The Effects of Prescribed Fire and Shrub-layer Mastication on Bird Communities in Ponderosa Pine Forests of the San Juan Mountains, CO

A Citizen Science Project conducted by members of the
Weminuche Audubon Society
and
Audubon Rockies

In cooperation with
The San Juan Headwaters Forest Health Partnership
and
Mountain Studies Institute

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Abstract:
The use of prescribed fire and mechanical thinning to reduce wildland fuels is becoming more common in the Ponderosa Pine-dominated forests of the American Southwest. The effects of these treatment methodologies on bird communities has received a great deal of attention across Arizona and New Mexico, but very little work has been done in southcentral or southwestern Colorado. The US Forest Service has been judicious in the strategic use of prescribed fire and mechanical thinning of the shrub-layer in forests surrounding residential communities in Archuleta County, Colorado. Working through the San Juan Headwaters Forest Health Partnership, a collaborative of local, state, and federal agencies and organizations, we assembled a team of volunteers associated with the local Weminuche Audubon Society to monitor bird community composition in three sites dominated by Ponderosa Pine that were subject to prescribed fire coincident with the initiation of the study (Turkey Springs site); mechanically thinned in 2017 (Fawn Gulch); and a mature Ponderosa Pine forested site that has not been burned or thinned for more than 75 years (Jackson Mountain). Tree density at the Fawn Gulch site (85 trees/ha) was significantly less than at either the Turkey Springs (128 trees/ha) or Jackson Mountain (132 trees/ha) sites. Gambel Oak dominated the shrub layer, which was largely absent at the Turkey Springs site; widely dispersed at Fawn Gulch; and notably most dense at Jackson Mountain. Data on bird species presence and individual bird counts by species were collected at 15 monitoring points at each site a minimum of four times across a six-week period beginning in early June, 2019. Of the 54 different species recorded, 15 species were common to all three sites. The most recently burned site (Turkey Springs) had the fewest number of species and lowest bird count (26 species; 185 birds). The un-treated site (Jackson Mountain) had the second highest species count (33 species) and count (278 birds), while 486 individual birds representing 40 species were identified at the Fawn Gulch site (with 354 birds representing 34 species when the dataset was re-balanced; see text for explanation). The Fawn Gulch site also had the highest number of species unique to that site (14 species), Jackson Mountain ranked second with 7 species, and Turkey Springs with 3 unique species. Grouping bird species into feeding guilds, and the application to our data of simple measures of species evenness, species diversity, and community similarity provide further insights that are discussed. Species-level responses to wildland fuel reduction treatments indicate that several species benefited from the effects of shrub-layer thinning treatments, including several species that have exhibited marked population declines over the past 50 years or so. These findings suggest that treatments contributing to forest heterogeneity have a net positive impact on bird communities at a regional scale.

Acknowledgments:
The data and information generated by this study is the work of many dedicated volunteers who collectively contributed more that 400 hours to the completion of this project. Their names (in alphabetical order) are:

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A Citizen Science Project:
The Effects of Prescribed Fire and Shrub-layer Mastication on Bird Communities in Ponderosa Pine Forests of the San Juan Mountains, CO

Introduction:
Engaging members of the general public in the conduct of scientific research has long been an emphasis of the National Audubon Society (https://www.audubon.org). The Christmas Bird Count and summer Breeding Bird Survey are just two examples of how members of the Audubon Society contribute to important scientific endeavors. This document describes a citizen science project in which members of the Weminuche Audubon Society (WAS - http://www.weminucheaudubon.org), partnering with Audubon Rockies (https://rockies.audubon.org), the San Juan Headwaters Forest Health Partnership (SJHFHP - http://sanjuanheadwaters.org) and its member organizations and agencies (e.g., Mountain Studies Institute - https://www.mountainstudies.org , United States Forest Service (USFS) Pagosa Ranger District - https://www.fs.usda.gov/detail/sanjuan/about-forest/districts/?cid=stelprdb5154746), investigated how bird community species composition and structure in Ponderosa Pine forests in the San Juan Mountains of southwestern Colorado may be affected by mastication and/or prescribed fire treatments designed to reduce woodland fuel loads, thereby mitigating potential wildfire occurrence and severity.

Forest management practices employed by federal and state agencies over the past century have virtually eliminated natural ground-fire occurrence, resulting in increased fuel loads and changes in forest understory and canopy densities in many areas in the western United States (Block and Conner, 2016; Harrington and Sackett, 1990; Korb et. al., 2013). The consequence of these changes in forest structure and composition across the western United States has in turn contributed to more catastrophic wildfires involving larger areas and having more extreme impacts on forested landscapes (Baker, 2018; Block and Conner, 2016; Covington, 1994; McWethy et al., 2019; Romme et al., 2009). Concurrently, people have increasingly chosen to build residential communities in forested areas, many of which are fire prone (Ager et. al., 2019; Technosylva, 2018). Over the past several decades, agencies charged with management of forested landscapes have employed various management practices (e.g., selective harvesting and/or thinning; prescribed fires; understory removal by mastication) to reduce the risk of catastrophic wildfires in wildland-urban interfaces (WUI), with varying impacts on wildlife in affected areas (Block and Conner, 2016; Lowe et. al., 1978).

USFS personnel with the Pagosa Ranger District in the San Juan National Forest, in collaboration with the SJHFHP, have used understory mastication and prescribed fire treatments to establish strategically defensible areas surrounding communities in Archuleta County, CO. Some local residents interested in bird conservation have asked the question – "How might fire mitigation practices affect the distribution and abundance of bird species in treatment areas?" While a great deal of research addressing this question has been conducted in Ponderosa Pine forests along the Mogollon Rim of Arizona and New Mexico (see for example Hurteau et al., 2010, and Jentsch et. al., 2008), the effects of fire mitigation work on bird communities has not been widely reported for forests in the San Juan Mountains of southwestern Colorado. This project was designed to investigate how changes in forest structure associated with wildland fuel management practices affect bird community diversity and composition by comparing bird communities in treated vs. untreated forested sites dominated by Ponderosa Pine in areas surrounding Pagosa Springs, CO.

As a citizen science project, this study incorporates several objectives complementary to the scientific question that was investigated. For example, volunteers participating in this study learned more about the ecology of fire and its importance to our surrounding forest ecosystems; how and why catastrophic wildfires have become more common and destructive; what agencies charged with forest management are doing to mitigate wildfire occurrence and severity; and why the residents living in the WUI should be interested in this issue. Added benefits of the study also included opportunities for participants to improve their birding skills by learning from one another; gain a better understanding of how scientific field studies are conducted; and through collaborative efforts central to this study, strengthen the community of conservation-minded birders in our area.

Study Areas:
Personnel from the Mountain Studies Institute (MSI) have conducted vegetation monitoring studies in several areas around Pagosa Springs, CO, to identify how forest management projects designed to reduce the probability or severity of wildfires affect the composition and structure of treated areas (MSI, unpublished data). Study sites selected for this project were identified in consultation with MSI and USFS personnel familiar with the history of

the region and who are directly involved in prioritizing, planning and implementing mastication, thinning, and prescribed fire treatments. Site selection criteria were further refined to accommodate access by volunteers, most of whom are retired senior citizens with two-wheel drive cars, and some of whom have physical limitations rendering them unable to negotiate steep terrain. The availability of study areas large enough to encompass an array of sample points (see section on Bird Community Sampling Methodology) also informed our selections.

Three areas were selected for this project (see Figs. 1 to 4). The Turkey Springs (TS) site, located approximately 24 km (15 miles) northwest of Pagosa Springs off of FR 919 in an area referred to as Brockover Mesa, was burned as this study was getting underway in early June of 2019. The Fawn Gulch (FG) site, located approximately 13 km (8 miles) east of Pagosa Springs off of FR 666, was masticated in 2017, with prescribed fire preceding mastication by several years. The Jackson Mountain (JM) site, located approximately 16 km (10 miles) east of Pagosa Springs off of FR 037, was selected because it had not been subject to either thinning or prescribed fire in the last 75 years, or longer. All sites are dominated by Ponderosa Pine (*Pinus ponderosa*) as the overstory species, but differ in the density of the overstory species, and the structure and composition of the understory and shrub-layer. General site characteristics of the three sites, are shown in Tables 1 and 2.

<u>General Study Site Characteristics</u> – The geographic coordinates, elevational ranges, and general aspects for the three sites chosen for study are shown in Table 1. Elevation and slope are similar enough across sites that we did not consider these to supersede historic fuel management practices, or other edaphic factors, in determining forest composition and structure. Our working hypothesis regarding the effects of forest structure on bird community composition relied on the assumption that the differences observed in plant community composition and structure is most strongly correlated with differing fuel management practices that have been implemented in these areas, and the length of time since implementation of fuel reduction treatments, if any. However, we also noted differences in soil properties that may contribute to stand differences. This was particularly true for the TS site, where sandstone outcrops indicated thinner soils than observed at the other two sites. United States Department of Agriculture (USDA) soil maps for these areas (USDA, 1974) indicate that the TS site is dominated by Dunton loam, characterized as moderately deep, well drained, and derived primarily from sandstone parent materials. The FG site is dominated by Pagosa loam, which is characterized as deep and well drained. The JM site is dominated by Woodrock silt loam, which is characterized as moderately deep, well drained, and derived from quartzite parent materials. The predominant soil types at both the TS and JM sites intergrade with Hunchback clay loams that are deep, poorly drained, and are derived from a mixture of alluvial and colluvial parent materials. Hence, information derived from USDA soil maps indicate that soil differences and other physical characteristics of the study areas interact with fuel management practices to produce the differences in plant community composition and structure noted in Tables 1and 2. While the differences in bird community composition observed between our study areas (Table 3) may be largely a consequence of plant community composition and structure that is proximally affected by fuel management practices implemented in recent years, edaphic factors certainly play a role in how the plant community responds to these treatments.

