Using birds to inform meadow restoration at Pickel Meadow

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Pickel Meadow Photo: Helen Loffland; Yellow Warbler (inset) Laura Gooch

Introduction

This report summarizes the results of pre-restoration multi-species bird monitoring at Pickel Meadow. In 2018, The Institute for Bird Populations (IBP) utilized a standard point count protocol to monitor bird species within the Pickel Meadow area to provide pre-restoration baseline data (Loffland et al. 2011a). This protocol is used to assess and describe the larger bird community and to detect population-level changes in meadow bird species in response to restoration activities. Pickel Meadow was identified as a priority site in *Restoring Walker Meadows: Assessment and Prioritization* (Hunt et al. 2015) and was one of twenty three sites surveyed in 2018 by IBP as part of multiple meadow restoration monitoring projects funded by The Truckee River Watershed Council and by the Desert Terminal Lake NFWF initiative. Results from all study sites are combined in the discussion to provide regional context.

Methods

Multi-species Bird Monitoring

In 2018, Multi-species monitoring (all bird species) in Pickel Meadow followed Loffland et al. (2011a), and consisted of two primary methods: point counts and area searches. Point counts were conducted at survey stations spaced 200 - 250 m apart, with all individuals of all species seen or heard counted during a 7-minute period. Area searches consisted of tallying all additional bird species detected incidentally outside of point count surveys, or during targeted searches of the sites.

Vegetation Monitoring

In 2018 we assessed vegetation, bare ground, surface water, and numerous other biotic and abiotic factors within 50 m of all multi-species point count stations, following Loffland et al. (2011a).

Cover classes were averaged across four quadrants of a 50-m radius circle centered at each point count station, and then averaged across all points within a meadow. These metrics are intended to serve as a point of reference for bird counts but are not intended to replace vegetation monitoring specific to meadow restoration. Habitat characteristics including water cover and riparian shrub cover were estimated because they are known to be particularly important to focal bird species. Additionally, measures of sagebrush and bare ground were recorded because they may provide a rough index of the extent of severely disturbed area within a meadow.

Results

Multi-species Bird Monitoring

In 2018 we surveyed 40 multi-species point count survey stations in Pickel Meadow (Figure 1). All visits to between late May and early July (Table 1). The visit to Pickel Meadow was split into two days to allow flows in the Walker River to recede adequately to allow safe crossing by surveyors.

Table 1. Dates for multi-species bird monitoring in the Pickel Meadow in 2018.

Site	2018 Visit 1
Pickel Meadow	6/11/2018 7/8/2018

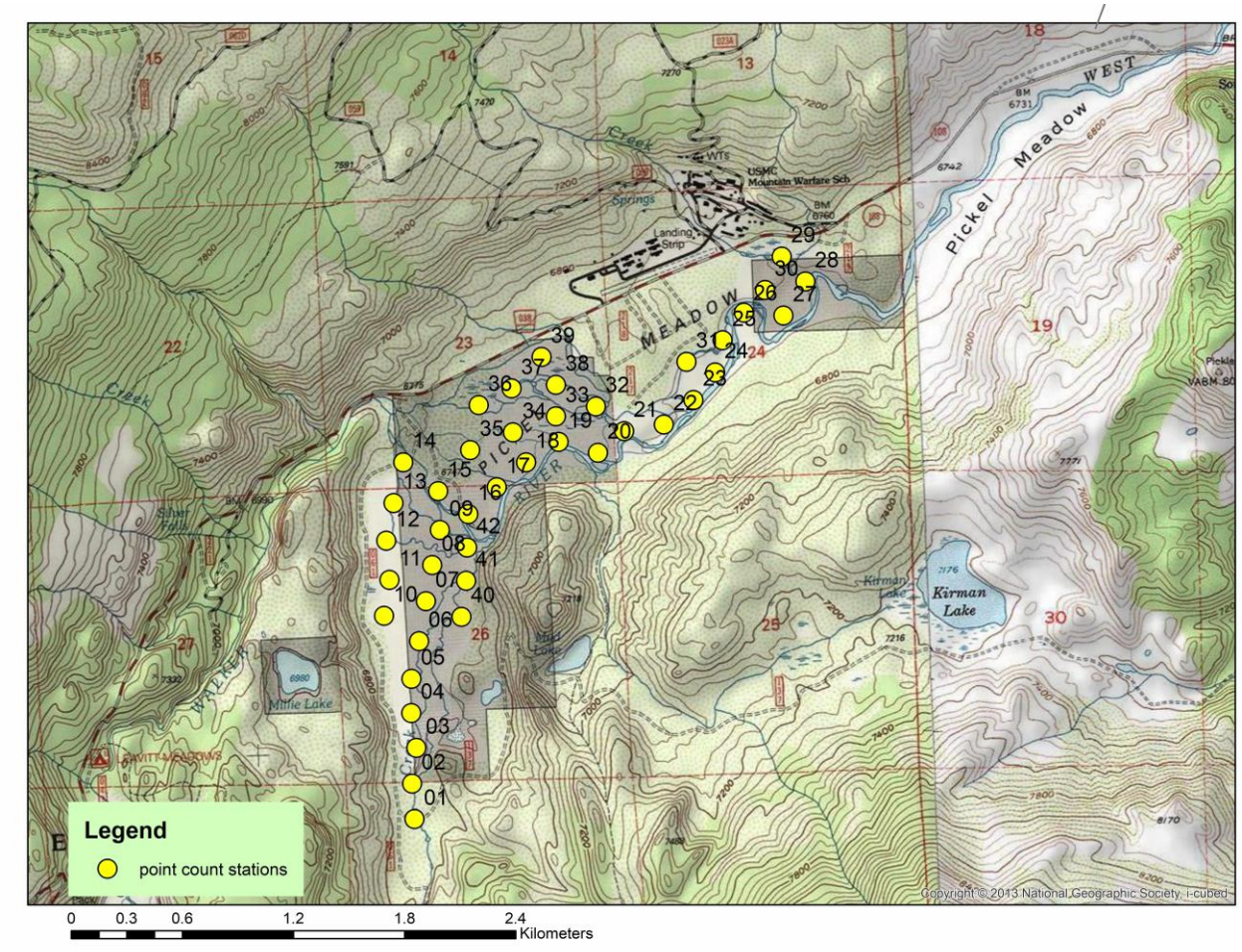

Figure 1. Multispecies avian point count station locations in Pickel Meadow on CDFW and Humboldt Toiyabe National Forest lands.

