Point Blue Report

Bird response to meadow restoration in the Little Truckee River watershed

Report for the National Fish and Wildlife Foundation

June 2020

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Conservation science for a healthy planet

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In partial fulfillment of project 0103.17.055252

Acknowledgements

Thank you to the many field staff that collected data for this project.

Suggested Citation

Campos, B.R., R.D. Burnett, and H.L. Loffland. 2020. Bird response to meadow restoration in the Little Truckee River watershed. Report to the National Fish and Wildlife Foundation. Point Blue contribution number 2311.

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INTRODUCTION

Riparian meadows of the Sierra Nevada in California are floodplains that, if hydrologically functional, retain water from high-flow events and slowly release it in summer months, maintaining streamflow and groundwater levels at or near the land surface in an otherwise seasonally dry landscape (Loheide II et al. 2009; Hunsaker et al. 2015). The interacting hydrological, geomorphological, and ecological processes of functional riparian montane meadows support biodiversity and provide critical ecosystem services including flood attenuation, water storage, water quality improvement, and carbon sequestration (Hammersmark et al. 2008; Norton et al. 2011; Purdy et al. 2011; Viers et al. 2013). Like the montane floodplains of larger, glaciated gravel-bed river systems of the U.S. and Canada (Hauer et al. 2016), the meadows and riparian areas of the Sierra Nevada are hotspots of biodiversity, with disproportionate use compared to their land area (Kattlemann & Embury 1996). Riparian corridors, including riparian meadows, comprise less than 2% of the Sierra Nevada (Kattlemann & Embury 1996; Viers et al. 2013), yet 20% of the Sierra Nevada's terrestrial vertebrate species depend on them (Graber 1996). Many of the vertebrate species most closely associated with Sierra Nevada meadows are endangered, threatened, or declining due in part to a history of meadow alterations and exploitation, such as deliberate channel modifications and long-term over-grazing by livestock (Kattlemann & Embury 1996; Menke et al. 1996).

Across the broader Mountain West of the United States, 61% of streams have medium to high human disturbance and 41% have streamside vegetation communities in fair or poor health (U.S. EPA 2006). In the Sierra Nevada, the hydrological and ecological integrity of most montane meadow streams have been compromised (Kattlemann & Embury 1996; Menke et al. 1996), with many exhibiting severe channel incision (Hunsaker et al. 2015). Channel incision reduces the hydrological connection between streams and their floodplains and dewaters the meadow (Hunsaker et al. 2015). Because a larger volume of water is needed to initiate flow over the meadow surface, incised channels limit the processes of scour and deposition crucial to the succession of riparian plant communities (Ward et al. 2002). Incised channels also increase groundwater discharge from meadow aquifers to streams, resulting in lower water table elevations, decreased groundwater retention, and conversion of meadows from wetland to upland habitat types (Loheide II & Gorelick 2007; Hunsaker et al. 2015). Without active intervention to re-elevate the water table and restore hydrologic connectivity between meadow surface and stream channel, heavily impacted meadows remain altered, resulting in a drastic loss of ecosystem services (Loheide II et al. 2009). In growing recognition of the value of the ecosystem services provided by functional montane meadows, the state of California and large regional partnerships established ambitious meadow restoration goals (Drew et al. 2016; CNRA 2016).

Hydrologic restoration of riparian meadows with incised channels aims to increase overbank flows during spring runoff and elevate groundwater levels in the dry season, with expected enhancement of the many ecosystem services provided by functional meadows (Hunsaker et al. 2015; Drew et al. 2016). However, resources are often lacking to evaluate whether restoration objectives for ecosystem services have been met at project sites. Because of the lack of rigorous and long-term evaluation (Ramstead et al. 2012) and sensitivity to variation in ecosystem context and methodology (reviewed by Hunsaker et al. 2015), the effectiveness of meadow restoration in achieving intended objectives is not well understood (c.f. Hammersmark et al. 2008, Pope et al. 2015). Yet understanding the efficacy of meadow restoration in general, and specific restoration techniques in particular, in achieving desired outcomes is critical to maximizing the multiple benefits of restoration (e.g., Dybala et al. 2019). Partial channel fill methods, including the pond-and-plug technique first used in California in 1995, have been the most frequently used for restoring the hydrology of riparian meadows of the Sierra Nevada and Southern Cascades since the mid-1990s (Wilcox et al. 2001; Hammersmark et al. 2008). Outcome-based evaluations of the dominant meadow restoration methods are needed to ensure objectives are being met and to guide modifications where needed.

