Using birds as indicators to measure progress of aspen and meadow restoration at Big Meadows

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On the cover:

Mountain Chickadee
Photograph by James Livaudais (© 2023)

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Introduction

Klamath Bird Observatory (KBO) is partnering with EcoTrust Forest Management (EFM) and the Scott River Watershed Council (SRWC) to use birds as indicators to inform forest planning, evaluate project outcomes, and improve restoration through adaptive management in aspen and meadow habitats in the Scott River watershed. We are using standardized bird monitoring techniques to quantify avian response to high elevation aspen and meadow restoration. Birds are widely recognized as excellent ecological and management indicators because they are closely associated with different components of vegetation structure and composition, they respond quickly to habitat change at multiple spatial scales, and they are relatively easy and cost-effective to monitor. Avian monitoring data are being used as metrics of habitat integrity and ecosystem function, to measure the success of restoration actions. By studying a suite of bird species' responses to restoration, we can quantify whether or not land management has reached its desired conditions on the ground. For instance, a different suite of bird species will be expected to use aspen stands with conifer encroachment compared to aspen stands restored via conifer thinning. Using data on wildlife utilization of the restored habitats provides a more meaningful and multi-dimensional assessment of restoration success than vegetation metrics alone. EFM and SRWC have identified high elevation aspen stands and meadows as restoration priorities. Thinning to reduce conifer encroachment, and cattle exclusion to enhance aspen recruitment, has been completed on a total of 22 acres around Big Meadows in a series of treatments implemented in 2020-2023. This report details analysis of monitoring data collected to compare the bird community before (2019) and soon after (2023) restoration treatments were carried out. Patterns in bird response to restoration can emerge at both the community level and the species level. We used ordination methods to investigate bird response at the community level, and we compared pre- and post-restoration abundance for a set of individual focal species expected to be impacted by restoration-associated changes in vegetation.

Methods

Field Methods

In 2019, KBO completed surveys of the baseline (pre-restoration) bird community at Big Meadows. In 2023, we conducted our first post-restoration surveys. We visited the site three times during the songbird breeding season (mid-June – mid-July at this high elevation meadow, partially based on snow levels and road access), and conducted two sets of surveys each visit. We used a combination of point count surveys in the meadow (n = 5) and area search surveys in the aspen stands (n = 4). During point count surveys, a trained observer recorded every bird seen or heard, as well as its distance from the observer, for standardized 5-minute survey periods (Stephens et al. 2010). We placed point count stations randomly throughout the meadow using GIS tools, enforcing a minimum distance of 200 m apart, in order to reduce overlap of individual birds detected at multiple stations. Area search surveys were used in the four main aspen stands; these habitat patches were generally too small for point count routes. During area searches, a trained observer spent 20-40 minutes within a defined polygon (~25 min./ha), recording the number and species of all birds seen or heard, and whether they were

inside or outside of the aspen stand (Stephens et al. 2010). Species checklists were also kept, recording every bird species detected during the survey day, whether within standardized point count or area search periods or not. We also completed relevé vegetation surveys at all point count stations, and at the centroid of each aspen stand area search plot, on two of the three visits using two different surveyors. Point count data were summarized as the mean number of birds observed within 75 m of each point, and area search data were summarized as the mean density of birds per hectare detected on-plot (i.e., in the aspen stands).

Analytical Methods

Community Composition

For the community composition analyses, we first attempted running ordinations on the same analysis datasets as for point counts (i.e., excluding detections >75m from the observer, excluding birds detected in the aspen/conifer stands) and area searches (i.e., excluding off-plot observations). Because avian taxa not well-detected by point count or area search methodologies (e.g., raptors, waterfowl) were not present in the analysis datasets, we made no further exclusions based on taxa. Some non-passerines, such as woodpeckers, hummingbirds, and galliforms, were retained in the analysis dataset as they are expected to have similar detectability as songbirds at these distances. We populated two separate community composition matrices with mean abundance per point (point count data) or per hectare (area search data) in 2019 and 2023 for the remaining 30 and 43 species, respectively. Avian community composition data were analyzed using a non-metric multi-dimensional scaling (NMS) ordination (Mather 1976) in PC-ORD version 7 (McCune and Mefford 2016). Similarities in breeding bird community composition among points were calculated using the Sørensen Bray-Curtis distance measure (Sørensen 1948, Bray and Curtis 1957). Random starting configurations were used with 250 runs of real data and 250 runs of randomized data. Monte Carlo randomization tests were used to determine whether the axes generated were stronger than those obtained by chance. Because useful ordination solutions were not found under these conditions, we added back in detections in all habitat types (including those in aspen-conifer stands), and re-ran the point count ordination with this larger sample size. For area search data, we attempted dropping species observed in just one of the four area search plots, but a useful ordination solution was still not found and we did not analyze these data further. We used a blocked multi-response permutation procedure (MRBP) in PC-ORD, that takes into account the repeated measures nature of sampling the same points over time, to test for differences in avian community composition in 2019 vs. 2023 (McCune and Mefford 2016).