During Sierra-wide baseline surveys in 2010 and 2012 we selected focal species for analysis based on Loffland et al (2011a), which identifies 18 focal bird species expected to respond positively to meadow restoration, or have other conservation implications making them especially worthy targets of monitoring at meadow restoration sites. In 2013 we worked collaboratively with researchers at Point Blue to refine this list to a smaller subset of focal species (Table 2) most appropriate for analysis based on expected distribution, sample size, and predicted direction of change with restoration (Campos et al. 2014). The observation status for these species and their typical habitat preferences are also indicated in Table 2. In 2018, 37 bird species were detected during point counts at Pickel Meadow, including 3 of the focal species (Table 2; Appendix A).

Table 2. Focal bird species observation status during surveys of Pickel Meadow in 2018.

Species	Usual habitat within meadows[1]	Observed in study area?
Wilson's Snipe	E	**yes**
Red-breasted Sapsucker	S,A	no
Calliope Hummingbird	M,S,A	no
Willow Flycatcher	S,E	no
Swainson's Thrush	S,A	no
Warbling Vireo	S,A	no
Yellow Warbler	S	**yes**
MacGillivray's Warbler	S,A	no
Wilson's Warbler	S,A	no
Song Sparrow	M	**yes**
Lincoln's Sparrow	M	no
White-crowned Sparrow	S,M	no
Black-headed Grosbeak	S,A	no

[1] A= Aspen, cottonwood; E = emergent vegetation and surface water; G = gravel bars and streamside zone; M = open meadow; S = riparian deciduous shrubs

For the purpose of assessing change in these sites over time and in response to future restoration we typically limit our analyses to birds detected within 50 meters of survey stations, in an effort to account for reductions in detection probability that occur with increasing distance from an observer. The following results are based only on detections within 50 m of survey stations unless otherwise noted.

The most common birds included generalist species such as Brewer's Blackbird, sagebrush associates such as Green-tailed Towhee and Brewer's Sparrow, and riparian associates including Red-winged Blackbird, Cliff Swallow, and Song Sparrow. Of particular interest are the meadow focal species (Loffland et al. 2011a, Campos et al. 2014). These species are meadow or riparian associates and are typically found in areas with a mix of shrubby and herbaceous vegetation. During our surveys in 2018 we detected 3 of the focal species at Pickel Meadow, but only 2 of those were detected within 50m of survey stations (Tables 2 and 3). Colonially nesting and flocking riparian and meadow species such as Red-winged blackbird and Cliff Swallow

(although abundant at Pickel Meadow) are not targeted for monitoring because their communal behavior make assessing abundance and modeling it with more territorial species is challenging.

Table 3. Total count[1] and index of relative abundance[2] for each focal species detected at Pickel Meadow during 2018.

Bird species	Total Count (any distance)	Index of abundance (within 50m) Avg #/acre
Wilson's Snipe	11	-
Yellow Warbler	12	0.08
Song Sparrow	31	0.09

[1]ITotal count is the sum of all individuals detected at any distance from any point count station

[2]Index of relative abundance calculated as number of individuals detected within 50 m of all point count stations averaged across the number of point count stations and visits and multiplied by 0.515 plots/acre.

Song Sparrow was by far the most abundant focal species, followed by Yellow Warbler and Wilson's Snipe. Of our focal species, Song Sparrows have the least restrictive habitat needs and will occur in both wet and dry meadows with small amounts of riparian or other shrub cover. Wilson's Snipe are almost always associated with flooded areas with shallow emergent wetland vegetation, usually beaked sedge (*Carex rosrata*). Yellow Warblers require abundant riparian shrub (usually willow) cover in both wet and mesic meadow settings. The remaining focal species (Table 2) were not detected within the study site, likely because they are typically associated with conditions that occur only in relatively small portions of Pickel Meadow. These conditions include: mesic meadow conditions and tall, dense herbaceous vegetation (Lincoln's Sparrow, White-crowned Sparrow), or dense and tall riparian shrubs mixed with riparian deciduous trees (MacGillivray's Warbler, Wilson's Warbler, Red-breasted Sapsucker, Warbling Vireo)(Ray 1903, Grinnell and Miller 1944, Orr and Moffit 1971, Stewart et al. 1977, Heath and Ballard 2003). Two declining species associated with perennially flooded meadow and riparian habitat in combination with dense shrub cover (Willow Flycatcher, Swainson's Thrush) were also not detected. In addition to our standard focal species, there were a few notable species at Pickel Meadow worthy of continued monitoring as they are either likely to respond positively to restoration, they are relatively uncommon wetland species, or both. These species include: Sora, Common Yellowthroat, and Savannah Sparrow.

In addition to monitoring how individual focal species respond to restoration, we measure an additional metric of restoration success known as "focal species richness" (Campos et al 2014). This metric assesses the number of the13 target focal species detected at a station, or averaged across stations for the entire site. By monitoring a standard suite of species we can then compare results at Pickel Meadow against other sites within the region. The mean in 2018 at Pickel Meadow was 0.24 focal species per station (0.13 focal species/acre).

