Using birds to inform meadow restoration at Wet Meadows Reservoir

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Wet Meadows Reservoir Photo: Helen Loffland

Introduction

This report summarizes the results of pre-restoration multi-species bird monitoring at Wet Meadows Reservoir. In 2018, The Institute for Bird Populations (IBP) utilized a standard point count protocol to monitor bird species within the Wet Meadows Reservoir 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. Wet Meadows Reservoir was identified as a priority site in the *Restoring Carson Meadows: Assessment and Prioritization* (Fair et al. 2018) 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 Wet Meadows Reservoir followed Loffland et al. (2011a). 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.

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 11 multi-species point count survey stations in Wet Meadows Reservoir (Figure 1). All visits occurred between late May and early July (Table 1).

Table 1. Dates for multi-species bird monitoring in the Wet Meadows Reservoir in 2018.

Site	2018 Visit 1
Wet Meadows Reservoir	7/9/2018

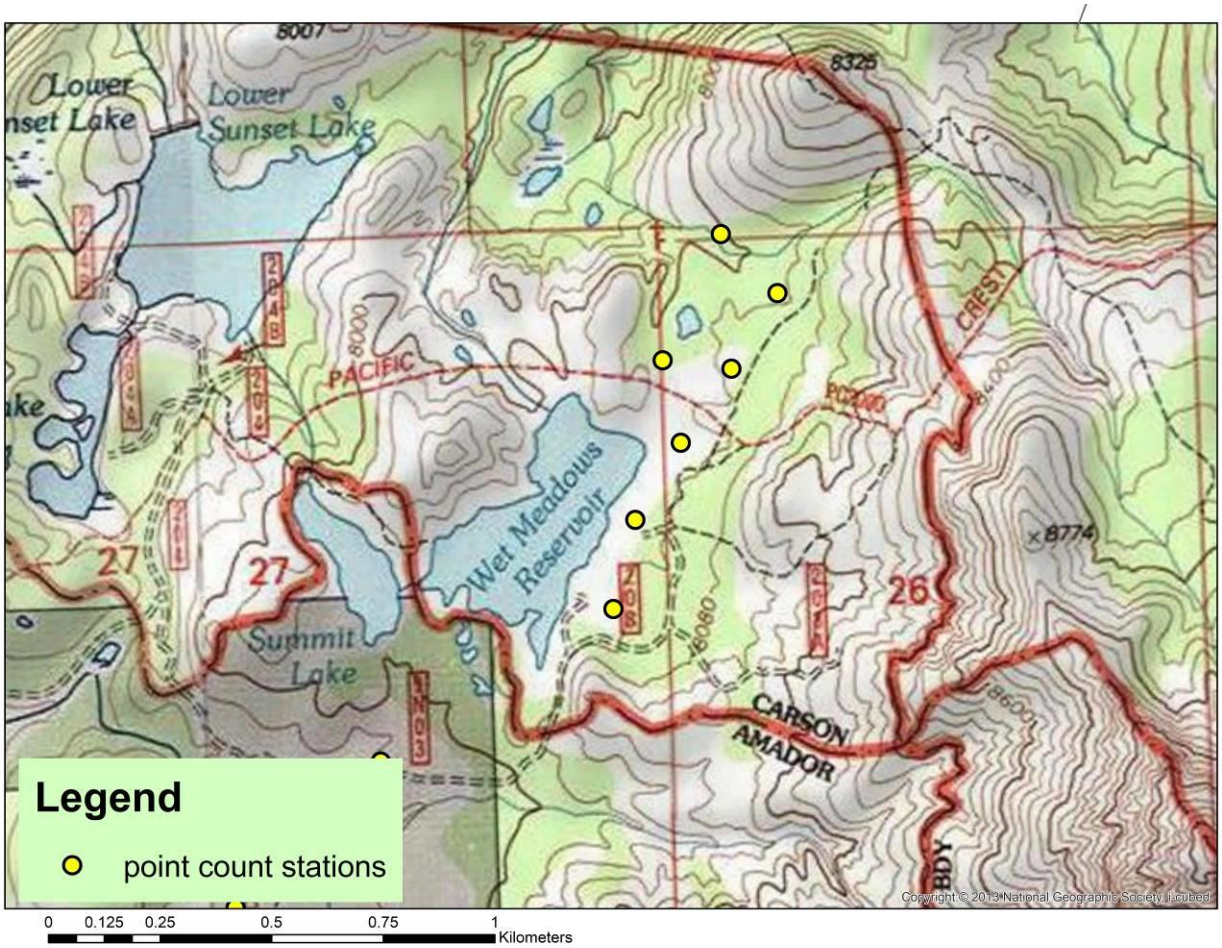

Figure 1. Multispecies avian point count station locations in Wet Meadows Reservoir.

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, 28 bird species were detected during point counts at Wet Meadows Reservoir, including 6 of the focal species (Table 2; Appendix A).

Table 2. Focal bird species observation status during surveys of Wet Meadows Reservoir in 2018.

Species	Usual habitat within meadows[1]	Observed in study area?
Wilson's Snipe	E	no
Red-breasted Sapsucker	S,A	**yes**
Calliope Hummingbird	M,S,A	no
Willow Flycatcher	S,E	no
Swainson's Thrush	S,A	no
Warbling Vireo	S,A	**yes**
Yellow Warbler	S	no
MacGillivray's Warbler	S,A	**yes**
Wilson's Warbler	S,A	**yes**
Song Sparrow	M	no
Lincoln's Sparrow	M	**yes**
White-crowned Sparrow	S,M	**yes**
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 riparian associates such as Lincoln's Sparrow, White-crowned Sparrow, Warbling Vireo, and Wilsons's Warbler, as well as generalist and forest species such as Dark-eyed Junco, Cassin's Finch and Pine Siskin (Appendix A). 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 6 of the focal species at Wet

Meadows Reservoir, but only 5 of those were detected within 50m of survey stations (Tables 2 and 3).

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

Bird species	Total Count (any distance)	Index of abundance (within 50m) Avg #/acre
Red-breasted Sapsucker	2	--
Warbling Vireo	6	0.22
MacGillivray's Warbler	3	0.15
Wilson's Warbler	6	0.44
Lincoln's Sparrow	11	0.37
White-crowned Sparrow	7	0.15

[1]Total 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 per meadow.