Individual Species Abundance

We identified a suite of focal bird species which are known to associate with specific habitat attributes targeted by the restoration treatments. We selected species representing montane meadow, aspen, and conifer habitat attributes by reviewing relevant Partners in Flight (PIF) conservation plans and applying expert opinion to other species common at this site. We selected three montane meadow species (Green-tailed Towhee, Lincoln's Sparrow, and Chipping Sparrow), four aspen species (Red-breasted Sapsucker, Warbling Vireo, MacGillivray's Warbler, and Western Wood-Pewee), and three conifer species (Red-breasted Nuthatch,

Mountain Chickadee, and Golden-crowned Kinglet) (Altman and Alexander 2012, Altman and Stephens 2022, RHJV 2004, Rockwell et al. 2022a, Rockwell et al. 2022b). We originally selected Hermit Warbler as an additional coniferous species, but had to drop it because of the very small number of observations. We used data from point count surveys for montane meadow species analyses, and data from area searches for aspen and conifer species analyses. In preparation for analysis, we removed individuals detected as flyovers, where a bird was only observed passing over the study area. For point count surveys, we limited analyses to birds detected within a 75 m radius of the observer and excluded detections of birds located within aspen stands. We also excluded any birds recorded as a duplicate detection, when an individual bird was detected at multiple points on the same day. For area searches, we limited analyses to birds detected within the aspen stand plots.

To investigate pre- and post-restoration differences in abundance for each focal species, we calculated the mean number of individual birds per point for montane meadow focal species, and per area search plot for aspen and conifer focal species. We used generalized linear mixed effects models with Poisson error distributions for analyses of both point count and area search data. We modeled abundance using a random intercept for point or plot ID in each model to account for repeated visits to each point count station or area search plot, and a fixed effect for time period (pre- vs. post-treatment). For area search data, we additionally included an offset term for the size of each area search stand to account for differences in plot size. Finally, we inspected residual plots for signs of model misspecification. All analyses were conducted using the programming language R, and the lme4 library (R core team 2023, Bates et al. 2015). For each model, we assessed the *p*-value for the 'time period' model coefficient to test for a hypothesized difference in abundance in response to restoration treatment. We also estimated model-based abundance and approximate 95% confidence intervals for pre- and post-treatment to determine how each species responded after treatment.

Results

Community Composition

The NMS ordination of point count data resulted in a four-dimensional solution, which was stronger than expected by chance (Monte Carlo test: $p = 0.004$), and had an unusually low minimum stress value of 0.15. The first axis of the ordination captured 54.3% of the variation in bird community composition and the first three axes together explained 86.5% (PC-ORD is unable to complete some calculations on more than three axes). Results indicated that bird communities did not differ significantly between 2019 and 2023 (MRBP: $A = 0.03$, $p = 0.21$; Figure 1). These non-significant differences are most visible in Axis 2 vs. Axis 3 (Figure 1), but note that these two axes represent a relatively small proportion of the variation in the data. There is a small amount of separation between point count points before vs. after restoration along both axes, with 2019 points tending towards the bottom righthand side of the figure, and 2023 points tending towards the upper lefthand side (Figure 1). Species such as Hammond's Flycatcher, Nashville Warbler, Hermit Warbler, and Western Tanager seemed most associated with the 'before' conditions. Species such as MacGillivray's Warbler, Orange-crowned Warbler, Fox Sparrow, Hermit Thrush, Pine Siskin, Downy Woodpecker, and Red-breasted Nuthatch

seemed most associated with the 'after' conditions, but again these differences were not supported statistically.

Individual Species Abundance

The focal species analysis resulted in 10 separate models of abundance for each of the focal species (three montane meadow species, four aspen species, and three conifer species). We derived *p*-values for differences pre- vs. post-treatment, and plotted before and after abundances (Figure 2 for meadow species, Figure 3 for aspen species, and Figure 4 for conifer species). *P*-values are reported in figure captions for each species.

For each of the montane meadow species, there was insufficient evidence to support a difference in abundance between pre- and post- treatment surveys. We found that estimated abundance declined for Chipping Sparrow, increased for Green-tailed Towhee, and declined for Lincoln's Sparrow, but these differences were all very slight. The 95% confidence intervals for pre- and post-treatment overlapped for all species, indicating no significant change in abundance. For each of the aspen species, there was insufficient evidence to support a difference in density between pre- and post- treatment surveys. We found a slight increase for Red-breasted Sapsucker and MacGillivray's Warbler and a slight decrease for Warbling Vireo and Western Wood-Pewee, but again 95% confidence intervals for pre- and post-treatment overlapped for all species. For two of the three conifer species (Golden-Crowned Kinglet and Red-breasted Nuthatch), differences in density before and after restoration were not significant. However, for Mountain Chickadee, there was a significant increase from pre- to post-treatment density (Figure 4).

Discussion

Using avian survey data from 2019 and 2023 we assessed differences in the Big Meadows bird community in response to aspen and meadow restoration treatments, including conifer thinning and fencing for cattle exclusion. In total, KBO surveyors conducted 24 area searches in aspen-conifer stands and 30 point count surveys in montane meadow habitat. To analyze changes in the bird community, we applied two separate approaches. Using NMS ordination, we evaluated whether there was evidence of change in the overall bird community in the aspen-conifer stands between the pre-treatment and post-treatment surveys. We also used an individual species approach to test for changes in abundance for a representative set of focal species in response to restoration.