Discussion

Hydrology is a primary factor restricting habitat quantity and quality for meadow focal bird species. All rely on lush herbaceous and woody vegetation, and the insect food resources (Erman 1984, 1996) associated with saturated wet meadows. Flooded conditions also may provide protection from nest predation, as some mammalian predators avoid surface water (Cain et al 2003, Borgmann 2010, Cocimano et al. 2012). Similarly, many riparian focal species require dense riparian shrubs or trees (aspen, alder, dogwood) that will germinate and grow only with consistent water within the root zone. Although willow requires consistent moisture for germination, mature willow will often persist at a site after meadow hydrology is altered, if roots are deep enough to remain in contact with the water table, despite its lowered elevation. Another factor significantly related to Willow Flycatcher occupancy specifically, and riparian birds generally, is the presence of beaver (Bombay 1999, Cooke and Zack 2008), due to the impoundments beavers create and the subsequent willow germination and recruitment associated with new sediment capture and inundation. Although beaver are present in the Walker River watershed, in Pickel Meadow signs of beaver activity were only observed in the middle section where willow is present. Although it would be difficult for beaver to dam the flow of the main channel they are likely denning within the banks and utilizing ponds in off channel oxbows for cover. In the remaining reaches of Pickel Meadow, there is not currently adequate woody vegetation for food and building supplies along most reaches, and tributaries, or deep pools to provide hiding cover for beaver to fully occupy this meadow system.

Habitat needs of individual meadow-associated bird species are diverse. We believe effective restoration efforts are best informed by considering the needs of the particular species that are being targeted with the restoration efforts. The following discussion is therefore organized around individual meadow focal species or groups of focal species.

Willow Flycatcher

The California-endangered Willow Flycatcher is the bird species in the region that is most strictly linked to wet meadows dominated by mature stands of willow (Figure 2). Most Willow Flycatcher breeding sites are found in meadows or riparian areas with season-long saturated soils and surface water (Harris et al. 1987, Bombay 1999, Bombay et al. 2003a, b, Mathewson et al. 2012). These conditions may occur in association with oxbows and ponds within a floodplain meadow community or in areas where perennial springs spread water across a variable-gradient meadow surface (Weixelman et al. 2011). Deciduous riparian shrubs, particularly willows, are a critical habitat component for Willow Flycatcher. Most Willow Flycatcher territories contain 50% or more willow cover, typically across a 1- 3 acre area

Figure 2. Willow Flycatchers are still found in a few locations in the Walker River watershed.

(Bombay 1999). Although Willow Flycatchers are not currently breeding in Pickel Meadow, the large size of this meadow and its close proximity to current breeding sites downstream make future colonization of restored habitat in Pickel Meadow a possibility (Mathewson et al. 2011, Loffland et al. 2014, Schofield et al. 2018). Sites larger than 40 acres and within already occupied watersheds are of highest priority for restoration for this declining species (Schofield et al. in prep). A restoration project that successfully brings overbank flows in contact with a significantly larger historic floodplain, creates ponded water settings, and results in 10 or more large willow patches (1+ acre in size) could provide suitable habitat for this species. These factors in combination with the presence of beaver suggest that targeted efforts could create habitat for 10 or more Willow Flycatcher territories over the next 10-20 years, if willow is planted and establishes within the first 5 years. Sites that support this many territories are more likely to be self-sustaining breeding sites over time, especially if nearby meadows, such as Leavitt Meadow are also restored.

Figure 3. Area within Pickel Meadow where Yellow Warblers were most abundant and willow stands are abundant within proximity of standing and running water.

Yellow Warbler

Yellow Warbler, a California Species of Special Concern is, like Willow Flycatcher, strongly linked to dense willow stands. This species is therefore an excellent indicator of the quality of willow habitat in the absence of Willow Flycatchers. However it is not as limited to extremely wet conditions (Heath 2008). Yellow Warblers do, however, occur in their greatest densities at sites with these characteristics. While present in the portions of Pickel Meadow where tall willow is present (stations 21-26, 15; Figure 3), they are absent from large portions of the meadow. Yellow Warblers are present in adequate numbers at the site to quickly colonize newly created habitat when new willow stands reach maturity. In 2018 Pickel Meadow had average relative abundance index of 0.15 Yellow Warblers per point count station (0.08 per acre). Campos et al. (2014) recommend a habitat

management target of 1.04 Yellow Warblers per station (0.54 Yellow Warblers per acre; Figure 4). This target value is six times greater than the current Pickel Meadow value. This index of abundance is also just slightly lower than the average value of 0.11 Yellow Warblers/acre detected across all the restoration monitoring sites visited by IBP in 2018. The primary channel of the Walker River is deeply incised below the historic floodplain, so seed deposition, and moist conditions necessary for new willow recruitment and establishment often occur only in the narrower new floodplain. If restoration reconnects the water table with the historic floodplains or channel widening and bank shaping increase the extent of the new floodplain, and natural recruitment or willow plantings are successful, new willow stands could mature in 10 to 15 years. Similarly if restoration treats the hydrology of the smaller tributary channels, willow is planted or recruited, and new willow is protected from browse, the reaches upstream of the current Yellow Warbler occupied area could provide extensive willow habitat for additional Yellow Warbler.