Lincoln's Sparrow and Wilson's Warbler were the most abundant focal species, followed by Warbling Vireo and White-crowned Sparrow. We detected 2 other focal species, MacGillivray's Warbler, and Red-breasted Sapsucker (although the last of these was not detected within 50m of survey stations). Of our focal species, White-crowned Sparrows have some of the least restrictive habitat needs and will occur in both wet and dry meadows with varying amounts of riparian or other shrub cover. Like White-crowned sparrows, Lincoln's Sparrows tend to be more abundant at higher elevations, but they differ in that they are more strongly associated with mesic meadow conditions and tall, dense herbaceous vegetation, especially where springs or small streams result in sheet flow across the meadow surface. Wilson's Warblers and MacGillivray's Warbler are also more abundant at higher elevations and in meadows with dense willow or other riparian shrub cover and mixed tree cover, often in more closed stringer-meadow settings. Warbling Vireo and Red-breasted Sapsucker are found along edges where conifers meet the meadows edge, and are especially abundant where there are dense and tall riparian shrubs mixed with sizeable aspen stands. The remaining focal species (Table 2) were not detected at all within the study site, likely because they are typically associated with conditions that occur only in relatively small portions of Wet Meadows Reservoir. These conditions include: large, open, flooded areas that include shallow emergent wetland vegetation (Wilson's Snipe), abundant and tall riparian shrub (usually willow) cover in both wet and mesic meadow settings generally below 8000 ft. elevation (Yellow Warbler; Ray 1903, Grinnell and Miller 1944, Orr and Moffit 1971, Stewart et al. 1977, Heath and Ballard 2003). Calliope Hummingbirds require spatially and temporally diverse stands of flowering plants often with a willow mosaic. 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, although Willow Flycatchers were detected at this site in 2008.

In addition to monitoring how individual focal species respond to restoration, we measured 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 Wet Meadows Reservoir against other sites within the region. The mean in 2018 at Wet Meadows Reservoir was 2.43 focal species per station (1.26 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 or seasonally flooded areas in 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 nearby in downstream reaches of the Carson River Watershed, in Wet Meadows Reservoir signs of beaver activity were not noted during point count visits or other assessments (Fair et al. 2018) 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 (Bombay 1999). Although Willow Flycatchers are not currently breeding in Wet Meadows Reservoir, a pair displaying breeding

Figure 2. Willow Flycatchers were historically found at Wet Meadows Reservoir.

behavior was observed at this site in 2008 and 2010. For this reason and because of its close proximity to current/recent breeding sites at Indian Valley, Red Lake Peak, Red Lake, and Hope Valley make future re-colonization of restored habitat in Wet Meadows Reservoir a possibility, and the opportunity to build a large complex of restored habitat within the upper reaches of the Carson Watershed make this site a high priority for this species (Mathewson et al. 2011, Loffland et al. 2014, Schofield et al. 2018). This is because even smaller meadows like Wet Meadows Reservoir that are within close proximity to nearby occupied sites can act as satellite breeding sites and be maintained over time if enough breeding territories occur nearby. Sites within already occupied watersheds are of highest priority for restoration for this declining species (Schofield et al. in prep). A restoration project that successfully restores existing gullies and brings overbank flows in contact with a significantly larger portion of the meadow, creates ponded and slow moving water settings, and results in 3 or more large willow patches (1+ acre in size) could provide suitable habitat for this species. Targeted efforts could create or enhance habitat for 2 or more Willow Flycatcher territories over the next 5-10 years, because substantial willow cover already exists on site. Sites that support this many territories when close to larger breeding areas (with the potential to support 10 or more territories such as Faith Valley, Hope Valley, and Red Lake complex) are more likely to be self-sustaining breeding sites over time, especially if nearby meadow restoration projects at Faith Valley and Little Indian Valley are implemented.

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 relatively common nearby in the appropriate portions of Carson Watershed, where tall willow in denser patches is present, they are absent from Wet Meadows Reservoir likely because the species is often restricted to elevations below 8000 feet. Campos et al. (2014) recommend a habitat management target of 1.04 Yellow Warblers per station (0.54 Yellow Warblers per acre; Figure 3). Because Yellow Warblers are present at many nearby meadows it is likely they could quickly colonize this site if climate change results in smaller winter snow pack and in turn willow stands become taller and denser.