Results from our analyses generally suggest little evidence for change in bird community composition or abundance of focal species this soon after aspen and meadow restoration efforts. Ordination results indicated that the overall bird community measured via point counts did not differ significantly between 2019 and 2023, despite a slight difference along two of the minor axes (Figure 1). The bird species most differentiated towards the "before" quadrant of the graph – Western Tanager, Nashville Warbler, Hammond's Flycatcher, and Hermit Warbler – are all associated with coniferous habitat, although most with habitat attributes that may have actually been enhanced by restoration treatments (e.g., canopy edges for Western Tanager,

shrub understory for Nashville Warbler, and an open mid-story for Hammond's Flycatcher; Altman and Alexander 2012). The birds that differentiated along these axes towards the "after" quadrant include species that prefer riparian deciduous vegetation that one might expect to increase post-aspen restoration, such as MacGillivray's Warbler, Orange-crowned Warbler, and Downy Woodpecker. However, this cluster also included coniferous birds such as Red-breasted Nuthatch and Pine Siskin, which would be expected to decrease in abundance after conifer removal, and thus be more associated with "before" conditions. This lack of clear directional change is less surprising considering there is no statistical evidence for an overall shift in the bird community, and may reflect the small acreage of the restored areas and/or short time since restoration actions were completed.

Lincoln's Sparrow, an inhabitant of wet meadows, and Green-tailed Towhee and Chipping Sparrow, which are associated with the interspersion of meadow habitat and woody shrubs, did not change in abundance. KBO surveyors noted that the meadow appeared densely vegetated even before cattle exclusion, so it is possible that not enough change in vegetation structure has occurred to affect these species. A previous study in the Marble Mountains found lower bird abundance and species richness at grazed montane meadows, but compared to sites rested from grazing for ≥3 years or ungrazed for ≥20 years (Alexander and Johnson 2001), as opposed to <3 years of cattle exclusion in this study. Lincoln's Sparrow is a focal species for montane wet meadows (a unique habitat within coniferous forest) in the landbird conservation plan for western Oregon and Washington (Altman and Alexander 2012), and their relative abundance at Big Meadows both before and after restoration is an indicator of healthy meadow habitat. However, note that abundance is not the ultimate measure of habitat quality – it is possible for a species to be present but not reproducing successfully (e.g., Van Horne 1983). The presence of cattle can reduce nest success, either indirectly by reducing nest vegetation cover and thus increasing predation risk, or directly by trampling ground nests. If an increase in nest success of ground-nesting birds has occurred since cattle exclusion, that effect could not measured here.

We did not expect this time scale (i.e., 0-3 years post-restoration) to be long enough for substantial aspen recruitment and growth, and thus we expected less change in aspen-associated birds. Because there is no specific landbird conservation plan written for birds in aspen habitats west of the Cascades, we chose bird species analogues for aspen-associates on the east side of the Cascades (e.g., Red-breasted Sapsucker rather than Red-naped Sapsucker), or birds associated with riparian or deciduous vegetation that use aspen stands at the Big Meadows site. Neither MacGillivray's Warbler, Red-breasted Sapsucker, Warbling Vireo, nor Western Wood-Pewee exhibited a significant change in abundance

We expected decreases in conifer-associated birds to occur on a shorter time scale, because the change in conifer cover is immediate after treatment, but we found little evidence of declines in our selected focal species. Anecdotally, two Hermit Warblers (a focal species for the habitat attribute of closed conifer canopy; Altman and Alexander 2012) were observed in 2019, but none were recorded in the study area in 2023, which may be due to the reduction in conifer canopy cover. However, density of Red-breasted Nuthatch and Golden-crowned Kinglet, both

species that occupy coniferous forest, did not change in the newly restored aspen stands. A notable exception was the significant increase observed in density of Mountain Chickadees on area search plots. Mountain Chickadee was selected as a focal species for its association with coniferous forest, and thus was expected to decline with the removal of conifers within aspen stands. However, this effect may have been negated by the availability of relatively unaltered conifer habitat surrounding the site.

We also note that no bird species – whether a meadow, aspen, or conifer-associate – was found to have declined significantly between pre- and post-treatment visits. This suggests that restoration treatments have at minimum achieved a do-no-harm objective, and did not adversely impact bird abundance and diversity (including coniferous birds) on the site as a whole while potentially making other important ecological gains. Alternatively, the effects of restoration on bird communities may be subtle at first, or take time to manifest as the habitat responds to treatment. In such cases, additional survey years may also be desirable to distinguish between short-term and long-term effects of aspen and meadow restoration on wildlife utilization of this site.

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Tables

Table 1. Mean and standard deviation (SD) of individuals per point of bird species observed during standard point count surveys in 2019 and 2023, within a 75 m radius of the observer, and not recorded as flyovers. Bird species four-letter codes are displayed for reference for Figure 1. Conservation status information available from selected plans is identified in rightmost columns. "X" denotes focal species in PIF conservation plans; "S" denotes a Common Species is Steep Decline from the PIF continental plan.

