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Avian Monitoring in Aspen and Meadow Habitats in the Northern Sierra Nevada

2011 Annual Report

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Front Cover Photo
Cloud shadows over high-elevation aspen and meadow habitat in the South Warner Wilderness, Modoc County, California. Photo by Daniel Lipp.

Chapter One Cover Photo
Regenerating aspen stands on the Lassen National Forest, Lassen County, California.

Chapter Two Cover Photo
Red Clover creek six years after pond and plug restoration, Plumas County, California.

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EXECUTIVE SUMMARY

PRBO Conservation Science (PRBO) has been conducting songbird monitoring in the Northern Sierra since 1997. In this report we present results from avian monitoring in 2011 of two of the most important habitats for birds in the Sierra Nevada: aspen and meadows.

In the first chapter we discuss results from the ongoing monitoring in aspen habitat (since 2004) on the Lassen National Forest. Our results illustrate the effectiveness of aspen restoration treatments for creating habitat for a suite of focal avian species. We found post-treatment increases in the abundance of four cavity-nesting focal species, pooled focal species abundance, and focal species richness. While there was no effect for 7 of the 11 focal species, none of them responded negatively to aspen enhancement. Trends in abundance in the 10 years following treatment indicate a mix of responses to aspen treatment from immediately positive, delayed positive, and initially negative but eventually positive. Together, our results suggest that the avian community responds positively to aspen restoration via a dynamic process that has differential effects on bird species as restoration sites age.

In the second chapter we present results from monitoring of meadows across the northern Sierra Nevada, primarily within the Feather River watershed. Our results illustrate the importance of deciduous shrub cover to meadow birds. Riparian deciduous shrub cover was the primary driver of indices of avian richness and the abundance of the majority of focal bird species across meadow sites in an analysis of habitat associations. Significant decreases in avian indices in the Poco project area from one year before restoration to one year after suggests that the disturbance caused by the mechanical restoration of meadows can have a negative impact on meadow birds. However, it is clear from previously restored reaches along Red Clover Creek that negative impacts of restoration are short-lived and overcome by significant increases in avian abundance and richness as deciduous shrubs regenerate. Bird populations appear to be stable in meadows that we have monitored since 2004, which have been rested from grazing and have not experienced a major riparian vegetation reducing disturbance. Together, our results highlight the importance of functional meadows supporting deciduous riparian shrubs through regular floodplain inundation to the birds of the Sierra.

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CHAPTER ONE

Avian Response to Aspen Stand Restoration on the Lassen National Forest

INTRODUCTION

Quaking aspen (*Populus tremuloides*) is the most widespread tree species in North America (Preston and Braham, 2002). The transcontinental distribution of quaking aspen (hereafter, aspen) lies primarily within the Canadian boreal forest but reaches its southern limits in the mountains of western USA (Perala, 1991). Throughout its range, for the latter half of the 20th century, aspen has been in a period of general decline (Frey et al., 2004; Di Orio et al., 2005). This decline is spatially and temporally heterogeneous with some regions realizing aspen persistence (Kulakowski et al., 2004, 2006; Binkley, 2008; Sankey, 2008). In regions where aspen is in decline, reversing the decline is an increasing management priority (Shepperd et al., 2006).

In the Sierra Nevada, the currently limited extent of aspen has been influenced by the combined effects of fire suppression, management favoring conifers (cutting and replanting commercial species), and over-grazing by livestock and wild ungulates (Shepperd et al., 2006). Without stand-replacing or stand-opening disturbances such as fire, in the presence of competitive conifers, shade-intolerant aspen will eventually be outcompeted via reduced regeneration through over shading (Bartos, 2001; Kaye et al., 2005). Under excessive grazing pressure, the over-consumption of aspen sprouts may also result in regeneration failure (Baker et al., 1997; Kaye et al., 2005). Forest inventory work on the Lassen National Forest found the vast majority of aspen stands to be in poor health because of conifer encroachment and excessive grazing. To avoid further degradation or complete stand loss, Lassen National Forest has implemented strategies to restore aspen habitat by mechanically removing and hand-felling competing conifers and excluding livestock grazing (Jones et al., 2005).

Wildlife conservation and management is one of a multitude of reasons to restore and conserve aspen habitats. In addition to providing desirable scenic value, aspen harbors a diversity of understory plants that occur in the filtered light under aspen trees, valuable grazing resources, and protection for soil and water. Aspen habitat in western North America can support a disproportionately rich and abundant avian community compared to surrounding habitats (Flack, 1976; Finch and Reynolds, 1987; Turchi et al., 1995; Mills et al., 2000; Rumble et al., 2001; Griffis-Kyle and Beier, 2003). Several bird species demonstrate a strong affinity with aspen, including Northern Goshawk (*Accipiter gentilis*), Red-naped and Red-breasted Sapsuckers (*Sphyrapicus nuchalis/ruber*), Dusky Flycatcher (*Empidonax oberholseri*), Warbling Vireo (*Vireo gilvus*), Swainson's Thrush (*Catharus ustulatus*), and MacGillivray's Warbler (*Oporornis tolmiei*) (Salt, 1957; Flack, 1976; Heath and Ballard, 2003; Richardson and Heath, 2004).

In 2004, PRBO began monitoring birds across aspen habitat on the Eagle Lake and Almanor Ranger Districts of the Lassen National Forest to inform the adaptive management of aspen habitats. The primary objective of this study is to evaluate and help guide aspen restoration treatments by monitoring the response of a suite of landbird species associated with a broad range of aspen habitat characteristics. In this chapter we (1) summarize point count data from our aspen avian monitoring project in 2011; (2) incorporate the data from 2011 into a before-after control-impact analysis to investigate the response of focal avian species to aspen enhancements; and, lastly we (3) assess the population trends of focal avian species for 10 years following aspen enhancement.

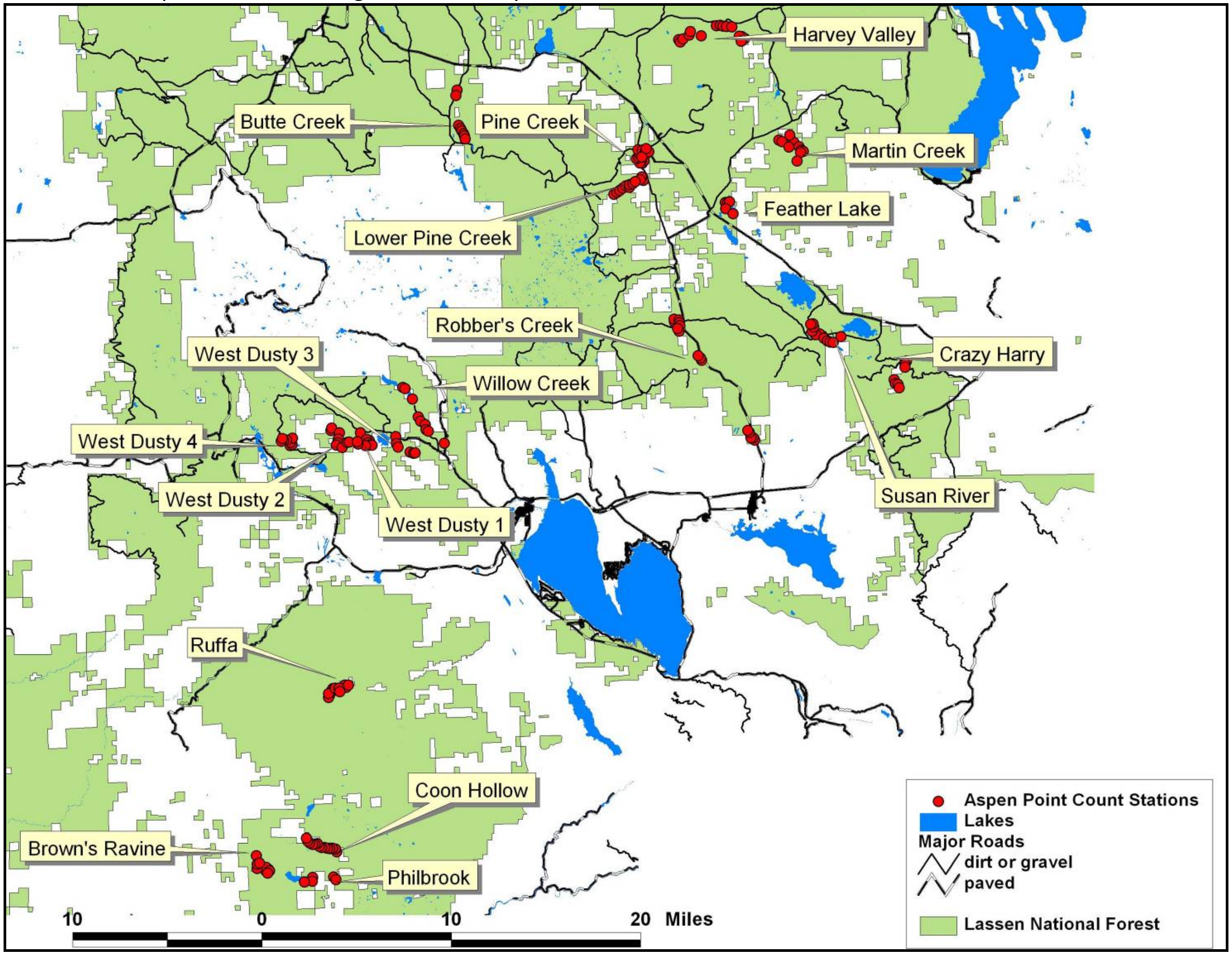
METHODS

Aspen Sampling Design

All field work in this report was conducted on the Lassen National Forest in the Eagle Lake and Almanor Ranger Districts (Figure 1-1) at the junction of the Sierra Nevada and Cascade Mountain Ranges (Lat 40^0 N, Long 120^0 W). Sites ranged in elevation from approximately 1500–2000 m.

To select areas with aspen stands in which to place point count transects we used GIS layers created by Forest Service staff that delineated aspen stands based on the results of forest inventories. We constrained our selection to only include areas that could be surveyed by one observer in a 4-h count window while containing sufficient area to fit a minimum of 4 point count stations with >220-m spacing between stations. Selected areas were composed of

Figure 1-1. Location of PRBO aspen bird monitoring stations surveyed in 2011 in the northern Sierra Nevada.



aspen stands ranging from as small as 1 stem to over 100 acres that contain thousands of stems. The number of point count stations in a transect (4-16) varied as a function of the density of aspen stands in selected areas with the upper limit (16) being the maximum that could be completed in four hours.

In the Eagle Lake Ranger District (ELRD) we non-randomly selected sites that represent the range of conditions in which aspen stands occur throughout the ELRD (Figure 1-1, Table 1-1). We preferentially selected post-treatment sites, which were limited in number, to bolster our sample of bird response to aspen treatments that were already five to nine years old. Thirty-six of the 84 points in the ELRD in this study were located in treated stands as of the 2011 breeding season: 2 on Butte Creek, 5 on Feather Lake, 9 on Harvey Valley, 6 on Martin Creek, and 14 on Pine Creek. With additional funding and interest from the Almanor Ranger District (ARD) in 2006 we selected sites that were within proposed aspen enhancement projects on the ARD (Figure 1-1, Table 1-1). Only 7 of the 97 points in the ARD were treated as of the 2011

Table 1-1. Aspen point count transects with transect codes, year established, ranger district, and dates surveyed in 2011.

Transect	Code	Number of PC Stations	Year Established	Ranger District	Date of 1st Visit	Date of 2nd Visit
Brown's Ravine Aspen	BRAS	4	2000	Almanor	--	--
Coon Hollow Aspen	COHO	14	2007	Almanor	7-Jul	--
Philbrook Aspen	PHAS	10	2007	Almanor	30-Jun	7-Jul
Robber's Creek Aspen	ROCA	16	2006	Almanor	16-Jun	28-Jun
Ruffa Aspen	ASPN	12	2001	Almanor	25-Jun	6-Jul
West Dusty Aspen 1	WDA1	10	2006	Almanor	14-Jun	24-Jun
West Dusty Aspen 2	WDA2	6	2006	Almanor	14-Jun	27-Jun
West Dusty Aspen 3	WDA3	8	2006	Almanor	14-Jun	24-Jun
West Dusty Aspen 4	WDA4	8	2006	Almanor	21-Jun	1-Jul
Willow Creek Aspen	WICA	9	2006	Almanor	15-Jun	28-Jun
Butte Creek Aspen	BCA	8	2004	Eagle Lake	14-Jun	28-Jun
Crazy Harry Aspen	CHA	7	2004	Eagle Lake	4-Jun	12-Jun
Feather Lake Aspen	FLA	5	2004	Eagle Lake	18-Jun	28-Jun
Harvey Valley Aspen	HVA	15	2004	Eagle Lake	12-Jun	25-Jun
Lower Pine Creek Aspen	LPA	12	2004	Eagle Lake	20-Jun	3-Jul
Martin Creek Aspen	MCA	11	2004	Eagle Lake	14-Jun	27-Jun
Pine Creek Aspen	PCA	14	2004	Eagle Lake	14-Jun	28-Jun
Susan River Aspen	SRA	12	2004	Eagle Lake	14-Jun	26-Jun

breeding season: 2 on West Dusty 2, 5 on West Dusty 3, and 1 on Willow Creek. All sites were selected without previous knowledge of the local micro habitat attributes or condition beyond treatment status. These sites ranged from high density to sites with as few as 1 aspen stem. In small stands where only one point count station could be established, points were placed in the center of stands. For larger stands where multiple points were established, we placed points strategically in order to maximize sample size within the stand while maintaining the minimum 220 m spacing. An aspen stem was always used as the center of the point count circle.

Aspen Enhancement Treatments

The primary objective of aspen enhancement treatments was to remove large conifers that were likely to compete with existing aspen stems for sunlight and/or water. This entailed removing all conifers within 9 m of existing aspen stems, except legacy trees (>76 cm dbh). The conifer removal treatment was a combination of commercial tree removal and hand thinning of non-merchantable trees. Harvest occurred outside of the avian breeding season from August through March. Residual woody material, a byproduct of timber harvest operations, was generally left in place within stands and prescribed fire was not used with the exception of the Butte Creek points where piles were burned within the stands. No conifer removal occurred in control stands.

Aspen enhancement treatments were implemented in 1999 and 2004-2008. As a result, the time since treatment varies among our transects, as does the number of years of pre-treatment data for each transect. In some cases, aspen stands within a transect received treatments over multiple years.

Point Count Surveys

Point count data allow us to measure secondary population parameters such as abundance of individual bird species, species richness, and diversity. This method is useful for making comparisons of bird communities across time, locations, habitats, and land-use treatments. Standardized five-minute exact-distance point counts (Reynolds et al. 1980, Ralph et al. 1995) were conducted at each station. We recorded all birds detected at each station during the five-minute survey and recorded the cue for the initial detection (i.e. song, visual, or call) and estimated distance to detections with the aid of laser rangefinders. We recorded separately those birds flying over the study area but not observed using the habitat (flyovers). Counts began around local sunrise and were completed within four hours. Surveys were conducted by observers whom received at least three weeks of training to identify the songs and call of northern Sierra birds and at least two-weeks of training in distance estimation. Most observers were well-versed in point count methodology prior to counting on this project.

We surveyed 177 point count stations across 17 transects in the study area in 2011 (Table 1-1). We visited each transect twice between 4 June and 7 July (Table 1-1), except for Coon Hollow which was visited only once because heavy snowpack prevented access until the last day of the point count season. Not all transects have been visited in all years of this study. In 2011 we did not attempt a visit to the Brown's Ravine aspen transect due to snowpack related access issues.

Analysis: general procedures with point count data

We restricted the analysis of our point count data to a subset of the species encountered. A priori, we excluded: (1) all birds >50 m from the observer, (2) flyovers, (3) species that do not breed in the study area, and (4) those species that are not adequately sampled using the point count method (e.g., waterfowl, raptors, waders; Appendix 1-1). A number of our analyses are further restricted to a suite of focal species (Table 1-2) that commonly breed in aspen habitats whose requirements define different spatial attributes, habitat characteristics, and management regimes representative of a healthy system. For all analyses we used naïve point count detections uncorrected for detection probability, thus our abundance metrics represent indices rather than true densities (Johnson 2010). The indices of bird abundance herein are defined as the mean number of individuals detected per point per visit in one year. Species richness is defined as the cumulative number of unique species detected per point in one year. Abundance and richness values from all points within a transect were averaged to produce point-scale estimates at the transect level for each year. This

Table 1-2. Avian focal species for aspen monitoring, listed in taxonomic order, and their four-letter codes.

Common Name	Species Name	Code
Red-breasted Sapsucker[‡]	*Sphyrapicus ruber*	RBSA
Hairy Woodpecker	*Picoides villosus*	HAWO
Western Wood-Pewee[‡]	*Contopus sordidulus*	WEWP
Dusky Flycatcher[‡]	*Empidonax oberholseri*	DUFL
Warbling Vireo[‡, CPF]	*Vireo gilvus*	WAVI
Tree Swallow	*Tachycineta bicolor*	TRES
Mountain Chickadee	*Poecile gambeli*	MOCH
Mountain Bluebird	*Sialia currucoides*	MOBL
MacGillivray's Warbler[‡]	*Geothlypis tolmiei*	MGWA
Chipping Sparrow[‡]	*Spizella passerina*	CHSP
Dark-eyed Junco	*Junco hyemalis*	DEJU

[‡] Nearctic-Neotropical Migratory Bird
[CPF] California Partners in Flight Riparian Focal Species (RHJV 2004)

calculation allows for comparisons between transects or habitats consisting of different numbers of point count stations.

Analysis: comparing pre-treatment abundances to post-treatment abundances

We used a modified before-after control-impact (BACI) analytical approach to compare pre-treatment and post-treatment indices of focal species abundance and richness. All points treated as of 2008 were classified as 'treated' points; all other points were classified as 'control' points. Because time since treatment varies among points within some transects, as well as among transects, and because treatment points were not paired with control points, we randomly assigned a pseudo treatment year for each control point in the dataset. Random years were restricted to be between 2004 and 2008 because all treated stands that were sampled in this data set were completed between those years , except for points along 2 transects which were treated in 1999. This yielded a random pseudo treatment history for control points, and actual treatment history for treated points. Data taken at control points in years before and after their randomly assigned pseudo treatments were categorized as 'pre-treatment' and 'post-treatment,' respectively. Data taken at treatment points before and after treatment were also categorized as 'pre-treatment' and 'post-treatment.' This yields two categorical variables for analysis: (1) treatment, indicating whether a point is classified as treatment or control, and (2) time, indicating data taken pre-treatment and post-treatment.

We built generalized linear mixed models with a Poisson probability distribution and log link function using the package lme4 in Program R (Bates et al., 2011; R Development Core Team, 2011) to explore interactions between the treatment and time categorical variables and point-level abundances and richness of focal species. The sample unit in this analysis was a single years' data for one point. The dependent variables included the abundances of each aspen focal species, the cumulative abundance of all aspen focal species, and the richness of aspen focal species. Unlike for the calculation of abundance metric we described above where we took the mean count of individuals for each species over two visits, for this analysis abundance was defined as the maximum count of individuals of each species among the visits within a year. Using the mean abundance as the response variable would have required us to include non-integers in the response variable, thus violating a major assumption of Poisson regression. Because detection probabilities are less than one and we have not incorporated detection probability into our abundance estimates, taking the maximum count may come closer to estimating the actual number of birds within 50 m than taking the mean over the two visits. The random effects in the model consisted of random intercepts for year and transect.

