Second Year Report: 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

Report Prepared By:
Herb Grover, and Jean Zirnhelt, Weminuche Audubon Society, Pagosa Springs, CO,
and
Keith Bruno, SW Colorado Community Naturalist for Audubon Rockies, Pagosa Springs, CO.

December, 2020

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 in 2019 and 2020 to monitor bird community composition in three sites dominated by Ponderosa Pine that were subject to prescribed fire in 2019, 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 after prescribed fire in 2019, but recovered by 2020; 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 seven-week period beginning in early June 2019 and was repeated beginning in late May, 2020. Looking across both years of the study, 72 bird species were observed, with 40 species, representing about 90% of sitings. There were 14 species unique to the 2019 season, and 18 species found only in our 2020 sample season. The Turkey Springs site, which had the fewest species and birds counted in 2019, showed noticeable recovery to 37 species and 688 individual birds in 2020. The Fawn Gulch site, which had the greatest number of species of the three sites in 2019 (40 species), was surpassed by the Jackson Mountain site in 2020 with 45 species and 683 birds. 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. New to our 2020 report, we analyzed nesting behaviors with a focus on cavity nesters. 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 than 400 hours to the completion of this project in 2019, and over 800 hours in 2020. Their names (in alphabetical order) are: (Note: a = 2019 participant; b = 2020 participant)

Carol Ashmore[a, b]	Suzanne Coe[a]	Gary Hopkins[b]	Joan Rohwer[b]
Ben Bailey[a]	Maurene Collins[a, b]	Rob Hagberg[a, b]	Darryl Saffer[a]
Bill Breding[a,b]	John Duvall[a, b]	Dana Hayward[b]	Marie Smith[b]
Brenda Breding[a, b]	Becky Endres[a]	Liz Jamison[b]	Loyette Stewart[a, b]
Pat Bremer[a, b]	Bob Endres[a, b]	Charles Martinez[a, b]	Anne Stevens[a, b]
Keith Bruno[a, b]	Gloria Godo[b]	Susan McAdams[a, b]	Kathy Strang[b]
Tricia Byers[a, b]	Byron Greco[a, b]	Randy McCormick[a, b]	Tom Strang[b]
Diane Cirksena[a]	Herb Grover[a, b]	Rita Peck[b]	Jean Zirnhelt[a, b]
	Jaqueline Hagberg[a]		

We also appreciate the assistance of USFS personnel Mat Tuten and Fred Elliot in locating prospective study sites, and Anthony Culpepper of Mountain Studies Institute for providing treatment and vegetation data used to characterize the sites chosen for our study. Thanks also go to several unnamed reviewers who commented on earlier drafts of this report.

Cover photo: *Marie Smith (2019 American Birding Association Bird Camp Scholarship recipient) and Jean Zirnhelt (Weminuche Audubon Society President) following Covid guidelines while birding at Jackson Mountain site.*

Second Year Report – 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:
In 2019, 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), initiated a study of how bird community species composition and structure in Ponderosa Pine forests in the San Juan Mountains of southwestern Colorado were affected by mastication and/or prescribed fire treatments designed to reduce wildland fuel loads. The report for the first year of the study (Grover et. al., 2019) can be downloaded from the Weminuche Audubon Society website at http://www.weminucheaudubon.org/bird-community-monitoring/. First year findings are also summarized in a YouTube video posted at https://www.youtube.com/watch?v=mfBiFN0gR6A . The monitoring program initiated in the summer of 2019 was repeated in the summer of 2020, the findings of which are the primary focus of this report.

Literature reviewed for the 2019 report underscores the consequences of prior policies and forest management practices that have contributed to a buildup of wildland fuel loads and increased densities of woody understory growth in dry and moist mixed-conifer forests across the western United States (e.g., Baker, 2018; Block and Conner, 2016; Covington, 1994; Harrington and Sackett, 1990; Korb et. al., 2013; McWethy et. al. 2019; and Romme et. al. 2009). As evidenced by the record expanse of wildland fires in western states over the past several years, and the catastrophic consequences of these fires for residential communities located in the wildland-urban interface (WUI) (e.g., Ager et. al., 2019), the buildup of wildland fuel loads warrants much greater emphasis by managers of forested landscapes. Notably, current forest management practices emphasize various approaches to reducing wildland fuel loads, including selective harvesting and/or thinning; prescribed fires; and understory removal by mastication. These management practices have the potential of impacting wildlife in affected areas, including forest bird communities (see Block and Conner, 2016; and Lowe et. al., 1978).