Common Name	Scientific Name	4-letter code	2019 Mean	SD	2023 Mean	SD	OR-WA PIF West Conifer[1]	OR-WA PIF East Conifer[2]	CA PIF Riparian[3]	OR-WA PIF West Riparian[4]	OR-WA PIF East Riparian[5]	Cont. PIF[6]
American Robin	*Turdus migratorius*	AMRO	0.60	0.49	0.53	0.18						
Chipping Sparrow	*Spizella passerina*	CHSP	0.40	0.43	0.33	0.33		X		X		
Dusky Flycatcher	*Empidonax oberholseri*	DUFL	0.27	0.15	0.73	0.55						
Green-tailed Towhee	*Pipilo chlorurus*	GTTO	0.13	0.18	0.33	0.41					X	
Hammond's Flycatcher	*Empidonax hammondii*	HAFL	0.13	0.18	0	0	X					
Lazuli Bunting	*Passerina amoena*	LAZB	0.73	0.15	0.33	0.24	X			X	X	
Lincoln's Sparrow	*Melospiza lincolnii*	LISP	0.80	0.51	0.33	0.41	X	X				
Mountain Chickadee	*Poecile gambeli*	MOCH	0.20	0.30	0.47	0.38		X				
Nashville Warbler	*Leiothlypis ruficapilla*	NAWA	0.07	0.15	0	0	X	X				
Warbling Vireo	*Vireo gilvus*	WAVI	0.73	0.64	0.80	0.30			X			
Brown-headed Cowbird	*Molothrus ater*	BHCO	0.40	0.55	0.07	0.15						
House Wren	*Troglodytes aedon*	HOWR	0.13	0.18	0.33	0.24				X		
Northern Flicker	*Colaptes auratus*	NOFL	0.20	0.18	0.33	0	X					
Red-breasted Sapsucker	*Sphyrapicus ruber*	RBSA	0.27	0.15	0.20	0.30						
Steller's Jay	*Cyanocitta stelleri*	STJA	0.07	0.15	0	0						
Western Wood-Pewee	*Contopus sordidulus*	WEWP	0.27	0.28	0.20	0.30		X		X		
Hermit Warbler	*Setophaga occidentalis*	HEWA	0.07	0.15	0.07	0.15	X					
Yellow-rumped Warbler (Audubon's subspecies)	*Setophaga coronata audubonii*	AUWA	0.07	0.15	0.20	0.30						
Tree Swallow	*Tachycineta bicolor*	TRES	0.07	0.15	0	0			X			
Western Tanager	*Piranga ludoviciana*	WETA	0.07	0.15	0.07	0.15	X					

Common Name	Scientific Name	4-letter code	2019 Mean	SD	2023 Mean	SD	OR-WA PIF West Conifer[1]	OR-WA PIF East Conifer[2]	CA PIF Riparian[3]	OR-WA PIF West Riparian[4]	OR-WA PIF East Riparian[5]	Cont. PIF[6]
Dark-eyed Junco (Oregon subspecies)	*Junco hyemalis oreganus*	ORJU	1.20	0.87	0.87	0.56						
Fox Sparrow	*Passerella iliaca*	FOSP	0	0	0.13	0.30	X					
Golden-crowned Kinglet	*Regulus satrapa*	GCKI	0	0	0.33	0.41						
Hermit Thrush	*Catharus guttatus*	HETH	0	0	0.07	0.15	X	X				
Hairy Woodpecker	*Dryobates villosus*	HAWO	0	0	0.07	0.15						
Wilson's Warbler	*Cardellina pusilla*	WIWA	0	0	0.13	0.18			X			S
Downy Woodpecker	*Dryobates pubescens*	DOWO	0	0	0.07	0.15				X		
MacGillivray's Warbler	*Geothlypis tolmiei*	MGWA	0	0	0.07	0.15						
Orange-crowned Warbler	*Leiothlypis celata*	OCWA	0	0	0.07	0.15	X					
Pine Siskin	*Spinus pinus*	PISI	0	0	0.13	0.3						S
Red-breasted Nuthatch	*Sitta canadensis*	RBNU	0	0	0.07	0.15						

[1] Habitat Conservation for Landbirds in the Coniferous Forests of Western Oregon and Washington (Altman and Alexander 2012)
[2] Conservation of Landbirds and Associated Habitats and Ecosystems in the East Cascade Mountains of Oregon and Washington (Altman and Stephens 2022)
[3] The Riparian Bird Conservation Plan: A strategy for reversing the decline of riparian associated birds in California (RHJV 2004)
[4] Population and Habitat Objectives for Landbirds in Prairie, Oak, and Riparian Habitats of Western Oregon and Washington (Rockwell et al. 2022b)
[5] Conservation Strategy for Landbirds in Sagebrush-Steppe and Riparian Habitats of Eastern Oregon and Washington (Rockwell et al. 2022a)
[6] Partners in Flight Landbird Conservation Plan: 2016 revision for Canada and Continental United States (Rosenberg et al. 2016)

Table 2. Mean density (individuals per ha) and standard deviation (SD) of bird species observed inside aspen-conifer stand area search plots at Big Meadows in 2019 and 2023. Conservation status information available from selected plans is identified in rightmost columns. "X" denotes focal species in PIF conservation plans; "S" denotes a Common Species in Steep Decline and "Y" denotes a Yellow Watch List species from the PIF continental plan; and "2nd" denotes a Species of Special Concern (Second Priority) in California.