Foreseeing that the random assignment of a treatment year for the control points could have an effect on the probability of the test statistic, we ran 100 iterations of this test. Each iteration contained an independent randomly assigned pseudo treatment year for every control point. We used the frequency distribution of the 100 p-values to assess the significance of the test.

Analysis: focal species trends following aspen enhancement treatments

We used linear regression to assess trends in abundance of each aspen focal species, pooled focal species abundance, and focal species richness, across 10 years post-treatment for all points in treated stands that we have monitored since 2004. The breeding season directly following treatment was defined as the first year post-treatment, the second breeding season following treatment was defined as the second year post-treatment, and so forth. Point-level abundance and richness estimates from each transect containing data for a given year post-treatment were averaged to produce point-level estimates of abundance and richness for each year post-treatment. We fit both linear and quadratic equations to the data for each dependent variable. Using a Chi-square test, we evaluated whether the quadratic equation described significantly more variation in the data to warrant the additional complexity of the quadratic fit. A non-significant test statistic meant no difference between the two equations, in which case the linear equation was chosen as the best fitting because it was simpler; a significant test statistic meant the quadratic equation was a better fit. We present only the best-fitting of the two models. Estimates from the pre-treatment data for each of the dependent variables (i.e. year post-treatment = 0) are included in the figures in the results for reference, but these data were not included in the regression.

Data Management and Access: Sierra Nevada Avian Monitoring Information Network

All avian data from this project is stored in the California Avian Data Center and can be accessed through the Sierra Nevada Avian Monitoring Information Network web portal (http://data.prbo.org/apps/snamin). At this site, species lists, interactive maps of study locations, as well as calculations of richness, density, and occupancy can be generated as selected by the user. Study site locations can also be downloaded in various formats for use in GPS, GIS, or online mapping applications as well. Non-avian data (e.g., site narratives, vegetation) are stored on PRBO's server and backed up off-site.

RESULTS

Among all 17 transects, total bird abundance (individuals/point/visit) ranged from a high of 9.00 at Feather Lake to a low of 3.46 at Lower Pine Creek with a mean of 4.97 (Figure 1-2). Total species richness (species/point/year) ranged from 9.40 at Feather Lake to 4.86 at Coon Hollow with a mean of 7.39 across all transects. Focal species abundance ranged from a high of

6.30 at Feather Lake to a low of 1.46 at Lower Pine Creek, with a mean of 2.61 across all transects (Figure 1-3). Focal species richness ranged from a high of 6.20 at Feather Lake to a low of 2.57 at Coon Hollow, with a mean of 4.04 across all transects. Dark-eyed Junco was the most abundant species across the project in 2011, averaging 0.51 individuals/point/visit, followed by Warbling Vireo (0.47), Mountain Chickadee (0.46), Yellow-rumped Warbler (0.34), and Western Wood-Pewee (0.23).

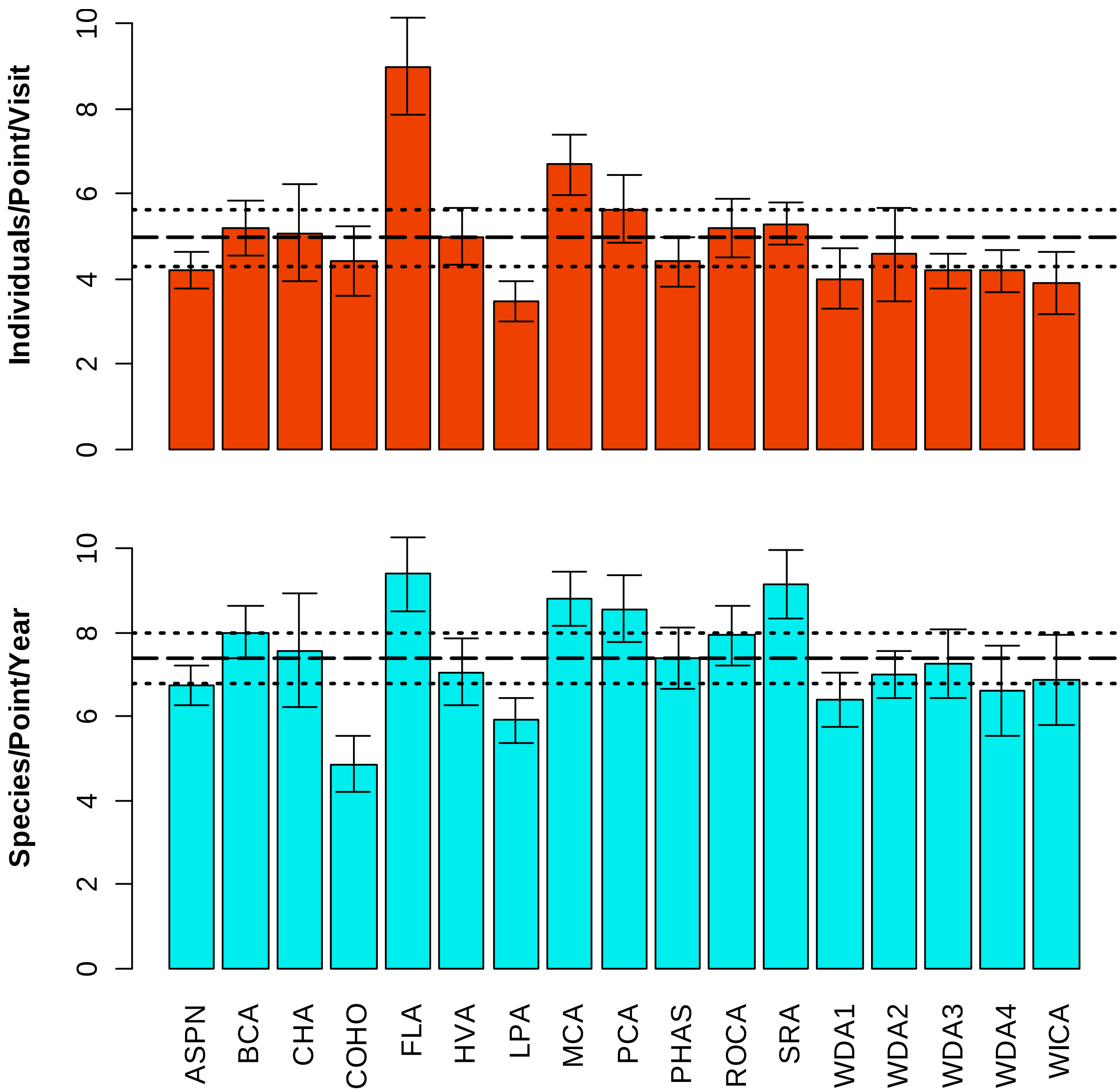


Figure 1-2. Total avian abundance (top panel) and avian species richness (bottom panel) at 17 aspen sites in the northern Sierra Nevada in 2011 (± SE). Dashed lines represent the mean for all sites combined and dotted lines the 95% confidence interval surrounding that estimate. Four-letter transect codes are defined in Table 1-1.

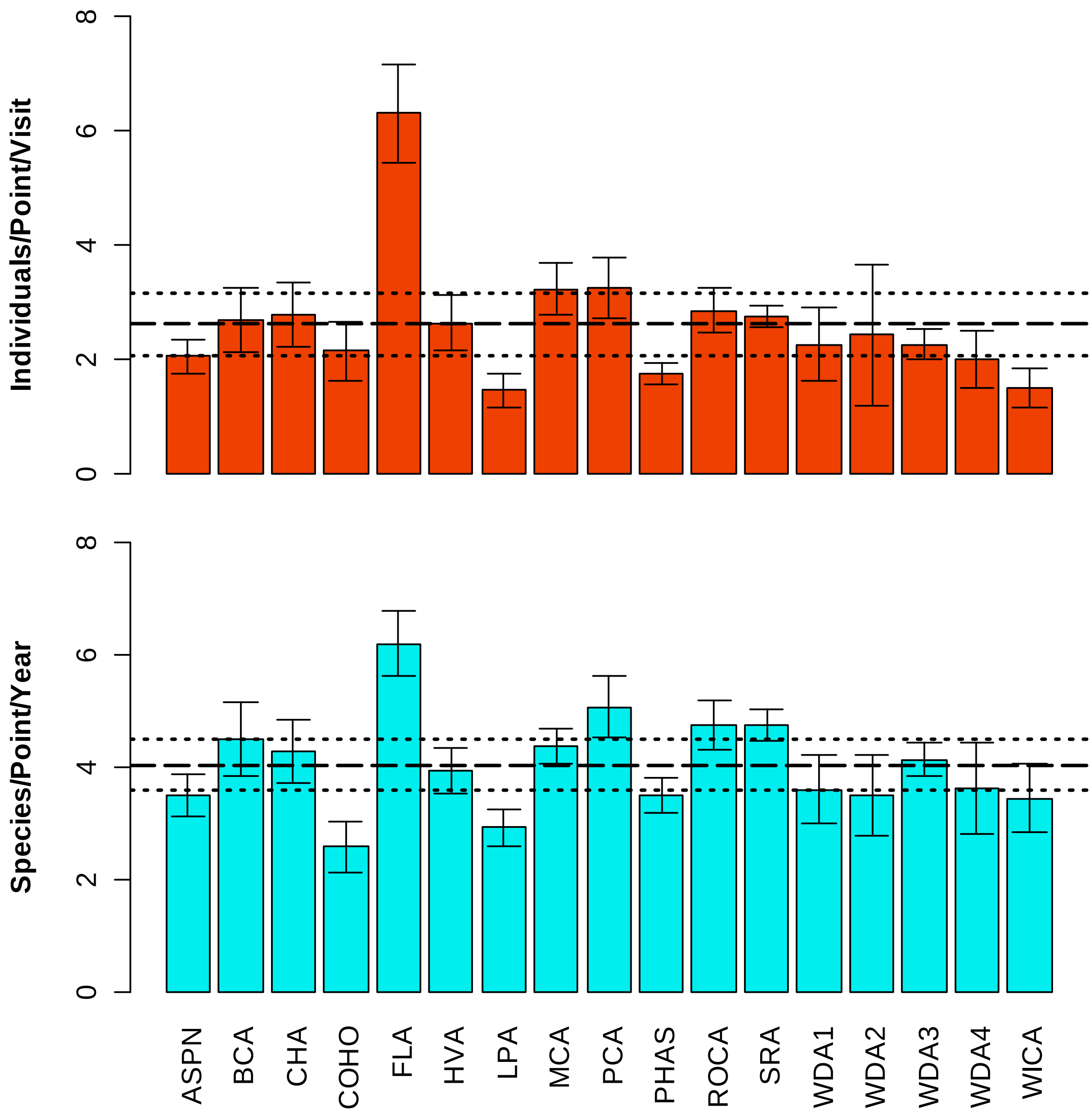


Figure 1-3. Pooled focal species abundance (top panel) and focal species richness (bottom panel) at 17 aspen sites in the northern Sierra Nevada in 2011 (± SE). Dashed lines represent the mean for all sites combined and dotted lines the 95% confidence interval surrounding that estimate. Four-letter transect codes are defined in Table 1-1.

Comparing pre-treatment abundances to post-treatment abundances

Of the 12 focal species, Red-breasted Sapsucker, Hairy Woodpecker, Tree Swallow, and Mountain Bluebird showed strong responses to aspen enhancement treatments through increased abundance from pre-treatment to post-treatment relative to the change in abundance at control points (Figure 1-4). For Red-breasted Sapsucker, the interaction between time and treatment was significant to the $P < 0.05$ and $P < 0.1$ levels for 63% and 91% of model iterations, respectively (median $P = 0.036$). For Hairy Woodpecker, the interaction between time and treatment was significant to the $P < 0.05$ for 100% of model iterations (median $P = 0.003$). For Tree Swallow, the interaction between time and treatment was significant to the $P < 0.05$ and $P < 0.1$ levels for 87% and 93% of model iterations, respectively (median $P = 0.009$) For Mountain Bluebird, of the 61 model iterations that properly converged, 0% were significant to the $P < 0.05$ level and 97% were significant to the $P < 0.1$ level (median $P = 0.083$). Chipping Sparrow demonstrated a weak response to aspen treatment, having an interaction between time and treatment significant to the $P < 0.05$ and $P < 0.1$ levels for 13% and 34% of model iterations, respectively (median $P = 0.136$). We did not detect a positive or negative change in the index of abundance for any other focal species that was attributable to the aspen treatments.

Pooled focal species abundance and richness increased significantly at treatment points from pre-treatment to post-treatment (Figure 1-5). For pooled focal species abundance, the interaction between time and treatment was significant to the $P < 0.05$ and $P < 0.1$ for 95% and 100% of model iterations, respectively (median $P = 0.013$). For focal species richness, the interaction between time and treatment was significant to the $P < 0.05$ for 100% of model iterations (median $P = 0.008$).

Focal species trends following aspen enhancement treatments

Only two of the focal species had trends in their abundance in the first 10 years following aspen enhancement treatment that could be explained by linear or quadratic equations (Figure 1-6). The best-fit equation for the post-treatment trend in Tree Swallow abundance was a positive quadratic equation, with a predicted peak in abundance at about five years post-treatment. For Chipping Sparrow, the best-fit equation indicated a linear increase in abundance by 1.5% for each year post-treatment. There was no significant post-treatment trend in Red-breasted Sapsucker abundance, Hairy Woodpecker abundance, Mountain Bluebird abundance, despite these metrics having a significant response to aspen treatment in the BACI analysis.

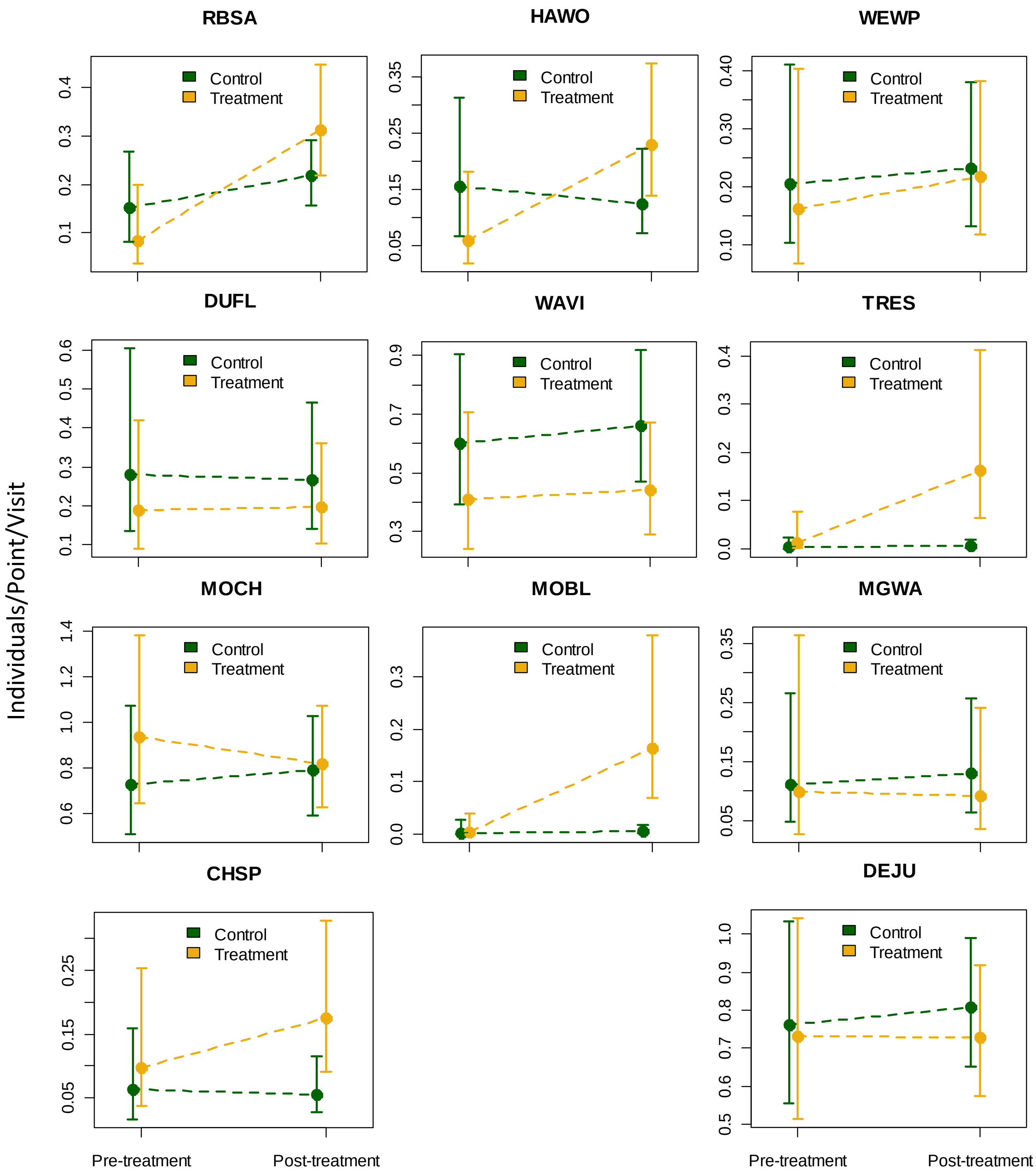


Figure 1-4. Predicted abundance of each focal species in treatment and control plots before and after aspen enhancement treatments with 95% confidence intervals. Four-letter species codes are defined in Table 1-2. The dots represent the median value of the mean estimates of abundance from the 100 iterations of each test. The extent of the vertical lines represent the maximum and minimum values for 95% confidence intervals around the mean estimates from the 100 iterations.

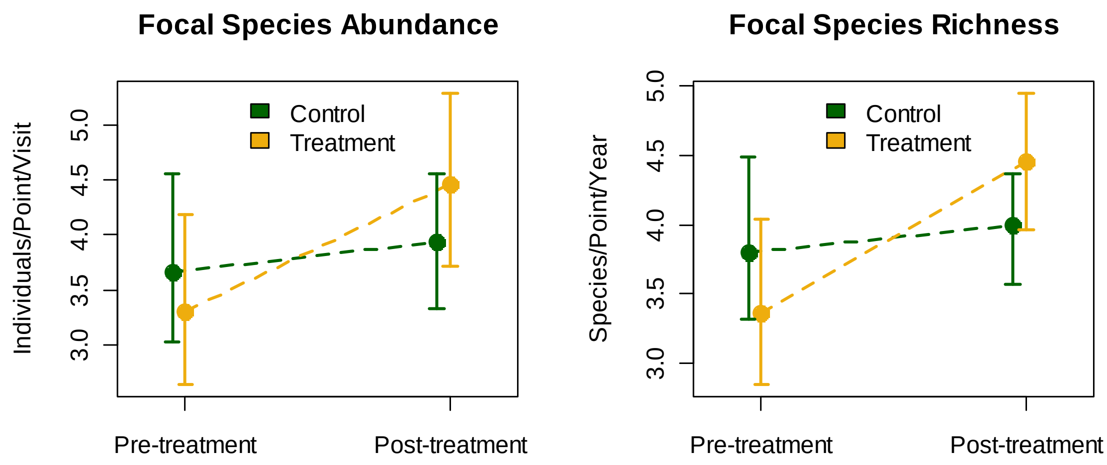


Figure 1-5. Predicted pooled focal species abundance and richness in treatment and control plots before and after aspen enhancement treatments with 95% confidence intervals. The dots represent the median value of the mean estimates from the 100 iterations of each test. The extent of the vertical lines represent the maximum and minimum values for 95% confidence intervals around the mean estimates from the 100 iterations.