Tree canopy data were collected for each study site using the point-quarter method (Cox, 2002; Mitchell, 2015). Points selected for bird monitoring were used as reference points for this plotless method (see section on Bird Community Sampling Methodology). From each reference point, four quadrants were established using perpendicular lines running in each of the cardinal directions. In each of the four quadrants for each reference point, the distance to the nearest tree was recorded, along with the DBH (diameter breast height; approximately 1.4 m [4.5 ft]) above the ground. For purposes of this study, a tree was defined as a woody plant with a DBH greater than 10 cm (about 4 in). Using these data, mean point-to-tree distances were calculated by species. Squaring the mean point-to-tree measurement yields an estimate of the mean area occupied per tree, and the reciprocal of this represents the total density of trees per unit area (Cox 2002; Mitchell 2015). Mean DBH values provide an estimate of tree size.

There were two modifications we made to the standard point-quarter method as it was implemented in this study. First, reference points were not established strictly at random, as the point-quarter method specifies. Instead, points selected as bird monitoring stations were used as the reference points. The approach followed to establish the location of these points is described in the Bird Community Sampling Methodology section of this report. Second, no distance limitation was set for point-to-tree distance recording. In many cases, if there are no trees within a pre-determined distance from a point within a given quadrant (e.g., 30 m), then a zero would be recorded. We recorded measurements without limit, resulting in two measurements exceeding 30 m, both of which were less than 35 m.

Although these modifications in sampling methodology diverge from the standard assumption of randomized point selection critical to the point-quarter method when used for forest inventories, applying these modifications uniformly across our study sites still allows for inter-site comparisons that meet the objectives of this study.

Table 1. General site characteristics of Turkey Springs, Fawn Gulch, and Jackson Mountain study areas.

	Turkey Springs (TS)	**Fawn Gulch (FG)**	**Jackson Mountain (JM)**
Approximate Study Area (ha)	23	26	16
Lat/Long Approx. Center Point:	37.29036; -107.15552	37.31866; -106.93801	37.34598; -106.94378
Elevational Range:	~ 2400 m to ~ 2470 m (~ 8000 ft to ~ 8100 ft)	~ 2380 m to ~ 2400 m (~ 7800 ft to ~ 7900 ft)	~ 2340 m to ~ 2400 m (~ 7675 to ~ 7875 ft)
Aspect:	E to ENE (gentle slope)	NW (gentle slope)	SSW (moderate slope)
***Tree Density (# trees/ha):**	128[a]	85[a]	132[a]
Tree Density (# trees/ha) – Ponderosa Pine Only	128	79	110
***Mean Inter-tree distance (m) [SE]**	8.8 [0.52][a]	10.9 [0.82][b]	8.7 [0.79][ab]
***Mean DBH (cm) [SE]**	41.1 [2.33]	42.8 [1.54]	36.6 [1.99]
***Mean Area/Tree (m^2)**	77.9	118.2	75.94
***Basal Area (m^2/ha)**	20.26	13.1	16.26

* Data shown are sums for all tree species in sample sets. See Table 2 for site-specific tree data.

General study site characteristics reveal that overstory tree species composition and density differs substantially across the three sites (Tables 1 and 2). FG is estimated to have about 35% fewer individual trees per hectare compared to TS or JM. Ponderosa Pine was the only tree species recorded for TS, with 4 Gambel Oak falling within sample points at FG. About 83% of the trees sampled at JM were Ponderosa Pine; with 7 Gambel Oak (*Quercus gambelii*), 2 White Fir (*Abies concolor*), and 1 Aspen (*Populus tremuloides*) encountered at our sample points, and a much denser sub-canopy presence of Gambel Oak. While the tree overstory was not as dense at FG compared to TS or JM, the FG site had a much better developed shrub layer of Gambel Oak, with the shrub layer at TS reduced to oak root sprouts of less than 50 cm (~1.5 ft) tall. Pairwise comparisons of inter-tree distance data using Student's t test revealed that differences in mean inter-tree distances were statistically significant between TS and FG ($p = 0.038$), and approached statistical significance between JM and FG ($p = 0.060$).

Specific study site characteristics – As noted earlier, Ponderosa Pine is the dominant tree species at all three study sites, with Ponderosa Pine trees recorded in at least one quadrant from all sample points (Table 2). Separating out Ponderosa Pine tree densities from all trees recorded (Tables 1 and 2) indicates a range of 79 Ponderosa Pine trees/ha out of an estimated 85 trees/ha for all species at FG, to 110 Ponderosa Pine trees/ha out of 132 trees/ha for all species at the JM site. A total of 3 Gambel Oak were found at 2 of the sample points at FG, with 7 Gambel Oak found at 5 of the sample points at JM, with White Fir and Aspen encountered at one point each at JM (Table 2). These data, along with photographic images taken at the four cardinal directions at each sample point (not shown), establish JM as the most diverse site in terms of number and density of woody species present, with FG intermediate in species composition, and TS having the simplest overstory and shrub layer composition.

One other measure of forest structure is tree size, in our case measured only as DBH (Tables 1 and 2). JM was found to have the smallest mean DBH across all species (36.6 cm vs. 42.8 cm at FG, and 41.1 cm at TS). Focusing on Ponderosa Pine only, however, reveals similar mean DBHs across sites – 41.2 cm at JM, 44.7 cm at FG, and 41.1 cm at TS (Table 2). Application of t-tests to DBH data for Ponderosa Pine indicates that the differences between sites are not statistically significant ($p > 0.05$).

Mean area per tree for Ponderosa Pine reveals another aspect of forest structure that may be meaningful to the bird community. At JM, mean area per Ponderosa Pine is 64.5 m^2; at FG 117.6 m^2; and at TS 77.9 m^2 (Table 2). These estimates indicate that, although Ponderosa Pine are only marginally larger in DBH at FG compared to the other two sites (i.e., by about 3.5 cm), the area each tree occupies is substantially larger at FG. These data indicate a more open tree canopy that, along with a greater abundance and size of Gambel Oak in the shrub understory, may provide more favorable habitat for some bird species.

Table 2. Tree data collected for Turkey Springs, Fawn Gulch, and Jackson Mountain sites using point-quarter method. [SE] = standard error of the mean; Pipo = *Pinus ponderosa*; Quga = *Quercus gambelii*; Abco = *Abies concolor*; Potr = *Populus tremuloides*.

Site	Species	Freq	n	Mean Dist (m) [SE]	Area/Tree (m^2)	DBH (cm) [SE]	Basal Area (m^2/ha)
Turkey Springs	**Pipo**	**15**	**60**	**8.8 [0.82]**	**77.9**	**41.1 [1.54]**	**20.3**
Fawn Gulch	Pipo	15	56	10.8 [0.87]	117.6	44.7 [1.30]	
	Quga	3	4	11.3 [1.08]	48.3	15.4 [0.68]	
Site Total				**10.9 [0.82]**	**118.2**	**42.8 [1.54]**	**13.08**
Jackson Mountain	Pipo	15	50	8.0 [0.80]	64.5	41.2 [1.77]	
	Quga	5	7	14.7	*	23.8 [8.94]	
	Abco	2	2	2.1	*	14.5 [4.05]	
	Potr	1	1	13.9	*	15 [na]	
Site Total				**8.7 [0.79]**	**75.9**	**36.6 [1.99]**	**16.26**

* Sample size too small for reliable estimate

Bird Community Sampling Methodology:
The bird community sampling design employed in this study is a modification of established methodologies used by the Bird Conservancy of Colorado to study riparian areas in southwestern Colorado (see van Boer et. al., 2018) and other similar studies of bird community response to wildland fuel reduction treatments or wildland fires (e.g., Hurteau et al., 2008; Jentsch et al., 2008). We identified areas within each study site where three "loops" of five monitoring points each were established. Monitoring points were located at least 75 m away from forest roads, and at distances of approximately 75 m from one another (see Figs. 2, 3, and 4). By arranging monitoring points in "loops", monitoring teams would end their session closer to the starting point of their transect, minimizing "downtime" walking back to their starting point. This design differs from other reported applications of the approach in that our monitoring points are closer together (in other studies points are typically 200 m or more apart; see Jentsch et al., 2008), and our sampling points are arranged in loops rather than at grid intersections or located at random along extended linear transects.