USFS personnel with the Pagosa Ranger District in the San Juan National Forest, in collaboration with the SJHFHP, have been proactive in implementing understory mastication and prescribed fire treatments to establish strategically defensible areas in the dry and moist mixed-conifer forests surrounding Pagosa Springs, CO. This led some local residents interested in bird conservation to wonder how fire mitigation practices implemented in these forests might affect the distribution and abundance of bird species in and around the treatment areas, resulting in a citizen science bird monitoring project in 2019 (Grover et. al., 2019) that continued with a second season of data collection in 2020.

As a citizen science project, this study incorporates several objectives complementary to the scientific question that is being investigated. For example, volunteers participating in both years of 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:
Detailed descriptions of the three study areas included in this project, and methodologies for characterizing these sites – Turkey Springs (TS); Fawn Gulch (FG); and Jackson Mountain (JM) – can be found in the first-year report (Grover et. al., 2019; http://www.weminucheaudubon.org/bird-community-monitoring/). Table 1 from the first-year report, summarizing site characteristics, is included below. Note that all three sites are located within approximately 10 miles of Pagosa Springs, CO and are comparable in elevation and slope characteristics. The sites differ, however, in overstory tree densities and shrub-layer characteristics, due in large part to the timing and types of fire mitigation measures aimed at reducing wildland fuel loads at TS and FG, while no such measures have been

implemented in recent years at JM. The TS site was subject to prescribed fire at the outset of the 2019 sample season in early June; the FG site was subject to shrub-layer mastication treatment in 2017; while there is no record of the JM site ever having been subject to intentional management to reduce wildland fuel loads.

Table 1. General site characteristics of Turkey Springs (TS), Fawn Gulch (FG), and Jackson Mountain (JM) study areas. (from Grover et. al. 2019)

	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

Bird Community Sampling Methodology: (see also Grover et. al. 2019)
The bird community sampling design employed in this study is a modification of established methodologies used by the Bird Conservancy of the Rockies 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.

For the second season of this study, special precautions were taken to adhere to established CDC guidelines with regard to the Covid pandemic. Participants were advised to refrain from participation if they felt ill; they were discouraged from carpooling to the sites; and distancing guidelines and wearing masks was also encouraged, even while in the field. Otherwise, the protocols established in 2019 were followed in 2020 for collecting data from each loop of monitoring points as follows:

- Teams of at least two volunteers each were identified and assigned responsibility to collect data for two loops per team at a particular study site over a period of seven weeks, beginning on or about May 23rd, and ending by July 11th, 2020.
- Each team was asked to visit their assigned loops at least four times over the period of the study. In addition, each team was asked to visit 2 loops at each of the other two sites. Team members were also encouraged to visit additional sites with other teams.
- 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.
- 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 in 2020 to assign 3 teams to each site, with one additional