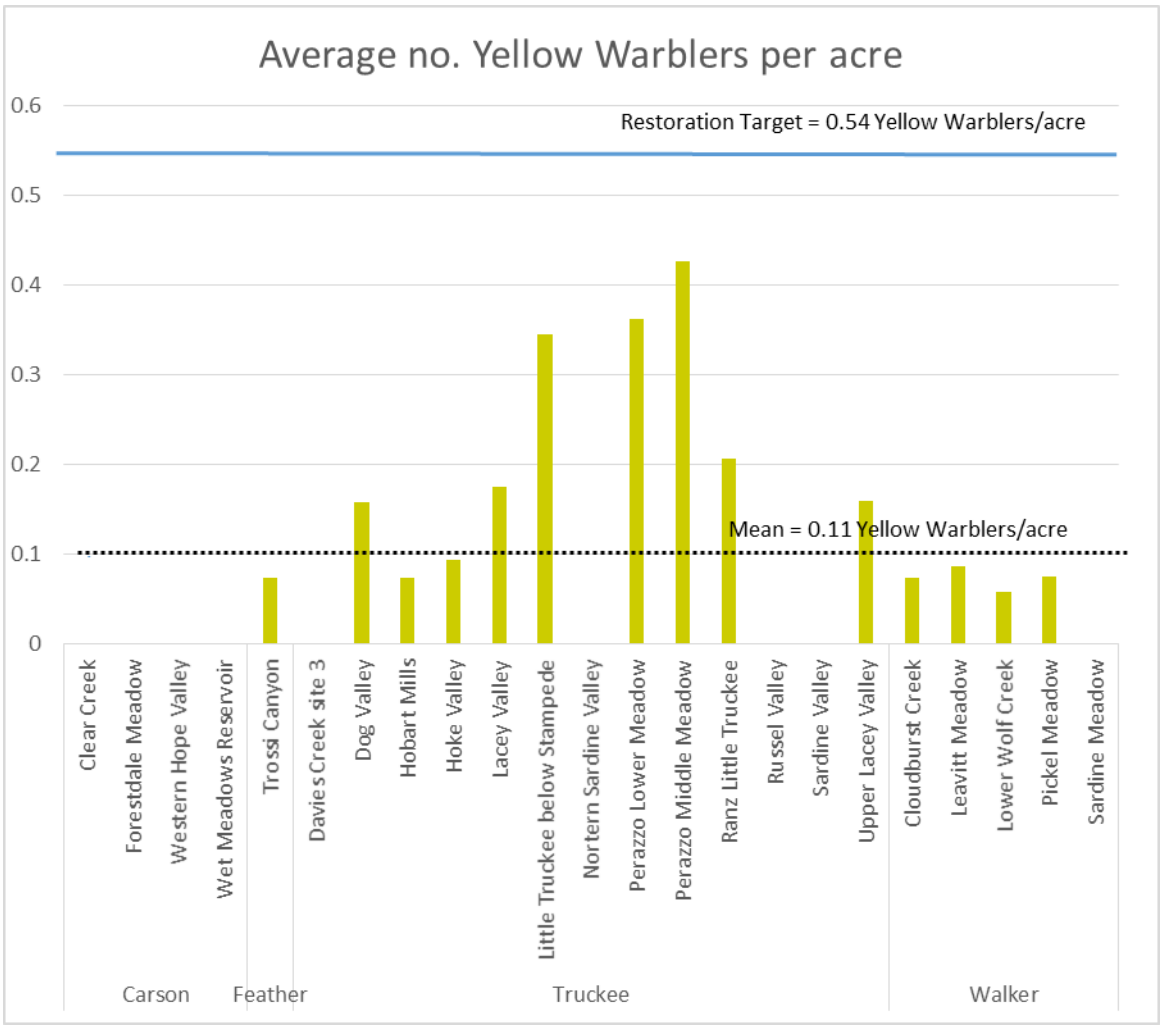

Figure 3. Average number of Yellow Warblers detected per acre at all 2018 survey sites, including Wet Meadows Reservoir, relative to regional target and regional mean.

Song Sparrow, White-crowned Sparrow

White-crowned Sparrows are common at Wet Meadows Reservoir where willow (or conifers) provide cover (mean relative abundance of 0.29/station or 0.15/acre; Figure 4). The species will likely respond positively to restoration that expands willow and dense herb communities into some of drier regions. Although not strictly necessary, willow is a preferred component of White-crowned Sparrow habitat. Song Sparrow were not detected in Wet Meadows Reservoir likely due to elevational constraints. If climate change results in reduced snowpack in this area, it is possible that the downslope Song Sparrow population would also expand into the site. These two sparrow species are important for restoration monitoring because their typically larger sample sizes and less restrictive habitat requirements allow for more robust analyses as post-restoration monitoring occurs.

Figure 4. Point count stations where White-crowned Sparrows were detected. Size of circle indicates number detected (within 50m).

Lincoln's Sparrow

Like the 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 typically linked to meadow areas 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 Sparrows were very common and detected in most portions of Wet Meadows Reservoir, especially in areas where springs fed the meadow and where herbaceous cover was more expansive (mean relative abundance of 0.71/station or 0.43/acre; figure 5).This species is often found at sites with intact tributary hydrology conditions that result in sheet flow. Because this site has multiple springs feeding the meadow and sheet flow intact in many areas it currently offers high quality habitat. If restoration restores the incised gullies and channel function and even more of the meadow 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 already quite common here, making colonization of new habitat likely.

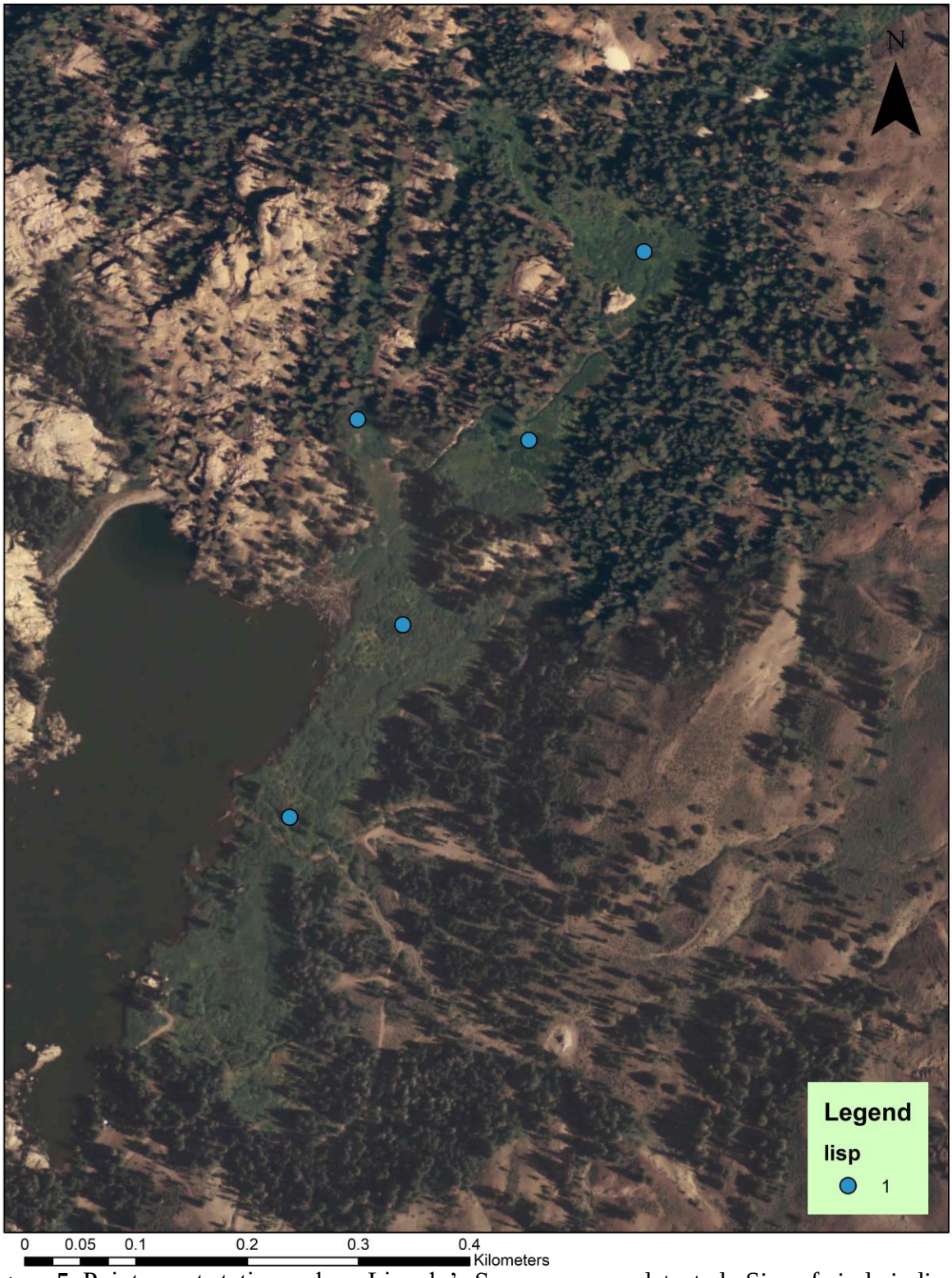

Figure 5. Point count stations where Lincoln's Sparrows were detected. Size of circle indicates number detected (within 50m).