The protocol for collecting data from each loop of monitoring points was as follows:

- Teams of at least two volunteers each were identified and assigned responsibility to collect data for two loops per team over a period of five weeks, beginning on or about June 4th, 2019, and ending by July 13th, 2019.
- Each team was asked to visit their assigned loops at least four times over the period of the study.
- Data collection consisted of visiting each point on each loop for 6 minutes and recording and counting birds identified by sight or song during that 6-minute sampling interval. In addition, teams were asked to identify the bird's gender (if possible), and estimate the distance from the monitoring point to the bird as it was identified.
- Only birds within approximately 35 m of the monitoring point, or halfway between points, were to be recorded.
- All sampling at the monitoring points was to be completed between the hours of 6 am and 10 am.
- Incidental bird identifications during the walk from one point to the next could be recorded separately;
- Incidental bird identifications in areas separate from established study loops (i.e. at or near where vehicles were parked) could also be recorded separately.

The overall study design consisted of 3 loops at each of the 3 sites previously described – TS; FG; and JM. A sufficient number of birders volunteered for the study to assign 3 teams to TS; 3 teams to FG; and 2 teams to JM. With the exception of JM, where only two teams were assigned, each loop had at least two teams assigned to conduct monitoring. The experience of the teams varied from accomplished birders to those self-identified as being at an intermediate skill level. Each site had one team of accomplished birders assigned. This design provided

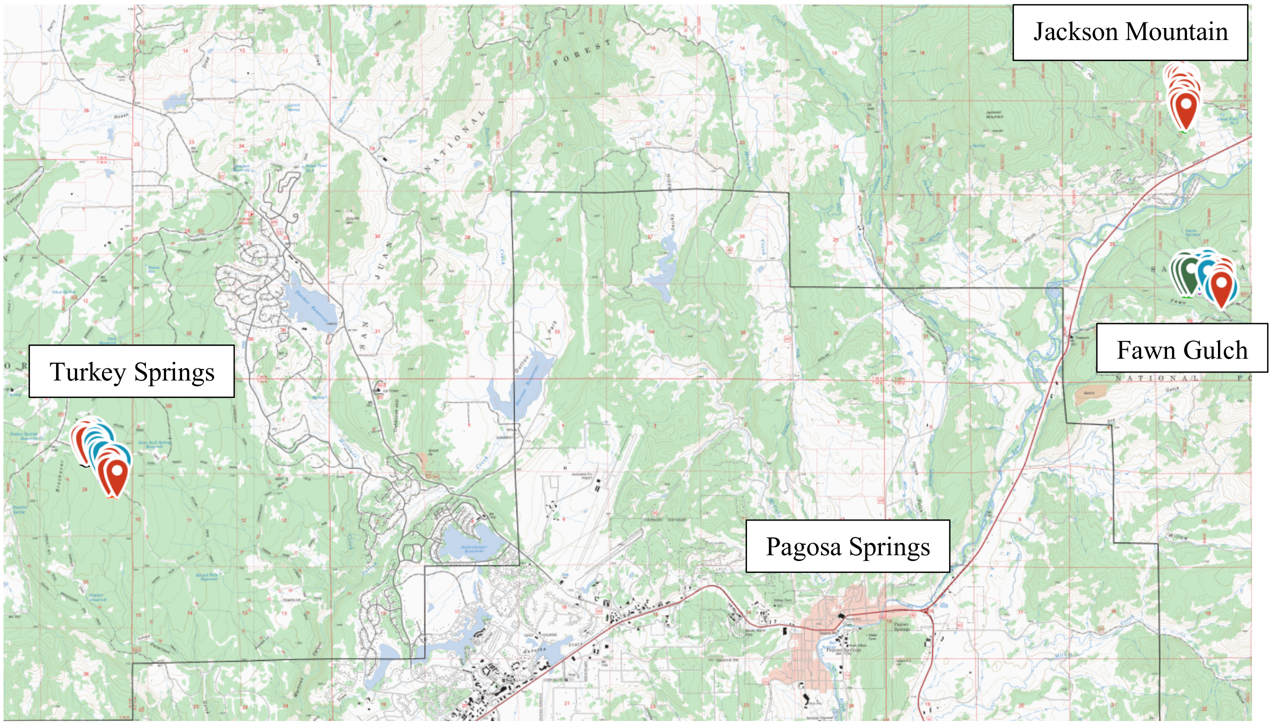

Figure 1. Map showing locations of Turkey Springs, Fawn Gulch, and Jackson Mountain study areas.

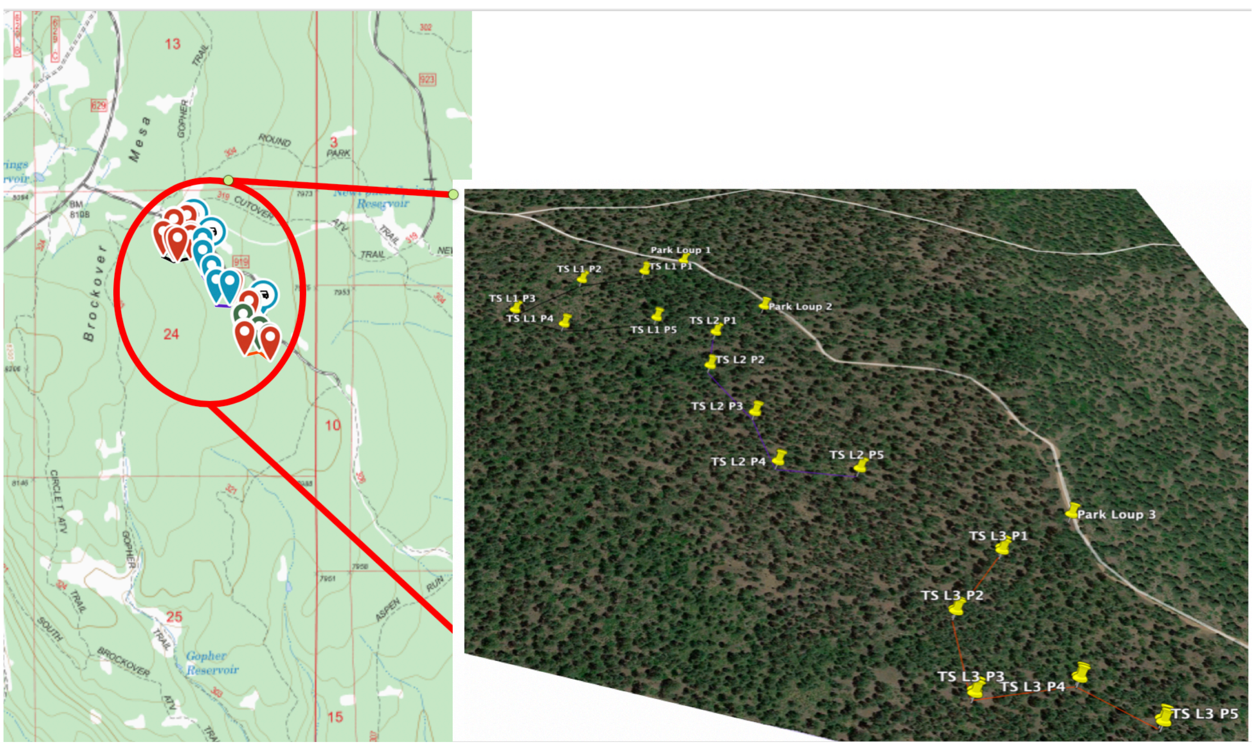

Figure 2. Map showing locations of monitoring points within Turkey Springs study area. TS = Turkey Springs; L # = Loop number; P # = Monitoring point number.

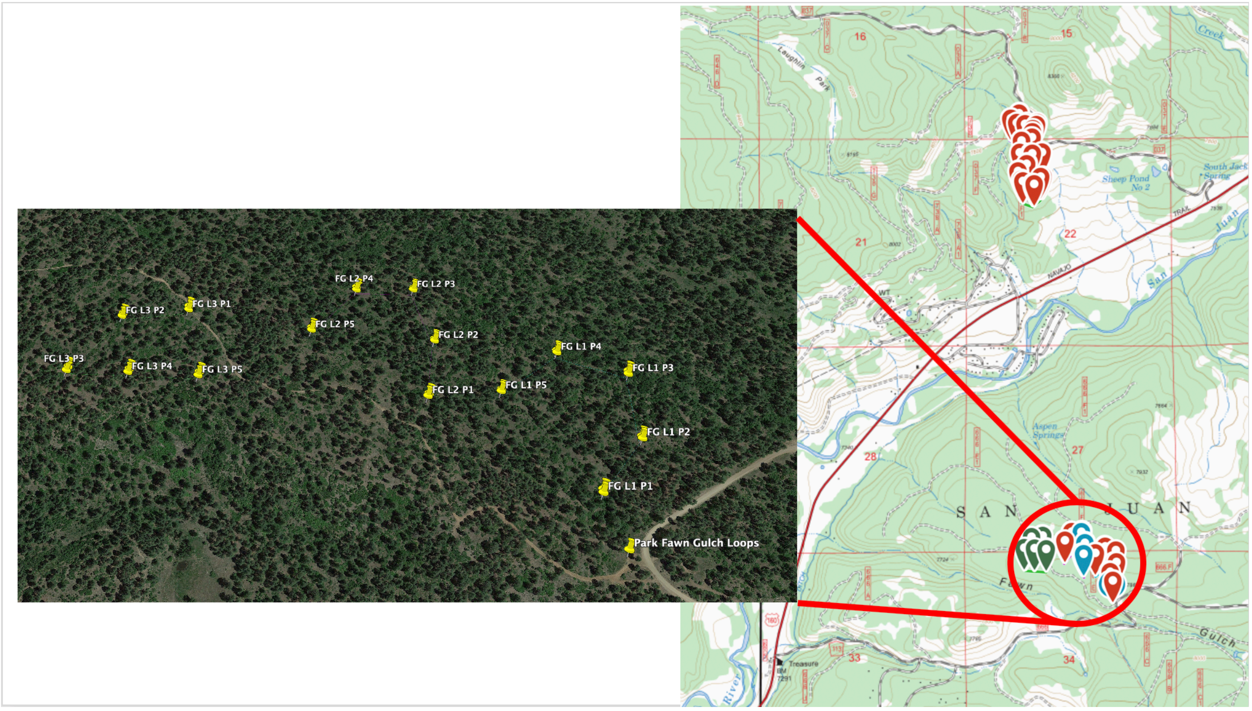

Figure 3. Map showing locations of monitoring points within Fawn Gulch study area. FG = Fawn Gulch; L # = Loop number; P # = Monitoring point number.