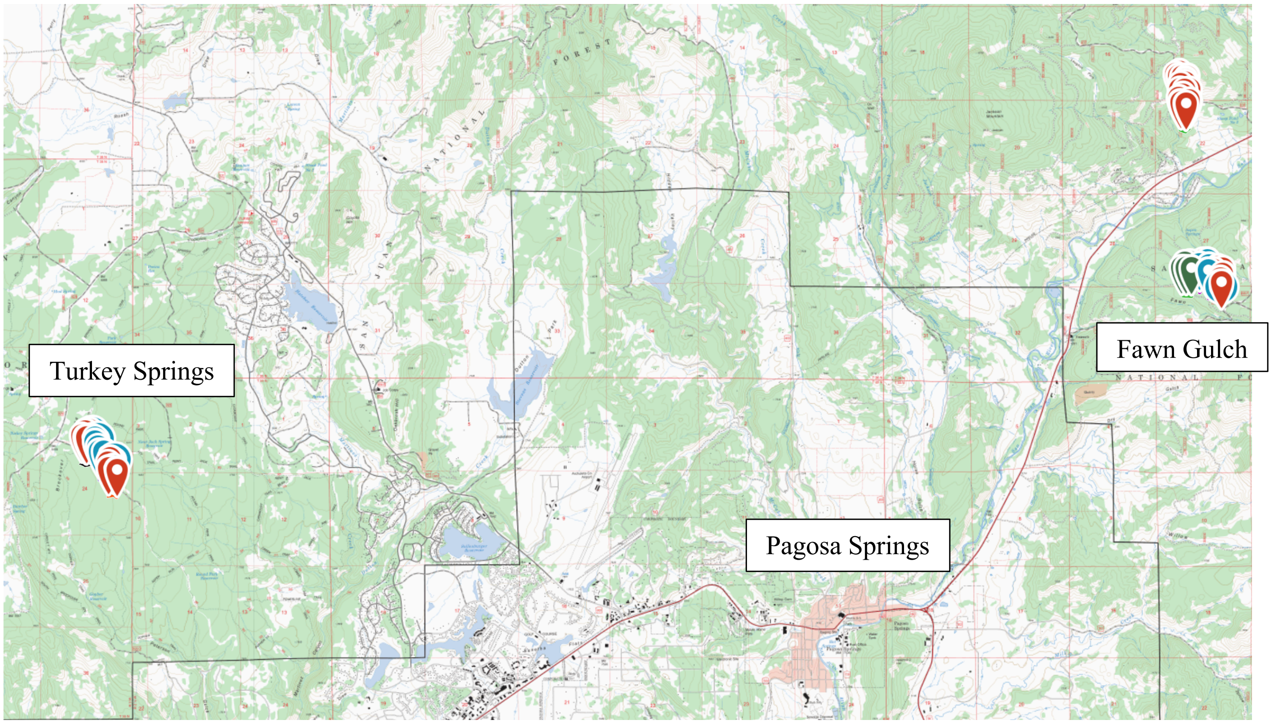

Figure 1. Map showing locations of Turkey Springs, Fawn Gulch, and Jackson Mountain study areas.