Common Name	Scientific Name	2019 Mean	SD	2023 Mean	SD	OR-WA PIF West Conifer[1]	OR-WA PIF East Conifer[2]	CA PIF Riparian[3]	OR-WA PIF West Riparian[4]	OR-WA PIF East Riparian[5]	CDFW[6]	Cont. PIF[7]
Brown Creeper	*Certhia americana*	0.05	0.1	0.35	0.25	X	X					
Northern Flicker	*Colaptes auratus*	0.13	0.18	0.32	0.28	X						
Western Wood-Pewee	*Contopus sordidulus*	0.9	0.46	1.24	0.16		X		X			
Steller's Jay	*Cyanocitta stelleri*	0.17	0.15	0.28	0.14							
Sooty Grouse	*Dendragapus fuliginosus*	0.08	0.08	0	0	X						
Hammond's Flycatcher	*Empidonax hammondii*	0.1	0.19	0.05	0.11	X						
Dusky Flycatcher	*Empidonax oberholseri*	0.49	0.43	0.81	0.6							
Cassin's Finch	*Haemorhous cassinii*	0.1	0.19	0.11	0.13							Y
Dark-eyed Junco	*Junco hyemalis*	1.2	0.87	1.7	1.21							
Lincoln's Sparrow	*Melospiza lincolnii*	0.39	0.37	0.29	0.3	X	X					
Brown-headed Cowbird	*Molothrus ater*	0.11	0.18	0.18	0.24							
Lazuli Bunting	*Passerina amoena*	0.58	0.31	1.06	0.67	X			X	X		
Mountain Chickadee	*Poecile gambeli*	0.46	0.27	1.47	0.48		X					
Golden-crowned Kinglet	*Regulus satrapa*	0.15	0.17	0.35	0.15							
Calliope Hummingbird	*Selasphorus calliope*	0.1	0.19	0	0		X					
Rufous Hummingbird	*Selasphorus rufus*	0.05	0.1	0.03	0.05	X			X			Y
Yellow-rumped Warbler	*Setophaga coronata*	0.12	0.18	0.31	0.1							
Hermit Warbler	*Setophaga occidentalis*	0.08	0.1	0	0	X						
Western Bluebird	*Sialia mexicana*	0.05	0.1	0	0		X					
Red-breasted Nuthatch	*Sitta canadensis*	0.2	0.16	0.57	0.06							
Red-breasted Sapsucker	*Sphyrapicus ruber*	0.35	0.27	0.97	0.54							
Chipping Sparrow	*Spizella passerina*	0.09	0.1	0.31	0.09		X		X			
House Wren	*Troglodytes aedon*	0.34	0.54	1.61	1.36				X			
American Robin	*Turdus migratorius*	0.18	0.17	0.73	0.1							

Common Name	Scientific Name	2019 Mean	SD	2023 Mean	SD	OR-WA PIF West Conifer[1]	OR-WA PIF East Conifer[2]	CA PIF Riparian[3]	OR-WA PIF West Riparian[4]	OR-WA PIF East Riparian[5]	CDFW[6]	Cont. PIF[7]
Warbling Vireo	*Vireo gilvus*	1.15	0.77	1.55	0.59			X				
Wilson's Warbler	*Cardellina pusilla*	0.01	0.02	0.16	0.2	X		X				S
Olive-sided Flycatcher	*Contopus cooperi*	0.01	0.02	0.06	0.13	X	X				2nd	Y
Hairy Woodpecker	*Dryobates villosus*	0.07	0.05	0.59	0.46							
Tree Swallow	*Tachycineta bicolor*	0.01	0.02	0	0			X				
MacGillivray's Warbler	*Geothlypis tolmiei*	0.06	0.07	0.11	0.13							
Wild Turkey	*Meleagris gallopavo*	0.09	0.19	0	0							
Western Tanager	*Piranga ludoviciana*	0.11	0.13	0.45	0.31	X						
Nashville Warbler	*Leiothlypis ruficapilla*	0.03	0.07	0.44	0.23	X	X					
Pine Siskin	*Spinus pinus*	0.03	0.07	0.05	0.09							S
Evening Grosbeak	*Coccothraustes vespertinus*	0	0	0.25	0.18							Y
Pileated Woodpecker	*Dryocopus pileatus*	0	0	0.21	0.36	X						
Fox Sparrow	*Passerella iliaca*	0	0	0.06	0.13	X						
Green-tailed Towhee	*Pipilo chlorurus*	0	0	0.21	0.36					X		
Purple Finch	*Haemorhous purpureus*	0	0	0.07	0.09	X			X			
Orange-crowned Warbler	*Leiothlypis celata*	0	0	0.2	0.34	X						
Hermit Thrush	*Catharus guttatus*	0	0	0.05	0.09	X	X					
Downy Woodpecker	*Dryobates pubescens*	0	0	0.11	0.21				X			
Red Crossbill	*Loxia curvirostra*	0	0	0.05	0.11							

[1] Habitat Conservation for Landbirds in the Coniferous Forests of Western Oregon and Washington (Altman and Alexander 2012)
[2] Conservation of Landbirds and Associated Habitats and Ecosystems in the East Cascade Mountains of Oregon and Washington (Altman and Stephens 2022)
[3] The Riparian Bird Conservation Plan: A strategy for reversing the decline of riparian associated birds in California (RHJV 2004)
[4] Population and Habitat Objectives for Landbirds in Prairie, Oak, and Riparian Habitats of Western Oregon and Washington (Rockwell et al. 2022b)
[5] Conservation Strategy for Landbirds in Sagebrush-Steppe and Riparian Habitats of Eastern Oregon and Washington (Rockwell et al. 2022a)
[6] California Bird Species of Special Concern (Shuford and Gardali 2008)
[7] Partners in Flight Landbird Conservation Plan: 2016 revision for Canada and Continental United States (Rosenberg et al. 2016)