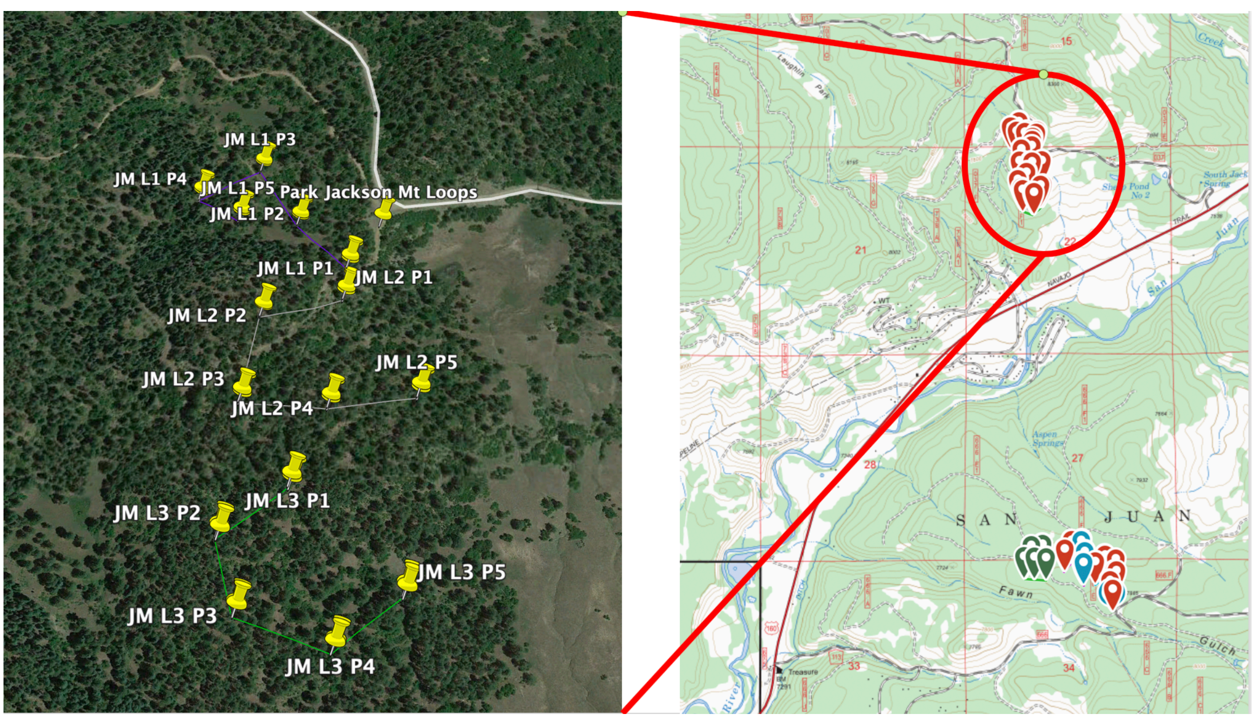

Figure 4. Map showing locations of monitoring points within Jackson Mountain study area. JM = Jackson Mountain; L # = Loop number; P # = Monitoring point number.

redundancy in loop coverage, and allowed for each site to be visited on a regular basis by a team of accomplished birders. Teams were encouraged to visit sites or loops other than those assigned to them as well, and accomplished birders were encouraged to assist the teams of intermediate birders as much as possible.

Data sheets were provided each study team, which were collected at the close of the study period. Data were entered into an Excel spreadsheet for review and analysis by a subset of project volunteers with experience interpreting scientific data. Because of the range of experience of our sampling teams, we decided to avoid complex statistics in our analyses of the final dataset and instead relied primarily on species identifications, estimated bird counts, and frequency of occurrence to draw our final conclusions.

Scheduling conflicts arose among the multiple teams of volunteer field observers, resulting in imbalances in the dataset generated by the study. For example, of the 3 teams assigned to the TS site, two of the teams completed 3 site visits, with the third team completing 4 site visits, for a total of 10 sample dates completed across all 3 teams at TS. At the FG site, two teams completed their expected 4 sample dates, with the third team completing 6 monitoring visits, for a total of 14 site visits at FG. Finally, of the two teams assigned to the JM site, one team completed 4 site visits, and the other team completed 6 site visits, for a total of 10 site visits at JM.

The resulting sampling density was 10 site visits for TS and JM, but 14 site visits for FG. For TS and JM, that translates to 10 site visits of 10 monitoring points each at 6 minutes per point, equaling 600 minutes of monitoring time. At FG, however, there were 4 additional sampling visits, translating to 40 additional monitoring point visits of 6 minutes each, resulting in an additional 240 minutes of monitoring time, or a total of 840 minutes of monitoring time for FG. We opted to include all data generated in the study in our analyses and refer to adjustments in sampling density as appropriate. The implications of these imbalances in monitoring intensity to the findings of the study are addressed in the Results and Discussion sections of this report.

Results:
Table 3 contains a summary of all bird species observed across the three areas sampled in this project[i]. A total of 54 species were observed, either by sight or by sound. In the full dataset, FG had the greatest total number of species observed with 40, followed by JM with 33, and TS with 26 (Table 3). As noted in the methods section the full dataset is unbalanced, meaning that the FG site was visited 14 times (two teams visiting 4 times each with the third team visiting 6 times), while the TS and JM sites were visited 10 times each by their respective monitoring teams. This translates to 140 points monitored at FG, while 100 points were monitored at TS and JM, respectively. We attempted to “re-balance” the dataset by filtering out data for 4 sample dates from the FG dataset. The dates removed were selected based on the distribution of all sample dates to even out the sample density across the term of the study.

Re-balancing the FG dataset resulted in the elimination of 6 species from the FG dataset – American Kestrel; Dark-eyed Junco; Mountain Bluebird; Bullock’s Oriole; Mountain Chickadee; and Warbling Vireo. In the full FG dataset, each of these species was documented by a single siting. The American Kestrel and Mountain Bluebird were reported only at FG, with the Bullock’s Oriole also recorded at TS, while the Mountain Chickadee and Warbling Vireo were also recorded at JM (Table 3). In terms of total bird counts, re-balancing the FG dataset resulted in 114 fewer birds recorded for that site, but this had no effect on the rank order of bird species observed for all three sites (Table 3). The results of the re-balancing effort moderates any conclusions that could be drawn from the full dataset regarding total species counts or total bird counts, but since the species most affected were uncommon, we decided to focus our analysis on the full dataset and reference the re-balanced dataset when appropriate. We also felt that including both the full and re-balanced datasets for FG would be instructive to participants in designing and implementing future iterations of this project.

Of the 54 species recorded in our study, 15 were observed at all three study sites (Table 3). The American Robin was most common across sites. The Western Wood-Pewee was among the top 4 most abundant species at all three sites, and the Northern Flicker was among the top 5 species at all three sites, but rankings of other species across sites within the common group were otherwise varied.

The total number of birds counted was highest for FG (486 in the total dataset vs. 300 in the re-balanced dataset), second highest at JM at 278, with TS having the fewest number of birds counted at 185 (Table 3). For all three sites, cumulative total relative abundance across the 15 shared species ranged from about 68% for both TS and JM to about 74% at FG (70% in the re-balanced dataset), meaning that 68% of all birds recorded at TS and JM were in the 15 commonly shared species, and 74% (70% in re-balanced dataset) of all birds recorded at FG were in the common group.

FG had the greatest number of species found only at that site with 14 (11 when re-balanced), followed by JM with 7 unique species, and TS with 3 unique species (Table 3). With the exception of the Northern Rough-winged Swallow at FG, where 25 individuals were recorded across 10 monitoring points, frequencies and abundances of all other unique species at all three sites were less than 4 individuals or 3 monitoring points per species, and most were represented by single individual sitings.

Of the remaining 15 species recorded, 4 were found at both TS and FG; 7 were found at both FG and JM; and 4 were found at both TS and JM (Table 3). The Bullock's Oriole, Mountain Chickadee, and Warbling Vireo dropped out of the FG dataset when it was re-balanced. This also resulted in the Bullock's Oriole becoming an additional unique species for TS, raising the total to 4 unique species at that site. Similarly, re-balancing the FG dataset resulted in JM gaining the Mountain Chickadee and Warbling Vireo as unique species.