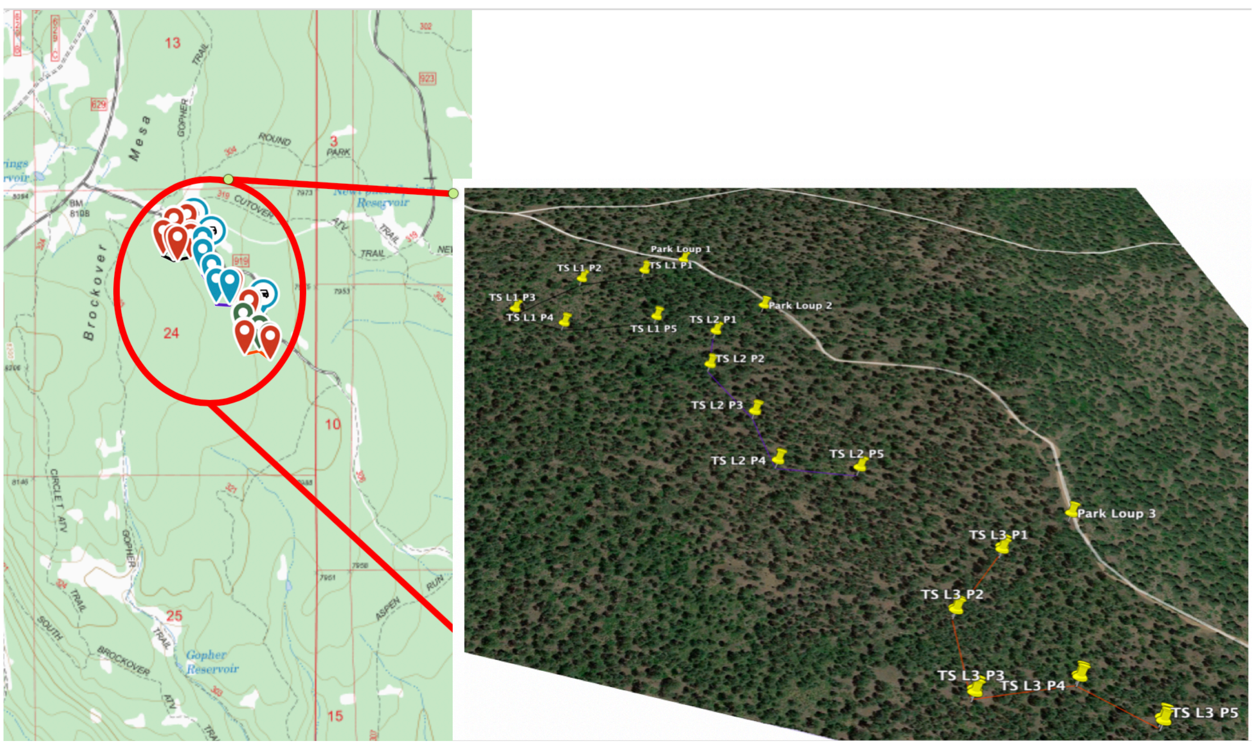

Figure 2. Map showing locations of monitoring points within Turkey Springs study area. TS = Turkey Springs; L # = Loop number; P # = Monitoring point number.

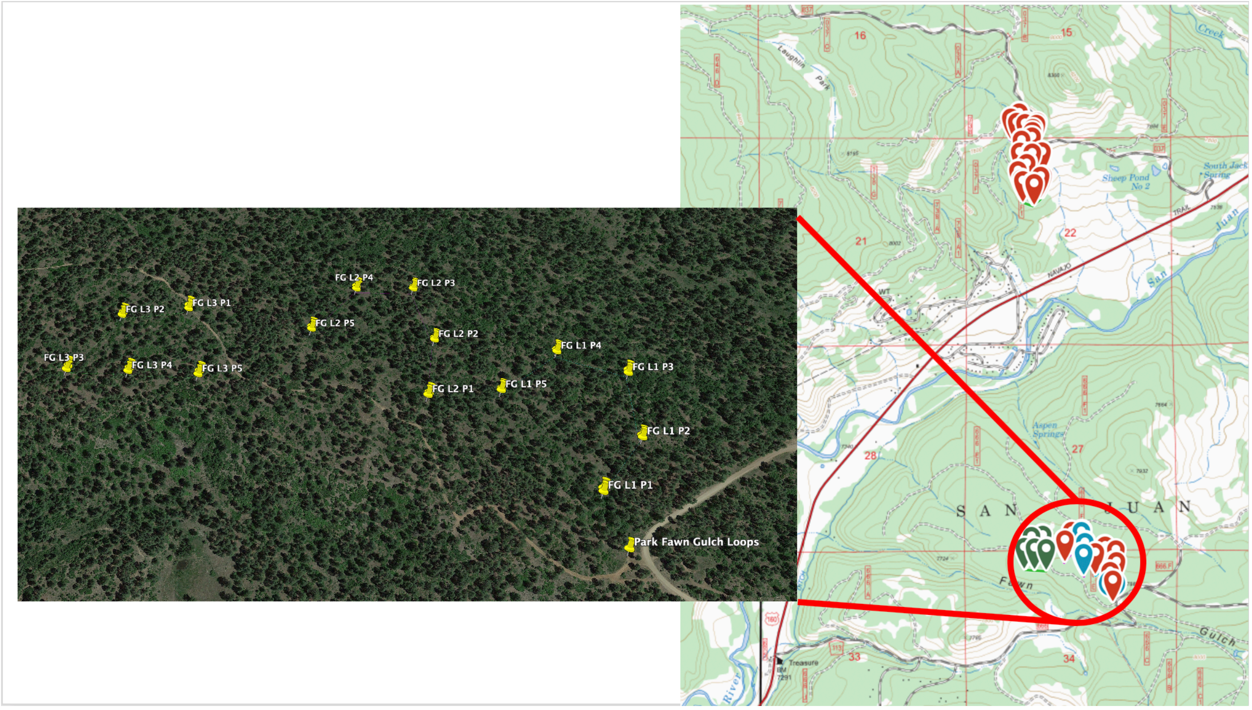

Figure 3. Map showing locations of monitoring points within Fawn Gulch study area. FG = Fawn Gulch; L # = Loop number; P # = Monitoring point number.