A frequent objective of riparian meadow restoration is to increase the abundance of target bird species following expected increases in riparian habitat quantity and quality (Drew et al. 2016). Meadows have been called the single most important habitat for birds in the Sierra Nevada (Siegel & DeSante 1999), and three bird species listed as Endangered or Threatened by the state of California—Willow Flycatcher (*Empidonax traillii*), Great Gray Owl (*Strix nebulosa*), Greater Sandhill Crane (*Grus canadensis tabida*)—rely on montane meadows (CDFG 1994, Mathewson et al. 2013, Kalinowski et al. 2014). However, published evaluations of the long-term response of birds to riparian meadow restoration are lacking. Riparian restoration elsewhere in the western US has resulted in clear benefits to bird abundance and diversity, primarily through increased structural complexity and abundance of vegetation, indicators of riparian habitat quality for birds (Kus 1998; Gardali et al. 2006; Golet et al. 2008; Rockwell & Stephens 2018). Yet these studies have largely focused on revegetation projects that did not restore or modify hydrologic connectivity (but see Dybala et al. 2018), the latter of which is the primary focus of most riparian meadow restoration projects.

We evaluated the expected outcome of increased abundances of birds following the restoration of hydrologic connectivity in riparian meadows by assessing the rate of change in abundance of focal bird species at sites restored using the pond-and-plug method. We assumed changes in bird abundance were in part attributable to vegetation structure created by the restoration project, and patterns and rates of change depended upon species-specific habitat requirements fulfilled as vegetation succession occurred and the floodplain changed over time. Specifically, we investigated which meadow-associated bird species responded to meadow restoration and at what rate, relative to changes in abundance of focal bird species at nearby control meadows. We expected bird abundance would increase with time since restoration, while abundance at controls would stay relatively constant or decline for those species experiencing range-wide declines.

METHODS

Study locations

We studied breeding birds at 8 montane riparian meadow study sites in or in close proximity the Little Truckee River watershed in the Sierra Nevada of California (Figure 1, Table 1). The 3 restoration sites in this study represent the only meadows in the Desert Terminal Lakes geography (Truckee, Carson, and Walker River watersheds) for which we have at least 4 years of long-term data, including 2 with some pre-restoration data. We chose 5 control meadows for which we also had long-term data that represent ambient conditions near the restoration sites. One planned restoration location, Perazzo Lower, was not restored until 2019, later than anticipated at the start of this study, and after data collection finished. We retained Perazzo Lower as a control location for analysis.

The 3 restoration sites used a similar pond-and-plug restoration method (Hammersmark et al. 2008). These sites received partial channel fill of a previously incised channel (plugs). Deep ponds, a result of mechanical excavation and unfilled sections of incised channels, were present after restoration during spring runoff. The mechanically excavated borrow pits were located on-channel. Stream channels after restoration were remnant channels reactivated by the hydrologic restoration.