Though they were non-significant, quadratic equations were a better fit than linear equations for the abundances of Dusky Flycatcher, Mountain Chickadee, and Mountain Bluebird in the 10 years following treatment. The negative quadratic relationships evident for Dusky Flycatcher and Mountain Chickadee abundances are indicative of a dip in abundance shortly following treatment with increasing abundance in the latter of the 10 years post-treatment. Like Tree Swallow abundance, the best-fit equation for Mountain Bluebird abundance also peaked at about 5 years post-treatment, indicating a potential decrease in abundance in the latter of the 10 years post-treatment.

The linear equation fit to focal species richness indicated a 12.4% increase each year post-treatment, though, the raw data also suggests a plateau in richness of 5-6 species per point per year is reached by the 6th year post-treatment and extends at least through the 10th year post-treatment (Figure 1-7). There was no trend in pooled focal species abundance post-treatment.

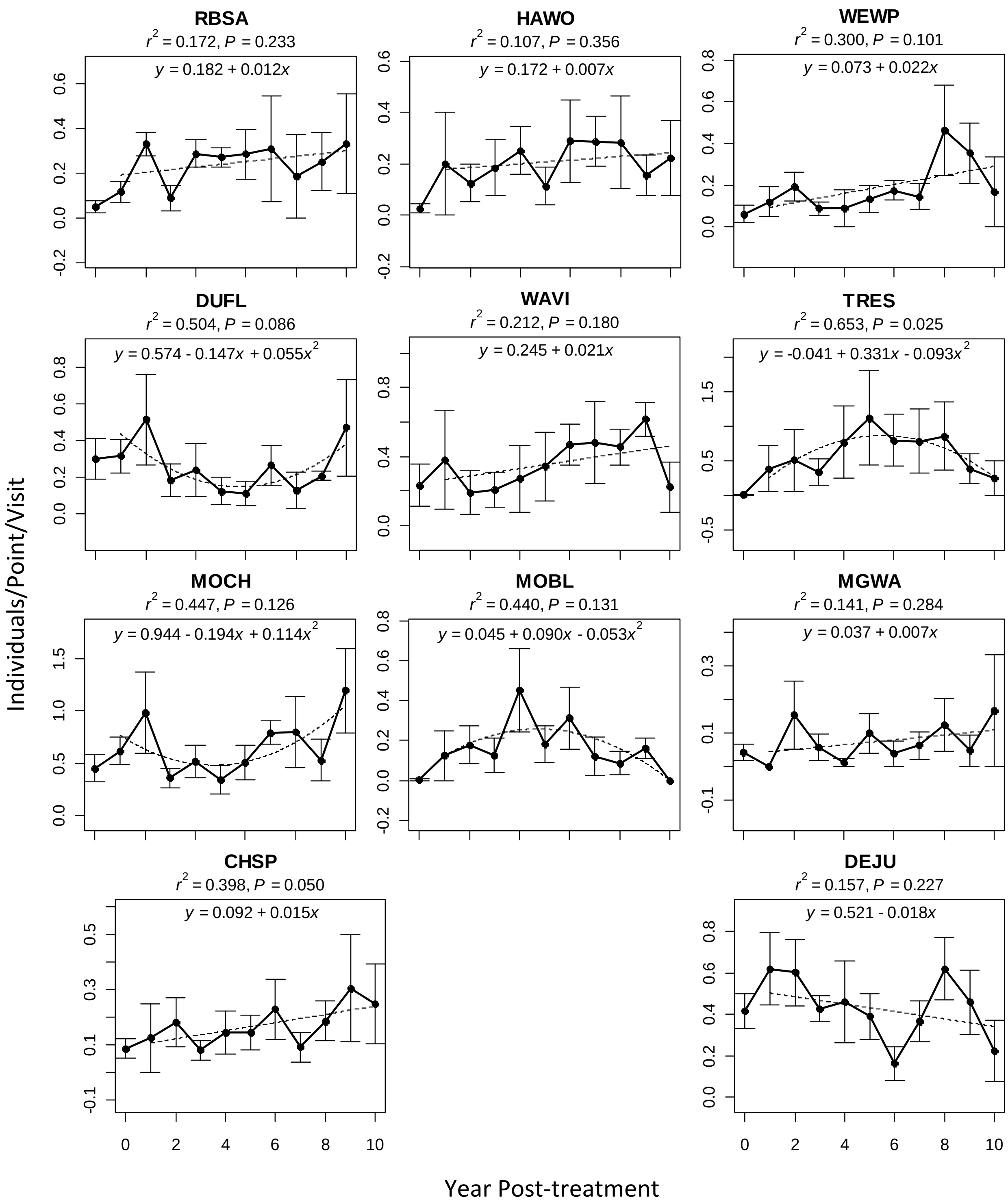


Figure 1-6. Trends in focal species' abundance for 10 years following aspen enhancement treatments. Four-letter species codes are defined in Table 1-2. Error bars represent SE.

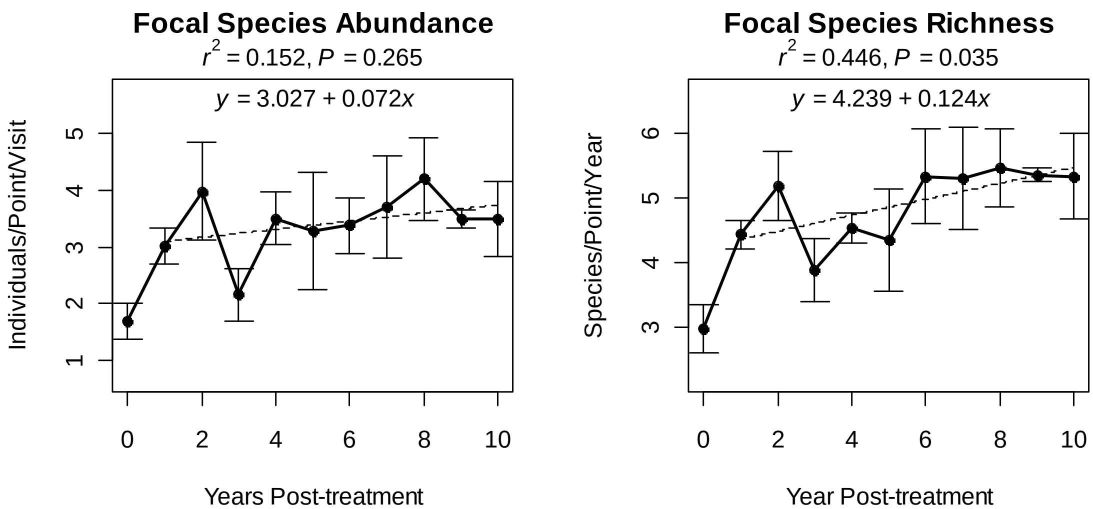


Figure 1-7. Trends in pooled focal species abundance and richness for 10 years following aspen enhancement treatments. Error bars represent SE.

DISCUSSION

Our results illustrate the effectiveness of aspen enhancement treatments for creating habitat for a suite of focal avian species on the Almanor and Eagle Lake Ranger Districts of Lassen National Forest. We found post-treatment increases in the abundance of at least four of eleven focal species, pooled focal species abundance, and focal species richness. While there was no significant effect for 7 of the 11 focal species, neither did any focal species respond negatively to aspen enhancement. We also found significant trends in the abundances and richness of focal species in the 10 years post-treatment, described by both linear and quadratic equations. Although the negative quadratic trends in post-treatment abundance for Dusky Flycatcher and Mountain Chickadee suggest that these species may have decreased in abundance shortly following aspen treatment, over time the effect was neutral. As with previous years, in 2011, we continued to see only moderate site-to-site and forest-wide variation in avian abundance and richness metrics in aspen habitat. Together, our results suggest that the avian community responds positively to aspen restoration via a dynamic process that has differential effects on species as restoration sites age.

Pre-treatment vs. post-treatment

The idea that conifers in aspen stands provide additional structural complexity that increases the richness and diversity of avian communities in aspen habitat has been refuted repeatedly in the Intermountain West. These studies have found either negative or no correlations between conifer canopy cover in aspen habitat and breeding bird abundance, richness, or diversity (Finch and Reynolds, 1987; Rumble et al., 2001; Richardson and Heath, 2004; Hollenbeck and Ripple, 2007).

Across its range, aspen habitat supports a diverse and abundant guild of cavity nesting species, with many studies showing cavity nesters disproportionately select aspen trees for nesting (Li and Martin, 1991; Dobkin et al., 1995; Martin and Eadie, 1999; Aitken and Martin, 2004). Our study is the first to test the effect of conifer cover on avian communities in aspen habitat through the experimental manipulation of conifer cover. Though our analyses were restricted to a suite of focal species, the results provide compelling evidence that cavity nesters are particularly sensitive to conifer encroachment.

All of the focal species with strong responses to aspen enhancement treatment – Red-breasted Sapsucker, Hairy Woodpecker, Tree Swallow, and Mountain Bluebird – are cavity nesters. However, Mountain Chickadee, the other cavity nester in the suite of focal species, showed no response. This result follows other studies that have shown chickadees and nuthatches, which are weak cavity excavators, are distinct from other primary and secondary cavity nesters in aspen habitat in both their habitat associations and interactions within cavity nest webs (Martin and Eadie, 1999; Martin et al., 2004).

The lack of a response from the other focal species may be attributable to the young age of the aspen enhancement treatments to-date. All of the focal species that did not respond to the aspen treatments, except Mountain Chickadee, either nest in overstory trees (i.e. Western Wood-Pewee, Warbling Vireo), understory trees and/or shrubs (Dusky Flycatcher, Chipping Sparrow, MacGillivray's Warbler), or on the ground in the proximity of dense ground cover (Dark-eyed Junco). Jones et al. (2005) found that aspen stems height between 1.4–2.5 cm dbh took four years to increase in abundance at the aspen restoration sites in the ELRD that were treated in 1999. While stems in that size class are likely large enough to support the nests of the focal species that nest in understory trees or shrubs, they may not yet be in the densities required by these species. As of 2011, our point count stations were located in treated stands ranging from 3 to 12 years post-treatment (3y, n=6; 4y, n=9; 6y, n=7; 8y, n=5; 9y, n=6; 12y, n=8). For those sites treated 12 years ago, regenerating aspen stems have yet to develop to a size class that can support the overstory tree-nesting species. The intentional avoidance of fire from these treated stands in order to protect weakened mature stems from being lost may be reducing regenerating stem densities and growth (Keyser et al., 2005). Understory shrubs have also been slow to regenerate at treated sites. It may be another decade or more before the regenerating aspen stems have developed enough to significantly influence the abundance of avian species associated with aspen overstory at even the oldest treated sites. Nonetheless, our results suggest that ensuring an aspen overstory component was retained has resulted in no significant decline in overstory aspen associates and an increase in a number of cavity nesters. In larger aspen stands (e.g. Pine Creek) we suggest introducing low to moderate severity fire at a small scale to enhance aspen recruitment and diversify stand structure.

Cavities

Red-breasted Sapsucker and Hairy Woodpecker are primary cavity nesters, meaning they excavate their own cavities. Both of these species require larger diameter (>20 cm dbh) trees for nesting. None of the regenerating aspen stems at treated sites have achieved this size. Currently the only trees within the aspen restoration areas post-treatment that are large enough for woodpecker nesting are the remnant trees that were also available pre-treatment. Thus an increase in nest-tree availability in treated aspen stands would not explain their increase in abundance. Rather, it may be that selection for nest placement in aspen trees in the open aspen habitat created by conifer removal is the cause for the increase in these species' abundance.

Tree Swallow and Mountain Bluebird are secondary cavity nesters that prefer open habitats for nesting and foraging (Robertson et al., 1992; Power and Lombardo, 1996). In coniferous landscapes with aspen, both of these species select aspen over conifers as nest trees

(Li and Martin, 1991; Martin and Eadie, 1999; Martin et al., 2004). Given their habitat preferences, the creation of open habitat created by conifer removal around mature aspen may have also triggered the increase in Tree Swallow and Mountain Bluebird abundance. While mature aspen – such as the remnant aspen in treatment stands – often contain numerous natural cavities, secondary cavity nesters strongly select for woodpecker-created cavities in both live aspen and aspen snags (Dobkin et al., 1995; Martin and Eadie, 1999; Aitken and Martin, 2004; Martin et al., 2004). The dependence of secondary cavity nesters on primary cavity nesters for nests, leads to strong positive correlations between the abundances of secondary cavity nesters and primary cavity nesters (Martin and Eadie 1999). Hence, the magnitude of the increase in abundance of Tree Swallow and Mountain Bluebird following aspen treatments is likely to be dependent on both the positive response of primary cavity nesters to aspen treatment and conifer removal around aspen stands.

Some evidence of a positive increase in Chipping Sparrow abundance after aspen restoration likely reflects this species' selection for breeding in early successional habitats. The majority of the aspen restoration sites are in the early stages of succession after conifer removal. There are many possible explanations for the rather weak response of Chipping Sparrow compared to the stronger responses demonstrated by other species; here we present two possibilities. The first is this species' apparently slow response to the aspen treatments, as evidenced by the positive linear trend in this species' abundance post-treatment. Given their slow response, the magnitude of the difference between post-treatment and control sites was likely small for the first five or more years post-treatment. Because most of the treatments in this study were relatively recent, the majority of the data in our BACI analysis is from 5 or less years post-treatment. This could explain both the small effect size and the large uncertainty around the mean estimates of abundance. The second possibility for a weak response is the well-documented preference of Chipping Sparrow for conifers as a nesting substrate (Middleton, 1998). If Chipping Sparrow primarily use the treated aspen for foraging while nesting in conifers at the edge of the opening created by the treatments, we would be less likely to detect them because the focal point of their activity (nests) is outside of the aspen. However, because Chipping Sparrow in aspen-conifer landscapes in southern Oregon nest in comparable abundance in aspen and conifer habitats (Sallabanks et al., 2005), we suspect the former explanation is more likely than the latter for the weak response of Chipping Sparrow to aspen treatments in the Northern Sierra.

The removal of conifers from aspen stands creates a habitat that is attractive to cavity nesters. Intriguingly the two primary cavity nesters in this analysis, Red-breasted Sapsucker and Hairy Woodpecker, are not equally abundant in aspen stands with mature aspen that are encroached by conifers even though they regularly nest in conifers. Both of these species are known to select for aspen as cavity nest trees, yet conifer-encroached aspen habitats appear to be avoided. If aspen boles irrespective of the surrounding habitat were selected for nesting, then abundances of cavity nesters pre- and post-treatment should not have changed because the availability of aspen boles suitable for nesting did not change. Instead, our results clearly demonstrate that the habitat surrounding aspen boles and stands can have a dramatic effect on the nesting choices for cavity nesters that select aspen trees for their nests. Lawler and Edwards (2002) also found that habitat in and surrounding aspen trees and aspen stands affects the aspen cavity-nesting community. They found higher cavity-nester species richness and abundance in sparsely stocked pure aspen stands than in dense pure aspen stands, and in aspen stands surrounded by meadows than stands surrounded by coniferous forest. This highlights the importance of habitat composition and landscape context in nest site selection by aspen cavity nesters.

Post-treatment trends

Continued aspen growth and regeneration at treated stands suggest that increases in avian richness and abundance will continue. However, the availability of certain habitat structures required by each focal species are likely to change. We expect that changes in habitat suitability will be reflected in the trends in avian abundance and richness for 10 years or more following aspen treatment. We described trends in abundance and richness in response to aspen succession up to 10 years and found that a positive quadratic trend for Tree Swallow abundance, and positive linear trends for Chipping Sparrow abundance and focal species richness. All three of these metrics also responded positively to aspen treatments. The abundance of Western Wood-Pewee, Dusky Flycatcher, Warbling Vireo, Mountain Chickadee, and Mountain Bluebird also showed interesting and near-significant trends that should become clearer with larger sample sizes from additional years of data collection and increased treatment events implemented by the Forest Service.

Tree Swallow and Mountain Bluebird showed a delayed response to treatment with predicted peaks in abundance at about five years after treatment followed by a decline in abundance. However, the trend for Mountain Bluebird was not significant. The increasing leg of their trends may reflect the accrual of available nesting cavities created by woodpeckers. This lends support to the hypothesis that the abundance of secondary cavity nesters may be limited by the abundance of nest cavities (Newton, 1994) and the abundance of cavity excavators (Martin and Eadie, 1999). However, if nest site availability was the only mechanism responsible for the increase in Tree Swallow and Mountain Bluebird abundances then we would not expect the predicted decline of these species after 5–6 years post-treatment when nest cavity availability likely does not decline. The transition of treated aspen stands in 5-10 years post-treatment from a freshly opened post-disturbance habitat to a regenerating habitat thick with aspen stems may be linked to the downward trend in Tree Swallow and Mountain Bluebird abundance.

Red-breasted Sapsucker and Hairy Woodpecker did not show a post-treatment trend in abundance despite responding positively to aspen treatment compared to control sites. This combination of results indicates a binary response to aspen treatment, with a rapid increase in abundance in the breeding seasons shortly after treatment and abundances that remain relatively constant for at least 10 years following treatment. This pattern of response supports the hypothesis that response to aspen treatment was triggered by the open post-treatment habitat structure. If Red-breasted Sapsucker and Hairy Woodpecker were responding to increasing nesting substrate or food availability attributable to regenerating vegetation, you would expect a positive trend in abundance post-treatment proportional to the availability of regenerating vegetation.

Pooled focal species abundance and focal species richness also increased sharply in the two years immediately following treatment. We originally hypothesized that treatments would result in a decrease in species richness and pooled focal species abundance in the lag between the loss of foliage volume and structural diversity from conifer removal and the time it takes for aspen to regenerate. However, both the results from our BACI analysis and the trends analysis counter our prediction. Though negative quadratic relationships apparent in the post-treatment trends of Dusky Flycatcher and Mountain Chickadee suggest that some species may have been negatively affected by the treatments, any decreases in the abundances of these and other species were overwhelmed by the increases in cavity nesters when calculating focal species abundance and richness.

Because we focused this analysis on species we knew to be associated with aspen dominated habitat, our species richness analysis did not incorporate any potential decreases in conifer associates. In our original hypothesis regarding the effect of treatment on abundance and richness, we failed to realize the enormous potential value of the mature remnant aspen to cavity nesters and the large conifers to overstory tree nesters in an open, post-disturbance habitat.

Additionally, we may have overestimated the value of the mid-successional conifer encroached aspen habitat that existed prior to treatment as evidenced by the relatively low avian metrics at untreated sites. The dramatic positive response of cavity nesting species to the opening of the habitat surrounding mature aspen and conifers supports the notion that management of aspen habitat should consider that importance of disturbance and the early successional habitat that results. It should also be noted that because we focused our analyses on species we knew to be associated with aspen dominated habitat, our species richness analysis did not incorporate any potential decreases in conifer associates. However, with the limited extent of aspen on the landscape compared to the available habitat for conifer associated species, any decline in these species is far less important than improving habitat for aspen associates.

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MANAGEMENT RECOMMENDATIONS

Management recommendations are updated annually and are based on the result of our monitoring, current literature, and expert opinion from our collective 16 years of studying birds in aspen habitat in the Sierra Nevada.

- Aspen habitat enhancement and expansion should be among the highest priorities in the Sierra Nevada as aspen is rare on the landscape and is especially diverse.
- Promote aspen regeneration to increase overall aspen cover of all size classes.
- Promote aspen habitat with a diverse and dense understory plant community that provides resources such as seeds, nectar, and cover for a variety of bird species.
- Manage aspen habitat for multiple age and cover classes within stands. Early successional open canopy aspen habitat supports a number of bird species of interest (e.g. Mountain Bluebird, Chipping Sparrow).
- Develop strategies for treating aspen within riparian areas that will support willows, alders, and other deciduous riparian vegetation. Aspen habitat with these components harbors a greater diversity and abundance of breeding birds than any other habitat in the Northern Sierra.
- Retain all snags over eight inches DBH in aspen treatments regardless of the tree species, though highest priority should be given to retaining aspen snags, thereby increasing availability of cavity nesting opportunities.
- Reduce or eliminate over-browsing/grazing in regenerating aspen stands through fencing or removal of livestock to ensure long-term continued regeneration and structurally diverse aspen stands.
- Consider the effects of grazing adjacent to aspen treatments due to increased abundance of cowbirds and their potential negative impact on open cup nesting birds.