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

Wilson's Warbler was the focal species with the highest index of relative abundance at Wet Meadows Reservoir. Wilson's Warbler was detected in willow stands wherever they occurred within the meadow (mean relative abundance of 0.86/station or 0.44/acre; Table 2, Figure 6). Warbling Vireo were detected throughout the site, likely due to the tree cover interspersed with willow (mean relative abundance of 0.43/station or 0.22/acre; Table 2, Figure 7). MacGillivray's Warbler were also somewhat common especially in the thickets at the north end of the site (mean relative abundance of 0.29/station or 0.15/acre; Table 2, Figure 8). It was somewhat surprising that we did not detect Red-breasted sapsucker (within 50m of stations), given that tree cover was interspersed and the meadow had a high edge to interior ratio. They were however present on site. All members of this suite of species will likely respond positively 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 lifestages of riparian shrubs and deciduous trees. Restoration activities may extend the length of growing season when the areas further from the streambed are saturated, and may expand some slow-water areas within the area immediately adjacent to the channel. This may allow establishment of aspen stands particularly along tributaries and meadow edges. If overall riparian deciduous shrub heterogeneity and aspen cover increase due to natural regeneration and/or plantings, these bird species could increase substantially, but it may take 10-15 years to establish additional woody stands because the growing season at this elevation is quite short.

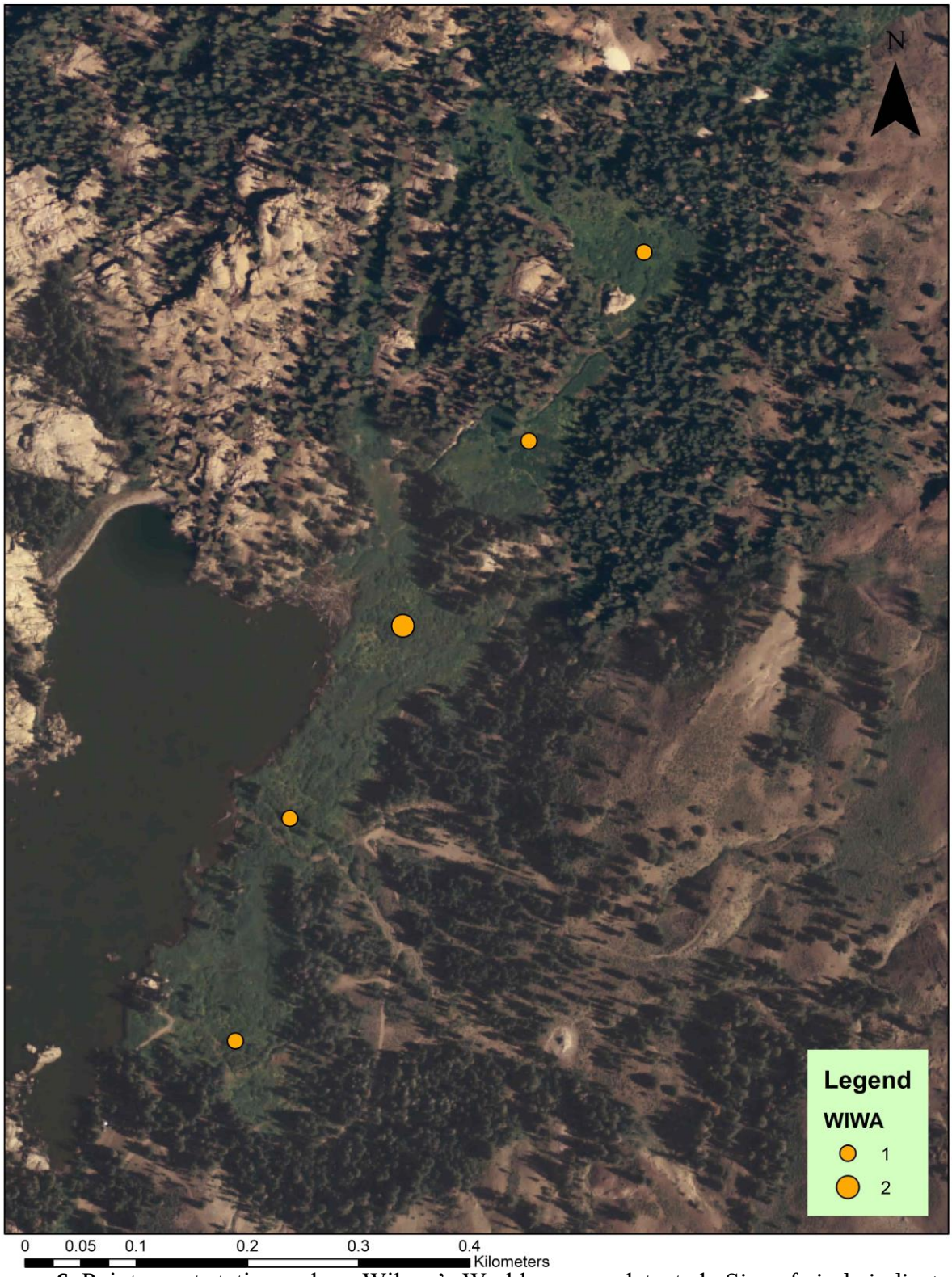

Figure 6. Point count stations where Wilson's Warblers were detected. Size of circle indicates number detected (within 50m).