The Mann-Whitney test was used to perform pairwise comparisons of bird abundance data between sites. Our analysis revealed that differences in the rank abundance of birds counted within species at each site were not statistically significant from any other site ($p < 0.05$).

Discussion:

Community-level response - The two broad-scale questions that we can address with our dataset concern, first, species diversity within bird communities across the three study areas, and second, a comparison of bird community similarity based on species counts and numbers of birds within species. The concept of species diversity has two components – species richness (the total number of species in an area or community), and evenness (how counts of individual birds are distributed among species). Data summarized in Table 3 reveals that species richness is greatest at FG (40 species, vs. 34 in the re-balanced dataset), followed by JM (33 species), and is lowest at TS (26 species).

Species evenness can be compared using the Simpson Index - D_s (Cox, 2002). The formula for this index is:

$$Ds = \frac{N(N-1)}{\Sigma n(n-1)}$$

Where N = Total number of individuals of all species; and n = Number of individuals of a species.

When comparing ecological communities, higher values for D_s indicate that individuals are more evenly distributed among species; lower values indicate greater dominance by a few species. A variation of the Simpson Index is to calculate its reciprocal, yielding numbers that, as they increase, reflect greater dominance by a subset of species in the community. Calculating D_s values for our sites (Table 4) yields the highest evenness ranking for TS (0.171) > JM (0.14) > FG (0.10 for the complete dataset and 0.08 for the re-balanced dataset). These index values indicate that, although FG has the greatest number of species, individual bird counts are more concentrated among a smaller number of species (see Table 3).

One of the most broadly used measures of biodiversity is the Shannon Index (H'), sometimes referred to as the Shannon-Weaver or Shannon-Wiener Index (Cox, 2002). Derived from information theory, this index describes the degree of uncertainty in predicting the species of the next individual picked randomly from a community. With increasing species richness and evenness (i.e., D_s), this uncertainty increases, which is reflected in increasing values of the index H'. The equation for H' is:

$$H' = -\sum p_i \log p_i.$$

Where p_i = the relative abundance of individuals of the i^{th} species. We used $\log_{10}$ for our calculations.

Calculations of H' for our sites (Table 4) reveal that the bird community is most diverse at JM (H' = 1.24), followed sequentially by FG rebalanced (1.19) > FG (1.16) > TS (1.09). While useful for inter-site comparisons within a

Table 3. Summary of all bird species observed across the three study areas monitored, including the FG Re-balanced data. Data shown are the number of birds counted (abundance) and number of monitoring points where the species were reported (frequency). Species lists represent those found at all three sites sorted by abundance; those unique to the sites shown sorted by abundance; or those found at two respective sites (unsorted).

	Turkey Springs					Fawn Gulch (Full Data)				Fawn Gulch (Re-balanced)					Jackson Mountain			
# Species	26				# Species	40				34				# Species	33			
# points w record	185		144		# points w record	486		300		354		204		# points w record	278		209	
	Abun	Rel Abun	Freq	Rel Freq		Abun	Rel Abun	Freq	Rel Freq	Abun	Rel Abun	Freq	Rel Freq		Abun	Rel Abun	Freq	Rel Freq
Species Found At All Three Sites (Sorted by Abundance)																		
American Robin	43	18.53	31	16.15	American Robin	130	25.95	67	21.47	81	22.88	47	23.04	American Robin	75	26.22	53	22.75
Violet-green Swallow	29	12.50	13	6.77	Western Wood-Pewee	83	16.57	59	18.91	64	18.08	41	20.10	Northern Flicker	29	10.14	25	10.73
Western Wood-Pewee	20	8.62	17	8.85	Northern Flicker	44	8.78	23	7.37	35	9.89	19	9.31	Western Tanager	16	5.59	14	6.01
Pygmy Nuthatch	17	7.33	14	7.29	Western Tanager	32	6.39	21	6.73	27	7.63	17	8.33	Western Wood-Pewee	14	4.90	13	5.58
Northern Flicker	16	6.90	13	6.77	White-breasted Nuthatch	23	4.59	14	4.49	17	4.80	9	4.41	Pygmy Nuthatch	12	4.20	6	2.58
White-breasted Nuthatch	11	4.74	11	5.73	Yellow-rumped Warbler	13	2.59	11	3.53	8	2.26	6	2.94	Yellow-rumped Warbler	12	4.20	9	3.86
American Crow	10	4.31	8	4.17	Violet-green Swallow	11	2.20	7	2.24	7	1.98	5	2.45	Steller's Jay	11	3.85	9	3.86
Yellow-rumped Warbler	4	1.72	3	1.56	Steller's Jay	10	2.00	10	3.21	5	1.41	5	2.45	Turkey Vulture	8	2.80	6	2.58
Brown-headed Cowbird	2	0.86	2	1.04	Pygmy Nutatch	7	1.40	4	1.28	4	1.13	2	0.98	Red-tailed Hawk	6	2.10	5	2.15
Hairy Woodpecker	2	0.86	1	0.52	Turkey Vulture	6	1.20	4	1.28	3	0.85	2	0.98	White-breasted Nuthatch	4	1.40	4	1.72
Broad-tailed Hummingbird	1	0.43	1	0.52	American Crow	4	0.80	3	0.96	4	1.13	3	1.47	Violet-green Swallow	3	1.05	1	0.43
Red-tailed Hawk	1	0.43	1	0.52	Brown-headed Cowbird	3	0.60	2	0.64	3	0.85	2	0.98	American Crow	2	0.70	2	0.86
Steller's Jay	1	0.43	1	0.52	Broad-tailed Hummingbird	2	0.40	2	0.64	1	0.28	1	0.49	Broad-tailed Hummingbird	2	0.70	2	0.86
Turkey Vulture	1	0.43	1	0.52	Hairy Woodpecker	2	0.40	2	0.64	1	0.28	1	0.49	Brown-headed Cowbird	1	0.00	1	0.43
Western Tanager	1	0.43	1	0.52	Red-tailed Hawk	1	0.20	1	0.32	1	0.28	1	0.49	Hairy Woodpecker	1	0.35	1	0.43
Species Unique to Respective Sites (Sorted by Abundance)																		
Lewis's Woodpecker	1	0.43	1	0.52														
MacGillvary's Warbler	1	0.43	1	0.52														
Osprey	1	0.43	1	0.52														
					Northern Rough-winged Swallow	25	4.99	10	3.21	25	7.06	10	4.90					
					American Goldfinch	3	0.60	2	0.64	3	0.85	2	0.98					
					Cassins's Finch	3	0.60	3	0.96	1	0.28	1	0.49					
					Cordilleran Flycatcher	3	0.60	2	0.64	3	0.85	2	0.98					
					Bald Eagle	2	0.40	2	0.64	2	0.56	2	0.98					
					Black-billed Magpie	2	0.40	2	0.64	1	0.28	1	0.49					
					Pine Siskin	2	0.40	1	0.32	2	0.56	1	0.49					
					Red-naped Sapsucker	2	0.40	2	0.64	1	0.28	1	0.49					
					Say's Phoebe	2	0.40	2	0.64	2	0.56	2	0.98					
					Yellow Warbler	2	0.40	2	0.64	2	0.56	2	0.98					
					American Kestrel	1	0.20	1	0.32									
					Dark-eyed Junco	1	0.20	1	0.32									
					Mountain Bluebird	1	0.20	1	0.32									
					Red Crossbill	1	0.20	1	0.32	1	0.28	1	0.49					
														House Wren	4	1.40	2	0.86
														Townsend's Solitaire	3	1.05	3	1.29
														Virginia's Warbler	3	1.05	2	0.86
														White-throated Swift	3	1.05	1	0.43
														Orange-crowned Warbler	2	0.70	1	0.43
														Black-capped Chickadee	1	0.35	1	0.43
														Hermit Thrush	1	0.35	1	0.43
Species Found At Two Respective Sites (Unsorted)																		
					Black-headed Grosbeak	5	1.00	5	1.60	5	1.41	5	2.45	Black-headed Grosbeak	5	1.75	5	2.15
Bullock's Oriole	1	0.43	1	0.52	Bullock's Oriole	1	0.20	1	0.32									
					Canada Goose	12	2.40	2	0.64	6	1.69	1	0.49	Canada Goose	5	1.75	1	0.43
Chipping Sparrow	6	2.59	5	2.60	Chipping Sparrow	10	2.00	5	1.60	8	2.26	3	1.47					
Common Nighthawk	6	2.59	7	3.65										Common Nighthawk	2	0.70	1	0.43
					Common Raven	1	0.20	1	0.32	1	0.28	1	0.49	Common Raven	11	3.85	9	3.86
Downy Woodpecker	1	0.43	1	0.52	Downy Woodpecker	3	0.60	1	0.32	3	0.85	1	0.49					
					Green-tailed Towhee	19	3.79	14	4.49	16	4.52	1	0.49	Green-tailed Towhee	7	2.45	7	3.00
					Mountain Chickadee	1	0.20	1	0.32					Mountain Chickadee	4	1.40	2	0.86
Mourning Dove	1	0.43	1	0.52										Mourning Dove	1	0.35	1	0.43
Plumbeous Vireo	2	0.86	2	1.04										Plumbeous Vireo	12	4.20	9	3.86
					Tree Swallow	7	1.40	3	0.96	7	1.98	3	1.47	Tree Swallow	4	1.40	1	0.43
					Warbling Vireo	1	0.20	1	0.32					Warbling Vireo	7	2.45	7	3.00
Western Bluebird	5	2.16	5	2.60	Western Bluebird	5	1.00	4	1.28	4	1.13	3	1.47					
Williamson's Sapsucker	1	0.43	1	0.52										Williamson's Sapsucker	7	2.45	4	1.72

single study, the value of H’ conflates species richness and evenness. This accounts for JM data providing the highest H’ index value compared to FG, where there was a greater number of species, but evenness (D_s) was lower. For example, summing relative abundance data (Table 3) for the top five most abundant bird species shared by all three sites reveals that about 63% of all birds recorded at FG are accounted for in the top 5 at that site, whereas only about 51% of birds counted at either TS or JM are included in the top 5 most abundant species for those sites.