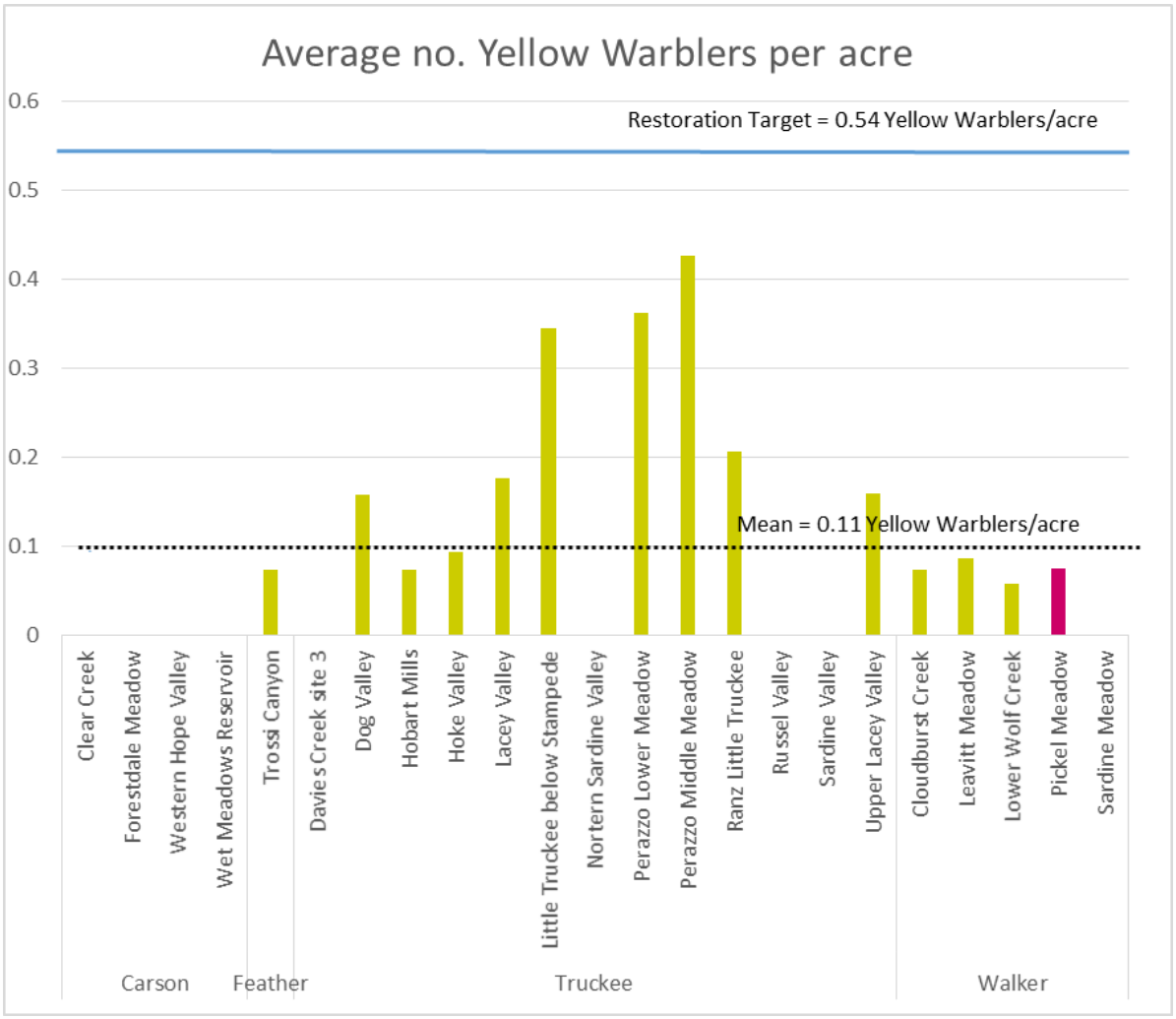

Figure 4. Average number of Yellow Warblers detected per acre at all 2018 survey sites, including Pickel Meadow (magenta bar), relative to regional target and regional mean.

Song Sparrow, White-crowned Sparrow

Song sparrows are found in some portions of Pickel Meadow (mean relative abundance of 0.17/station or 0.09/acre). This species is mostly restricted to the large willow area between stations 20-30, and in the gravel bar willow patches along the Walker and upstream of the Poore Creek confluence (Figure 5). The species will likely respond positively to restoration that expands willow and dense herb communities into some of regions dominated by sagebrush. Although not strictly necessary, willow is a preferred component of White-crowned and Song Sparrow habitat. White-crowned Sparrow are surprisingly absent from Pickel Meadow. It is possible that the elevation is somewhat lower than the ideal for this species, but if willow cover was expanded it is possible that White-crowned Sparrow would colonize the meadow from upstream breeding sites in Cloudburst Creek and Wolf Creek. These two sparrow species are important for restoration monitoring because their typically larger sample sizes and more generalist habitat requirements allow for more robust analyses as post-restoration monitoring occurs. We also recommend monitoring an additional sparrow species at this site. Savannah Sparrows are almost as common as Song Sparrows and will also increase in abundance as tall dense herbaceous vegetation expands with higher water tables and displaces sagebrush. Savannah Sparrow will likely increase in numbers in response to restoration even if willow cover does not increase.