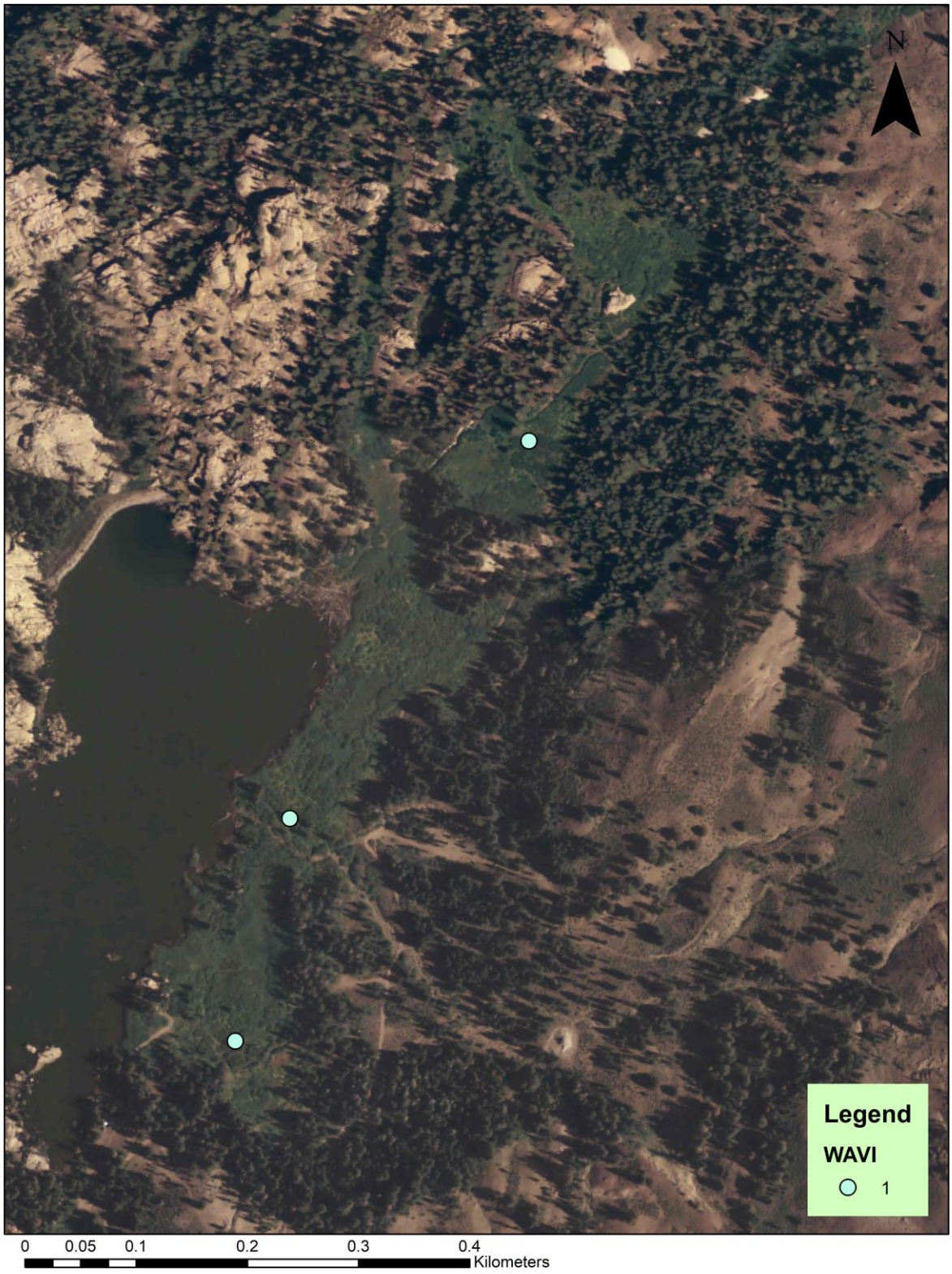

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Figure 7. Point count stations where Warbling Vireos were detected. Size of circle indicates number detected (within 50m).