LITERATURE CITED

Aitken, K.E.H., Martin, K., 2004. Nest cavity availability and selection in aspen-conifer groves in a grassland landscape. Canadian Journal of Forest Research 34, 2099–2109.

Baker, W.L., Munroe, J.A., Hessl, A.E., Baker, W.L., Munroe, J.A., Hessl, A.E., 1997. The effects of elk on aspen in the winter range in Rocky Mountain National Park, The effects of elk on aspen in the winter range in Rocky Mountain National Park. Ecography, Ecography 20, 20, 155, 155–165, 165.

Bartos, D.L., 2001. Landscape dynamics of aspen and conifer forests, in: Shepperd, W.D., Binkley, D., Bartos, D.L., Stohlgren, T.J., Eskew, L.G. (Eds.), Sustaining Aspen in Western Landscapes: Symposium Proceedings; 13-15 June 2000; Grand Junction, CO, Proceedings RMRS-P-18. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp. 5–14.

Binkley, D., 2008. Age distribution of aspen in Rocky Mountain National Park, USA. Forest Ecology and Management 255, 797–802.

Dobkin, D.S., Rich, A.C., Pretare, J.A., Pyle, W.H., 1995. Nest-site relationships among cavity-nesting birds of riparian and snowpocket aspen woodlands in the northwestern Great Basin. The Condor 97, 694–707.

Finch, D.M., Reynolds, R.T., 1987. Bird response to understory variation and conifer succession in aspen forests, in: Emerick, J., Foster, S.Q., Hayden-Wing, L., Hodgson, J., Monarch, J.W., Smith, A., Thorne, O., Todd, J. (Eds.), Proceedings III: Issues and Technology in the Management of Impacted Wildlife. Thorne Ecological Institute, Boulder, CO.

Flack, J.A.D., 1976. Bird populations of aspen forests in western North America. Ornithological monographs 1–97.

Frey, B.R., Lieffers, V.J., Hogg, E., Landhäusser, S.M., 2004. Predicting landscape patterns of aspen dieback: mechanisms and knowledge gaps. Canadian Journal of Forest Research 34, 1379–1390.

Griffis-Kyle, K.L., Beier, P., 2003. Small isolated aspen stands enrich bird communities in southwestern ponderosa pine forests. Biological Conservation 110, 375–385.

Heath, S.K., Ballard, G.S., 2003. Patterns of breeding songbird diversity and occurrence in riparian habitats of the eastern Sierra Nevada, in: Faber, P.M. (Ed.), California Riparian Systems: Processes and Floodplain Management, Ecology, and Restoration, Riparian Habitat and Floodplains Conference Proceedings, Riparian Habitat Joint Venture, Sacramento, CA. pp. 21–34.

Hollenbeck, J.P., Ripple, W.J., 2007. Aspen and conifer heterogeneity effects on bird diversity in the northern Yellowstone ecosystem. Western North American Naturalist 67, 92–101.

Jones, B.E., Rickman, T.H., Vazquez, A., Sado, Y., Tate, K.W., 2005. Removal of encroaching conifers to regenerate degraded aspen stands in the Sierra Nevada. Restoration Ecology 13, 373–379.

Kaye, M.W., Binkley, D., Stohlgren, T.J., 2005. Effects of conifers and elk browsing on quaking aspen forests in the central Rocky Mountains, USA. Ecological Applications 15, 1284–1295.

Keyser, T.L., Smith, F.W., Shepperd, W.D., 2005. Trembling aspen response to a mixed-severity wildfire in the Black Hills, South Dakota, USA. Canadian Journal of Forest Research 35, 2679–2684.

Kulakowski, D., Veblen, T.T., Drinkwater, S., 2004. The persistence of quaking aspen (*Populus tremuloides*) in the Grand Mesa area, Colorado. Ecological Applications 14, 1603–1614.

Kulakowski, D., Veblen, T.T., Kurzel, B.P., Kulakowski, D., Veblen, T.T., Kurzel, B.P., 2006. Influences of infrequent fire, elevation and pre-fire vegetation on the persistence of quaking aspen (*Populus tremuloides* Michx.) in the Flat Tops area, Colorado, USA. Journal of Biogeography, Journal of Biogeography 33, 33, 1397, 1397–1413, 1413.

Li, P., Martin, T.E., 1991. Nest-site selection and nesting success of cavity-nesting birds in high elevation forest drainages. The Auk 405–418.

Martin, K., Aitken, K.E.H., Wiebe, K.L., 2004. Nest sites and nest webs for cavity-nesting communities in interior British Columbia, Canada: Nest characterstics and niche partitioning. The Condor 106, 5.

Martin, K., Eadie, J.M., 1999. Nest webs: A community-wide approach to the management and conservation of cavity-nesting forest birds. Forest Ecology and Management 115, 243–257.

Middleton, A.L.A., 1998. Chipping Sparrow (*Spizella passerina*), in: Poole, A. (Ed.), The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, NY.

Mills, T.R., Rumble, M.A., Flake, L.D., 2000. Habitat of birds in ponderosa pine and aspen/birch forest in the Black Hills, South Dakota. Journal of Field Ornithology 71, 187–206.

Newton, I., 1994. The role of nest sites in limiting the numbers of hole-nesting birds: A review. Biological Conservation 70, 265–276.

Di Orio, A.P., Callas, R., Schaefer, R.J., 2005. Forty-eight year decline and fragmentation of aspen (*Populus tremuloides*) in the South Warner Mountains of California. Forest Ecology and Management 206, 307–313.

Perala, D.A., 1991. *Populus tremuloides* Michx., in: Burns, R.M., Honkala, B.H. (Eds.), Silvics of North America. Volume 2. Hardwoods. United States Department of Agriculture, Forest Service, Agriculture Handbook, pp. 555–569.

Power, H.W., Lombardo, M.P., 1996. Mountain Bluebird (*Sialia currucoides*), in: Poole, A. (Ed.), The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, NY.

Preston, R.J., Braham, R.R., 2002. North American trees, 5th ed. Iowa State Press, Iowa.

Richardson, T.W., Heath, S.K., 2004. Effects of conifers on aspen-breeding birds in the Sierra Nevada. Transactions of the Western Section of the Wildlife Society 40, 68–81.

Richardson, T.W., Vander Wall, S.B., 2007. Yellow pine chipmunks cannot climb quaking aspens: implications for avian nest site selection. Western North American Naturalist 67, 251–257.

Robertson, R.J., Stutchbury, B.J., Cohen, R.R., 1992. Tree Swallow (*Tachycineta bicolor*), in: Poole, A. (Ed.), The Birds of North America Online. Cornell Lab of Ornithology, Ithaca, NY.

Rumble, M.A., Flake, L.D., Mills, T.R., Dykstra, B.L., 2001. Do pine trees in aspen stands increase bird diversity?, in: Shepperd, W.D., Binkley, D., Bartos, D.L., Stohlgren, T.J., Eskew, L.G. (Eds.), Sustaining Aspen in Western Landscapes: Symposium Proceedings; 13-15 June 2000; Grand Junction, CO, Proceedings RMRS-P-18. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, CO, pp. 185–192.

Sallabanks, R., Christofferson, N.D., Weatherford, W.W., Anderson, R., 2005. Restoring high priority habitats for birds: Aspen and pine in the Interior West, in: Ralph, C.J., Rich, T.D. (Eds.), Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20-24; Asilomar, California, General Technical Report PSW-GTR-191. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA, pp. 391–404.

Salt, G.W., 1957. An analysis of avifaunas in the Teton Mountains and Jackson Hole, Wyoming. The Condor 59, 373–393.

Sankey, T.T., 2008. Learning from spatial variability: Aspen persistence in the Centennial Valley, Montana. Forest Ecology and Management 255, 1219–1225.

Shepperd, W.D., Rogers, P.C., Burton, D., Bartos, D.L., 2006. Ecology, biodiversity, management, and restoration of aspen in the Sierra Nevada (General Technical Report No. RMRS-GTR-178). U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, Fort Collins, Colorado.

Tewksbury, J.J., Hejl, S.J., Martin, T.E., 1998. Breeding productivity does not decline with increasing fragmentation in a western landscape. Ecology 79, 2890–2903.

Turchi, G.M., Kennedy, P.L., Urban, D., Hein, D., 1995. Bird species richness in relation to isolation of aspen habitats. The Wilson Bulletin 107, 463–474.

APPENDICES

Appendix 1-1. List of species excluded from all aspen analyses.

American Bittern	Long-billed Curlew	Townsend's Warbler
American Coot	Mallard	Turkey Vulture
American Kestrel	Northern Goshawk	Vaux's Swift
American White Pelican	Northern Harrier	Violet-green Swallow
Bald Eagle	Northern Pintail	Virginia Rail
Bank Swallow	Northern Pygmy-Owl	Western Grebe
Barn Swallow	Northern Rough-winged Swallow	White-faced Ibis
Black-crowned Night-Heron	Northern Shoveler	Willet
Brown-headed Cowbird	Orange-crowned Warbler	Wilson's Phalarope
Bufflehead	Osprey	Wilson's Snipe
Canada Goose	Pied-billed Grebe	Wood Duck
California Gull	Peregrine Falcon	Unid. Blackbird
Cinnamon Teal	Prairie Falcon	Unid. Empidonax Flycatcher
Cliff Swallow	Ring-billed Gull	Unid. Finch
Cooper's Hawk	Red-shouldered Hawk	Unid. Tyrant Flycatcher
Double-crested Cormorant	Red-tailed Hawk	Unid. Hawk
Eurasian Collared-Dove	Ruddy Duck	Unid. Hummingbird
European Starling	Rufous Hummingbird	Unid. Rail
Forster's Tern	Sandhill Crane	Unid. Sapsucker
Gadwall	Sora	Unid. Sparrow
Great Blue Heron	Spotted Sandpiper	Unid. Woodpecker
Great Egret	Sharp-shinned Hawk	Unid. Bird
Green-winged Teal	Swainson's Hawk	

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CHAPTER TWO

Avian Monitoring in Northern Sierra Nevada Meadows

INTRODUCTION

Montane meadows are among the most unique habitat types In the Sierra Nevada. Access to perennial water and distinctive soil types in riparian areas leads to distinct plant communities from the adjacent upland (Kondolf et al., 1996). Meadows generally form where streams and rivers flow into to low-gradient, alluvial valleys and the shallow water table promotes a unique riparian vegetation community.

Meadows are disproportionately valuable compared to the area they cover in the Sierra Nevada for the ecological services they provide (Kattlemann and Embury, 1996; Kondolf et al., 1996). Ecologically functional montane meadows are hotspots for biodiversity in the Sierra Nevada (Kattlemann and Embury, 1996), and provide vital services such as flood attenuation, sediment filtration, water storage, and water quality improvement (DeLaney, 1995; Woltemade, 2000; Hammersmark et al., 2008), carbon sequestration (Povirk et al., 2001), and livestock forage (Torrell et al., 1996). Though less than 1% of the area of the Sierra Nevada is comprised of riparian habitat (Kattlemann and Embury, 1996), approximately one-fifth of the 400 species of terrestrial vertebrates that inhabit the Sierra Nevada are strongly dependent on riparian areas (Graber, 1996). Montane meadows are among the most important habitats for birds in the Sierra Nevada (Siegel and DeSante, 1999; Burnett and Humple, 2003; Burnett et al., 2005). In the Sierra Nevada, meadows support several rare and declining bird species and are utilized at some point during the year by almost every bird species that breeds in or migrates through the region (Siegel and DeSante, 1999).

The majority of the meadows in the Sierra Nevada have undergone a long history of degradation to a state that is less productive and supports fewer species and individuals of native animals and plants, and they provide fewer ecological services (Ratliff, 1985; Knapp and Matthews, 1996; Castelli et al., 2000; Sarr, 2002; Krueper et al., 2003). Grazing, timber harvest, roads, culverts, dams, diversions, mining, and alien species invasions have all contributed to meadow degradation (Ratliff, 1985). While many meadows have been resilient to these impacts, once a threshold has been passed many of these systems cannot readily recover on their own (Allen-Diaz, 1991; Micheli and Kirchner, 2002; Chambers et al., 2004; Briske et al., 2008). Once significant channel incision and down-cutting has occurred and floodplain connectivity has been lost, actions may be necessary to restore form and function (Micheli and Kirchner, 2002).

Meadow management and restoration should consider the importance of the habitat to birds and other wildlife. A disproportionate number of the special status wildlife species in the Sierra Nevada are tied to meadows, including four bird species – Greater Sandhill Crane, Great Gray Owl, Willow Flycatcher, and Yellow Warbler. Using meadow-dependent bird species (focal species) as indicators of meadow form and function can be a powerful adaptive management tool for informing management and restoration decisions in Sierra Nevada meadows. Through such a focal species approach, it is possible to identify conservation priorities, help guide meadow restoration design and management prescriptions, and establish and evaluate management and conservation targets (Burnett et al., 2005; Chase and Geupel, 2005).

In this chapter we summarize point count data from avian monitoring of meadows (both public and private) in the Feather River and Deer Creek watersheds in Plumas, Sierra, and Tehama counties, California. We assess trends of avian abundance and species richness for meadows that have been monitored since 2004, analyze the response of the avifauna to recent restoration effort in the Red Clover Valley, and examine the habitat associations of focal meadow bird species.

METHODS

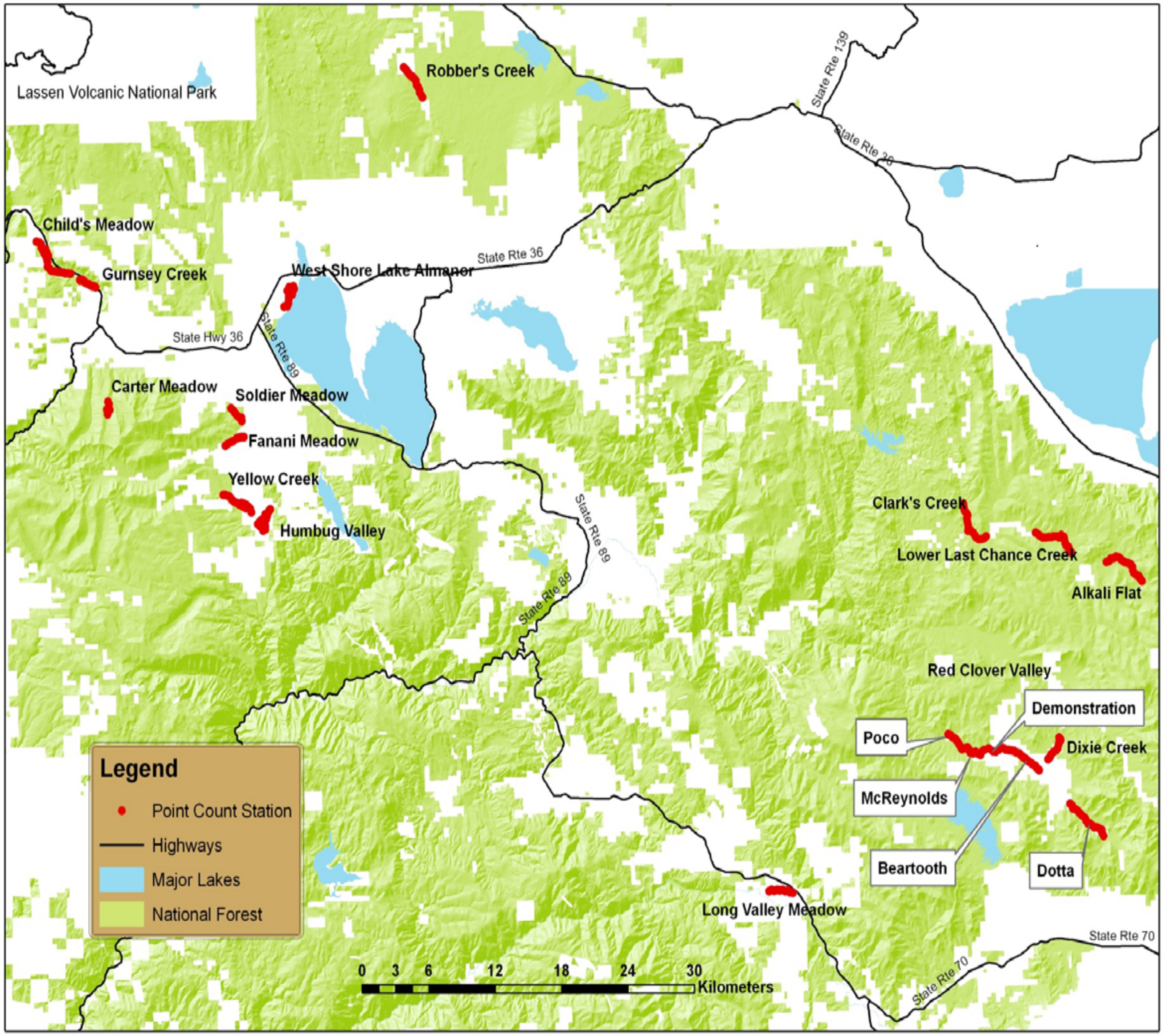
Site Selection

Several considerations went into selecting the meadow sites we sampled (Table 2-1; Figure 2-1). Following an inventory of 16 meadows in the greater Almanor Ranger District (ARD) area from 2000–2003, we selected eight meadows in the Upper North Fork Feather River and Deer Creek watersheds for long-term bird monitoring. We were interested in surveying wet meadows that supported (or should support) a riparian deciduous shrub community, and especially those sites that had recently undergone management changes (e.g. active restoration and/or removal of grazing). With these two considerations in mind we attempted to choose sites that represented a range of elevations and habitat conditions. In 2009 we added Child's Meadow to our list of sites following its acquisition by The Nature Conservancy because it was adjacent to another long-term study site and is one of the larger meadows in the area and therefore of conservation interest. Sites within the Last Chance, Red Clover, and Spanish Creek watersheds in eastern Plumas County (referred to herein as eastern Plumas sites) were selected in 2009 and 2010 to monitor proposed or completed meadow restoration projects being carried out by the Feather River Coordinated Resource Management group (FRCRM). In 2011,

Table 2-1. Meadow point count transects surveyed by PRBO in the northern Sierra Nevada in 2011 with transect codes, year established, and dates surveyed.