Cox (2002) suggests using a simple coefficient of community (C_c), using actual or relative values of species occurrence, to quantify similarities between ecological communities. The simple formula for this index is:

$$C_c = 2w/(A + B)$$

Where A = the sum of values for community A; B = the sum of values for community B; and w = the sum of the lower of these two values for shared species.

A C_c value of 1 indicates that the two communities being compared are identical; decreasing values of C_c indicate increasing differences between communities for the metric used in the equation. Note that this is a variation of the Bray-Curtis dissimilarity index, obtained by the formula 1 - C_c, which is considered one of the more reliable indices for comparing ecological communities (e.g., Bloom 1981).

Pairwise comparisons in our dataset rank bird community similarities based on species richness and abundance as follows (Table 4): FG re-balanced x JM (C_c = 0.86) > TS x JM (0.69) > TS x FG re-balanced (0.57) > FG total dataset x JM (0.51) > TS x FG total dataset (0.47). These results largely reflect the patterns in species richness and evenness discussed earlier, revealing greater similarity between the FG and JM site than between TS and either of the other two sites. Recall that re-balancing the FG dataset to account for an imbalance in sampling frequency reduced the total species count by six and reduced the total bird count by about 25% (see Table 3).

Table 4. Summary of indices of bird community diversity and pairwise comparisons of the community similarity index.

Site:	**TS**	**FG-Re-Balanced**	**FG - Total**	**JM**	
Diversity Indices					
Species Richness	26	34	40	33	
D_s	0.171	0.08	0.1	0.14	
H’	1.09	1.19	1.16	1.24	
Community Similarity Index – Pairwise Comparison					
	FG-Re-Balanced x JM	**TS x JM**	**TS x FG-Re-balanced**	**FG x JM**	**TS x FG**
C_c	0.86	0.69	0.57	0.51	0.47

Taken together, indices of bird species diversity and bird community similarity indicate that the FG bird community is the most diverse and is least similar to the recently treated TS site compared to the un-treated JM site. This is consistent with general patterns in bird community composition reporting a negative association between bird species richness and Ponderosa Pine tree density and canopy cover, and a positive association with tree size and presence of Gambel Oak (Jentsch et al., 2008; Kalies and Rosenstock, 2013). The FG site had the lowest tree density of the three sites used in our study and largest mean tree area for Ponderosa Pine (Tables 1 and 2), with the JM site having the highest tree density. As noted earlier, Gambel Oak was largely absent from the TS site, but was present in widely dispersed clusters at FG, with more extensive and dense clusters at JM.

<u>*Species-level response*</u> – Table 5 provides a summary of species recorded across the three study sites grouped by feeding habit. Groupings are based largely on listings by Bock and Lynch (1970) and Lowe et. al. (1978), with the Timber-Drilling and Timber-Gleaning guilds combined, and the addition of corvids, raptors, and nectar feeding categories that were not defined in these earlier studies. Frequency values reported for each species represent the number of sample points where birds of that species were recorded.

Species counts by feeding guilds shown in Table 5 reveal that Ground-Brush Foraging (GBF) and Timber Foliage-searching (TF) birds are most common across all three sites. About half of the species at TS (12 of 26 species) and FG (20 of 40 species) fall into these two categories. About one-third of the species at JM are categorized as GBF (11 of 33 species) and another one-quarter of the species found at that site are categorized as TF (8 of 3 species). These trends affirm that the condition of the overstory and shrub forest layers are key habitat features for the bird communities in these Ponderosa Pine stands.

Table 6 summarizes the feeding guild data to show the relative frequencies of guilds across the three study sites. GBF species account for 40% of bird sightings at TS, 44% of bird sightings at FG, and 48% of bird sightings at JM. The most common GBF species across all sites was the American Robin and Northern Flicker, with the Green-tailed Towhee relatively common at FG and JM (Table 5). TF species accounted for only about 6% of the bird sightings at TS, but 15% and 25% of bird sightings at FG and JM, respectively (Table 5). Western Tanagers were the most common TF species at FG and JM, with Yellow-rumped Warblers and Steller's Jay rounding out the top three most common TF species at these sites. The Western Wood-Pewee, which was the second most common species at TS and FG by frequency of occurrence, and fourth most common species at JM by frequency (Table 5), accounts for the high frequency of occurrence of TF species at TS and FG (Table 6). As a Timber Drilling/Gleaning (TD/G) species, the White-breasted Nuthatch was relatively common at TS and FG (Table 5), with the Pygmy Nuthatch relatively common at TS as well.

Previous studies in Ponderosa Pine forests across the American southwest reported increases in populations of GBF and Aerial Flycatcher (AF) species, and decreases in TF species in recently burned sites, consistent with the trends observed in this study (Blake, 1982; Lowe et al., 1978). Kalies et al., (2010) in their meta-analysis of 25 studies on fire and thinning effects on Ponderosa Pine forests across Arizona noted that thinning and fuel reduction treatments favored passerine bird populations in general, with neutral impacts on GBF bird species and neutral to positive impacts on AF and Timber Gleaning (TG) species.

Western Bluebirds are reported to respond positively to prescribed fire (Hurteau et al., 2008). This is consistent with our observations, with Western Bluebirds sighted

Table 5. Comparison of bird species by study area, sorted by feeding habit and frequency of occurrence.

	Turkey Springs	Fawn Gulch	Jackson Mountain
# species	26	40	33
Feeding Guild	Freq	Freq	Freq
Ground-Brush Foraging			
American Robin	31	67	53
Northern Flicker	13	23	25
Green-tailed Towhee		14	7
Black-headed Grosbeak		5	5
Chipping Sparrow	5	5	
Western Bluebird	5	4	
Brown-headed Cowbird	2	2	1
Canada Goose		2	1
Cassin's Finch		3	
Townsend's Solitaire			3
American Goldfinch		2	
Bullock's Oriole	1	1	
House Wren			2
Mourning Dove	1		1
Black-capped Chickadee			1
Dark-eyed Junco		1	
Hermit Thrush			1
Mountain Bluebird		1	
Pine Siskin		1	
Red Crossbill		1	
TOTALS	58	132	100
Timber-Foliage-searching			
Western Tanager	1	21	14
Yellow-rumped Warbler	3	11	9
Steller's Jay	1	10	9
Plumbeous Vireo	2		9
Warbling Vireo		1	7
Mountain Chickadee		1	2
Virginia's Warbler			2
MacGillvary's Warbler	1		
Orange-crowned Warbler			1
TOTALS	8	44	53
Aerial Flycatcher			
Violet-green Swallow	13	7	1
Northern Rough-winged Swallow		10	
Common Nighthawk	7		1
Tree Swallow		3	1
White-throated Swift			1
TOTALS	20	20	4
Flycatcher			
Western Wood-Pewee	17	59	13
Cordilleran Flycatcher		2	
Say's Phoebe		2	
Yellow Warbler		2	
Lewis's Woodpecker	1		
TOTALS	18	65	13
Timber Drilling/Gleaning			
Williamson's Sapsucker	1		4
Red-naped Sapsucker		2	
Downy Woodpecker	1	1	
Hairy Woodpecker	1	2	1
White-breasted Nuthatch	11	14	4
Pygmy Nuthatch	14	4	6
TOTALS	28	23	15
Corvid			
American Crow	8	3	2
Common Raven		1	9
Black-billed Magpie		2	
TOTALS	8	6	11
Raptor			
Red-tailed Hawk	1	1	5
Bald Eagle		2	
American Kestrel		1	
Osprey	1		
Turkey Vulture	1	4	6
TOTALS	3	8	11
Nectar Feeding			
Broad-tailed Hummingbird	1	2	2
TOTALS	1	2	2

at the recently burned TS site and FG site, but absent from the non-treated JM site. In the same study by Hurteau et al., (2008), Mountain Chickadee populations were noted to decline in thinned areas. While not a decisive trend in our study, Mountain Chickadees were absent from TS, a single bird was recorded at FG, with two records totaling

Table 6. Summary of feeding guilds by site showing relative frequencies.