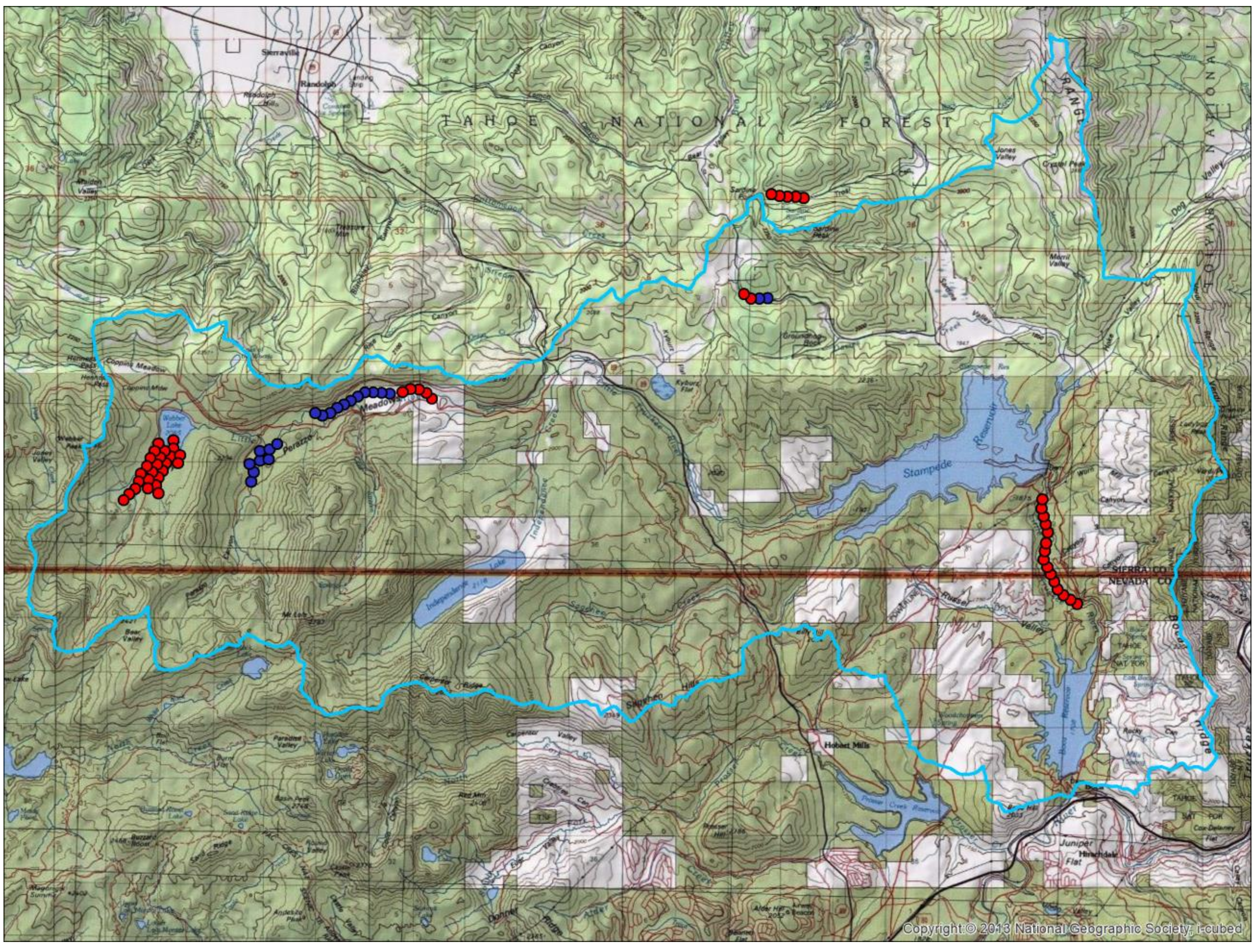

Figure 1. Restored impact (blue) and unrestored control (red) meadow point count sample locations relative to the Little Truckee River watershed (turquoise outline).

We considered the boundaries of a restoration site to be the area in which the groundwater table was expected to be raised as described on project documentation, or, where this documentation was lacking, the upstream and downstream extent of channel fill and ponding within the riparian meadow. We considered the boundaries of control meadows to be anywhere within the meadow. Riparian meadow was the dominant hydrogeomorphic type at all sites (Weixelman et al. 2011). At each site we distributed sample locations ≥ 250 m apart while maximizing the number of locations in restored areas, resulting in 2–25 sample locations per site.

Bird data

Our surveyors conducted standardized five-minute point counts at sample locations (Ralph et al. 1995). We counted from sunrise up to four hours after sunrise, without counting in inclement weather (i.e., precipitation, fog, or high wind). All surveyors passed identification field tests with supervisors after at least two weeks of training to identify birds and estimate distances. Sample locations were visited up to twice in a given year from 1 June through 10 July, the period of peak songbird breeding activity in the study region. We completed 602 point counts from 2010 to 2019 at 73 sampling locations across the 8 restoration and control sites. We sampled birds at each site 6–12 times up to 10 years after restoration, with pre-restoration data at 6 sites (Table 1).