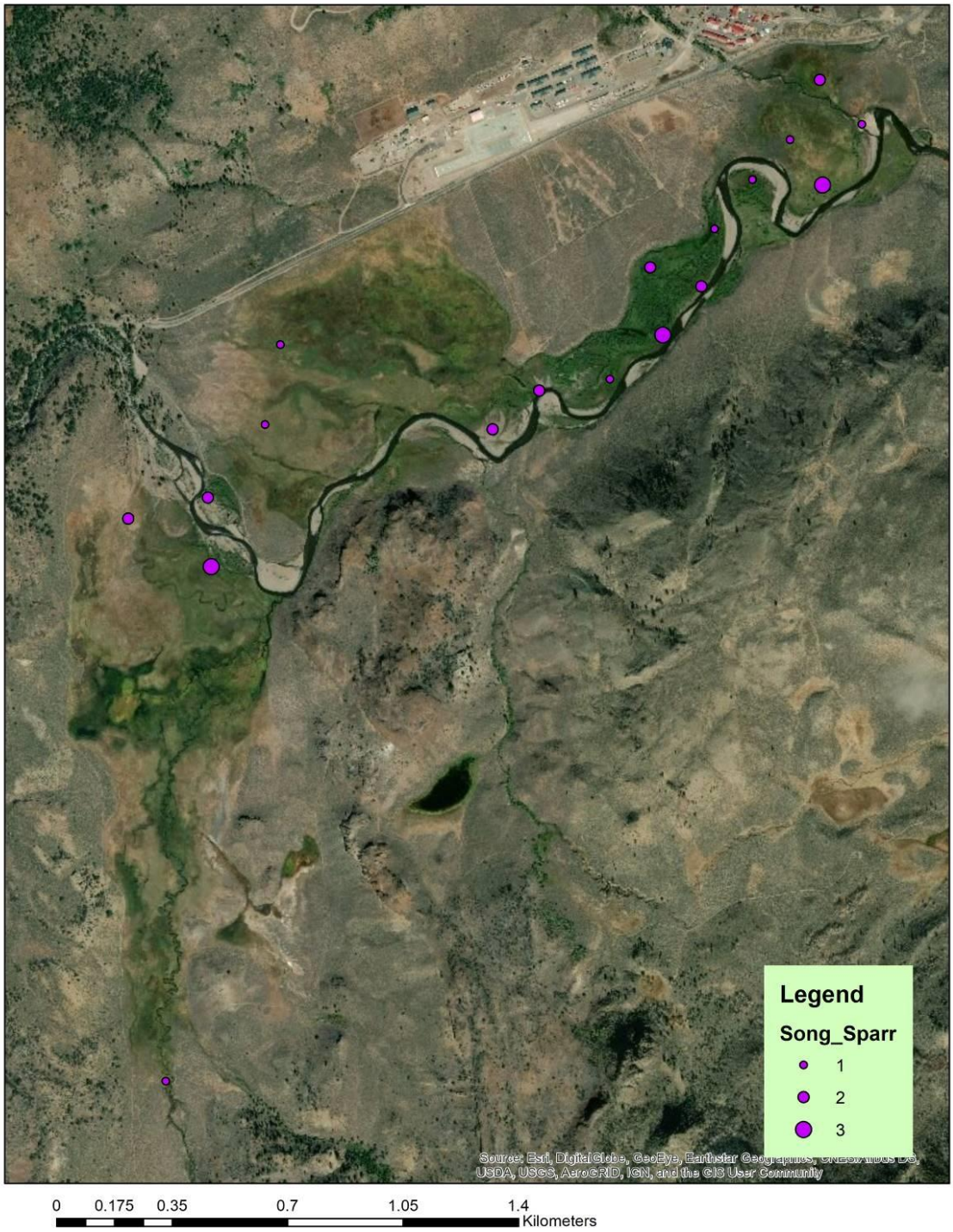

Figure 5. Point count stations where Song Sparrows were detected. Size of circle indicates number detected.

Lincoln's Sparrow

Like the more common Song Sparrow and White-crowned Sparrow, Lincoln's Sparrow requires open meadow habitat with dense herbaceous cover and, ideally, some scattered shrubs. This species, however, is linked to sites that are wetter and have more continuous sedge cover than are other sparrow species. They also sometimes utilize stands of corn lily for nesting. Lincoln's Sparrow was not detected in 2018 at Pickel Meadow. This species is often found at sites with intact tributary hydrology conditions that result in sheet flow. If restoration restores the water table (at least for the tributaries) and more of the historic floodplain is consistently wetted, this species would likely almost immediately occupy newly created habitat because they do not need to wait for willow cover to become established, and because they are present upstream in the nearby Leavitt Meadow, Sardine Meadow, and Lower Wolf Creek sites, making colonization likely.

Red-breasted Sapsucker, Warbling Vireo, Wilson's Warbler, MacGillivray's Warbler

This suite of species is completely absent from Pickel Meadow, but will likely respond to any increases in willow or alder cover that occur with a more natural overbank flooding regime, as a result of active planting, or as a result of other land management changes that improve germination and recruitment to mature life stages of riparian shrubs and trees. Restoration activities may extend the length of season when the meadow edges are saturated, and may expand some slow-water moist areas. This may allow establishment of aspen or cottonwood stands particularly along tributaries and meadow edges. If overall riparian deciduous shrub heterogeneity and aspen or cottonwood cover increase due to natural regeneration and/or plantings, these species could increase substantially, but given the almost complete lack of woody vegetation across much of the western 2/3rds of the site, it is likely to take at least 10-15 years to establish the needed dense heterogeneous stands. These species are present immediately upstream in Leavitt Meadow indicating that this site is within their normal range, and that colonization would be likely with appropriate habitat conditions.

Wilson's Snipe

In the Sierra Nevada, this species is found only in marshy emergent vegetation in large meadows (or other wetlands) with flooded oxbows, beaver ponds, or sites with sheet flow occurring across the meadow surface. Wilson's Snipe are relatively easy to detect and are therefore excellent for monitoring changes to this habitat type after restoration. Currently snipe are found in the areas where sheet flow occurs, primarily where tributaries flow in from the west side of Pickel Meadow along Poore Creek, in spring fed areas along the north side, or in the small wetland patches that occur in the old oxbows along the middle channel where willow is abundant (Figure 6). If restoration restores overbank flows, results in sheet flow, and creates ponded areas that mimic oxbows or beaver impoundments, the sedge-dominated nesting cover and the mud/peat foraging requirements of snipe are likely to increase dramatically and result in almost immediate (within 1-2 years) increase in snipe abundance. Although not included in the focal species list due to its secretive nature and difficulty in detecting, Sora were relatively common in the wetland areas of Pickel Meadow. We recommend continuing to monitor this

species for indications of population growth with restoration. Other notable wetland obligate species that may colonize the site if restored include Virginia Rail, Wilson's Phalarope, the California endangered Sandhill Crane, (whose range has been expanding southward again over the last decades), and California endangered Yellow Rail, known from wetlands further east.

Figure 6. Point count stations with Wilson's Snipe detections. The size of blue circle indicates number of snipe detected (at all distances)

Brown-headed cowbirds and European Starlings

Both of these nest parasites and nest usurpers are present at Pickel Meadow, but considering its proximity to a large human settlement and to grazing livestock the numbers were relatively low (Appendix A). We recommend that the monitoring of these species continues, because population increases in these species may unravel restoration related gains for riparian focal species in some instances.

