190	0.134	0.122	0.277	0.159	0.114	0.169	0.023	0.017	0.188	-0.015	0.016	0.333
Total snag dominance	-0.005	0.006	0.369	-0.050	0.082	0.540	0.020	0.077	0.800	0.005	0.008	0.537	-0.012	0.008	0.117
Total shrub cover (%)	-0.038	0.010	0.000	0.511	0.268	0.063	0.041	0.253	0.873	-0.023	0.015	0.132	-0.020	0.014	0.158
Salix spp. cover (%)	0.008	0.012	0.502	1.284	0.260	<0.0001	0.548	0.245	0.029	-0.062	0.017	0.000	-0.038	0.016	0.015
Populus spp. sapling cover (%)	0.003	0.005	0.558	-0.059	0.061	0.335	0.005	0.057	0.935	-0.006	0.008	0.406	-0.009	0.007	0.198
Max. canopy height (m)	-0.025	0.005	<0.0001	-0.574	0.102	<0.0001	-0.129	0.096	0.184	0.003	0.007	0.730	0.004	0.007	0.509
Index of Grazing Intensity	-0.019	0.004	<0.0001	0.083	0.055	0.141	-0.002	0.052	0.966	-0.005	0.007	0.430	0.001	0.006	0.837
Total weed cover (%)	0.018	0.010	0.080	-0.074	0.176	0.675	0.125	0.166	0.452	-0.017	0.015	0.244	-0.041	0.014	0.003

[a] Madison River set as reference section