Table 1. Montane riparian meadow study sites ordered by longitude.

Meadow Site	No. Sample Locations	Latitude	Longitude	Year Restoration Completed (Assigned)	Post-Restoration Years Sampled
Lacey Valley Control	25	39.474	-120.420	(2009)	3, 7-10
Perazzo Upper Restoration	8	39.476	-120.383	2009	3, 5, 7-8
Perazzo Middle Restoration	11	39.492	-120.353	2010	0, 2, 4, 6-9
Perazzo Lower Control	5	39.495	-120.324	(2010)	0, 1-2, 6-8
Davies Site 1 Control	2	39.522	-120.210	(2010)	0, 2, 4, 6-9
Davies Site 1 Restoration	2	39.521	-120.202	2010	0, 2, 4, 6-9
Trossi Canyon Control	5	39.549	-120.195	(2010)	0, 2, 6-7
Little Truckee Below Stampede Control	15	39.458	-120.104	(2010)	0, 2, 8-9

We selected for analysis an *a priori* subset of 13 bird species (hereafter, focal species; Table 2; Campos et al. 2014). These species reach their greatest breeding abundance in montane meadow and riparian habitat in the study area, are appropriately sampled by passive point count methods, and were expected to respond positively to habitat conditions created or enhanced by the restoration of meadow form and function, specifically: (a) floodplain inundation at a less than 2 year interval; (b) water table within the rooting zone of meadow plants for growing season, including some flooded or perennially saturated areas in secondary channels or other depressional areas; (c) vigorous herbaceous layer dominated by native obligate or facultative wetland graminoid species; (d) riparian deciduous shrubs with active recruitment; and (e) riparian deciduous trees. Detections of Song Sparrow and Yellow Warbler dominated our focal species detections, comprising 55 and 29% of all detections, respectively (Table 2). We did not detect Swainson's Thrush or Black-headed Grosbeak, so we dropped them from further consideration.

Table 2. Meadow focal bird species ordered by total number of detections within 50 m of surveyors.

Common Name	Species Name	Detections
Song Sparrow	*Melospiza melodia*	442
Yellow Warbler	*Setophaga petechia*	312
White-crowned Sparrow	*Zonotrichia leucophrys*	124
Wilson's Warbler	*Cardellina pusilla*	47
Wilson's Snipe	*Gallinago delicata*	43
Lincoln's Sparrow	*Melospiza lincolnii*	41
Calliope Hummingbird	*Selasphorus calliope*	38
Warbling Vireo	*Vireo gilvus*	33
Willow Flycatcher	*Empidonax traillii*	29
Red-breasted Sapsucker	*Sphyrapicus ruber*	13
MacGillivray's Warbler	*Geothlypis tolmiei*	11
Black-headed Grosbeak	*Pheucticus melanocephalus*	0

Swainson's Thrush	*Catharus ustulatus*	0

Analysis

We hypothesized focal species abundance would increase with time since restoration at impact locations, while abundance at control locations would be stable or decline. This would lead to an interaction between the rate of response with time since restoration at control and impact locations. No interaction would suggest trends in abundance at control locations was not different from impact locations. This could happen because a species was either little affected by restoration, the effect of restoration was not greater than any improved management at control locations, sample sizes were insufficient to detect a response given the variance in the sample, or, a response was immediate following restoration and changed little with time thereafter.

To estimate the effect of time since restoration and environmental variables on focal species abundance, we built generalized linear mixed models with Poisson error and logarithmic link function using the package lme4 version 1.1-20 (Bates et al. 2015) in program R x64 version 3.5.1 (R Core Team 2018). Our sample unit was a single point count survey visit and the dependent variable was the count of a focal species within 50 m. We also included a random intercept for each location nested within each restoration site and a random intercept for year of data collection. We ran a single model with time since restoration, a binary treatment variable to indicate control/impact sample, and an interaction between time and treatment. The year of restoration for the impact sample was designated as the year restoration was implemented. We designated the year of restoration for the control sample as the year of restoration for the nearest impact sample. We used z scores of coefficients in the final models to assess the importance of variables in describing bird abundance. We standardized time since restoration with a mean of zero and standard deviation of one.