Multi-species Results

Campos et al. (2014) recommended that management and restoration activities should strive to meet a species richness target of 1.99 focal species per station (or 1.04 focal species per acre). Our current species richness measurement for Pickel Meadow is 0.24 focal species/station (0.13 focal species/acre), so meeting that target at the meadow scale will require a ten-fold increase. Pickel Meadow would require an almost a five-fold increase to even reach the average value of 0.56 focal species/acre as measured across all the restoration monitoring sites visited by IBP in 2018 (Figure 7). Closer inspection of data from individual stations reveals that it was rare to detect more than one focal species at any station, and the cases where that occurred are at stations where the meadow is wetter and has at least a small amount of willow (station 15, 23, 24; Figure 1). Based on assessment of focal species richness values from other sites within the watershed (Figure 5), we suggest that the most reliable way to boost focal species richness is to use restoration techniques that re-wet the drier portions of the meadow and create areas of season-long ponded water, and especially through creating conditions necessary for germination and recruitment of native woody vegetation (and subsequently protecting it from browsing while it becomes established). Because there is such a shortage of riparian shrubs we recommend planting at least a few large patches in an attempt to jump start this habitat component. Similarly, through planting of aspen or cottonwood along meadow edges or within the stream channels where hydrology is appropriate, additional bird species are likely to respond positively over the next 10+ years.

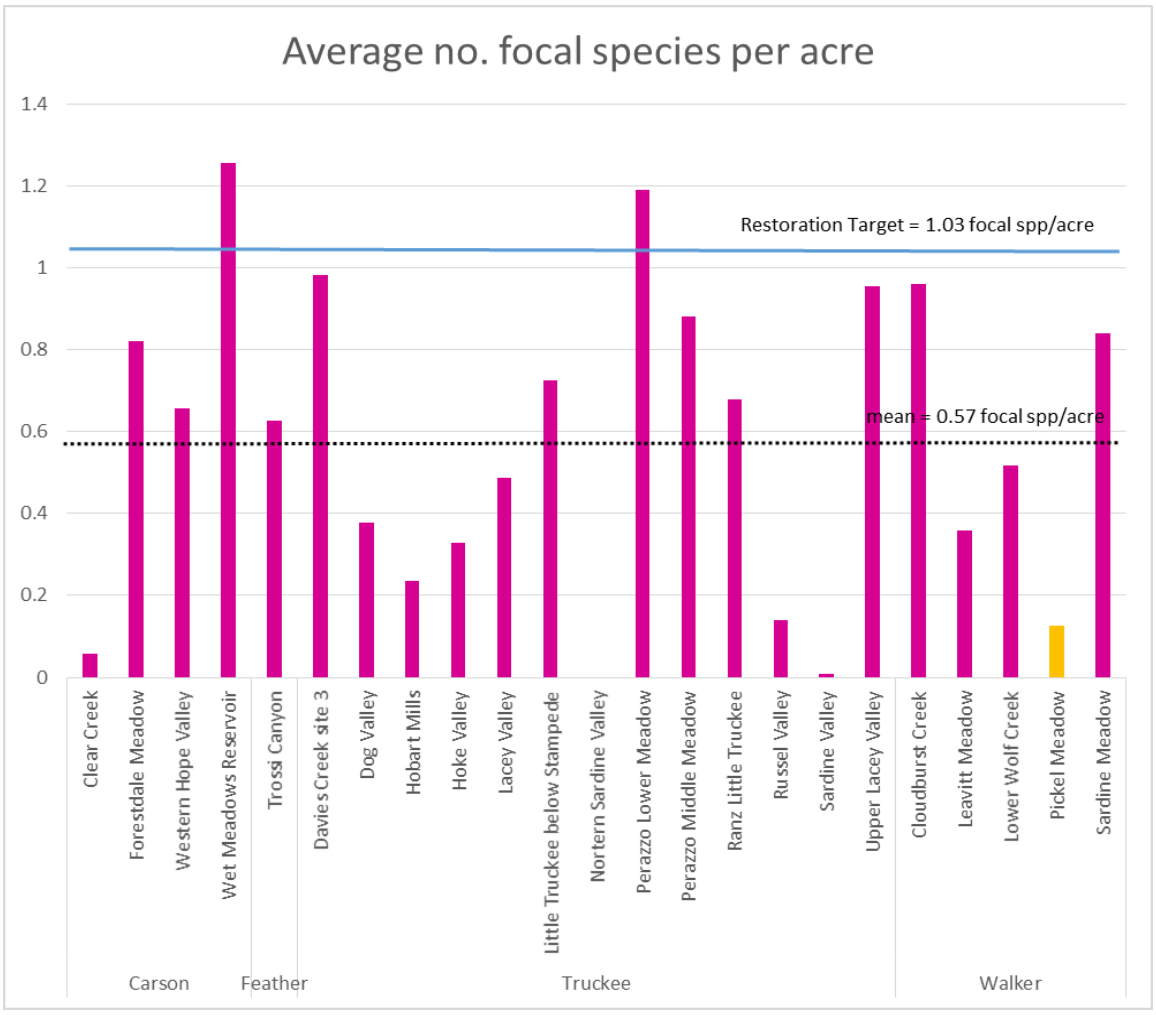

Figure 7. Average riparian focal species richness per acre at all 2018 survey sites, including Pickel Meadow (yellow bar), relative to regional target and regional mean.

Vegetation Surveys

Pickel Meadow has similar willow and sagebrush cover values when compared to all sites visited in 2018, but generally higher values for water cover, and lower values for tree cover (Table 4). Higher values for water cover are positive, but tree values indicate a lowered water table and drier conditions.