	Turkey Springs		Fawn Gulch		Jackson Mountain	
Feeding Guild	Freq	Rel Freq	Freq	Rel Freq	Freq	Rel Freq
Ground-Brush Foraging	58	0.40	132	0.44	100	0.48
Timber-Foliage-searching	8	0.06	44	0.15	53	0.25
Aerial Flycatcher	20	0.14	20	0.07	4	0.02
Flycatcher	18	0.13	65	0.22	13	0.06
Timber Drilling/Gleaning	28	0.19	23	0.08	15	0.07
Corvid	8	0.06	6	0.02	11	0.05
Raptor	3	0.02	8	0.03	11	0.05
Nectar	1	0.01	2	0.01	2	0.01
TOTALS	144		300		209	

four birds at JM (Table 3). Brawn and Balda (1988) noted a positive impact of increased tree density and canopy cover on the Western Wood-Pewee and Black-headed Grosbeak. This is not consistent with our findings, in which the Western Wood-Pewee is the second most abundant species at TS and FG (Table 3), but drops to the third most abundant species at JM, where tree density and canopy cover is greatest (Tables 1 and 2).

The length of time since fire disturbance has an influence on bird occupation of a site. Lowe et al., (1978) studied bird community composition across several Ponderosa Pine sites in Arizona subject to wildfires at intervals of 1, 3, 7, and 20 years before monitoring. They identified a pattern of increasing total bird densities in the early years after a burn, then decreasing total bird population numbers as the forest recovered, as demonstrated by the Western Bluebird, a member of the GBF feeding guild. A similar pattern was particularly evident in their data for birds in the TF feeding guild (e.g., Yellow-rumped Warbler and Steller's Jay). Timber-Drilling/Gleaning (TD/G) species, in particular the Pygmy Nuthatch, showed a decreasing trend across years. Dickson et al., (2009), reported similar findings with a positive response to prescribed fire for Steller's Jay, Plumbeous Vireo, and Hairy Woodpeckers. A temporal gradient is not as well represented in our study compared to findings reported by Lowe et al., (1978), and our sample size is small compared to many other studies reported in the literature, but comparing FG to the other sites in our study yields similar patterns in total bird counts and species richness to their results, suggesting that FG represents a forest community in which feeding habitat is more productive for a wider range of bird species than provided by either the TS (recently burned) or JM (old age) sites (Table 6). Gillihan (1997) also noted a positive response of several bird species to the presence of Gambel Oak, including the Brown-headed Cowbird, Green-tailed Towhee, and Virginia's Warbler, all of which were found at both our FG and JM sites where the oak shrub layer was well developed.

Consistent with Lowe et al., (1978), TD/G species show a consistent decline across our study sites from TS > FG > JM (Tables 3 and 5), a pattern that is particularly evident for the Pygmy Nuthatch. One reason for TD/G bird species increasing in response to recent prescribed fire has to do with a concurrent increase in bark beetles following a burn over the following seasons (Pope et al., 2009). A parallel finding regarding the abundance of Hairy Woodpeckers in recently burned Ponderosa Pine stands subject to wildfire indicates an increase in this species in the first few years following burning in response to elevated populations of bark beetles and wood borers (Covert-Bratland et al., 2006). These findings suggest that the higher frequency and abundance of TD/G species noted for the TS site in our study (Tables 3, 5, and 6) may be sustained through the coming winter and into next year, at least.

The high-ranking abundance and frequency of the Western Wood-Pewee across all three of our sites (Table 3) runs counter to observations reported by Dickson et al., (2009). They noted a short-term decline in Western Wood-Pewee in response to prescribed fire across several Ponderosa Pine sites in Arizona and New Mexico.

Notable Observations - The Cornell University Laboratory of Ornithology provides a summary of findings included in the 2016 State of North America's Birds (SONAB) report on their "All About Birds" website (Cornell, 2019). The conservation status of over eleven-hundred birds in North America is summarized with a score reflecting the level of concern for each species (Table 7). Factors included in the SONAB assessment include population size, breeding distribution, nonbreeding distribution, threats to breeding, threats to nonbreeding, and population trends (see www.stateofthebirds.org). The resulting conservation concern (CC) scores range from 4 for common, widespread bird species that are thriving, to 20 for species of greatest concern for the sustainability of that species. Of the 54 bird species documented in this study, 26 species have shown population declines since the late 1960's, and 22 species have CC scores of 10 or greater (Table 7). Three of the species we recorded in our study – Lewis's Woodpecker, Virginia's Warbler, and Cassin's Finch (see Tables 3 and 7) – are included on the bird conservation watch list because of steep declines in population numbers, resulting in their "near-threatened" status. Although Lewis's Woodpecker is commonly observed in several areas surrounding Pagosa Springs, it was recorded as a single bird at the TS site in our study. Similarly, Virginia's Warbler was documented only at the JM site, and Cassin's Finch was one of the unique species at the FG site, with 3 or fewer individual birds recorded.

Of the remaining bird species with CC scores > 10, four were found at all three of our study sites (Table 7). These include the Broad-tailed Hummingbird, Pygmy Nuthatch, Steller's Jay, Western Wood-Pewee, and Northern Flicker. The Western Wood-Pewee, Northern Flicker, and Steller's Jay were relatively common in our dataset (see also Table 3). The Northern Rough-winged Swallow, another species with a CC score > 10, was notably abundant at the FG site.

One of the most exhilarating sightings in our study was that of a nesting pair of Common Nighthawks at the TS site (Tables 3 and 7). The Common Nighthawk is a reclusive species typically observed foraging for flying insects at dawn or dusk (Conservancy, 2019) and has been documented as a component of Ponderosa Pine bird communities in our region (Gillihan, 1997). It is estimated that Common Nighthawk populations have declined by more that 60% since the late 1960's (Ornithology, 2019) for reasons that are not well understood. Volunteers at the TS site observed a ground nest with 2 eggs in early June, which may have been destroyed when the area was burned at that time. Subsequent site visits confirmed that the nest was re-occupied after the initial prescribed fire and the parents were apparently successful in hatching either the original or a second brood consisting of two eggs.

The Pine Siskin, another species in steep decline, was observed at the FG site (Table 7). The estimated 80% decline in this species over the past 50 years has been attributed to predation and disease, particularly in suburban habitats (Cornell, 2019). Its presence in forested sites dominated by White Fir and along forest roads has been reported in our region (Gillihan, 1997). As discussed earlier in this report, the FG site had the lowest tree density and greatest inter-tree distances (Tables 1 and 2), representing conditions consistent with Gillihan's observations regarding the preferred habitat for Pine Siskin.

Equally notable was the discovery of Plumbeous Vireo, Williamson's Sapsucker, and House Wren nests at the JM site, and the cavity nest for Northern Flickers at the TS and FG sites. All of these species were observed in earlier studies in Ponderosa Pine forests in our region by Gillihan (1997). Because of its relatively low estimated global population estimate (300k; see Table 7), the Williamson's Sapsucker has a CC score of 12. CC scores for the Northern Flicker and Plumbeous Vireo species reflect less concern (CC scores of 10; see Table 7), but both of these species are estimated to have declined by 49% and 56%, respectively, since the late 1960's (Cornell, 2019). The House Wren has a very stable or increasing population status and is not of particular concern with regard to its conservation status. It was particularly rewarding that volunteers were able to track the successful hatching of young from the nests of each of these species.

Scanning the conservation notes from SONAB (Cornell, 2019) regarding the species encountered in our study (Table 7) reveals several species that should benefit from the prescribed fire and shrub-layer thinning treatments applied to the TS and FG sites included in our study. For example, Lewis's Woodpecker, Cassin's Finch, MacGillvary's Warbler, Warbling Vireo, and Downy Woodpecker respond negatively to over-mature forest conditions. Other species, cavity nesters in particular, benefit from dead trees common in mature forest stands intergrading with patches of younger forested areas recovering from fire, and the presence of a well-developed shrub layer (e.g., Mountain Bluebird, Williamson's Sapsucker, Pygmy Nuthatch, Green-tailed Towhee, etc.). This leads us to the conclusion that forest heterogeneity resulting from the prescribed fire and thinning treatments encountered in our study areas represents a net benefit to the extended bird community in the forests of the San Juan Mountains.

Table 7. Summary of conservation status of bird species recorded in this study. Conservation status categories, concern scores, and estimates of population status are taken from Cornell Laboratory of Ornithology website – www.allaboutbirds.org. [yellow box] = common to all sites; [pink box] = unique to one site; [white box] = found at two sites.