Transect	Code	Number of PC Stations	Year Established	Date of 1st Visit	Date of 2nd Visit
Upper N. Fork Feather River Watershed					
Fanani Meadow	FAME	8	2003	12-Jun	28-Jun
Humbug Valley	HUVA	17	2003	9-Jun	23-Jun
Robber's Creek	ROCR	14	2004	24-Jun	5-Jul
Soldier Meadow	SOME	7	2001	12-Jun	28-Jun
West Shore Lake Almanor	WSLA	13	2004	3-Jun	20-Jun
Yellow Creek Riparian	YCRI	18	2001	2-Jun	29-Jun
Deer Creek Watershed					
Carter Meadow	CAME	7	2004	2-Jul	2-Jul
Gurnsey Creek	GUCR	10	1997	10-Jun	27-Jun
Child's Meadow	CHME	22	2010	10-Jun	27-Jun
Last Chance Creeek Watershed					
Alkali Flat	ALFL	18	2009	2-Jun	28-Jun
Clark's Creek	CKCR	18	2009	3-Jun	22-Jun
Lower Last Chance Creek	LLCH	18	2009	30-May	22-Jun
Red Clover Creek Watershed					
Dixie Creek	DXCR	10	2010	27-May	28-Jun
Red Clover Beartooth	RCBT	11	2010	15-Jun	1-Jul
Red Clover Demonstration	RCDE	5	2010	15-Jun	1-Jul
Red Clover Dotta	RCDO	18	2010	15-Jun	1-Jul
Red Clover McReynolds	RCMC	13	2010	3-Jun	22-Jun
Red Clover Poco	RCPO	10	2010	3-Jun	22-Jun
Spanish Creek Watershed					
Long Valley Meadow	LVME	10	2010	31-May	14-Jun
Middle Fork Feather River Watershed					
Lemon Canyon Ranch	LCRA	18	2011	7-Jun	30-Jun

Figure 2-1. Location of PRBO meadow bird monitoring transects surveyed in 2011 in the northern Sierra Nevada. Note Lemon Canyon Ranch is not on the map and is located approximately 50km southeast of Red Clover Valley.



another new site on private land in Sierra County was added to monitor the response of meadow vegetation replanting along Lemon Creek in the Middle Fork Feather River watershed.

Point Counts

Point count data allow us to measure secondary population parameters such as avian abundance, species richness, and diversity. This method is useful for making comparisons of bird communities across time, locations, habitats, and land-use treatments. We conducted standardized five-minute variable circular plot point counts (Reynolds et al., 1980; Ralph et al., 1995) at each of the 265 points in the study area in 2011, including: 77 points in the Upper North Fork Feather River watershed; 39 points in the Deer Creek watershed; 54 points in the Last Chance Watershed; 67 points in the Red Clover Creek watershed; 10 points in Spanish Creek watershed; and 18 points in the Middle Fork Feather River watershed (Table 2-1). Point count stations were placed a minimum of 50 m from meadow edges where feasible, and within 50 m of the primary stream channel where they existed. If the riparian corridor was less than 100 m wide, points were placed equidistant from each edge. Points along each transect were spaced at 200–250 m intervals.

We recorded all birds detected at each station during the five-minute survey. We placed detections in one of six distance categories (< 10 m, 10–20 m, 20–30 m, 30–50 m, 50–100 m, and >100 m) based on the initial detection distance from the observer, and recorded the method of initial detection (song, visual, or call). We recorded separately those birds flying over the study area but not observed using the habitat. Counts began around local sunrise and were completed within four hours. We visited each transect twice each year between 27 May and 5 July (Table 2-1 for 2011 dates). Surveys were completed by highly experienced observers with extensive knowledge of the songs and call of northern Sierra birds and well-versed in point count methodology. Observers used an electronic range finder to assist with distance estimation at each point count station.

Vegetation Surveys

Vegetation data was collected at all meadow point count stations in 2011. We measured vegetation within a 50-m radius plot centered at each point following a modified relevé protocol outlined in Appendix 2-1. On these plots we visually estimated herbaceous cover, shrub cover, understory tree cover, and overstory tree cover, as well as the relative cover of each species.

Statistical Analysis

We restricted the analysis of our point count data to a subset of the species encountered. We excluded: (1) all birds >50 m from the observer and flyovers, (2) species that do not breed in the study area, and (3) those species that are not adequately sampled using the point count method (e.g., waterfowl, raptors, waders; see Appendix 2-2. Some of the analyses are further restricted to a suite of focal species (Table 2-2) that are relatively confined to meadow habitats and represent a range of meadow conditions. A focal species group is likely to provide a better measure of the health of meadow habitat than using all species combined (Chase and Geupel, 2005). For all analyses we used naïve point count detections uncorrected for detection probability, thus abundance metrics herein represent indices rather than true densities (Johnson, 2008). We had no reason to suspect that detectability of species varied

Table 2-2. Avian focal species for meadow monitoring, listed in taxonomic order, with their four-letter codes and conservation status.

Common Name	Species Name	Code	Conservation Status
Sandhill Crane	*Grus canadensis*	SACR	CA State Threatened
Red-breasted Sapsucker[‡]	*Sphyrapicus ruber*	RBSA	Declining in the Sierra Nevada[1]
Willow Flycatcher[‡, CPF]	*Empidonax traillii*	WIFL	State Endangered, USFS Sensitive
Warbling Vireo[‡, CPF]	*Vireo gilvus*	WAVI	Declining locally in CA[2]
Swainson's Thrush[‡, CPF]	*Catharus ustulatus*	SWTH	USFS Priority Land Bird Species
Yellow Warbler[‡, CPF]	*Setophaga petechia*	YEWA	CA Species of Special Concern
MacGillivray's Warbler[‡]	*Geothlypis tolmiei*	MGWA	none
Wilson's Warbler[‡, CPF]	*Cardellina pusilla*	WIWA	Declining in the Sierra Nevada[1]
Song Sparrow[CPF]	*Melospiza melodia*	SOSP	none
Lincon's Sparrow[‡]	*Melospiza lincolnii*	LISP	none
Black-headed Grosbeak[‡, CPF]	*Pheucticus melanocephalus*	BHGR	none

[‡] Nearctic-Neotropical Migratory Bird; [CPF] California Partners in Flight Riparian Focal Species (RHJV 2004);
[1] Sauer et al. 2008; [2] Gardalli et al. 2000

across transects because the vast majority of detections were auditory and listening conditions within 50 m were excellent at all transects. The indices of bird abundance herein are defined as the mean number of individuals detected per point per visit in one year. Species richness herein is defined as the cumulative number of species detected per station in one year. Abundance and richness estimates from all points within each transect within a year were averaged to produce the point-level estimates of abundance and richness for each transect, each year. Calculating means of the indices of abundance and species richness for transects allows for comparisons between transects or habitats consisting of different numbers of point count stations, but does not provide a measure of the total number of individuals or species across an entire transect or individual meadow.

We used simple linear regression to assess trends in abundance for all of the meadow focal species (excluding Sandhill Crane), individually and pooled, and focal species richness, from 2004–2011 at 8 meadow transects in the North Fork Feather River and Deer Creek watersheds that have been monitored since 2004 or earlier. Abundance estimates from each transect were averaged within a year to yield estimates of yearly abundance.

In the fall of 2010, the Feather River Coordinated Resource Management team (FRCRM) implemented pond and plug restoration of the Red Clover Poco area. Pond and plug restoration is a technique in which (a) alluvial materials are excavated from the floodplain using heavy equipment, forming ponds; (b) excavated alluvial materials are used to plug incised channels; and (c) smaller dimension channels are restored to the floodplain surface. We used paired t-tests to test for differences in total avian abundance, total species richness, pooled focal species abundance, focal species richness, Song Sparrow abundance and Yellow Warbler abundance, between the pre-restoration 2010 breeding season and post-restoration 2011 breeding season at Red Clover Poco. As a control, we compared these results to the same analysis for all points at all other sites in the Red Clover watershed (referred to as Red Clover reference points in this analysis), none of which experienced restoration activities between the 2010 and 2011 breeding season.

We compared metrics of avian abundance and richness at FRCRM-restored and unrestored point count stations in the Red Clover Creek, Last Chance Creek, Spanish Creek, and Middle Fork Feather River watersheds. We used t-tests to test for differences total avian abundance, total species richness, pooled focal species abundance, and focal species richness.

We built generalized linear mixed models with a Poisson probability distribution and log link function using the package lme4 in Program R (Bates et al., 2011; R Development Core Team, 2011) to explore point-level relationships of seven separate dependent variables with meadow habitat covariates. Dependent variables included the abundances of five meadow focal species for which there were enough detections to model habitat relationships – (1) Warbling Vireo, (2) Yellow Warbler, (3) MacGillivray's Warbler, (4) Wilson's Warbler, (5) Song Sparrow; (6) the pooled abundance of all meadow focal species; and (7) the richness of meadow focal species. Unlike the analyses described above where we took the mean count over two visits for each species, for this analysis we used the maximum count for each species over the two surveys in 2011 for all individuals within 50 m of the observer. Using the mean abundance as the response variable would have required us to include non-integers in the response variable, thus violating a major assumption of Poisson regression. In addition, because detection probabilities are less than one, taking the maximum count comes closer to estimating the actual number of birds than taking the mean across multiple visits. The sample unit was a single 50-m radius point count station. We considered transect a random effect, because points were clustered into spatially dependent groups (transects), and modeled a separate intercept for each transect.

Using the vegetation variables recorded at each point count station (described above), we created a set of 36 *a priori* models which represented multiple hypotheses (Appendix 2-3). This *a priori* model set excluded conifer cover variables. We fit the entire model set (in addition to the null model) to each of the dependent variables and then ranked the models using an information theoretic approach, Akaike Information Criteria (AIC; Burnham and Anderson, 2002). Residual plots of the most parameterized models indicated that the Poisson distribution fit the data well. We fit the same model set to each dependent variable to facilitate comparison among dependent variables, even though we suspected *a priori* that particular model combinations would likely not work for all species. Models with all-significant coefficients within two AIC points of the top model were considered competitive models. For example, if there were four models within two AIC points of the top model, but three of them included an insignificant coefficient, only the one with all-significant coefficients was considered a competitive model. We then tested the hypothesis that conifer cover has an effect on focal species abundance and richness by refitting the competitive models for every dependent variable with the addition of two independent variables: the linear and quadratic forms of overstory and understory conifer tree cover.

All statistical analyses were performed in program R version 12.3.2 (R Development Core Team, 2011). The threshold level of significance for all statistical tests, unless otherwise noted, was $P = 0.05$.

Data Management and Access: Sierra Nevada Avian Monitoring Information Network

All avian data from this project is stored in the California Avian Data Center and can be accessed through the Sierra Nevada Avian Monitoring Information Network web portal (http://data.prbo.org/apps/snamin). At this site, species lists, interactive maps of study locations, as well as calculations of richness, density, and occupancy can be generated as selected by the user. Study site locations can also be downloaded in various formats for use in GPS, GIS, or online mapping applications as well. Non-avian data (e.g., site narratives, vegetation) are stored on PRBO's server and backed up off-site.

RESULTS

In 2011, we monitored 21 meadows in the northern Sierra Nevada. Among all transects, total bird abundance (individuals/point/visit) ranged from a high of 7.90 at Red Clover Demonstration to a low of 1.08 at Yellow Creek PG&E with a mean of 4.58 (95% CI: 3.77 – 5.38; Figure 2-2). Species richness (species/point/year) ranged from 8.60 at Gurnsey Creek to 1.50 at Yellow Creek PG&E, with a mean of 4.76 (95% CI: 4.01 – 5.52) across all transects. Focal species abundance ranged from a high of 4.12 at West Shore Lake Almanor (Chester Meadow) to a low of 0.00 at Yellow Creek PGE, with a mean of 2.31 (95% CI: 1.63 – 2.98) across all transects (Figure 2-3). Focal species richness ranged from a high of 3.90 at Gurnsey Creek to a low of 0.00 at Yellow Creek PG&E, with a mean of 2.01 (95% CI: 1.50 – 2.52) across all transects. There was more variation among meadows in focal species abundance and richness than total species abundance and richness, as exemplified by the widths of the 95% CIs with respect to the

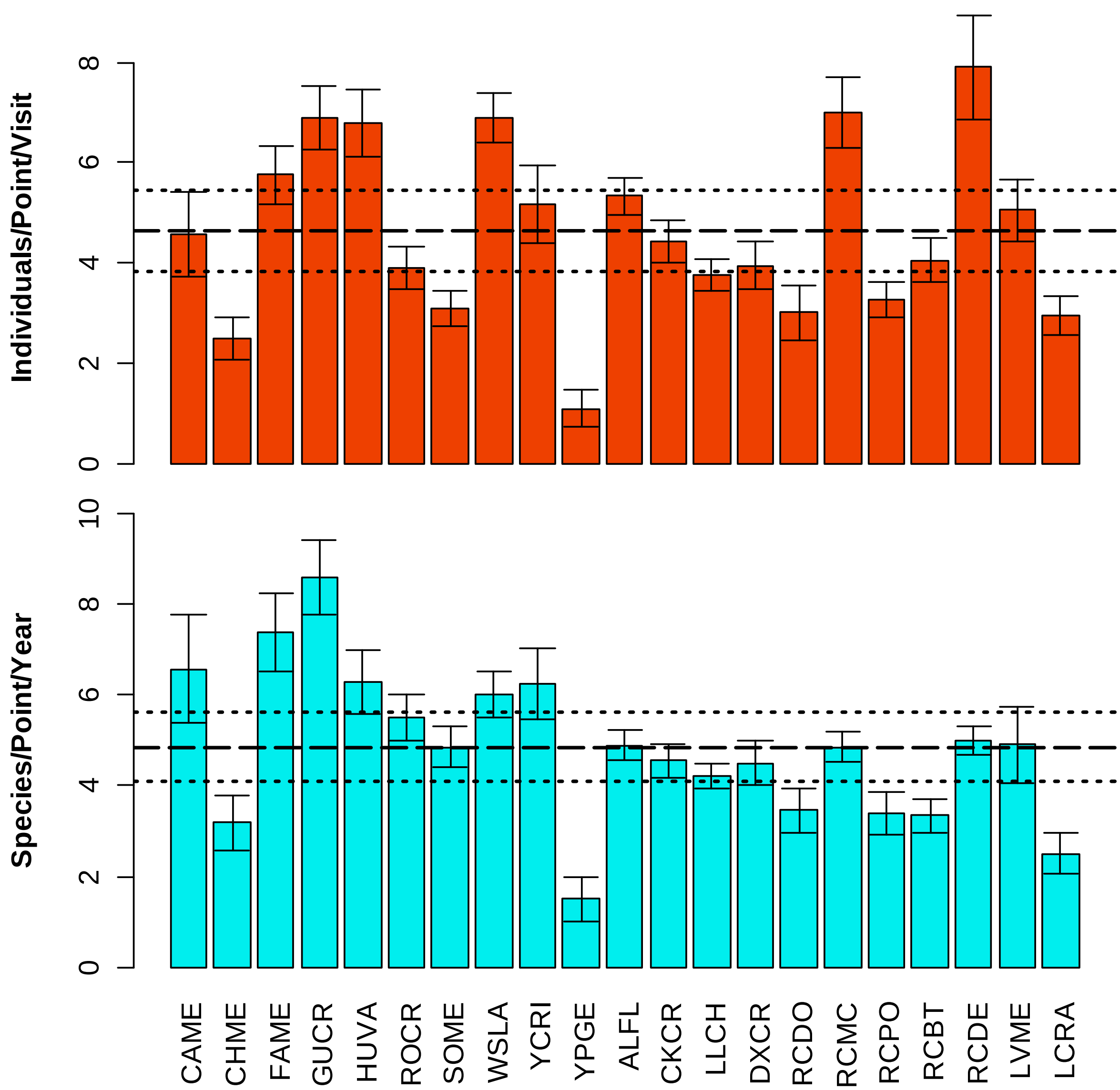


Figure 2-2. Total bird abundance (top panel) and avian species richness (bottom panel) at 21 meadow sites in the northern Sierra Nevada in 2011 (± SE). Dashed lines represent the mean for all sites combined and dotted lines the 95% confidence interval surrounding that estimate. Four-letter transect codes are defined in Table 2-1.

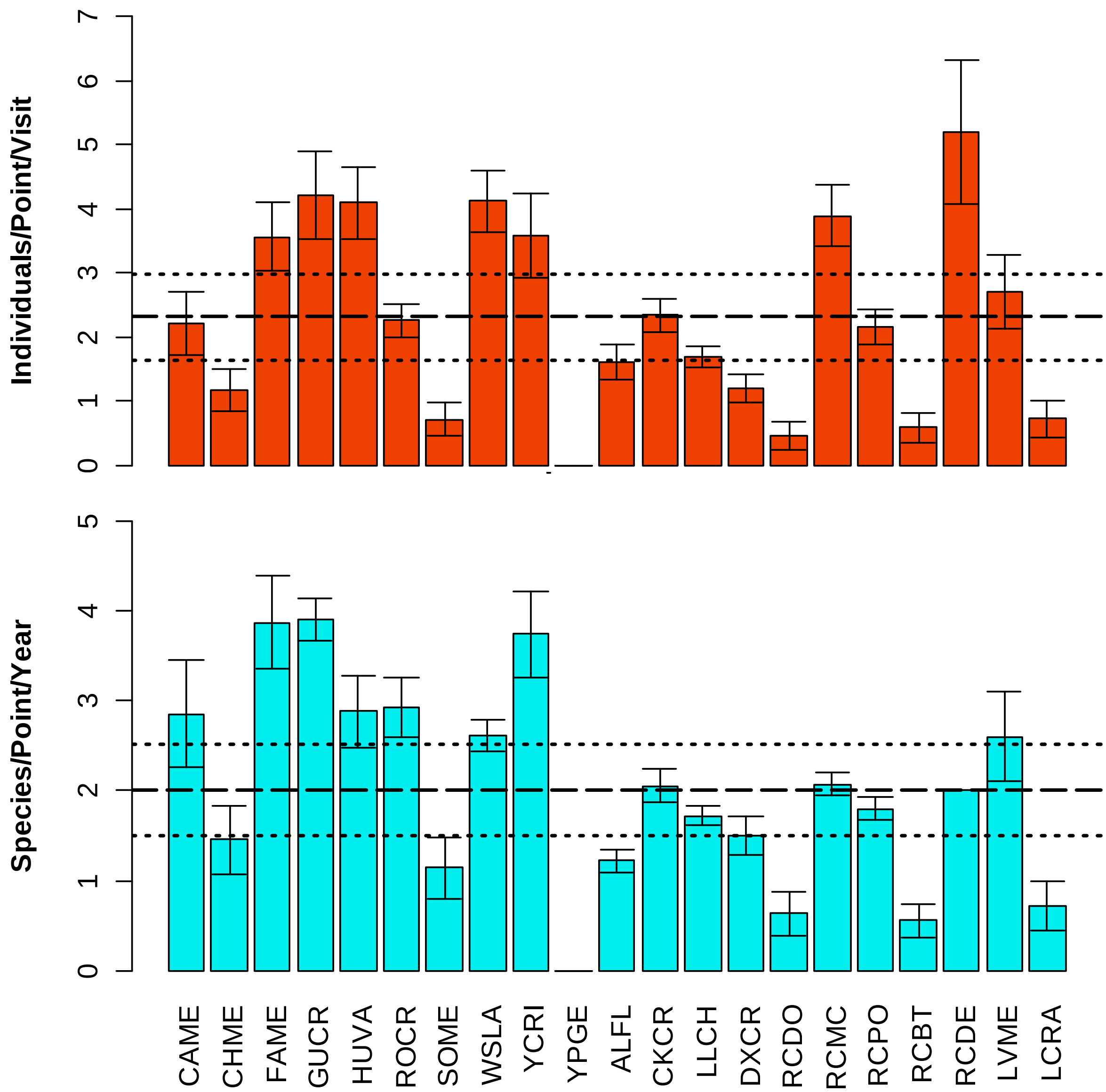


Figure 2-3. Focal species abundance (top panel) and focal species richness (bottom panel) at 21 meadow sites in the northern Sierra Nevada in 2011 (± SE). Focal species are shown in Table 2-2. Dashed lines represent the mean for all sites combined and dotted lines the 95% confidence interval surrounding that estimate. Four-letter transect codes are defined in Table 2-1.

magnitude of their means. For focal species abundance and richness, half the width of the confidence intervals comprised 29.4% and 25.2% of the magnitude of the mean estimates, respectively. Whereas, for total species abundance and richness, half the width of the confidence intervals comprised 17.7% and 15.8% of the mean estimates, respectively. The newest addition to our meadow monitoring project, Lemon Canyon Ranch, had the third lowest total bird abundance (2.94), the second lowest species richness (2.5), the fifth lowest focal species abundance (0.72), and the fourth lowest focal species richness (0.72). Song Sparrow was the most abundant species across the project, averaging 0.93 individuals/point/visit, followed by Yellow Warbler (0.77), Red-winged Blackbird (0.41), Brewer's Blackbird (0.32), and Savannah Sparrow (0.27).