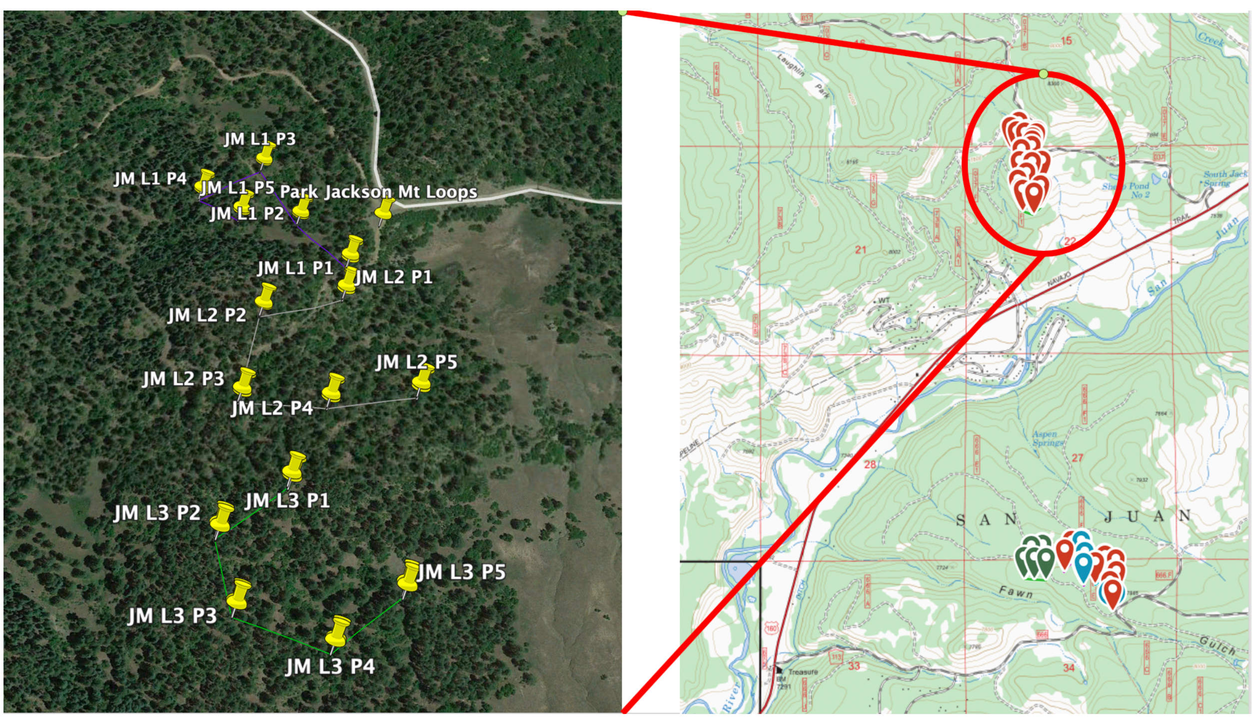

Figure 4. Map showing locations of monitoring points within Jackson Mountain study area. JM = Jackson Mountain; L # = Loop number; P # = Monitoring point number.

team “floating” across all three sites. The experience of the team members varied from accomplished birders to those self-identified as being at an intermediate skill level. Each site had at least one team of accomplished birders assigned. This design provided 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.

In 2019, FG received 14 site visits, compared to 10 site visits each to TS and JM, requiring some data conditioning to re-balance the overall dataset (Grover et. al., 2019). This complication did not occur in the 2020 sampling season, during which TS and JM received 18 site visits, and FG received 17.5 site visits (one site visit involved only one loop being sampled). More important, there was much more collaboration between teams in 2020, resulting in a much greater number of observers visiting each site over the course of the study. Multiplying the number of team members per visit times the number of visits and loops per visit reveals 108 observer-visits at TS; 114 observer-visits at FG; and 100 observer-visits at JM in 2020. With the benefit of the experience from the 2019 field season, the bird identification skills of many of our observers was also markedly improved.

We conservatively estimate that each observer-visit entails about 2.5 hours of volunteer time, which leads to an estimate of at least 805 volunteer hours invested in conducting the 2020 field season. By comparison, we estimated a total of about 450 volunteer hours for the 2019 sampling season.

Results:
Table 2 summarizes the bird species documented for 2020 that were common to all three sites, or unique to each of the three sites. Of the 58 total species recorded for 2020, 26 were found at all three sites. Thirty-seven species were recorded for TS, with 4 species unique to that site; 39 total species were recorded for FG, with 7 species unique to that site; and 45 total species were recorded for JM, with 10 species unique to that site.