Table 4. Average cover values in percentage of vegetation and hydrology habitat components at all sites visited in 2018

		Avg. percent cover by type %					
Watershed	Site name	Riparian shrub	Sagebrush	Flowing water	Standing water	Tree	Aspen or cottonwood present?
Carson	Clear Creek	1.5	5.7	2.1	0.4	6.8	yes
Carson	Forestdale Creek	33.3	0.0	2.5	13.8	0.5	
Carson	Hope Valley West Meadow	20.9	20.2	0.8	5.1	13.2	yes
Carson	Wet Meadows Reservoir	42.1	7.3	0.5	1.5	11.4	yes
Feather	Trossi Canyon	15.5	28.8	1.5	5.5	26.2	yes
Truckee	Davies Creek	21.3	19.7	1.5	5.4	7.8	
Truckee	Dog Valley	5.5	19.8	1.2	0.8	0.9	yes
Truckee	Hobart Mills	4.4	16.7	2.5	4.2	2.5	
Truckee	Hoke Valley	8.0	27.8	2.1	7.0	15.0	yes
Truckee	Lacey Valley Lower	10.0	0.0	3.3	4.3	1.6	
Truckee	Little Truckee Below Stampede	15.8	23.6	3.0	2.6	6.2	yes
Truckee	North Sardine Valley	0.6	5.2	0.4	25.3	0.6	
Truckee	Perazzo Lower	26.2	11.8	8.3	0.1	5.8	
Truckee	Perazzo Middle	31.2	10.4	6.9	25.1	8.7	
Truckee	Ranz Little Truckee	20.4	16.2	5.7	1.1	17.1	yes
Truckee	Russel Valley	1.8	19.8	2.2	3.3	1.5	
Truckee	Sardine Valley	0.1	49.2	1.8	1.2	0.0	
Truckee	Upper Lacey Valley	25.7	0.0	1.1	7.5	16.2	
Walker	Cloudburst Creek	11.9	7.8	2.3	9.3	30.5	yes
Walker	Leavitt Meadow	15.4	15.7	2.9	0.8	2.5	yes
Walker	Lower Wolf Creek Meadow	10.9	12.0	4.6	1.3	22.3	yes
Walker	Pickel Meadow	10.4	11.6	4.3	9.0	0.5	yes
Walker	Sardine Meadow	17.5	25.0	5.9	0.6	29.6	
	Mean across all sites	11.7	17.2	2.9	4.6	6.4	

Recommendations

Meadow restoration is a complex and challenging process that is not completed in one season. The restoration actions undertaken at Pickel Meadow may take many years to create habitat conditions needed for some focal bird species. We recommend continued monitoring efforts at these and other restoration sites so that future practitioners can better understand the complex and temporally dynamic responses of bird populations to restoration of this sort and identify those practices that create the best outcomes for birds, fish, plants, hydrologic systems, recreation, and downstream water users. Long-term monitoring is necessary to generate science-based best management practices.

The primary issue constraining bird habitat quality at Pickel Meadow is a lowered water table and lack of riparian shrub recruitment. This is especially noticeable in the western portion of the meadow where neither beaver impoundments nor spring-fed sheet flow ameliorate the effects of stream incision. Restoration to fully restore the primary channel of the Walker River to its historic floodplain may not be feasible due to the high flows typical of a stream of this size, but even if that is the case, through use of techniques such as beaver dam analogs, complete channel fill, or pond and plug could provide improved hydrology to many of the tributaries that enter from the North and Poore Creek from the west. Techniques such as these could improve hydrology and vegetative communities in the shortest time frame and most benefit the region's rapidly declining Willow Flycatcher population at a temporal scale best matching the species' rate of decline. Similarly, irrigation strategy and season of use and intensity of livestock on the Junction allotment could be assessed and potentially modified to incorporate or increase seasonal fencing or rest rotation (or other actions) in the meadow to improve woody vegetation recruitment in areas wet enough to support it

East and Middle Meadow

In the eastern and middle areas of Pickel Meadow, the Walker River is incised with very large, bare gravel bars. Also in this area, Silver Creek joins the meadow and is incised up and under the highway and USMC MWS. Sagebrush has encroached along Silver Creek. Nonetheless, the presence of oxbows and side channels to the Walker River allow the middle section to support standing water and dense willow thickets. These conditions result in some of the richest bird habitat on the site, and the vegetative source material for plant colonization into future restored areas. This is also the only portion of the meadow that beaver have colonized due to generous woody forage and dam building supplies, and because the off channel areas providing ponded hiding cover. On the main channel and upstream beaver have not had success with damming, likely because the flows are too swift, and possibly also because there are few opportunities for beaver to secure or anchor dams to natural formations (e.g., boulders or granite outcrops), and there is little forage or dam building supplies available near the channel. Upstream of this area as the river turns north abruptly, the willow is more sparsely distributed and primarily occurs along the inset floodplain directly adjacent to the river. It is likely that prior

to road construction, base construction and historic mining and grazing pressure altered hydrology, there may have been sheet flow of water across the meadow surface from both the main channel, tributaries and the numerous springs for much of the warm season. This would have resulted in wet conditions summer-long and regular disturbance required for woody vegetation germination and establishment. If stream restoration techniques are applied to the main channel (where feasible) and especially tributaries, this middle and eastern portion along Silver Creek inflow could again have a mesic nature more suitable to riparian birds. Overbank flows might encourage new willow establishment, but active willow planting could also improve the size and continuity of stands within the more uniformly saturated parts of the meadow (especially within oxbows, regardless of restoration techniques used).

West Meadow

The western portion of Pickel Meadow also has an incised condition along the main channel of the Walker, but the flow coming in from springs to the north and Poore Creek to the south keep the portions of meadow close to the stream and springs relative mesic. Some parts are still supporting shallow emergent wetlands and the riparian birds that utilize them. The primary habitat components that are missing are woody riparian shrubs and trees, and off channel ponds and oxbows. Beaver have not effectively colonized the area along Poore Creek, likely due to a lack of ponded hiding cover and little, if any, willow or other woody vegetation. This area is without substantial woody riparian shrubs and could benefit from a number of large plantings (10 or more 1 acre patches with subsequent fencing to protect against browse if possible). This western end of the meadow is also a good candidate area for aspen or cottonwood planting along the meadow edges (or efforts to release any existing aspen stands).

Recommended Restoration Actions

1. Treat Silver Creek, Poore Creek and other small tributaries (via complete fill, pond and plug, beaver dam analogs, etc.) to increase soil saturation, standing water and sheet flow on the existing elevated floodplain (with subsequent willow, alder or aspen planting as feasible).