Figures

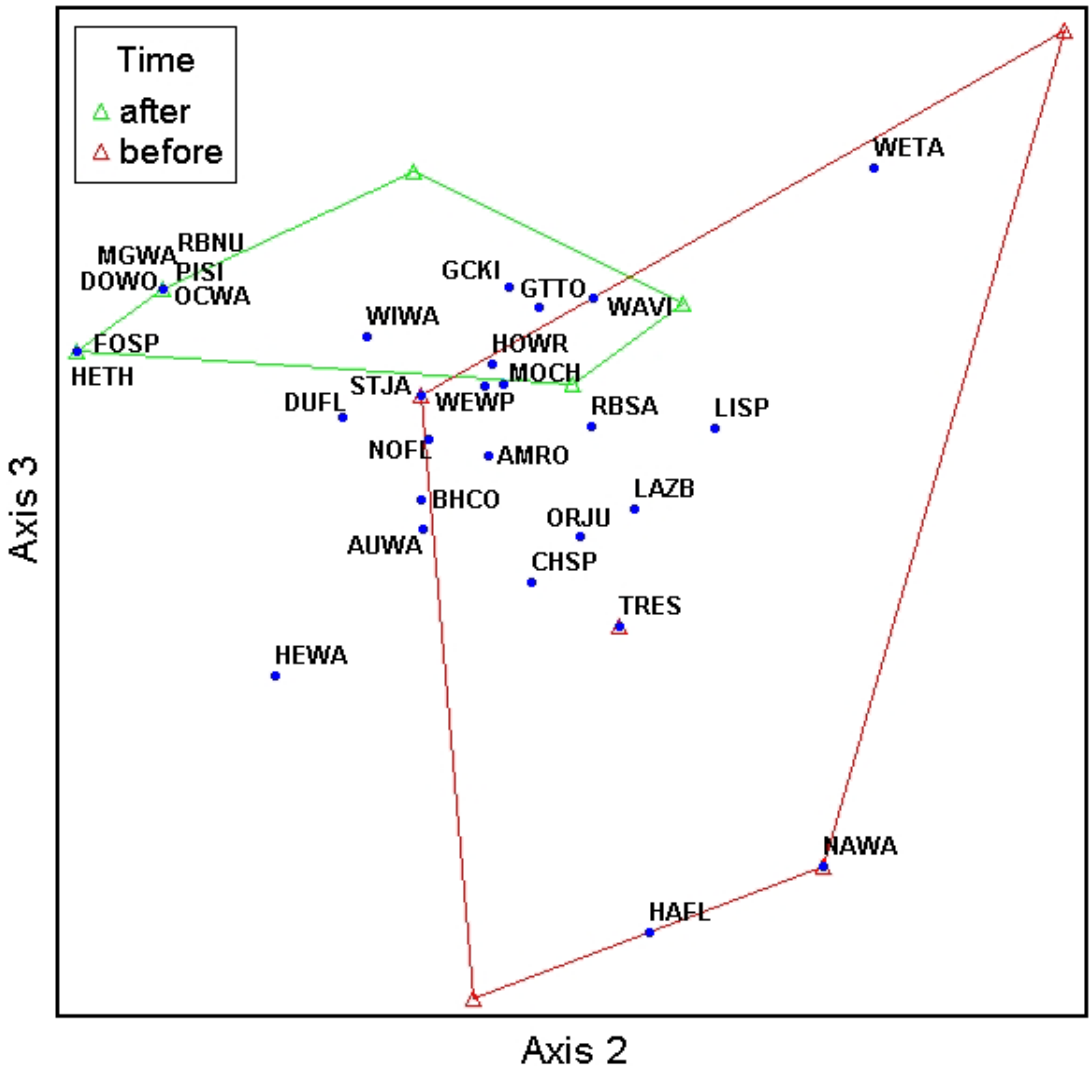

Figure 1. Non-metric multidimensional scaling (NMS) ordination of bird communities before (2019) and relatively soon after (2023) restoration actions at Big Meadows, CA. A four-dimensional ordination solution was reached, but only two dimensions are shown here for readability. Axes have no units, but represent underlying factors describing variation in the bird community. Each red or green triangle represents a point count survey point and its relative position in species-space compared to other survey points; each of the five survey points are displayed twice, once in each time period. Survey points that are further apart along either or both axes differ more in species composition. Blue dots represent the centroid of each bird species in species-space. See Table 1 for four-letter species code abbreviations.