Our analytical approach optimized the benefit of having pre-restoration data for some control and impact sites with the imbalanced sampling through time at control and impact sites. Restricting our analysis to just those sites with pre-restoration data would have reduced our sample and inference.

RESULTS

Of the eleven focal species in our analysis, we found evidence for a positive effect of restoration on abundance of one species and a negative effect on abundance of one species (Table 3). Abundance of Willow Flycatcher was predicted to increase by 213% from before restoration to 10 years after restoration, while abundance was predicted to decline by 98% over the same time period, to essentially zero birds, at locations that did not receive hydrologic restoration treatments (Figure 2). Abundance of White-crowned Sparrow were predicted to decrease by 95% at impact locations from before restoration to 10 years after restoration, while abundance was predicted to decline by a slower 19% over the same time period at control locations (Figure 2). For one species, MacGillivray's Warbler, abundance declined at both treatment and control locations over time and the rate of decline was statistically indistinguishable in both treatment types (Table 3, Figure 2). Abundance increased at both treatment and control locations over time for five species: Song Sparrow, Yellow Warbler, Calliope Hummingbird, Wilson's Warbler, and Wilson's Snipe. For all these species except Calliope Hummingbird, abundance was higher at restoration locations, but the rate of increase was statistically indistinguishable between treatment types (Table 3, Figure 2). Warbling Vireo also increased with time in the control sample, while the trend in abundance in the impact sample was relatively flat and highly uncertain, with some evidence that the rate of increase was statistically different between the treatment types. For the remaining two species, Lincoln's Sparrow and Red-breasted Sapsucker, evidence was insufficient to suggest clear trends over time in the impact or control samples.

Table 3. Parameter estimates (and SEs) for generalized linear mixed models of annual abundance of bird species in relation to time since restoration (tsr), the restoration sample relative to the control sample (impact), and the interaction between time and sample type (tsr:impact). ***** indicates $p \leq 0.1$ based on *z*-test for difference from zero. ****** indicates $p \leq 0.05$ based on *z*-test for difference from zero.

Species	Parameter			
	intercept	tsr	sample	tsr:sample
Calliope Hummingbird	-3.78 (0.80)**	1.31 (0.49)**	0.43 (0.86)	-0.73 (0.58)
Lincoln's Sparrow	-3.30 (0.58)**	-0.03 (0.23)	-0.16 (0.87)	-0.48 (0.36)
MacGillivray's Warbler	-5.77 (1.44)**	-1.49 (0.64)**	0.57 (1.29)	0.55 (0.88)

Red-breasted Sapsucker	-4.57 (0.86)**	0.00 (0.56)	0.71 (1.03)	-0.72 (0.60)
Song Sparrow	-1.05 (0.30)**	0.45 (0.15)**	1.10 (0.41)**	-0.13 (0.12)
Warbling Vireo	-3.25 (0.63)**	0.80 (0.28)**	0.31 (0.90)	-0.85 (0.46)*
White-crowned Sparrow	-1.77 (0.32)**	-0.07 (0.20)	-0.89 (0.49)*	-0.92 (0.29)**
Willow Flycatcher	-7.10 (1.48)**	-1.30 (0.83)	3.64 (1.29)**	1.69 (0.87)**
Wilson’s Snipe	-4.66 (0.80)**	1.57 (0.76)**	2.42 (0.79)**	-1.06 (0.76)
Wilson’s Warbler	-3.97 (0.48)**	0.72 (0.28)**	1.10 (0.57)**	-0.12 (0.41)
Yellow Warbler	-1.57 (0.36)**	0.23 (0.08)**	1.09 (0.55)**	-0.10 (0.12)