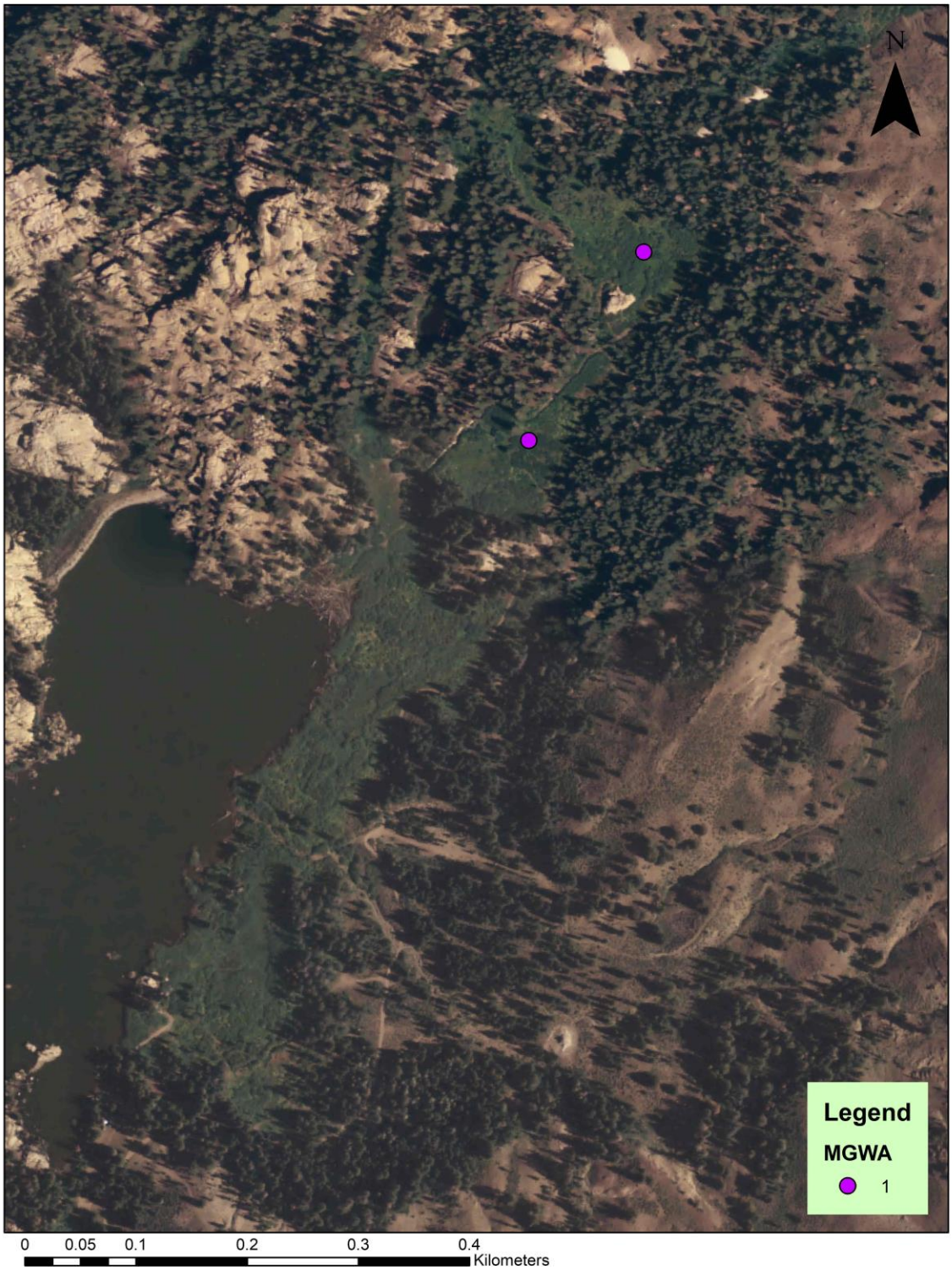

Figure 8. Point count stations where MacGillivray's Warblers were detected. Size of circle indicates number detected (within 50m).

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. Wilson's Snipe were not detected in Wet Meadows Reservoir despite ample sheet flow and sedge mats. If restoration restores overbank flows near gullies, results in sheet flow along other incised springs, 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 and could result in colonization by snipe. Wilson's Snipe are abundant in nearby Hope Valley Lower and Upper, and Red Lake area, so habitat improvements and newly created habitat would likely be quickly colonized.

Calliope Hummingbird

Calliope Hummingbirds were detected but other hummingbird species were detected in migration, suggesting good foraging habitat. They often benefit from wetter meadows with abundant willows. These conditions usually result in more diverse microclimates and longer growing season for the diverse floral resources they require.

Brown-headed Cowbird

Brown-headed cowbirds are nest parasites that may negatively affect meadow focal species where they are abundant. During our surveys brown-headed cowbirds were absent from Wet Meadows Reservoir, but occur relatively nearby in the Hope Valley and Red Lake areas. We recommend that the monitoring of this species continues because population increases 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 Wet Meadows Reservoir is 2.43 focal species/station (1.26 focal species/acre), and therefore exceeds the target even in its current condition. Closer inspection of data from individual stations reveals that 14% of stations had four focal species (within 50m), 43% had three focal species, 14% had 2 focal species and 14% had a single focal species (Figure 10). Wet Meadows Reservoir also has a focal species richness that is substantially higher than the average value of 0.56 focal species/acre as measured across all the restoration monitoring sites visited by IBP in 2018 (Figure 11).

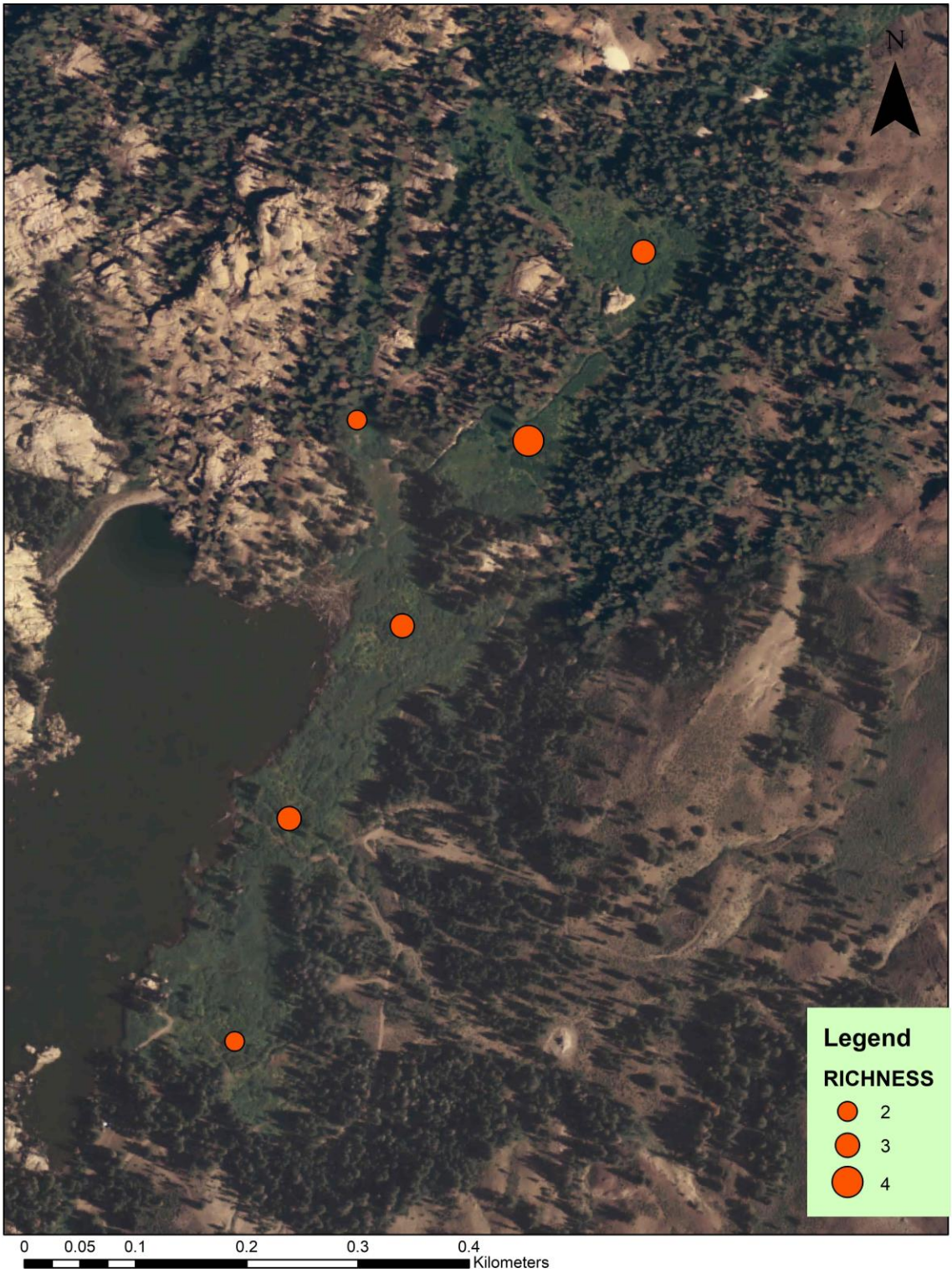

Figure 10. Locations within Wet Meadows Reservoir where one or more focal species were detected within 50m of survey stations. The size of the peach circle indicates number of focal species detected.