Trends in focal species abundance

Trends in the abundance of individual focal species in the Deer Creek watershed and Upper North Fork Feather River watershed meadows were relatively stable between 2004 and 2011, though for many species there was marked annual variation (Figure 2-4). The only focal species with a trend in abundance significantly different than zero percent growth was Warbling Vireo, which has increased at a rate of 1.7% per year (P = 0.046). Only one Swainson's Thrush was detected within 50 m, at Fanani Meadow in 2008, so this species graph was omitted from Figure 2-4. While there was no significant trend in pooled focal species abundance (P = 0.508), the trend in pooled focal species richness was significant and increasing at 4.9% per year (P = 0.054; Figure 2-5). Notably, 2011 marked the lowest pooled focal species abundance in the meadows of Deer Creek and North Fork Feather River monitored since 2004, and mean abundances in 2011 were lower than 2010 levels for each meadow focal species.

Restoration effects at Red Clover Poco

Comparing metrics of avian abundance and richness from point count stations at Red Clover Poco and at reference locations in the Red Clover Valley suggests some immediate negative impacts on the avifauna at Red Clover Poco project area following implementation of restoration actions in August 2010 (Figure 2-6). From 2010 (pre-restoration) to 2011 (post-restoration), total bird abundance declined in the project area ($\bar{x}_{2010}$ = 4.9, $\bar{x}_{2011}$ = 3.3, t_9 = 2.213, P = 0.054), but remained stable at all other sites in the Red Clover watershed Red Clover reference points ($\bar{x}_{2010}$ = 4.6, $\bar{x}_{2011}$ = 4.8, t_{56} = -0.758, P = 0.452). While focal species abundance was stable at RCPO ($\bar{x}_{2010}$ = 2.8, $\bar{x}_{2011}$ = 2.2, t_9 = 1.378, P = 0.202), at the remainder of sites in the valley there was a significant increase ($\bar{x}_{2010}$ = 1.4, $\bar{x}_{2011}$ = 1.8, t_9 = -2.553, P = 0.013). Total species richness ($\bar{x}_{2010}$ = 5.3, $\bar{x}_{2011}$ = 3.4, t_9 = 3.353, P = 0.008) and focal species

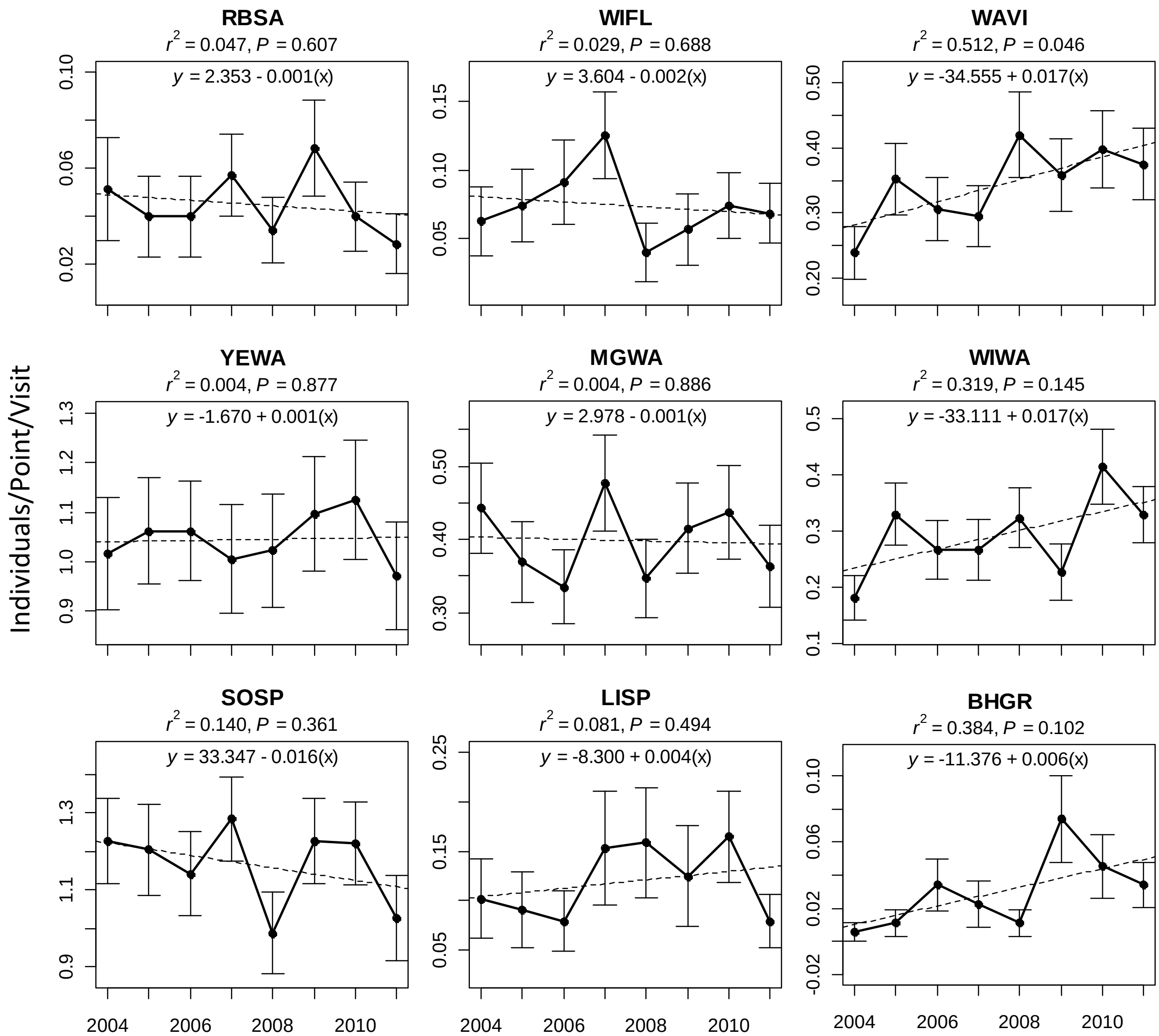


Figure 2-4. Linear trends in individual focal species abundance at 8 meadow sites in the northern Sierra Nevada from 2004 to 2011 (± SE). Dashed lines represent a fitted line through the data. Four-letter species codes are defined in Table 2-2. Note the differing scales on the y-axes.

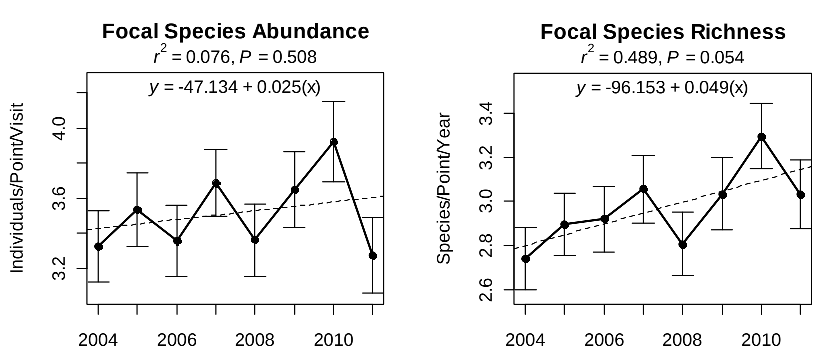


Figure 2-5. Trends in pooled focal species abundance and richness at 8 meadow sites in the northern Sierra Nevada in from 2004 to 2011 (± SE). Dashed lines represent a fitted line through the data.

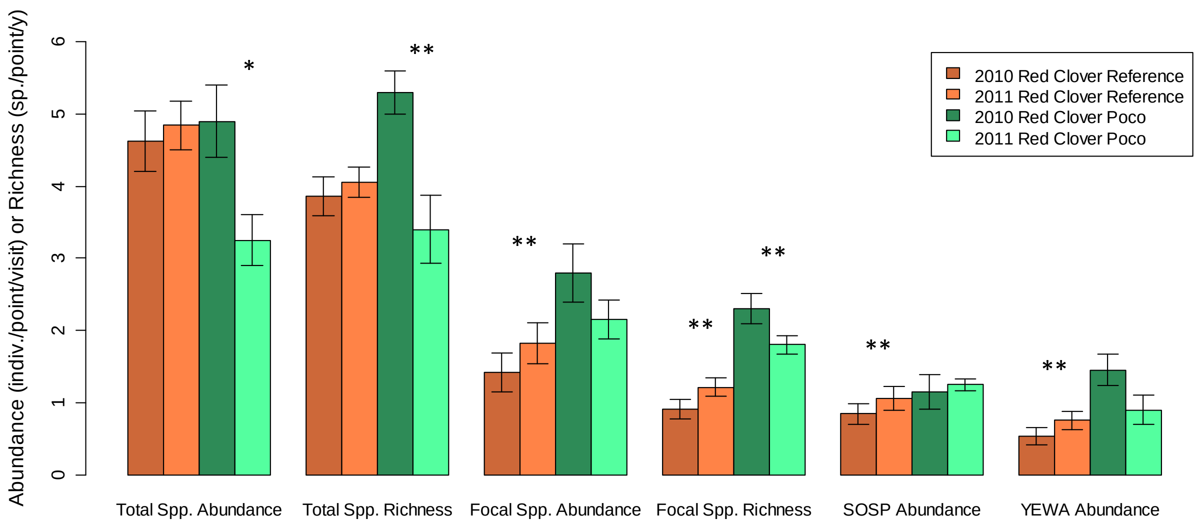


Figure 2-6. Metrics of avian abundance and richness (± SE) based on point count data from the breeding season prior to and the breeding season following fall 2010 restoration activities at Red Clover Poco, compared to all other points in the Red Clover Valley that did not experience restoration activities at that time (Red Clover Reference). Four-letter species codes defined in Table 2-2. ** Indicates a paired-*t* test statistic with a *P*-value lower than 0.05. * Indicates significance to the 0.1 level, a relaxed threshold due to the low sample size (*n* = 10 points) at Red Clover Poco.

richness ($\bar{x}_{2010}$ = 2.3, $\bar{x}_{2011}$ = 1.8, t_9 = 3.000, *P* = 0.015) both declined at RCPO, whereas at Red Clover reference points total species richness was stable ($\bar{x}_{2010}$ = 3.9, $\bar{x}_{2011}$ = 4.1, t_{56} = -0.849, *P* = 0.399) and focal species richness increased ($\bar{x}_{2010}$ = 0.9, $\bar{x}_{2011}$ = 1.2, t_{56} = -3.080, *P* = 0.003). We did not detect a difference between pre-restoration and post-restoration Song Sparrow abundance ($\bar{x}_{2010}$ = 1.2, $\bar{x}_{2011}$ = 1.3, t_9 = -0.375, *P* = 0.716) or Yellow Warbler abundance ($\bar{x}_{2010}$ = 1.5, $\bar{x}_{2011}$ = 0.9, t_9 = 1.819, *P* = 0.102) at RCPO, whereas at Red Clover reference points there was a significant increase in both species (SOSP: $\bar{x}_{2010}$ = 0.8, $\bar{x}_{2011}$ = 1.1, t_{56} = -2.155, *P* = 0.036; YEWA: $\bar{x}_{2010}$ = 0.5, $\bar{x}_{2011}$ = 0.8, t_{56} = -2.453, *P* = 0.017). Despite the short-term negative effects of restoration in the Red Clover Poco project area, we continued to see positive long-term effects of restoration at FRCRM-restored meadow sites where the riparian vegetation has had time to regenerate (Figure 2-7). Total species abundance was 41% higher at restored sites compared to unrestored sites ($\bar{x}_{restored}$ = 5.5, $\bar{x}_{unrestored}$ = 3.9, t_{98} = 4.680, *P* = <0.001). However, there was no difference in total avian species richness between restored and unrestored sites ($\bar{x}_{restored}$ = 5.5, $\bar{x}_{unrestored}$ = 5.1, t_{118} = 1.606, *P* = 0.111). Focal species

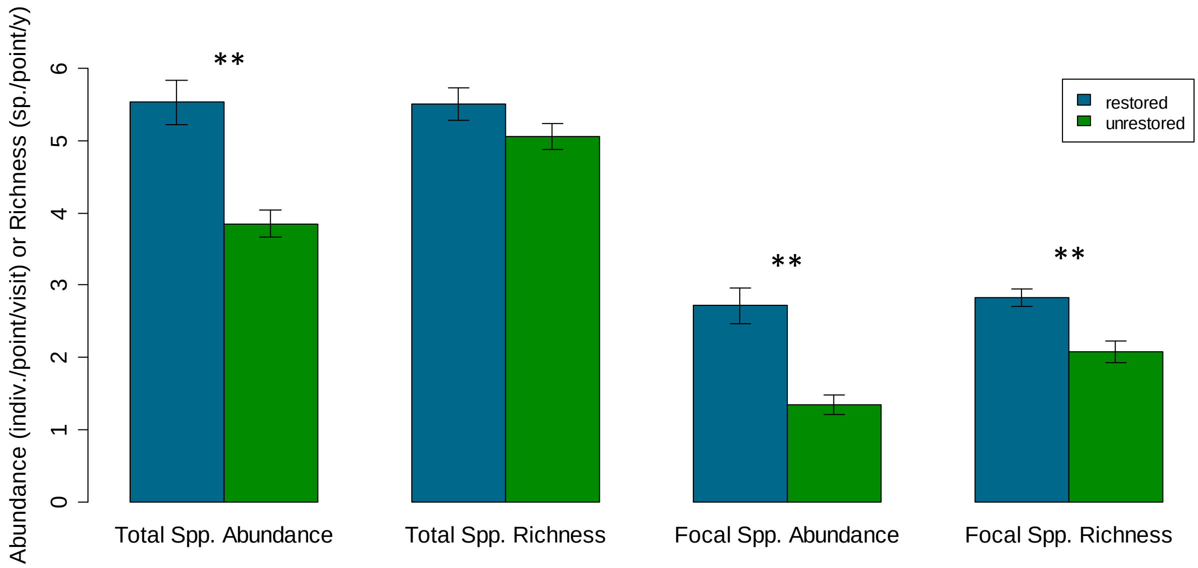


Figure 2-7. Metrics of avian abundance and richness (± SE) in 2011 at Feather River Coordinated Resource Management group restored and unrestored point count stations in the Red Clover Creek, Last Chance Creek, Spanish Creek, and Middle Fork Feather River watersheds. ** Indicates a paired-*t* test statistic with a *P*-value lower 0.05.

abundance and richness were 103% higher ($\bar{x}_{restored}$ = 2.7, $\bar{x}_{unrestored}$ = 1.3, t_{89} = 4.898, *P* = <0.001) and 36% higher ($\bar{x}_{restored}$ = 2.8, $\bar{x}_{unrestored}$ = 2.1, t_{128} = 3.766, *P* = <0.001), respectively, at restored compared to unrestored sites.

Habitat associations of focal meadow species

We used a model selection approach to assess the habitat associations of focal species in meadows in the northern Sierra Nevada. After the first step of the habitat association analysis, only one competitive model emerged for each dependent variable, except for Wilson's Warbler abundance which had two competitive models (Table 2-3). The percent cover and height of deciduous shrubs (deciduous in general and *Salix* spp. specifically) were the variables that were the most consistently correlated with focal species abundances and richness. Each of these variables appeared in six of seven competitive models and in every case they were positively correlated with the bird index (dependent variable). The number of snags was the next most prevalent variable, appearing in three of seven competitive models, again with only positive effects on avian indices. Deciduous tree and water cover were the least prevalent of

Table 2-3. Models within two AIC points of the top model for explaining habitat associations of meadow focal species in the northern Sierra Nevada in 2011 based on point count data.

Dependent Variable	Model[1]	k	Δ AIC	AIC	AIC Weight	Deviance
Focal Spp. Abundance	**+ rs.DECID + hishrubht + t.DECID + h2o**	5	0.000	304.003	0.489	292.003
	+ rs.DECID + hishrubht + t.DECID + h2o + snagsg30	6	1.527	305.530	0.228	291.530
Focal Spp. Richness	**+ rs.DECID + hishrubht + snagsg30**	4	0.000	188.841	0.324	178.841
	+ rs.DECID + hishrubht + t.DECIDUOUS **+ snagsg30**	5	0.218	189.059	0.291	177.059
	+ rs.DECID + hishrubht + h2o **+ snagsg30**	5	1.902	190.743	0.125	178.743
	+ rs.DECID + hishrubht + t.DECID + h2o **+ snagsg30**	6	1.924	190.765	0.124	176.765
WAVI	**+ hishrubht**	2	0.000	144.609	0.154	138.609
	+ hishrubht - h2o	3	0.863	145.472	0.100	137.472
	+ rs.DECID **+ hishrubht**	3	0.990	145.599	0.094	137.599
	+ rs.DECID **+ hishrubht** + t.DECID	4	1.673	146.283	0.067	136.283
	+ rs.DECID **+ hishrubht** - h2o	4	1.769	146.379	0.064	136.379
	+ hishrubht + snagsg30	3	1.785	146.394	0.063	138.394
	+ rs.SALISP **+ hishrubht**	3	1.997	146.607	0.057	138.607
YEWA	**+ rs.SALISP + hishrubht + t.DECID** + h2o	5	0.000	213.902	0.342	201.902
	+ rs.SALISP + hishrubht + t.DECID	4	0.106	214.008	0.324	204.008
	+ rs.SALISP + hishrubht + t.DECID + h2o - snagsg30	6	1.509	215.411	0.161	201.411
	+ rs.SALISP + hishrubht + t.DECID - snagsg30	5	1.619	215.521	0.152	203.521
MGWA	**+ rs.DECID + snagsg30**	3	0.000	125.064	0.268	117.064
	+ rs.DECID + t.DECID **+ snagsg30**	4	1.243	126.307	0.144	116.307
	+ rs.DECID + hishrubht **+ snagsg30**	4	1.434	126.498	0.131	116.498
	+ rs.DECID - h2o **+ snagsg30**	4	2.000	127.064	0.099	117.064
WIWA	**+ rs.DECID + hishrubht + snagsg30**	4	0.000	108.765	0.290	98.765
	+ rs.DECID + hishrubht	3	1.903	110.668	0.112	102.668
	+ rs.DECID + hishrubht - h2o **+ snagsg30**	5	1.912	110.677	0.111	98.677
	+ rs.DECID + hishrubht - t.DECID **+ snagsg30**	5	1.977	110.742	0.108	98.742
SOSP	**+ rs.SALISP + hishrubht + h2o** - snagsg30	5	0.000	225.811	0.296	213.811
	+ rs.SALISP + hishrubht + h2o	4	0.005	225.816	0.295	215.816
	+ rs.SALISP + hishrubht + t.DECID **+ h2o** - snagsg30	6	1.533	227.344	0.137	213.344
	+ rs.SALISP + hishrubht + t.DECID **+ h2o**	5	1.612	227.423	0.132	215.423

[1] The sign preceding each variable indicates the sign of the coefficient. Text in bold indicates statistically significant parameters. rs.DECID = percent cover of deciduous shrubs; rs.SALISP = percent cover of *Salix* spp.; hishrubht = high height bound of the shrub layer (see Appendix B for a detailed definition); t.DECID = percent cover of deciduous trees and tree shrubs; snagsg30 = number of snags >30 cm DBH; h2o = percent cover of surface covered by water.

the dependent variables, each appearing in two competitive models, and also with consistently positive effects.