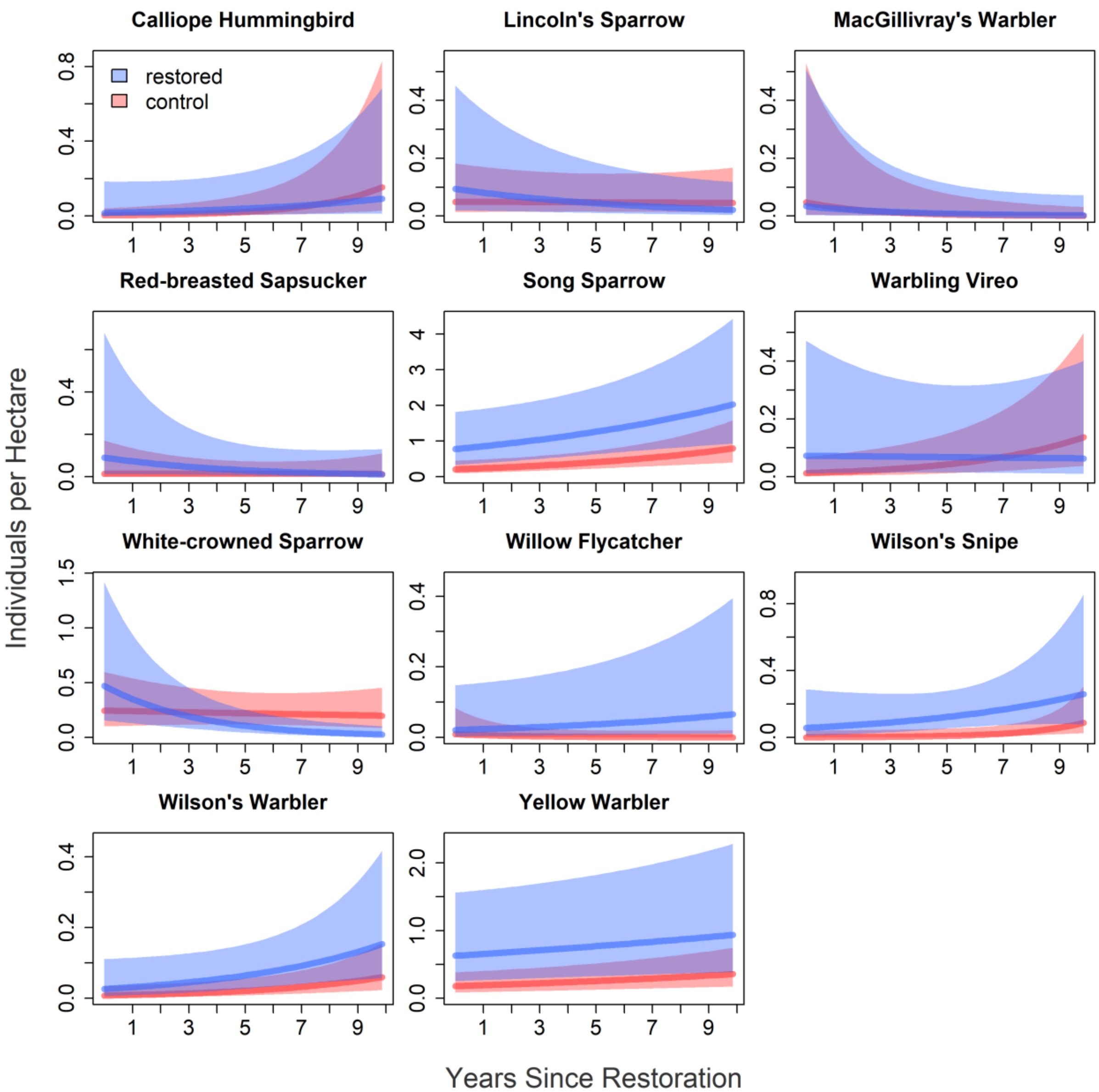

Figure 2. Mean predictions and 95% confidence intervals for the marginal effect of time since meadow restoration on abundance for 11 bird species across 3 restoration sites and 5 control sites in the Little Truckee River watershed. All other parameters were held at mean values. Scientific names are in Table 1.