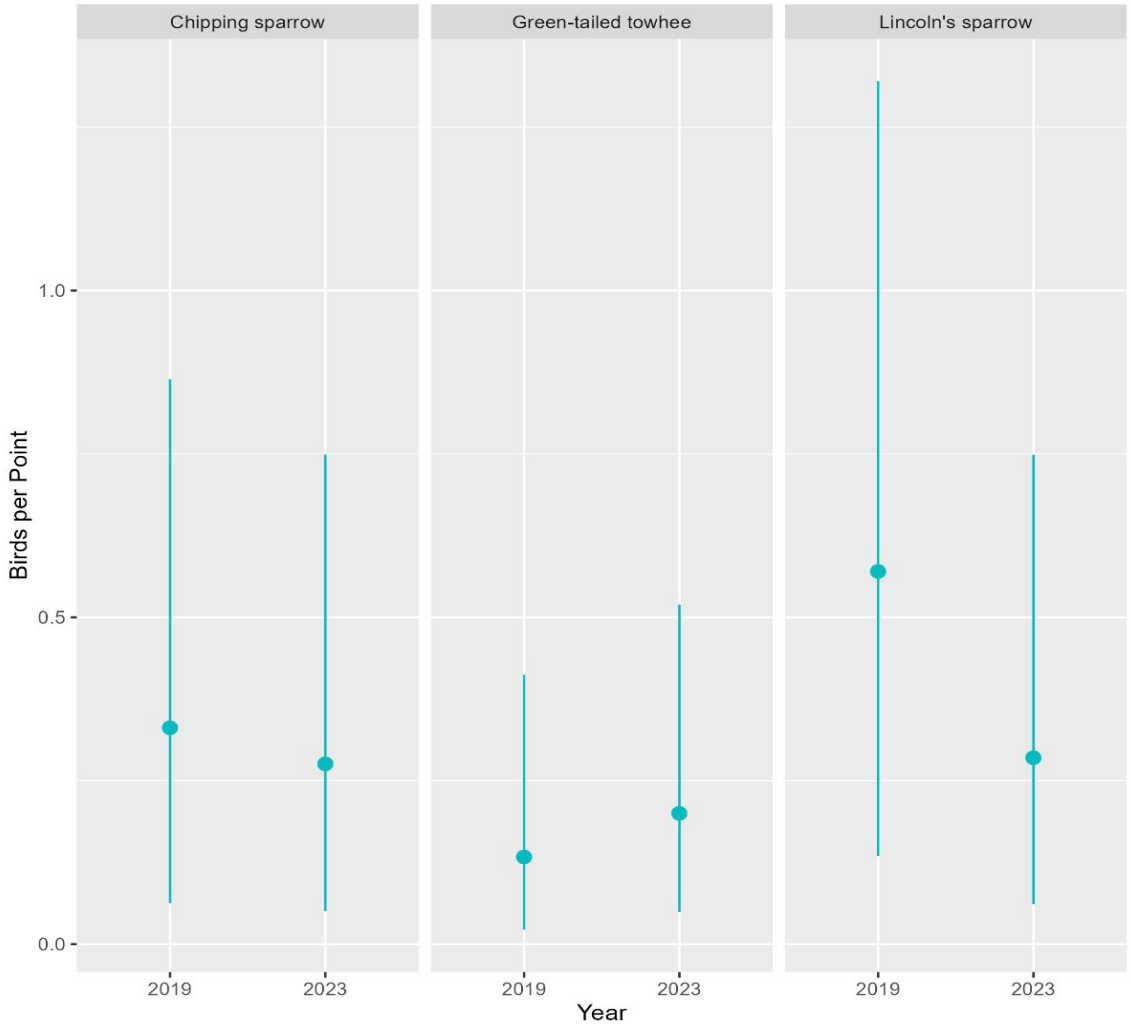

Figure 2. Mean birds per point during point count surveys for the three montane meadow focal species selected for analysis. Figures display means and approximate 95% confidence intervals for each species based on species-specific generalized linear mixed-effects models. Model-based *p*-values for the differences between pre- and post-treatment counts are as follows: Chipping Sparrow (0.763), Green-tailed Towhee (0.657), and Lincoln's Sparrow (0.206).