The addition of conifer cover variables considerably improved on the competitive models' fit to the abundance data for each of the five individual focal species, but not for pooled focal species abundance or richness (Table 2-4). After the inclusion of conifer cover variables, competitive models demonstrated either a negative linear correlation with conifer cover or a correlation with an intermediate amount of conifer cover (e.g. Figure 2-8); no models

Table 2-4. The effects of the inclusion of conifer cover variables to confidence models for habitat associations of meadow focal species in the northern Sierra Nevada in 2011 based on point count data.

Dependent Variable	Model[1]	k	Δ AIC	AIC	AIC Weight	Deviance
Focal Spp. Abundance	**+ rs.DECID + hishrubht + t.DECID + h2o**	5	0.000	304.003	0.378	292.003
	+ rs.DECID + hishrubht + t.DECID + h2o - t1.CONIF	6	0.638	304.641	0.275	290.641
	+ rs.DECID + hishrubht + t.DECID + h2o + ts.CONIF	6	1.730	305.733	0.159	291.733
	+ rs.DECID + hishrubht + t.DECID + h2o + t1.CONIF - t1.CONIF^2	7	2.158	306.161	0.128	290.161
	+ rs.DECID + hishrubht + t.DECID + h2o + ts.CONIF - ts.CONIF^2	7	3.691	307.694	0.060	291.694
Focal Spp. Richness	**+ rs.DECID + hishrubht + snagsg30**	4	0.000	188.841	0.321	178.841
	+ rs.DECID + hishrubht + snagsg30 + t1.CONIF **- t1.CONIF^2**	6	0.030	188.871	0.316	174.871
	+ rs.DECID + hishrubht + snagsg30 + ts.CONIF	5	1.254	190.094	0.171	178.094
	+ rs.DECID + hishrubht + snagsg30 - t1.CONIF	5	1.988	190.829	0.119	178.829
	+ rs.DECID+ hishrubht + snagsg30 + ts.CONIF - ts.CONIF^2	6	2.955	191.796	0.073	177.796
WAVI	**+ hishrubht + t1.CONIF - t1.CONIF^2**	4	0.000	135.554	0.824	125.554
	+ hishrubht + ts.CONIF	3	4.325	139.878	0.095	131.878
	+ hishrubht + ts.CONIF - ts.CONIF^2	4	6.202	141.755	0.037	131.755
	+ hishrubht + t1.CONIF	3	6.275	141.829	0.036	133.829
	+ hishrubht	2	9.056	144.609	0.009	138.609
YEWA	**+ rs.SALISP + hishrubht + t.DECID - t1.CONIF**	5	0.000	207.793	0.659	195.793
	+ rs.SALISP + hishrubht + t.DECID - t1.CONIF - t1.CONIF^2	6	1.997	209.790	0.243	195.790
	+ rs.SALISP + hishrubht + t.DECID - ts.CONIF	5	5.132	212.925	0.051	200.925
	+ rs.SALISP + hishrubht + t.DECID	4	6.216	214.008	0.029	204.008
	+ rs.SALISP + hishrubht + t.DECID - ts.CONIF - ts.CONIF^2	6	7.131	214.924	0.019	200.924
MGWA	**+ rs.DECID + snagsg30 + ts.CONIF - ts.CONIF^2**	5	0.000	118.427	0.918	106.427
	+ rs.DECID + snagsg30	3	6.638	125.064	0.033	117.064
	+ rs.DECID + snagsg30 + ts.CONIF	4	7.479	125.906	0.022	115.906
	+ rs.DECID + snagsg30 + t1.CONIF - t1.CONIF^2	5	8.461	126.888	0.013	114.888
	+ rs.DECID + snagsg30 + t1.CONIF	4	8.487	126.913	0.013	116.913
WIWA	**+ rs.DECID** + hishrubht **+ ts.CONIF - ts.CONIF^2**	5	0.000	107.517	0.225	95.517
	+ rs.DECID + hishrubht + snagsg30 **+ ts.CONIF** - ts.CONIF^2	6	0.064	107.581	0.218	93.581
	+ rs.DECID + hishrubht + snagsg30	4	1.248	108.765	0.121	98.765
	+ rs.DECID + hishrubht + snagsg30 + ts.CONIF	5	1.704	109.221	0.096	97.221
	+ rs.DECID + hishrubht + snagsg30 + t1.CONIF	5	2.120	109.636	0.078	97.636
	+ rs.DECID + hishrubht + snagsg30 + t1.CONIF - t1.CONIF^2	6	2.522	110.039	0.064	96.039
	+ rs.DECID + hishrubht + t1.CONIF	4	2.741	110.257	0.057	100.257
	+ rs.DECID + hishrubht + ts.CONIF	4	3.007	110.523	0.050	100.523
	+ rs.DECID + hishrubht	3	3.151	110.668	0.047	102.668
	+ rs.DECID + hishrubht + t1.CONIF - t1.CONIF^2	5	3.236	110.752	0.045	98.752
SOSP	**+ rs.SALISP + hishrubht + h2o - t1.CONIF**	5	0.000	221.880	0.464	209.880
	+ rs.SALISP + hishrubht + h2o - ts.CONIF	5	1.558	223.438	0.213	211.438
	+ rs.SALISP + hishrubht + h2o - t1.CONIF - t1.CONIF^2	6	1.923	223.803	0.178	209.803
	+ rs.SALISP + hishrubht + h2o - ts.CONIF - ts.CONIF^2	6	3.517	225.397	0.080	211.397
	+ rs.SALISP + hishrubht + h2o	4	3.936	225.816	0.065	215.816

[1] The sign preceding each variable indicates the direction of the effect on each avian metric (positive or negative). Text in bold indicates statistically significant parameters. rs.DECID = percent cover of deciduous shrubs; rs.SALISP = percent cover of *Salix* spp.; hishrubht = high height bound of the shrub layer (see Appendix B for a detailed definition); t.DECID = percent cover of deciduous trees and tree shrubs; snagsg30 = number of snags >30 cm DBH; h2o = percent cover of surface covered by water; t1. CONIF = percent cover of conifer trees in the overstory; ts.CONIF = percent cover of conifer trees in the nderstory.

within two AIC points of the top model had a positive linear correlation with conifer cover. Those avian indices with a positive quadratic relationship with conifer cover were positively correlated with relatively low conifer cover, with predicted values of abundance and richness peaking between 10% and 18% conifer cover and a strong negative correlation with the higher levels of conifer cover.

Models containing both overstory and understory conifer tree cover were never within two AIC points of the top model for a single avian index, except for Song Sparrow abundance. This result supports either overstory conifer trees or understory conifer trees, but not both, as the best explanatory variable for each dependent variable. The abundances of Yellow Warbler and Song Sparrow, the two species with negative linear relationships with conifer cover, were best explained by overstory conifer tree cover. The best models for MacGillivray's and Wilson's Warbler, which tend forage very low in the vegetative strata, contained a quadratic relationship with understory conifer tree cover, demonstrating peak abundances with an intermediate amount of understory conifer tree cover. The best model for Warbling Vireo, which tends to forage high in the vegetative strata, contained a quadratic relationship with overstory conifer cover, demonstrating peak abundances with an intermediate cover of overstory conifers. Though conifer cover variables did not significantly improve on the confidence model for focal species richness, the relationship between focal species richness and the quadratic form of overstory conifer cover was nearly significant and the model containing this variable was ranked nearly as high as the model without it. Conifer cover did not explain a significant amount of the variation in pooled focal species abundance.

Figure 2-8 provides a representative example of the relationships of the indices of bird abundance and richness with deciduous shrub cover and a quadratic relationship with conifer cover. The effect of the independent variables in each model depends on the values of the other variables. In figure 2-8, all variables in the top model for species richness that contained conifer cover were held constant, except where allowed to vary according to the x-axes in each panel of the figure. In this example, we simulated "diverse" meadow habitat with deciduous shrub cover of 40%, high shrub height of 6 m, 15 snags per 50 m radius, and 5% overstory

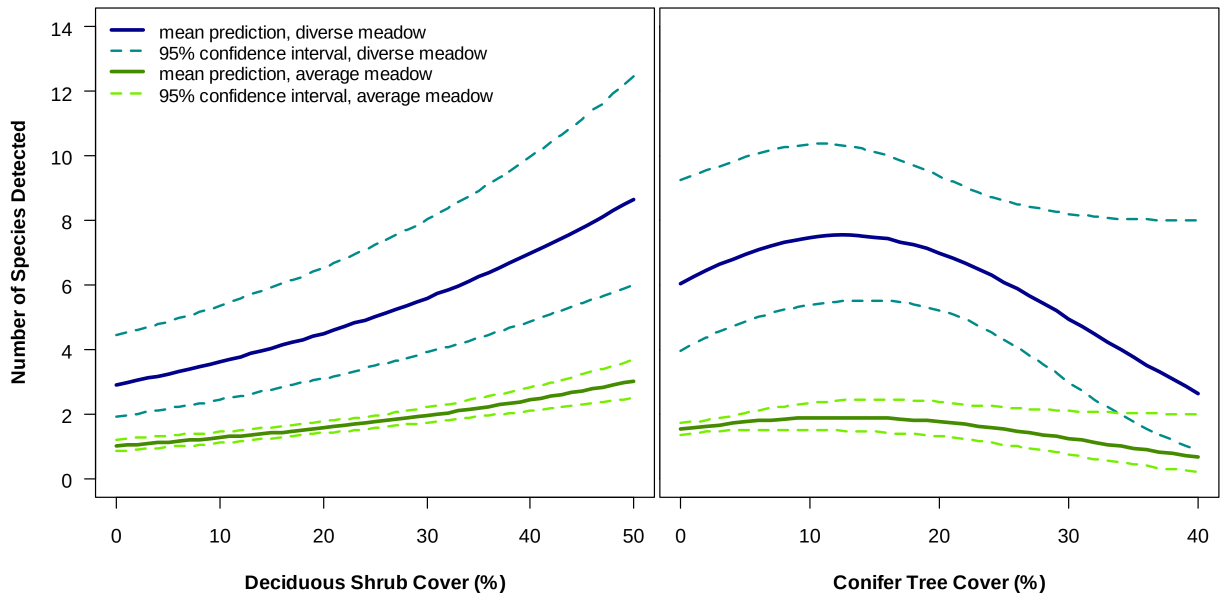


Figure 2-8. The predicted relationships of deciduous shrub cover and overstory conifer tree cover with focal species richness for simulated "diverse" and "average" meadow habitats in the northern Sierra Nevada in 2011. Relationships were predicted using the highest ranking model that included conifer cover (see Table2-4). Except where allowed to vary according to the x-axes in the figure, the following variables were held constant for diverse and average meadow habitats, respectively: rs.DECID at 40 and 20, hishrubht at 6 and 3, snagsg30 at 15 and 1, and t1.CONIF at 5 and 1.

conifer cover. We simulated the "average" meadow with deciduous shrub cover of 20%, high shrub height of 3 m, 1 snag per 50 m radius, and 1% overstory conifer cover. In this example, the effects of deciduous shrub cover and overstory conifer tree cover on focal species richness are much more pronounced at points where the shrubs are taller, there are more snags, and there is more conifer cover than points where shrubs are half the height, there are far fewer snags, and very little conifer cover.

DISCUSSION

Meadows monitored in this project range widely in their health, from highly functional and productive to severely degraded and dysfunctional, as evidenced by the riparian bird community they support. Several patterns emerged when evaluating avian indices across sites. Meadows with higher indices have greater willow and other deciduous shrub cover, and are wetter with regular flood plain inundation. These patterns are further supported by our analysis of habitat associations, which showed riparian deciduous shrub cover to be the primary driver of avian richness and the abundance of the majority of focal bird species across meadow sites. Meadow focal species indices appear to be rather stable across these sites in the last eight years. Our results also continue to show a large discrepancy between restored and unrestored reaches along Red Clover Creek, although we did find significant decreases in avian indices in the Poco project area from one year before restoration to one year after.

Restoration

Our results continue to show that meadow sites restored by the Feather River CRM support greater avian diversity and abundance than unrestored reaches of the same streams. The McReynolds and Demonstration project area have the greatest abundance of birds of the meadows we monitored in 2011 in the Northern Sierra. The decrease in meadow bird indices within the Red Clover Poco project area following restoration is likely attributable to several factors. The Poco reach of Red Clover Creek had a rather wide (about 10 m) inset floodplain supporting greater willow cover than previously restored sections of Red Clover Creek. Thus, it supported a more diverse and abundant bird community prior to restoration than other reaches of the creek (e.g. Dotta, Dixie Creek, Beartooth). Poco is also the first FRCRM project we have monitored in the first year following restoration.

We had originally hypothesized the benefits to birds of plug and pond restoration would take a number of years to manifest while the riparian vegetation regenerates. Riparian vegetation is as or more important to birds as floodplain function. Using the restored reaches in Red Clover that have had a chance to mature as evidence, it is likely that the similarly constructed and functioning Poco project area will support greater avian diversity and abundance five-to-ten years post-restoration than before restoration. While decisions on prioritizing restoration projects are complex, this does illustrate that when using plug and pond technique restoring the most degraded reaches (e.g. Dotta, Beartooth, Yellow Creek PG&E) will likely have the greatest net benefit to meadow birds. With limited resources available for restoration, using birds to help prioritize plug-and-pond restoration in the Sierra Nevada can be a useful tool for maximizing benefits of limited conservation dollars.

Several other restored meadows, including Soldier Meadow in the Upper North Fork Feather River watershed and Alkali Flat in the Last Chance Creek watershed, lag behind the “average” meadow in riparian bird habitat. While floodplain function has been restored at both of these sites, the lack of vegetative structural diversity and complexity are limiting the abundance and diversity of riparian birds at these sites. Additional actions such as willow planting and potentially a reduction in grazing pressure within the riparian pasture at Alkali Flat would increase the value of these sites for birds and increase the benefits of floodplain restoration.

In several meadows where floodplain function is fairly intact, past and current grazing pressure appear to be limiting the value of these sites to the full complement of meadow dependent bird species. These sites lack deciduous woody vegetation, the nesting and foraging substrate for most montane riparian birds. Hence many of our focal meadow bird species simply do not occupy such meadows. Both Lemon Canyon Ranch and Child’s Meadow have historically been heavily grazed. Though the current owners of these properties have reduced grazing pressure considerably in recent years and are employing fencing to control grazing, a period of rest coupled with substantial willow planting efforts at both of these sites could dramatically improve the quality of the riparian bird habitat. Several thousand willows were planted at Lemon Canyon Ranch in spring 2011 and the pasture containing Lemon Creek is being rested from grazing. Riparian bird habitat may be improved by reducing grazing pressure in the other pastures with stream channels at Lemon Canyon Ranch and with additional willow planting. Our baseline surveys in 2011 coupled with long term monitoring of this site will help us evaluate the effectiveness of willow planting and rest from grazing.

Based on long-term monitoring of the Forest Service-owned reach of Gurnsey Creek downstream from the Child’s Meadow property, we are confident that efforts to fence off the lower third of Child’s Meadow to release it from grazing pressure will improve riparian bird habitat. We also recommend willow planting to expedite the creation of meadow bird habitat by a decade or more. Fencing along the stream corridor for the length of the property in conjunction with additional infrastructure to provide off-stream water should be considered if current grazing levels will continue. The discovery of breeding Cascade frogs on this property in 2011 and the continued presence of several Willow Flycatcher increase the conservation value of this site. Future management decisions should be accordant with best-management practices for these special status species.

Trends

In the meadows of the Deer Creek and Upper North Fork Feather River watersheds, trends in focal species' metrics from 2004 to 2011 indicate relatively stable avian populations. Only focal species richness and Warbling Vireo abundance showed significant linear trends, both of which were positive. An increase in structural complexity may explain the increase in focal species richness at these sites. Structurally complex habitats may provide more niches and diverse ways of exploiting the environmental resources and thus increase species diversity (Bazzaz, 1975). Because all of the sites in the trends analysis have not experienced a major disturbance since they were restored and/or rested from grazing before our monitoring began, many of the habitat attributes that drive meadow bird richness (e.g. willow cover and height) have likely increased since 2004, thereby creating more available habitat in both horizontal and vertical space. While it is clear that these meadows support a richer and more abundant meadow bird community than they did prior to restoration, we believe they still have the potential to provide even higher quality habitat. Relatively modest restoration actions, such as the removal of encroaching conifers to increase growing space for riparian deciduous shrubs at Robber's Creek and planting riparian deciduous shrubs in Swain Meadow, Humbug Valley, West Shore Lake Almanor, and Soldier Meadow, should improve habitat. Additionally, head cuts forming along Robber's Creek and Humbug Creek should be evaluated as they may result in further degradation of these sites, potentially even reversing gains in habitat realized by the removal or reduction in grazing pressure.

Habitat Associations

Our analysis of focal species' relationships with meadow habitats revealed several habitat attributes of importance to the avifauna at the 50-m point-count-station scale. The volume of deciduous shrub cover (i.e. cover and height) was the single most important factor for individual and pooled focal species abundance and focal species richness. This concurs with the hypothesis that birds choose to nest in patches of habitat with more potential nest sites (Martin and Roper, 1988; Steele, 1993). Deciduous shrubs provide nesting substrate and cover for all of the focal species in the habitat relationships analysis except Warbling Vireo, which was the only species whose abundance did not correlate with deciduous shrub cover. Deciduous shrubs are also an important reservoir of insect prey in conifer-dominated forested landscapes (Werner, 1983; Willson and Comet, 1996; Hagar et al., 2007). While deciduous shrubs in general were the best predictors for most of the focal species and focal species as a whole, Yellow Warblers and Song Sparrows were more closely tied to the willow (*Salix* spp.) component of the deciduous shrub layer. Re-establishing or enhancing a riparian deciduous shrub component in meadows should be among the top priorities of meadow managers and restoration practitioners to benefit birds in the Sierra Nevada. Our data suggests that species richness continues to increase as shrub cover exceeds 50% of a 50-m radius. Managing for dense clumps of riparian shrubs interspersed with openings would provide habitat for the greatest number of species and total abundance of meadow dependent birds.

The number of snags was also an important predictor of meadow focal species richness. There was a tight correlation (0.88) between the number of snags and the meters of logs at a site. Because snags fall to create logs, where the conditions to create snags exist, snags and logs both tend to be plentiful. We decided to use snags in this analysis because of the higher visibility and applicability of snags to forest management. However, it is possible that logs are as important as snags or more important than snags to focal species' abundance and richness. Except for Red-breasted Sapsucker, which will excavate cavities in snags, generally none of the meadow focal species use snags or logs directly for nesting. However, many of the focal species use snags for foraging or as singing perches, and logs create on- and off-channel pools that can increase soil moisture, habitat heterogeneity, and prey abundance.