		Abundance by site			Conservation	Concern	Population		Estimated	
Common Name	Scientific Name	TS	FG	JM	Status	Score	Status	% decline	Population	Notes
Lewis's Woodpecker	*Melanerpes lewis*	1			Watch	15	decline	72	69k	threats - increased forest densities due to fire suppression
Virginia's Warbler	*Leiothlypis virginiae*			3	Watch	14	decline/uncommon	46	950k	threats - nest parasitism; loss of breeding habitat due to prescribed fire
Cassin's Finch	*Haemorhous cassinii*		3		Watch	13	near threatened	nr	2.9M	threats - over-mature forests; lack of thinning and fires
Broad-tailed Hummingbird	*Selasphorus platycercus*	1	2	2	Low	12	decline/common	52	10M	threats - climate variability affecting food availability
MacGillvary's Warbler	*Geothlypis tolmiei*	1			Low	12	decline	56	11M	threats - loss of habitat - favor early to mid-successional forest stands
Mountain Bluebird	*Sialia currucoides*		1		Low	12	decline/common	24	4.6M	require combination of open forests for foraging and old-growth for nest cavities
Williamson's Sapsucker	*Sphyrapicus thyroideus*	1		7	Low	12	stable	na	300k	return to burned areas within decade after fire
American Kestrel	*Falco sparverius*		1		Low	11	decline	50	4M	threats - pesticide pollution; access to nesting cavities
Bullock's Oriole	*Icterus bullockii*	1	1		Low	11	decline/numerous	29	7M	threats - pesticide pollution; habitat loss
Common Nighthawk	*Chordeiles minor*	6		2	Steep Decline	11	steep decline/common	61	16M	threats - food supply; access to nest sites
Cordilleran Flycatcher	*Empidonax occidentalis*		3		Low	11	stable	na	3M	
Pygmy Nuthatch	*Sitta pygmaea*	17	7	12	Low	11	stable	na	3.3M	threats - loss of large dead trees for nesting
Steller's Jay	*Cyanocitta stelleri*	1	10	11	Low	11	stable	na	2.8M	
Western Wood-Pewee	*Contopus sordidulus*	20	83	14	Low	11	decline	48	9.2M	threats - logging and forest fires
Green-tailed Towhee	*Pipilo chlorurus*		19	7	Low	10	stable	na	4.1M	benefits - favor shrubby habitats following forest fires
Mountain Chickadee	*Poicile gambeli*		1	4	Low	10	decline	53	7.5M	
Northern Flicker	*Colaptes auratus*	16	44	29	Low	10	decline/common	49	9-M	
Northern Rough-winged Swallow	*Stelgidopteryx serripennis*		25		Low	10	decline/common	18	18M	threats - pesticide pollution; reduced food availability
Pine Siskin	*Spinus pinus*		2		Steep Decline	10	steep decline/common	80	38M	threats - predation; disease
Plumbeous Vireo	*Vireo plumbeus*	2		12	Low	10	decline	79	3M	
Townsend's Solitaire	*Myadestes townsendi*			3	Low	10	stable	na	1M	benefits from forest thinning
White-throated Swift	*Aeronautes saxatalis*			3	Low	10	decline	56	3.2M	population decline uncertain; pesticide pollution and reduced food source
Bald Eagle	*Haliaeetus leucocephalus*		2		Low	9	increasing/recovered	na	250k	recovered from endangered status
Black-headed Grosbeak	*Pheucticus melanocephalus*		5	5	Low	9	stable/increasing	na	14M	
Orange-crowned Warbler	*Leiothlypis celata*			2	Low	9	decline/common	34	80M	64% decline in US; benefit from increased shrub cover in forests
Red-naped Sapsucker	*Sphyrapicus nuchalis*		2		Low	9	stable	na	2M	
Say's Phoebe	*Sayornis saya*		2		Low	9	increasing/common	na	4M	
Violet-green Swallow	*Tachycineta thalassina*	29	11	3	Low	9	decline/common	28	7M	threats - pesticide pollution; reduced food availability
Western Bluebird	*Sialia mexicana*	5	5		Low	9	stable	na	6.7M	threats - habitat loss; fire suppression; lack of nest cavities
Chipping Sparrow	*Spizella passerina*	6	10		Low	8	decline/common	36	230M	
Dark-eyed Junco	*Junco hyemalis*		1		Low	8	decline/numerous	50	200M	
Red Crossbill	*Loxia curvirostra*		1		Low	8	decline	12	2M	threats - feed on conifer seeds; extensive forest fires etc. reduce food source
Tree Swallow	*Tachycineta bicolor*		7	4	Low	8	decline/common	49	17M	threats - reduced cavity nesting sites; food availability
Warbling Vireo	*Vireo gilvus*		1	7	Low	8	increasing/numerous	na	51M	benefit from forest clearing/thinning
Western Tanager	*Piranga ludoviciana*	1	32	16	Low	8	increasing/common	na	11M	benefits from forest patchiness/edges
Black-billed Magpie	*Pica hudsonia*		2		Low	7	decline	26	5.4M	threats - pesticide use; greatest decline in prairie habitats
Black-capped Chickadee	*Poecile atricapillus*			1	Low	7	increasing/common	na	41M	benefits from forest patchiness/edges
Brown-headed Cowbird	*Molothrus ater*	2	3	1	Low	7	decline/numerous	31	120M	nest parasite; benefits from open habitat frequented by grazing herds
Downy Woodpecker	*Dryobates pubescens*	1	3		Low	7	stable/numerous	na	14M	benefit from forest clearing/thinning
Osprey	*Pandion haliaetus*	1			Low	7	increasing/recovered	na	500k	
American Crow	*Corvus brachyrhynchos*	10	4	2	Low	6	stable/numerous	na	27M	threats - West Nile virus
American Goldfinch	*Spinus tristis*		3		Low	6	numerous	na	42M	
Canada Goose	*Branta canadensis*		12	5	Low	6	increasing/common	na	5.6M	
Common Raven	*Corvus corax*		1	11	Low	6	increasing/common	na	20M	
Hairy Woodpecker	*Dryobates villosus*	2	2	1	Low	6	increasing/common	na	9M	
Hermit Thrush	*Catharus guttatus*			1	Low	6	stable	na	40M	leave burned forests until recovery occurs
Red-tailed Hawk	*Buteo jamaicensis*	1	1	6	Low	6	increasing	na	2.3M	
White-breasted Nuthatch	*Sitta carolinensis*	11	23	4	Low	6	increasing/common	na	9.2M	benefits from presence of dead trees for nesting cavities
Yellow Warbler	*Setophaga petechia*		2		Low	6	decline	25	90M	favor riparian habitat for nesting
Yellow-rumped Warbler	*Setophaga coronata*	4	13	12	Low	6	stable	na	130M	
American Robin	*Turdus migratorius*	43	130	75	Low	5	stable/increasing	na	310M	
House Wren	*Troglodytes aedon*			4	Low	5	stable/increasing	na	160M	
Mourning Dove	*Zenaida macroura*	1		1	Low	5	decline/common	15	120M	
Turkey Vulture	*Cathartes aura*	1	6	8	Low	5	increasing	na	18M	

Recommendations for Future Work:
The volunteers who worked on this project in 2019 agree that we should continue bird monitoring into next year at the same sites. A second year of data will provide important insights regarding inter-annual variability in bird community composition, particularly with regard to the TS site that was subject to prescribed fire coincident with the start of our monitoring project. Collecting bird community data in 2020 will document the first-year response of the forest to fuel reduction treatments at TS.

If we pursue a second year of this study, we intend to modify our sampling protocols and team assignments to avoid imbalances in data collection across sites. Differences in numbers of bird species and bird counts between the FG total dataset and re-balanced dataset indicates that increasing the number of sample dates will yield a more robust dataset. Training workshops will also be held to improve bird identification skills of participants.

We also recognize the need for more detailed data on plant community structure. In particular, tree heights and the size and distribution of Gambel Oak clusters have significant influences on bird communities. While we have some data regarding these habitat characteristics, we need to standardize how we characterize measures of forest structure across sites and expand our dataset to more effectively represent the shrub layer.

Summary and Conclusions:
The primary objective of this project was to identify possible differences in bird community composition and structure between Ponderosa Pine forested sites recently subjected to wildland fuel reduction treatments compared to an un-treated, old-growth site. Our data reveals a reduction in bird species richness, abundance and overall diversity on the TS site, which was burned in early June, 2019, but a higher D_s index value for bird species evenness at TS relative to the other two sites. Bird species richness and abundance was highest on the FG site that had been subject to shrub-layer mastication treatments in 2017, but species evenness was lowest at that site, reflecting a pattern of dominance by fewer species compared to the other two sites. Bird species richness, abundance, and evenness were intermediate at the untreated, old-growth JM site, resulting in a higher index of overall species diversity (H') for this site. These findings are broadly consistent with patterns in bird community response to prescribed and wildland fires reported in the literature. Species-level responses to wildland fuel reduction treatments indicate that several species benefited from the effects of shrub-layer thinning treatments, including several species that have exhibited marked population declines over the past 50 years or so. These findings suggest that treatments contributing to forest heterogeneity have a net positive impact on bird communities at a regional scale.

The secondary objectives of this study concerned raising the awareness of participants regarding the importance of fire in Ponderosa Pine forest ecosystems; the role of wildland fuel management in protecting residential communities in the WUI; and improving their understanding of how field studies are conducted. The feedback participants provided to project coordinators affirms that we have been very successful in accomplishing these objectives.

Finally, through the conduct of this project we anticipated that participants would enjoy improving their bird identification skills and, by working as teams to accomplish the goals of our study, they would also form a more cohesive group of citizen scientists concerned with conservation issues. In these regards, feedback from participants affirm that our study has been wildly successful. Certainly, among the most rewarding and somewhat surprising outcomes of this project was the dedication participants exhibited toward the success of this study, and their enthusiasm for continuing the project for a second year.

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[i] (Nomenclature for bird scientific names and English names are consistent with the IOC World Bird List; see https://www.worldbirdnames.org).