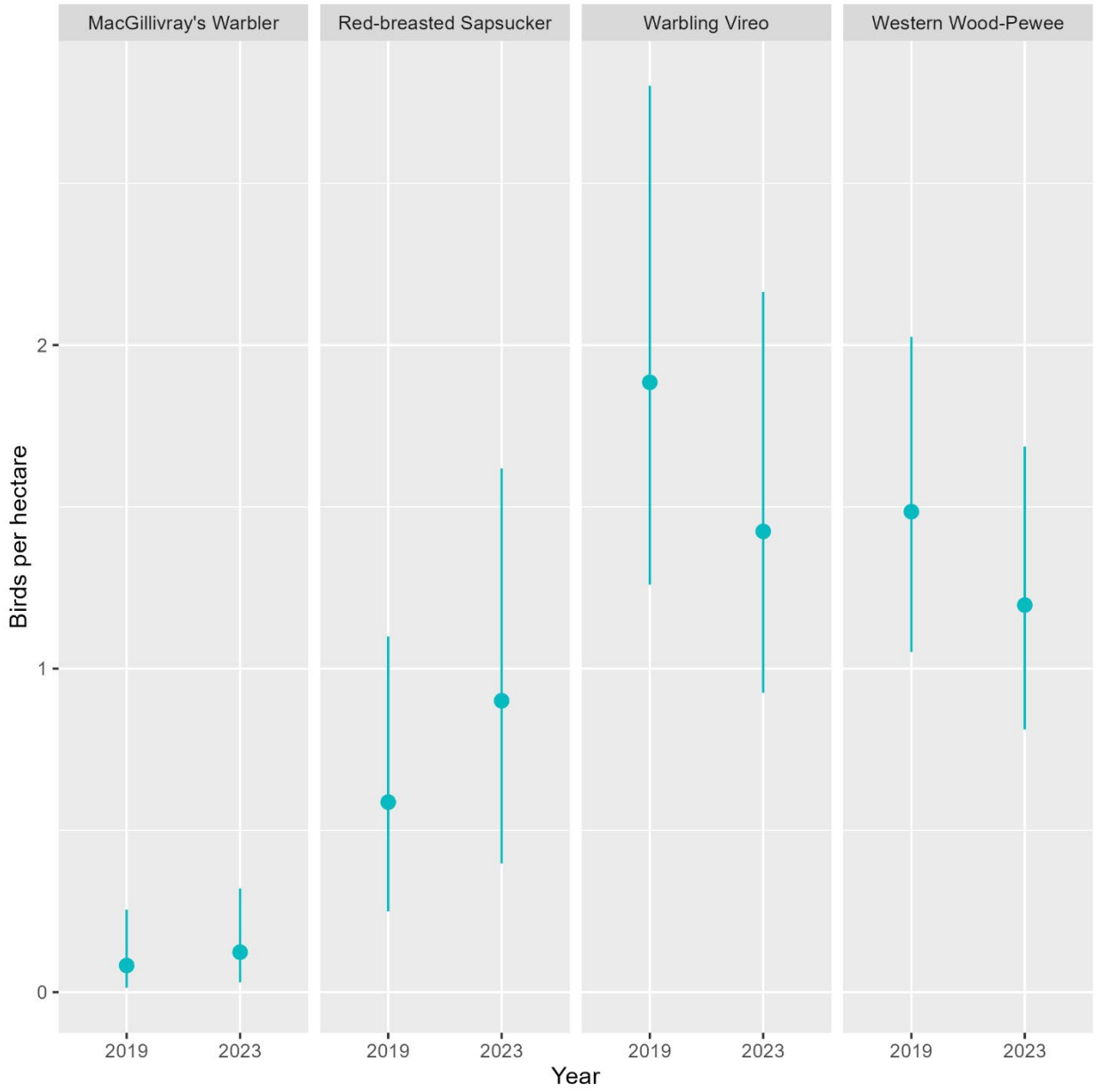

Figure 3. Mean birds per hectare during area search surveys for the four aspen-associated focal species. Figure displays means and approximate 95% confidence intervals from species-specific generalized linear mixed-effects models. The model-based *p*-values for the differences between pre- and post-treatment densities are as follows: MacGillivray's Warbler (0.066), Red-breasted Sapsucker (0.196), Warbling Vireo (0.217), and Western Wood-Pewee (0.386).

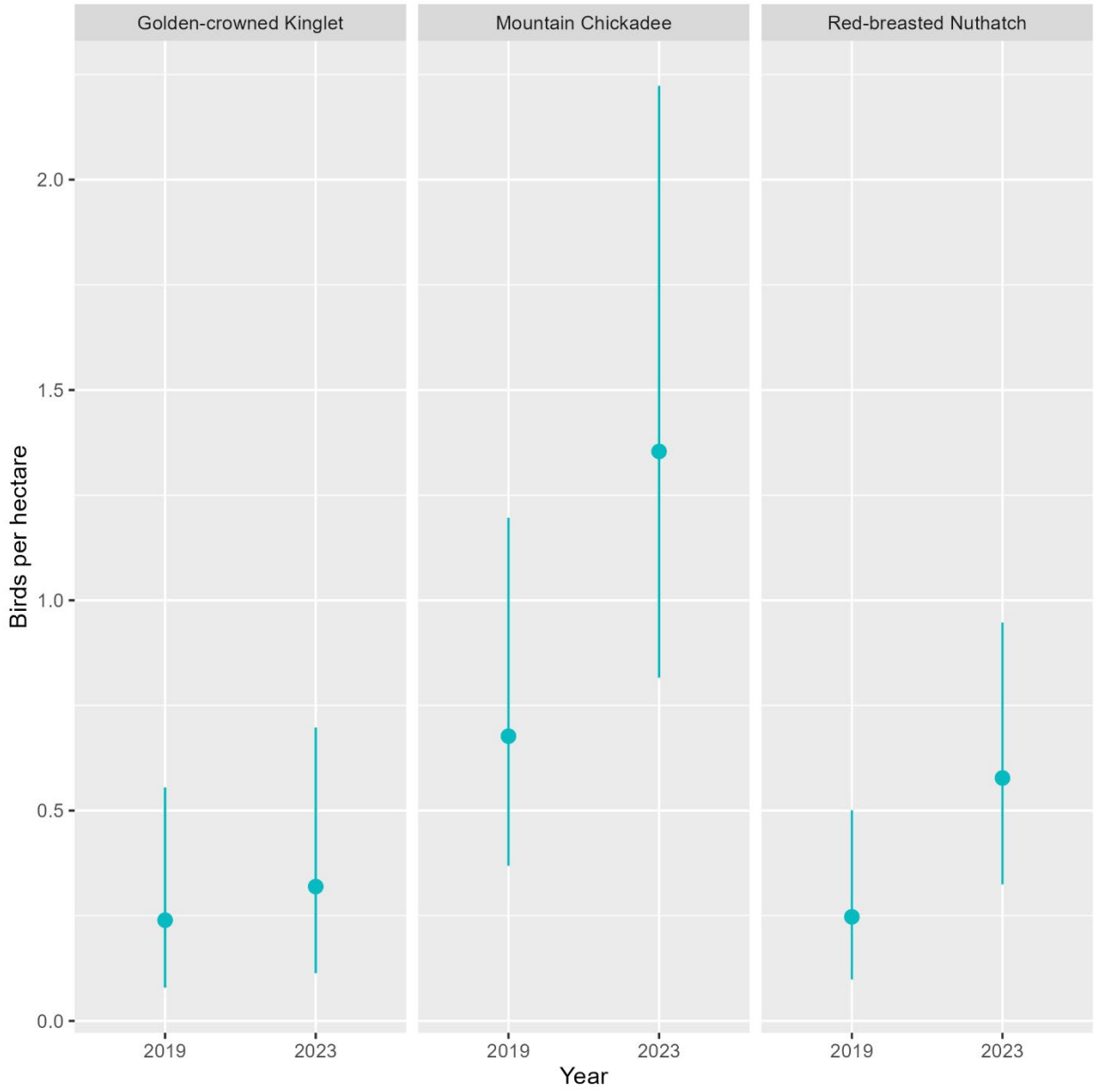

Figure 4. Mean birds per hectare during area search surveys for the three conifer-associated focal species. Figure displays means and approximate 95% confidence intervals from species-specific generalized linear mixed-effects models. The model-based *p*-value for the differences between pre- and post-treatment densities are as follows: Golden-crowned Kinglet (0.592), Mountain Chickadee (0.023), Red-breasted Nuthatch (0.082).