DISCUSSION

Among the eleven focal bird species, clear evidence of a response to pond-and-plug riparian meadow restoration at Perazzo Meadows and Davies Creek in the Little

Truckee River watershed was limited to two bird species with contrasting responses, Willow Flycatcher and White-crowned Sparrow. Evidence that benefits accrued to the state-endangered Willow Flycatcher, the primary avian target of these restoration efforts, is encouraging. This species continues to decline precipitously in the Sierra Nevada region, with their range receding northward (Loffland et al. 2014). Increases in Willow Flycatcher were only observed in Perazzo Meadows, where the species was present before restoration, and not Davies Creek, which is only marginally suitable habitat for Willow Flycatcher given the narrow meadow corridor. Hydrologic restoration of riparian meadows in close proximity to established Willow Flycatcher population should be a high priority (Loffland et al. 2014). Following results from Matthewson et al. (2012) we recommend prioritizing restoration within 12km of known Willow Flycatcher breeding sites (e.g. Vernon et al. 2019). In other riparian systems of California, restoration in close proximity to established populations of target bird species has helped to accelerate the reestablishment of populations at restoration sites, including endangered Least Bell's Vireo (Kus 1998, Gardali & Holmes 2011). It is also important to restore meadows with characteristics selected for by Willow Flycatcher, such as those with a large area to perimeter ratio, andupstream watersheds that receive high annual precipitation. Actively replanting dense clumps of willow may also increase the response time of this species (Campos et al. 2020).

The decline in White-crowned Sparrow attributable to hydrologic restoration efforts observed in this study aligns with the decline observed in a similar evaluation at a larger scale (Campos et al. 2020). Their preference for open ground for foraging within their breeding territories (Chilton et al. 2020) may explain their decline. Impact locations had only 0-5% bare ground because of the strong response of sedges and rushes to restoration. Considering the decline of the *oriantha* subspecies of White-crowned Sparrow that occupies meadows of the Sierra Nevada (Sauer 2018), as reflected in the control sample in this study, the negative effect of hydrologic restoration on White-crowned Sparrow abundance should be considered in future riparian meadow restoration efforts where this species is present.

While we did not detect a clear positive effect of restoration for any other species, five species increased in abundance at impact locations and control locations; an additional species appeared to increase in control meadows while remaining relatively stable at impact locations. At the larger scale of the Sierra Nevada for the same time period as this study, trends in abundance of these same focal species are either statistically negative or statistically constant (Sauer 2018). This points to a potential improvement in habitat at the control meadows occurring concurrently with improvements for some species at hydrologically restored meadows. Changes to meadow management without hydrologic restoration, such as the reduction, modification, or cessation of grazing, can have large positive effects on vegetation biomass and bird populations in riparian areas (Krueper et al. 2003, Earnst et al. 2012). Any improvements in the control sample meadows may have confounded our ability to detect a positive effect of hydrologic restoration for some species, resulting in a potential type II error (i.e. a false negative finding).

The lack of positive responses with a clear attribution to meadow restoration from any of the other nine focal species somewhat contrasts findings from a similar evaluation of bird response to hydrologic meadow restoration with samples taken at a Sierra-wide scale. Campos et al. (2020) found abundance of Song Sparrow, Yellow Warbler, Warbling Vireo, Red-breasted Sapsucker, and Wilson's Warbler increased as a function of time from 1 to 18 years after restoration; Black-headed Grosbeak, essentially absent from the meadows in this study, also increased. In addition to the potential for type II error as described for the species above, this lack of congruency between the two studies could arise for other reasons. Population dynamics in the Little Truckee River watershed may differ relative to the larger Sierra Nevada. For example, observed increases in abundance of Willow Flycatcher in this study were not evident across the Sierra Nevada because of dispersal limitations (Schofield et al. 2018). Alternatively, the shorter time scale of this study may mean that the same thresholds for response were not yet reached relative to Campos et al. (2020). The relatively high shrub cover prior to restoration at these sites may have also dampened the pace of bird response (Campos et al. 2020). This combined with our relatively small sample size in this study may have limited our ability to detect smaller increases in abundance than the larger sample sizes in Campos et al. (2020).

In conclusion, pond-and-plug techniques in the Little Truckee River watershed improved habitat for the state endangered Willow Flycatcher and decreased habitat value for another species, while evidence of a response to restoration was inconclusive or lacking for all other species. Continued monitoring is needed to inform adaptive management that ensures restoration projects deliver the best possible results for the investment. A larger-scale analysis of the effect of meadow restoration on birds using before-after control-impact data from across the Sierra Nevada would be helpful to confirm the patterns observed in Campos et al. (2020) derived from a space-for-time substitution analysis.