Our results supported the hypothesis that conifer cover is correlated with focal species abundance and richness. Adding variables for percent conifer cover to confidence models generally improved model fit for individual focal species compared to when conifer cover was excluded. Conifer cover was generally more important for explaining species-level variation than community-level variation (i.e. pooled focal species abundance and focal species richness). Focal species' relationships with conifer cover were less consistent among species than all of the other independent variables. Among individual focal species, relationships with conifer cover varied from negative linear to positive quadratic. The variation in relationships with conifer cover could reflect niche partitioning through the selection of different successional states of meadows, or selection for different meadow widths. In other words, some of the variation that is explained by conifer cover may also be explained by meadow width, with narrower meadows having more upland forest within 50 m of a point count station. While we were not able to include meadow width in this analysis, we hope to investigate this relationship in future analyses. Despite the variation in selection for the lower levels of percent conifer cover, all avian metrics were negatively correlated with conifer cover greater than 15-18% at the 50-m scale. Accordingly, we recommend that managers remove encroaching conifers when the combined percent cover of overstory and understory conifer trees in a meadow exceeds 15% or where they are clearly reducing other important meadow attributes (e.g. willow vigor, soil moisture).

CONCLUSIONS

Results from 2011 monitoring in meadows of the northern Sierra Nevada continue to suggest that ecologically functional meadows with extensive deciduous riparian shrubs harbor meadow-dependent breeding birds, whereas ecologically dysfunctional meadows harbor few to none. The process of meadow desiccation and conversion through channel down cutting that is rampant throughout Sierra meadows is of major concern for conservation of meadow-dependent birds. A positive trend in the richness of meadow-dependent bird species at restored and/or rested sties that we have monitored since 2004 indicates that the benefits of restoration or release from grazing continue to accrue as woody meadow vegetation regenerates. In addition to providing habitat for birds, fish, and other wildlife, functional meadows offer a suite of valuable ecosystem services that are disproportionate to the <1% of the Sierra Nevada landscape that meadows comprise. Because so many of the wet meadows in the Sierra Nevada have been degraded over the past century to the point that they no longer provide such services, meadow restoration and conservation should be among the highest priorities of land managers in the region.

Avian monitoring is a cost-effective medium through which to guide ecological restoration, and meadows are arguably the single most important habitat for birds in the Sierra Nevada. Hence, avian monitoring and the management recommendations generated from it should be viewed as an integral tool to achieving successful meadow management in the Sierra Nevada. Working together to restore this small fraction of the Sierra Nevada landscape, the U.S. Forest Service, local government agencies (e.g. Feather River Coordinated Resource Management Group) and non-profit organizations (e.g. The Nature Conservancy, Feather River Land Trust, PRBO Conservation Science) have the opportunity to make profound positive impacts on bird populations and society alike.

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MANAGEMENT RECOMMENDATIONS

Management recommendations are updated annually and are based on the result of our monitoring, current literature, and expert opinion from our collective 16 years of studying meadow birds in the Sierra Nevada.

- Make meadow restoration a high priority on public and private lands.
- Restore and/or preserve floodplain connectivity and promote wet meadow conditions.
- Prioritize management and restoration resources on meadows that will support a riparian deciduous plant community.
- Promote deciduous shrubs and trees in meadow habitats. Deciduous woody vegetation is the primary driver of avian abundance and richness in Sierra Nevada meadows.
- Promote dense and tall herbaceous plant community dominated by sedges and rushes.
- Carefully track impacts of grazing and adjust when important riparian resources (such as those listed above) are being compromised.
- If the primary goal is managing for meadow birds, including restoring endangered Willow Flycatcher populations, consider removal of grazing to lessen impacts from Brown-headed Cowbird and deleterious effects of grazing on habitat quality for this species.
- Use fencing to regulate livestock pressure near stream channels in meadows. Replace riparian watering sources with watering stations in upland habitats. Fencing width should be based on meadow size but 50m would be considered a minimum exclusion.
- Retain snags wherever they are present. Snags provide forage and nesting substrates for birds. Large woody debris can contribute to raising water tables and promoting habitat complexity.
- Reduce open water in active floodplain by creating deeper or more linear ponds and including islands – where feasible place ponds away from the active channel where the highest quality meadow bird habitat is likely to exist.
- Create gentle slopes on pond edges to enhance ecotones that promote small mudflat conditions that provide habitat for shorebirds (e.g. spotted sandpiper) and unique transitional wetland/meadow plant communities.

- Consider conifer removal when >15% of a meadow is covered by conifers. The abundances of all meadow-dependent bird species are negatively correlated with conifer cover >15%.
- Monitor avian communities and other important resources in meadows as part of an adaptive management strategy.

LITERATURE CITED

Allen-Diaz, B.H., 1991. Water table and plant species relationships in Sierra Nevada meadows. American Midland Naturalist 126, 30–43.

Bates, D., Maechler, M., Bolker, B., 2011. lme4: Linear mixed-effects models using S4 classes, R package version 0.999375-42.

Bazzaz, F.A., 1975. Plant species diversity in old-field successional ecosystems in southern Illinois. Ecology 485–488.

Briske, D.D., Bestelmeyer, B.T., Stringham, T.K., Shaver, P.L., 2008. Recommendations for development of resilience-based state-and-transition models. Rangeland Ecology & Management 61, 359–367.

Burnett, R.D., Humple, D.L., 2003. Songbird monitoring in the Lassen National Forest: Results from the 2002 field season with summaries of 6 years of data (1997-2002) (Report to the U.S. Forest Service). PRBO Conservation Science, Petaluma, CA.

Burnett, R.D., Humple, D.L., Gardali, T., Rogner, M., 2005. Avian Monitoring in the Lassen National Forest: 2004 Annual Report (Report to the U.S. Forest Service). PRBO Conservation Science, Petaluma, CA.

Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference a Practical Information-Theoretic Approach, 2nd ed. Springer, New York, New York, USA.

Castelli, R.M., Chambers, J.C., Tausch, R.J., 2000. Soil-plant relations along a soil-water gradient in Great Basin riparian meadows. Wetlands 20, 251–266.

Chambers, J.C., Tausch, R.J., Korfmocher, J.L., Germanoski, D., Miller, J.R., Jewett, D., 2004. Effects of geomorphic processes and hydrologic regimes on riparian vegetation, in: Chambers, J.C., Miller, J.R. (Eds.), Great Basin Riparian Areas: Ecology, Management, and Restoration. Island Press, Washington, D.C.

Chase, M.K., Geupel, G.R., 2005. The use of avian focal species for conservation planning in California, in: Ralph, C.J., Rich, T.D. (Eds.), Bird Conservation Implementation and Integration in the Americas: Proceedings of the Third International Partners in Flight Conference. 2002 March 20-24; Asilomar, California, General Technical Report PSW-

GTR-191. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA, pp. 130–142.

DeLaney, T.A., 1995. Benefits to downstream flood attenuation and water quality as a result of constructed wetlands in agricultural landscapes. Journal of Soil and Water Conservation 50, 620–626.

Graber, G.D., 1996. Status of Terrestrial Vertebrates, in: Sierra Nevada Ecosystems Project: Final Report to Congress. Davis: University of California, Centers for Water and Wildland Resources, pp. 709–734.

Hagar, J.C., Dugger, K.M., Starkey, E.E., 2007. Arthropod prey of Wilson's Warblers in the understory of Douglas-fir forests. The Wilson Journal of Ornithology 119, 533–546.

Hammersmark, C.T., Rains, M.C., Mount, J.F., 2008. Quantifying the hydrological effects of stream restoration in a montane meadow, northern California, USA. River Research and Applications 24, 735–753.

Johnson, D.H., 2008. In defense of indices: The case of bird surveys. The Journal of Wildlife Management 72, 857–868.

Kattlemann, R., Embury, M., 1996. Riparian Areas and Wetlands, in: Sierra Nevada Ecosystems Project: Final Report to Congress. University of California, Centers for Water and Wildland Resources, Davis.

Knapp, R.A., Matthews, K.R., 1996. Livestock grazing, golden trout, and streams in the Golden Trout Wilderness, California: impacts and management implications. North American Journal of Fisheries Management 16, 805–820.

Kondolf, G.M., Kattlemann, R., Embury, M., Erman, D.C., 1996. Status of Riparian Habitat, in: Sierra Nevada Ecosystems Project: Final Report to Congress. University of California, Centers for Water and Wildland Resources, Davis, CA.

Krueper, D., Bart, J., Rich, T.D., 2003. Response of vegetation and breeding birds to the removal of cattle on the San Pedro River, Arizona (U.S.A.). Conservation Biology 17, 607–615.

Lack, D., 1969. The numbers of bird species on islands. Bird Study 16, 193–209.

MacArthur, R.H., Wilson, E.O., 1967. The Theory of Island Biogeography. Princeton University Press, Princeton.

Martin, T.E., Roper, J.J., 1988. Nest predation and nest-site selection of a western population of the Hermit Thrush. Condor 90, 51–57.

Micheli, E.R., Kirchner, J.W., 2002. Effects of wet meadow riparian vegetation on streambank erosion. 1. Remote sensing measurements of streambank migration and erodibility. Earth Surface Processes and Landforms 27, 627–639.

Povirk, K.L., Welker, J.M., Vance, G.E., 2001. Carbon Sequestration in Arctic and Alpine Tundra and Mountain Meadow Ecosystems, in: Follett, R.F., Kimble, J.M., Lal, R. (Eds.), The Potential of U.S. Grazing Lands to Sequester Carbon and Mitigate the Greenhouse Effect. CRC Press, Boca Raton, Florida, p. 442.

R Development Core Team, 2011. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria.

Ralph, C.J., Droege, S., Sauer, J.R., 1995. Managing and monitoring birds using point counts: Standards and applications, in: Ralph, C.J., Sauer, J.R., Droege, S. (Eds.), Monitoring Bird Populations by Point Counts, General Technical Report PSW-GTR-149. U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, Albany, CA, pp. 161–169.

Ratliff, R.D., 1985. Meadows in the Sierra Nevada of California: State of knowledge (General Technical Report No. PSW-84). Pacific Southwest Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, Berkeley, CA.

Reynolds, R.T., Scott, J.M., Nussbaum, R.A., 1980. A variable circular-plot method for estimating bird numbers. Condor 82, 309–313.

Sarr, D.A., 2002. Riparian livestock exclosure research in the western United States: A critique and some recommendations. Environmental Management 30, 516–526.

Siegel, R.B., DeSante, D.F., 1999. The draft avian conservation plan for the Sierra Nevada bioregion: Conservation priorities and strategies for safeguarding Sierra bird populations (No. Version 1.0), Institute for Bird Populations report to California Partners in Flight.

Simpson, E.H., 1949. Measurement of diversity. Nature 163, 688–688.

Steele, B.B., 1993. Selection of foraging and nesting sites by Black-Throated Blue Warblers: Their relative influence on habitat choice. The Condor 95, 568–579.

Torrell, L.A., Fowler, J.M., Kincaid, M.E., Hawkes, J.M., 1996. The importance of public lands to livestock production in the U.S. (No. 32), Range Improvement Task Force. New Mexico State University, Las Cruces.

Werner, R.A., 1983. Biomass, density, and nutrient content of plant arthropods in the taiga of Alaska. Canadian Journal of Forest Research 13, 729–739.

Willson, M.F., Comet, T.A., 1996. Bird Communities of Northern Forests: Ecological Correlates of Diversity and Abundance in the Understory. The Condor 98, 350–362.

Woltemade, C.J., 2000. Ability of restored wetlands to reduce nitrogen and phosphorus concentrations in agricultural drainage water. Journal of Soil and Water Conservation 55, 303–309.

APPENDICES

Appendix 2-1. Protocol for habitat assessment at point count stations.

All data is collected within a 50-m radius circle centered on the point count station.

General Information
State: The state you are standing in.
Station: 4 letter code of the point count transect (e.g., GUCR)
Point #: The actual point number of the point count along the transect.
Date: The date you are collecting the data
Initials: The three-letter initials for all observers aiding in data collection.
Habitat 1: General classifications. For example, Wet Meadow, Mixed Conifer Forest, Mixed Conifer Pine, Mixed Conifer Aspen, Aspen, Riparian, Riparian Aspen, Riparian.
Hab1%: An estimate of the percentage of the plot occupied by habitat 1.
Habitat 2: Only record this if there is a distinct habitat edge (i.e., point is bisected by a clear cut or forest edge).
Hab2%: An estimate of the percentage of the plot occupied by habitat 2.
Aspect: The direction of the slope given in degrees (the direction a drop of water would flow if poured onto the point). Collect magnetic direction.
Slope: The average slope of the plot with 90 degrees being vertical and 0 degrees being flat. 45 degrees is a 1:1 slope and is about as steep as you can walk up.
Water: True or false, for the presence of running and standing water on the plot.
Snags >60cm: The total number of snags >60 cm DBH.
Snags 30-60: The total number of snags between >30 and 60 cm DBH (see above for more details).
Snags 10-30: Total number of the snags in the plot between >10 and 30 cm DBH (this includes things that still have dead branches on it but it must be appear to be completely dead, leaning snags that are uprooted but not on the ground or almost on the ground count).

Cover Layers
These are divided up into 4 layers (Tree, Tree Shrub, Real Shrub, and Herbaceous). For each layer estimate the percentage of the plot covered by all vegetation in that layer.

The Tree Shrub Layer is all tree species that are less than 5 meters tall. This means a 25 cm tall white fir counts in this category. Tree species are the conifers, black oak, maple, white alder, canyon oak, etc.

Real Shrubs Layer are the true shrub species as well as a few shrubby trees that rarely get above 5 meters tall (Dogwood, Mountain Alder, Manzanita, Willow, Ceanothus, Artemisia, etc.). Record the total cover of these species regardless of height. Note that real shrubs over 5 m high are counted in the Tree Layer and the Real Shrub Layer.

The Herbaceous Layer is all non-woody vegetation, regardless of height.
Note that although the maximum cover is 100% for each of these categories but that is rarely achieved. The sum of the total percent cover for all the layers can be over or less than 100%

Appendix 2-1. Protocol for habitat assessment at point count stations (continued).

Height Bounds

Low: An estimate, to the nearest 0.5 meter, of the average height of the bottom quartile of heights for the lowest living foliage in that layer. This is done for the tree and aspen layers only. In other words, of the lowest 25% of living foliage in the plot, what is the average height?

High: An estimate, to the nearest 0.5 meter, of the average height of the top quartile of heights for all plants in each vegetation layer (tree, tree shrub, real shrub). This is not the height of the absolute tallest outlier in that layer. In other words, of the tallest 25% of trees in the plot what is the average height?
Low and High Species: Record the plant species that dominates the low and high height quartiles that were averaged.

Max DBH: The diameter at breast height (at 4.5 feet or 1.4 meters) of the largest tree in the plot, and the species of that tree. If the tree is on a slope or the trunk is on greatly uneven ground, stand on the side of the tree with the highest ground when measuring the DBH.

Cover by Species

Record these as T1 (tree layer), TS (true shrub), RS (real shrub), and H1 (herbaceous).
Record, for each of these layers, the % each species comprises of the total cover for that layer (this number should add up to 100% regardless of the % total cover). List as many species as can easily be recorded in a timely manner. Chasing down that lone shrub off in the corner of the plot is not worth the effort. For the herbaceous layer, determine relative abundance by the following 3 categories: 1) grass, 2) sedges and rushes, and, 3) forbs.

Last Section, Various Info

Riparian width: The average width of the riparian zone (think of this as the green ribbon that is a unique habitat type from the surrounding upland. It does not have to have willows. However areas with heavy sagebrush encroachment that no longer support riparian plants (sedges, rushes, etc.) should not be counted.

Average willow low height: An estimate, to the nearest 10 cm, of the average height of the bottom quartile of heights for the lowest living foliage of the willows.

Standing and running water: Estimate the percent of plot covered by standing water and running water. A 4-m wide stream running straight through the plot center comprises about 5% of the entire plot.
Photos taken: Take photos in all four magnetic cardinal directions. Write on the corner of a piece of paper or a whiteboard the station, point number and direction of the photo. Hold this photo label up in the corner of the photo at arm's length away from the camera when taking each photo. Check the box once photos have been taken in all four magnetic cardinal directions.

Appendix 2-2. List of species excluded from all meadow analyses.

American Bittern	Long-billed Curlew	Townsend's Warbler
American Coot	Mallard	Tree Swallow
American Kestrel	Northern Goshawk	Turkey Vulture
American White Pelican	Northern Harrier	Vaux's Swift
Bald Eagle	Northern Pintail	Violet-green Swallow
Bank Swallow	Northern Pygmy-Owl	Virginia Rail
Barn Swallow	Northern Rough-winged Swallow	Western Grebe
Black-crowned Night-Heron	Northern Shoveler	White-faced Ibis
Brown-headed Cowbird	Orange-crowned Warbler	Willet
Bufflehead	Osprey	Wilson's Phalarope
Canada Goose	Pied-billed Grebe	Wilson's Snipe
California Gull	Peregrine Falcon	Wood Duck
Cinnamon Teal	Prairie Falcon	Unid. Blackbird
Cliff Swallow	Ring-billed Gull	Unid. Empidonax Flycatcher
Cooper's Hawk	Red-shouldered Hawk	Unid. Finch
Double-crested Cormorant	Red-tailed Hawk	Unid. Tyrant Flycatcher
Eurasian Collared-Dove	Ruddy Duck	Unid. Hawk
European Starling	Rufous Hummingbird	Unid. Hummingbird
Forster's Tern	Sandhill Crane	Unid. Rail
Gadwall	Sora	Unid. Sapsucker
Great Blue Heron	Spotted Sandpiper	Unid. Sparrow
Great Egret	Sharp-shinned Hawk	Unid. Woodpecker
Green-winged Teal	Swainson's Hawk	Unid. Bird

Appendix 2-3. List of models in the *a priori* set of models used to assess habitat associations of focal meadow species.

1 (null model)
Hishrubht
hishrubht + h2o
hishrubht + snagsg30
hishrubht + snagsg30 + h2o
rs.SALISP
rs.SALISP + h2o
rs.SALISP + t.DECIDUOUS
rs.SALISP + t.DECIDUOUS + h2o
rs.SALISP + hishrubht
rs.SALISP + hishrubht + h2o
rs.SALISP + hishrubht + t.DECIDUOUS
rs.SALISP + hishrubht + t.DECIDUOUS + h2o
rs.DECIDUOUS
rs.DECIDUOUS + h2o
rs.DECIDUOUS + t.DECIDUOUS
rs.DECIDUOUS + t.DECIDUOUS + h2o
rs.DECIDUOUS + hishrubht
rs.DECIDUOUS + hishrubht + h2o
rs.DECIDUOUS + hishrubht + t.DECIDUOUS
rs.DECIDUOUS + hishrubht + t.DECIDUOUS + h2o
rs.SALISP + snagsg30
rs.SALISP + h2o + snagsg30
rs.SALISP + t.DECIDUOUS + snagsg30
rs.SALISP + t.DECIDUOUS + h2o + snagsg30
rs.SALISP + hishrubht + snagsg30
rs.SALISP + hishrubht + h2o + snagsg30
rs.SALISP + hishrubht + t.DECIDUOUS + snagsg30
rs.SALISP + hishrubht + t.DECIDUOUS + h2o + snagsg30
rs.DECIDUOUS + snagsg30
rs.DECIDUOUS + h2o + snagsg30
rs.DECIDUOUS + t.DECIDUOUS + snagsg30
rs.DECIDUOUS + t.DECIDUOUS + h2o + snagsg30
rs.DECIDUOUS + hishrubht + snagsg30
rs.DECIDUOUS + hishrubht + h2o + snagsg30
rs.DECIDUOUS + hishrubht + t.DECIDUOUS + snagsg30
rs.DECIDUOUS + hishrubht + t.DECIDUOUS + h2o + snagsg30

h2o = percent cover of water over the plot; hishrubht = the average height of shrubs in the tallest quartile; rs.DECIDUOUS = percent cover of deciduous shrubs; rs.SALISP = percent cover of plants in the Salix genus; snagsg30 = number of snags greater than 30 cm DBH; t.DECIDUOUS = percent cover of deciduous trees and tree shrubs.