Based on assessment of focal species richness values from other sites within the watershed and elsewhere (Figure 11), we suggest that the priority at this site is to protect the conditions that are creating higher than average focal species richness by treating incised channels (and the road crossings affecting them) to prevent future dewatering. 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). Although the site is well covered with riparian shrubs, if it is determined that there is a shortage of riparian shrubs in any specific areas, we recommend planting large patches (0.5 acre in size). Similarly, through planting of aspen 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.

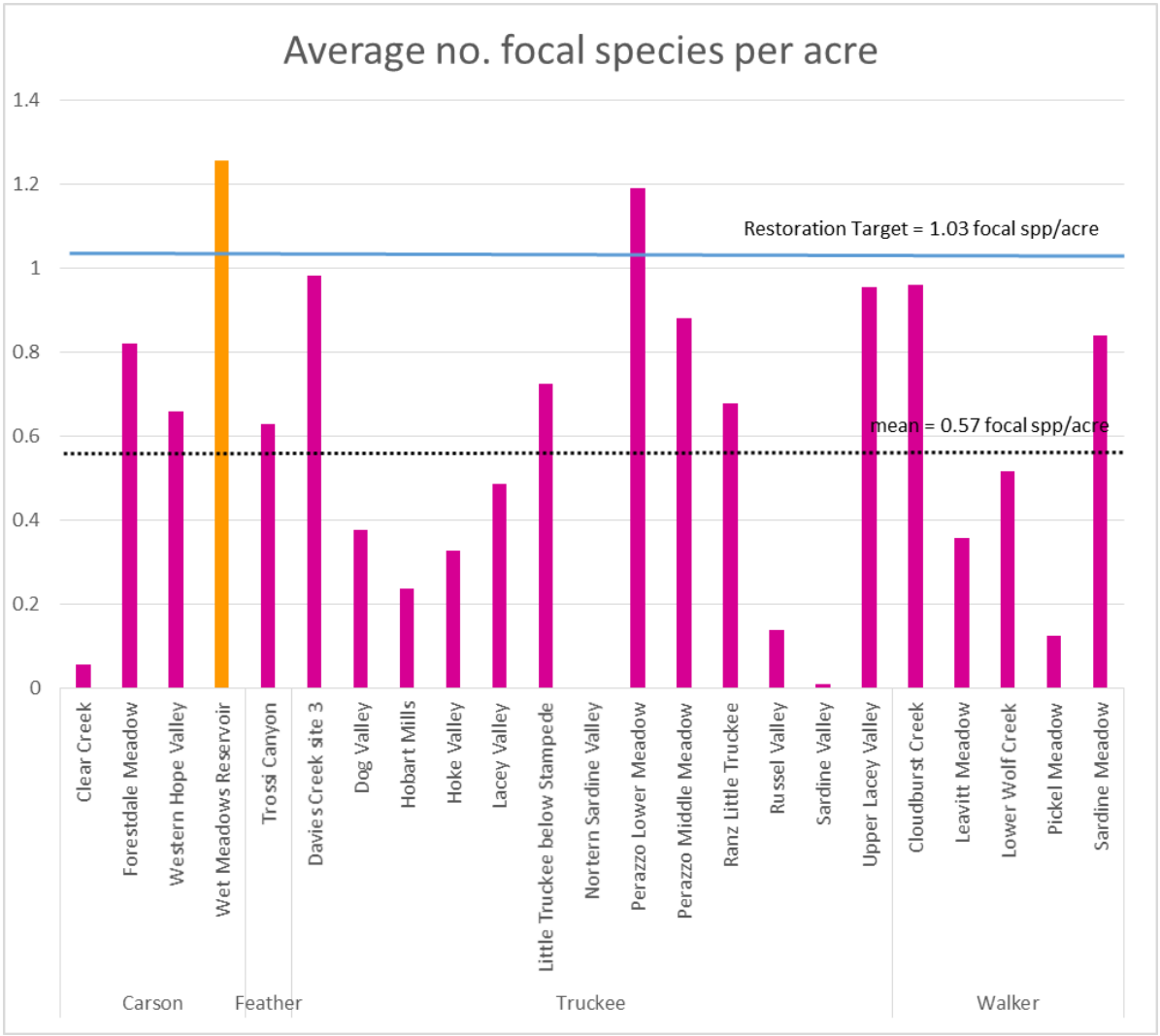

Figure 11. Average riparian focal species richness per acre at all 2018 survey sites, including Wet Meadows Reservoir (yellow bar), relative to regional target and regional mean.

Vegetation Surveys

Wet Meadows Reservoir had dramatically higher riparian shrub cover vales than all other sites surveyed in 2018. This factor likely plays a large role in the good focal species richness values for the site. Despite the shrub cover, Wet Meadows Reservoir had little standing or flowing water. Although the site is almost entirely spring fed and some sheet flow occurs, the many incised gullies are likely reducing the surface water considerably (Table 4).

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. If restoration actions are undertaken at Wet Meadows Reservoir they 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 Wet Meadows Reservoir is a series of incised channels and lowered water tables likely resulting from upstream road crossings to the east of the meadow. The dirt road crosses the small head-water streams or otherwise funnels surface water creating incised ditches along the natural stream course or through areas that were historically spring fed sheet flow across the meadow surface (Figure 12). These conditions have resulted in localized portions of the meadow being dry adjacent to the incised channels. Because the site is fed by numerous springs that erupt within the meadow, the site remains relatively mesic overall despite channel degradation. Restoration to fully restore the site would likely involve addressing the issues at road crossings that create new disturbance annually, but if those could be repaired (and maybe even if not) treating existing incised channels through use of techniques such as beaver dam analogs, complete channel fill, or pond and plug could provide improved hydrology to the small channels and springs that supply the site with water. 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. Beaver have not colonized the area, but ample of hiding cover in the form of deep water along the lake margin and plentiful food resources should not be limiting here. It would be informative to assess whether beaver populations are being actively controlled at the site (or nearby), and how management of beaver could be used to improve conditions. Similarly, although the Indian Valley allotment is currently vacant, prior to issuance of future permits, season of use and intensity of use by livestock could be assessed and modified to incorporate or increase rest rotation (or other actions) in the meadow to insure continued woody vegetation recruitment in areas wet enough to support it

It is possible that prior to the period when road construction, reservoir development, and historic mining and grazing pressure altered hydrology, there was sheet flow of water across more of the meadow surface(especially in the areas around the deeply incised channels at the north and south ends of the meadow). If stream restoration techniques are applied here it would improve overall wetness of the site and likely increase areas of sedge cover and insure continued willow seedling establishment. The willow community here is already abundant but it is important to maintain conditions that will allow for continued recruitment over time. Typically meadows that are wet for most of the season and have dense riparian woody vegetation support a rich insect community and provide hiding and nesting cover. Wet Meadows Reservoir is also a good candidate area for aspen planting along the meadow edges (or efforts to release any existing aspen stands). Because Wet Meadows Reservoir already supports high focal species

richness, restoration efforts would be valuable to protect the site against continued meadow drying and maintain it as a potential source location for riparian birds to colonize other nearby restoration projects.