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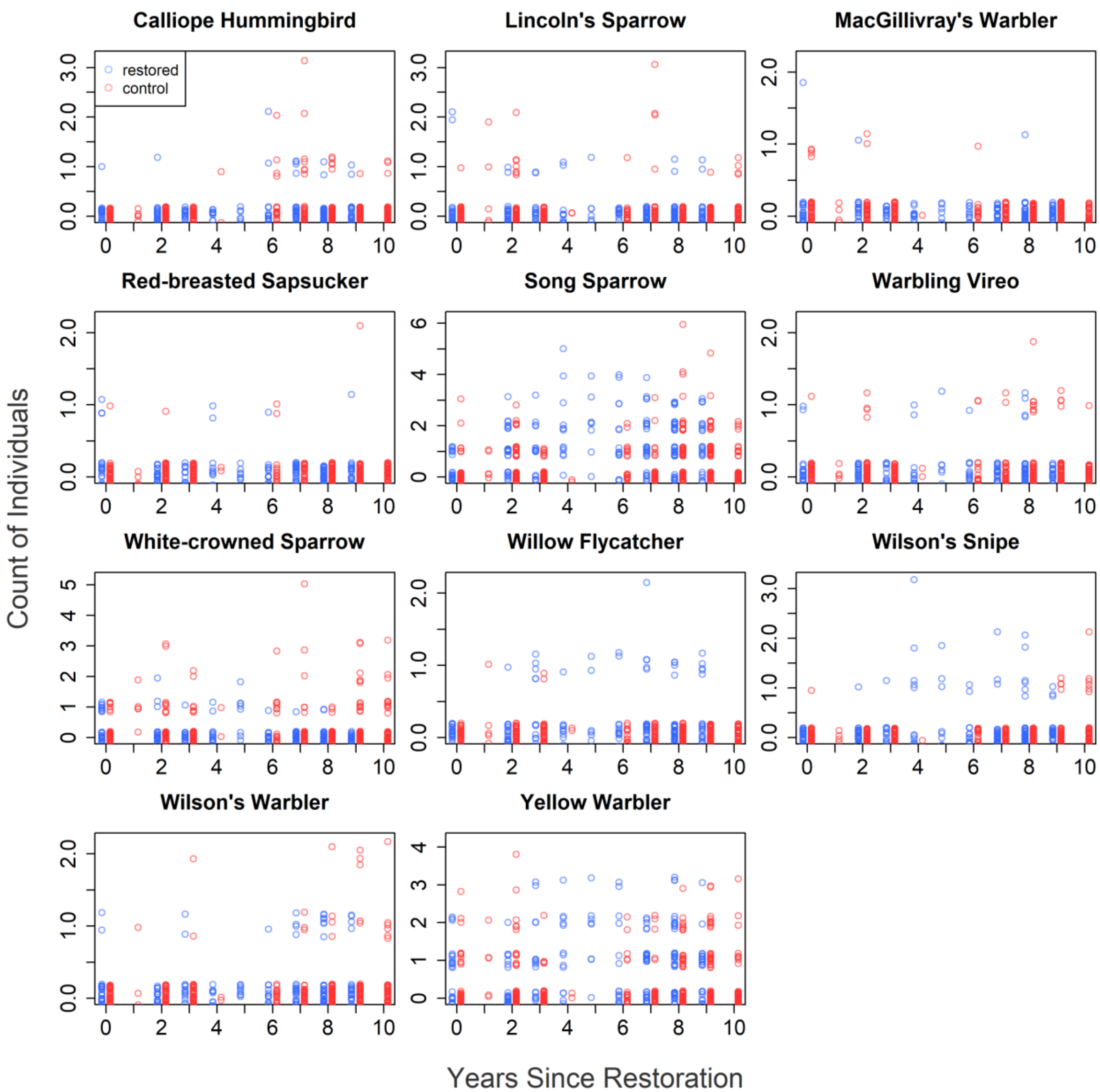
APPENDIX



Appendix A. Raw counts of individuals at individual point count sample locations over time since meadow restoration for 11 bird species across 3 restoration sites and 5 control sites in the Little Truckee River watershed. Points are jittered on the y-axis to display otherwise overlapping values. All displayed values are integers despite appearing as non-integer due to the jitter. Scientific names are in Table 1.