2. Treat primary channel of West Walker River if feasible (via grade alterations, bank shaping pond and plug, beaver dam analogs, or other methods, etc.) to increase soil saturation and standing water by raising the water table or by widening the channel and creating lower flow areas and improving revegetation of sandbars (with subsequent willow planting as feasible).

3. Lower oxbow base levels or create artificial oxbows to match the water table in or adjacent to existing (or restored) stream channels to create standing water and shallow emergent wetland settings (with subsequent willow planting as feasible).

4. Plant and protect willow and other riparian deciduous shrubs in areas where existing or restored hydrology provides necessary flooding and/or soil saturation levels. Plant patches at least 1 acre in size if possible.

5. Plant and protect aspen along meadow edge or treat existing aspen stands to stimulate new growth as feasible.

6. Assess and revise irrigation and grazing plans as needed to support hydrologic stability, vegetation recruitment, and restoration goals.

7. After restoration is complete and willow stands are mature, attempt to help Willow Flycatcher reestablish at Pickel Meadow by using the conspecific attraction technique (Schofield et al. 2018).

Climate-Smart context

We are already experiencing the effects of climate change in the Sierra Nevada. Projections suggest that the region is likely to continue to experience profound changes through the end of the 21st century. Rising temperatures, reduced snowpack, changing hydrological conditions, and increased frequency and intensity of extreme events threaten Sierra meadows and meadow-associated species. Restoring Sierra meadows in the context of historical conditions and the range of historic variability is unlikely to be adequate to ensure that desired meadow restoration outcomes, such as hydrological processes and habitat for diverse species, are able to persist under future climate change. In order to retain our investment in meadow restoration, it is necessary to design and implement climate-smart meadow restoration projects in the context of a changing climate and associated uncertainty about future conditions (Veloz et al. 2013), in a manner that makes them resilient to the consequences of climate change. Below we summarize the projections for the Sierra Nevada and outline some climate-smart actions that may increase the likelihood of success. For more information, please see "A guide to climate-smart meadow restoration in the Sierra Nevada and southern Cascades" (Vernon et al. 2019).

Climate Projections**.** The Sierra Nevada is projected to experience large changes in climate and hydrology by the mid-21st century relative to conditions observed in the 20th century. Below is a summary of projections for the Northern Sierra Nevada from a CA-wide water balance model (Flint et al. 2014) and the Assessment of Climate Change in the Southwest US (Garfin et al. 2013):

- Large reductions in April 1st snowpack
- Higher maximum and minimum daily temperatures throughout the year
- Increased evapotranspiration rates (water demand) by plants in meadows
- Higher proportion of winter precipitation falling as rain instead of snow, including rain on snow
- Larger, longer ,and more frequent heavy rain events that cause large floods
- Hotter, longer and more frequent droughts and heat waves
- Increased probability of high severity fire

Potential Climate-Smart Actions

- Promote beaver occupancy (e.g. by managing for sufficient willow cover) to maintain hydrologic function and increase habitat complexity. In general, Sierra Nevada riparian meadows historically had a high capacity for beaver dams. Beaver dams prolong floodplain activation and hold more water in the meadow during droughts.
- Plant a diversity of riparian shrubs that occur in the vicinity to increase the duration fruits and flowers are available to wildlife to compensate for divergences in plant and animal phenology. Plant along the channel, meadow edges, and other moisture gradients, and consider sourcing material from drier areas and lower elevations that may be more tolerant of the future climate.
- Identify and plant more drought-tolerant species and phenotypes. Source species for plantings from areas lower in the watershed that are warmer and drier. Plant large

numbers of willows cuttings from all willow species in the meadow to increase the likelihood of survival of some individuals following severe drought.

- Provide thermal refugia (shade, shelter, water, and food) for wildlife species by planting willows and other shrub species to promote large clumps of dense foliage with diverse plant understories near and over water. Shrubs and sedges along the stream channel promote complex instream habitat and may reduce stream temperatures by shading.
- If the meadow is grazed, maintain riparian fencing to protect streamside vegetation and adaptively manage grazing pressure to achieve desired objectives, especially during drought years or following major disturbance (e.g. large flood).
- Monitor the restoration project to inform agile and adaptive management, and provide context for understanding climate-related impacts and vulnerabilities.

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Appendix A. Bird Species detected during point count surveys in Pickel Meadow in 2018, including total number of individuals detected and relative abundance[1]. Tan highlighting indicates meadow focal species.

Bird species	# detected (all distances)	Index of abundance (within 50m) Avg #/acre
Prairie Falcon	1	
Canada Goose	2	
Mallard	7	0.04
Mountain Quail	2	
Sora	6	
American Coot	2	
Killdeer	6	0.01
Spotted Sandpiper	12	0.03
Wilson's Snipe	11	
Rufous Hummingbird	1	0.01
Northern Flicker	10	
Steller's Jay	1	
Clark's Nutcracker	3	
Black-billed Magpie	13	
Common Raven	2	
Horned Lark	2	0.01
Tree Swallow	2	
Violet-green Swallow	1	
Cliff Swallow	219	0.2
Rock Wren	3	
House Wren	4	
American Robin	6	
European Starling	1	
Orange-crowned Warbler	2	
Yellow Warbler	12	0.08
Yellow-rumped Warbler	3	0.04
Common Yellowthroat	3	0.03
Green-tailed Towhee	17	
Brewer's Sparrow	17	0.01
Vesper Sparrow	8	0.04
Savannah Sparrow	10	0.11
Song Sparrow	31	0.09
Red-winged Blackbird	166	0.3
Western Meadowlark	16	0.08

Bird species	# detected (all distances)	Index of abundance (within 50m) Avg #/acre
Brewer's Blackbird	43	0.11
Brown-headed Cowbird	4	0.01
Lesser Goldfinch	2	

[1] number of individuals detected within 50m radius plot around survey stations divided by the number of station visits and multiplied by 0.515 plots per acre.