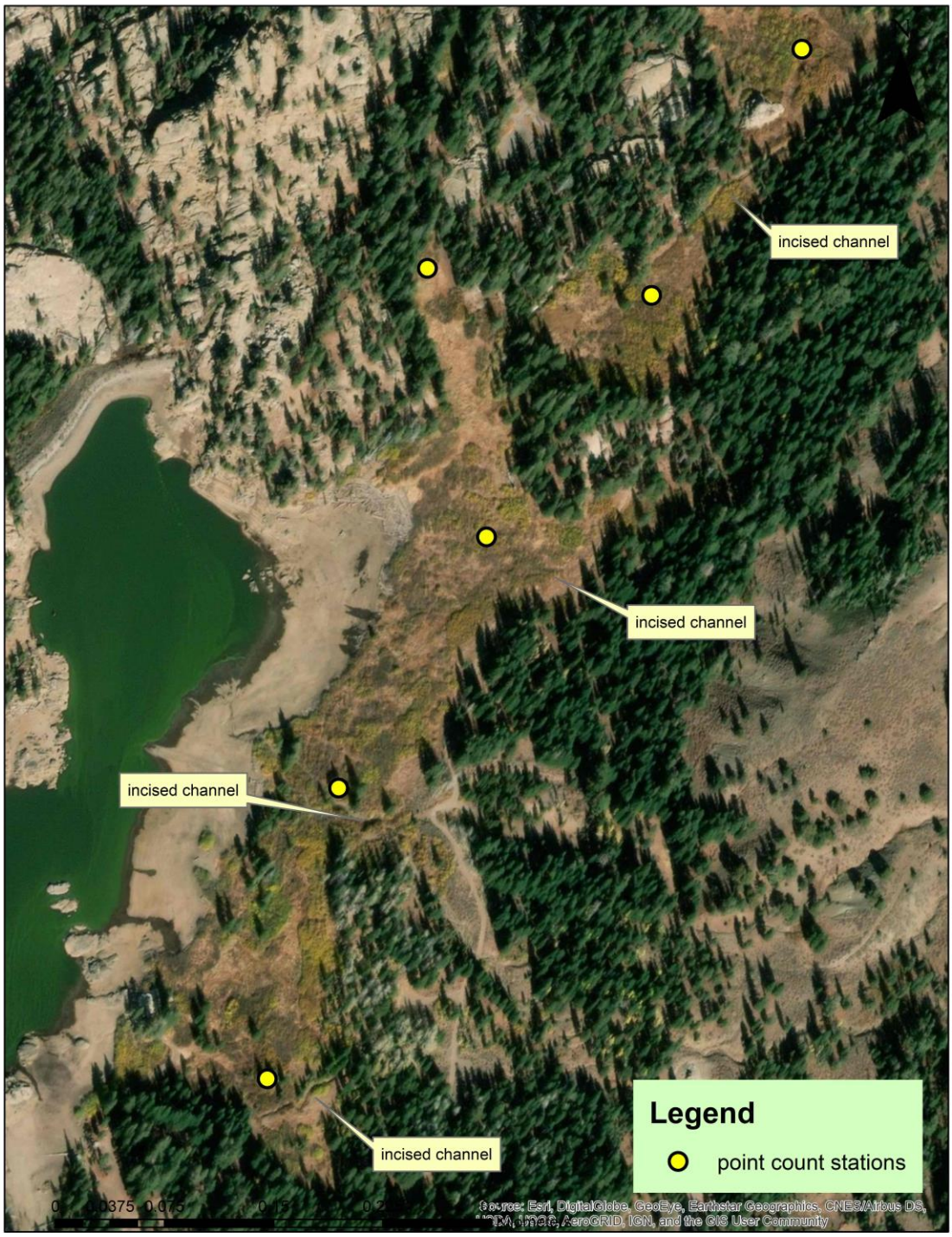

Figure 12. Wet Meadows Reservoir showing incised channel locations.

Recommended Restoration Actions

1. Treat the road and stream crossings along the east side of the meadow, to resolve ongoing erosion and headcut creation.

2. Treat the incised channels(via complete fill, pond and plug, beaver dam analogs, etc.) to reduce incision and increase soil saturation, standing water and sheet flow on the meadow surface (with subsequent willow, alder, or aspen planting as feasible).

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

4. Assess future road management plans and consider permanent stream crossings, road re-routing, or road closures (seasonal or permanent) as needed to support hydrologic stability.

5. Assess future grazing plans for the Indian Valley allotment as needed to support hydrologic stability, riparian vegetation recruitment, and restoration goals.

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 Wet Meadows Reservoir 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
Spotted Sandpiper	1	0.07
Rufous Hummingbird	3	0.22
Unidentified Hummingbird	1	0.07
Red-breasted Sapsucker	2	
Unidentified Sapsucker	3	0.07
Hairy Woodpecker	2	0.15
Northern Flicker	1	
Western Wood-Pewee	2	0.15
Dusky Flycatcher	4	0.22
Cassin's Vireo	1	
Warbling Vireo	6	0.22
Steller's Jay	3	0.15
Clark's Nutcracker	1	
Common Raven	1	0.07
Mountain Chickadee	1	
Red-breasted Nuthatch	4	
Ruby-crowned Kinglet	3	0.07
Hermit Thrush	3	
American Robin	5	0.07
Yellow-rumped Warbler	5	0.15
MacGillivray's Warbler	3	0.15
Wilson's Warbler	6	0.44
Western Tanager	4	
Fox Sparrow	2	
Lincoln's Sparrow	11	0.37
White-crowned Sparrow	7	0.15
Dark-eyed Junco	2	0.15
Red-winged Blackbird	3	0.22
Cassin's Finch	5	0.07
Pine Siskin	5	0.29

[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.