The cumulative relative frequency for the 26 species common to all three sites totaled 91.6% of all sightings (Table 2). For those species unique to a particular site, the Band-tailed Pigeon, found only at FG; and Virginia’s Warbler, found only at JM, were recorded 5 or more times. For those species found at any two sites, the cumulative relative frequency was 5.3%. This indicates that species common to all three sites represented the majority of bird sightings recorded. Similar patterns were found when totaling bird abundance values.

A similar analysis by site confirms this pattern (Table 2), with the most common bird species representing 95.5% of bird sightings at TS; 92% of bird sightings at FG; and 88% of bird sightings at JM. These cumulative frequencies are higher than found in the 2019 dataset, where there were 15 common species reported. In 2019, TS and JM had cumulative frequencies of 68% for common species, with FG posting 74% (Grover et. al., 2019). These results suggest that the increased sampling frequency and efficiency (i.e., sampling density) in 2020 resulted in a more thorough representation of the bird community compared to 2019.

Excluding incidental sitings, which will be discussed separately, a total of 72 bird species were recorded across both years of this study, with 58 bird species recorded across all three sample sites in 2020 (Table 2), and 54 species recorded across all three sites in 2019 (Table 3). Of the 72 total species recorded, 40 were identified in both 2019 and 2020; 14 were observed only in 2019; and 18 were observed only in 2020.

The frequency columns in Tables 2 and 3 represent the number of points at which a species was documented. Notably, summing relative frequencies reveals that the species common to both years represented 95% of all sitings in 2019, and 97% of all sitings in 2020. For those species observed in only one of the two years of the study, only the Northern Rough-winged Swallow in 2019, and Band-tailed Pigeon, Grace’s Warbler, and Spotted Towhee in 2020, exceeded 5 or more sitings.

Another important difference between sample years is shown in Table 3 by the total number of points at which species were recorded in each year – 653 in 2019 vs. 1578 in 2020. This reflects the greater number of site visits in 2020 (at least 36 loops per site), vs. 2019 (at least 20 loops per site, with 28 loops visited at FG; see Grover et. al., 2019) and the greater number of observers participating in many of the site visits in 2020.

Table 4 provides a comparison of the frequency and relative frequency of a subset of the 40 bird species found in both years of the study. Ten of the most commonly sighted bird species in the top-ranked 15 species were observed in both years, with 5 documented only in 2019 and an additional 5 recorded only in 2020. In 2019, the 15 most frequently recorded species accounted for about 82.5% of the total number of points where birds were observed, vs. a cumulative frequency of 78% for the 2020 dataset. Among the top 5 ranked species across both years, the American Robin ranks first for both years, with the Pygmy Nuthatch, Violet-green Swallow, and Western Wood-Pewee rounding out the top 4 most common bird species in both years. The fifth most common species in 2019 was the Northern Flicker, with the Yellow-rumped Warbler occupying that rank for 2020.

Table 2. Summary of all bird species observed across the three study areas in 2020. Data shown are the number of sample points at which respective bird species were recorded (i.e., frequency); and the number of birds of the respective species observed (i.e., abundance). Species lists represent those found at all three sites, sorted by abundance within the respective sites; those unique at one of the three sites, sorted by abundance within the respective sites; and those found at two of the three sites, unsorted

	Turkey Springs					Fawn Gulch					Jackson Mountain			
# Species	37				# Species	39				# Species	45			
# point records	471	# birds	688		# point records	571	# birds	856		# point records	536	# birds	683	
	Freq	Rel Freq	Abund	Rel Abund		Freq	Rel Freq	Abund	Rel Abund		Freq	Rel Freq	Abund	Rel Abund
Species Found At All Three Sites (Sorted by Abundance)														
Violet-green Swallow	50	10.2	109	15.7	Western Wood-Pewee	93	16.3	153	17.9	American Robin	76	14.2	103	15.1
Pygmy Nuthatch	44	9.0	81	11.6	American Robin	78	13.7	110	12.9	Pygmy Nuthatch	41	7.6	57	8.3
American Robin	61	12.5	77	11.1	Mourning Dove	32	5.6	63	7.4	Northern Flicker	44	8.2	52	7.6
Western Wood-Pewee	51	10.4	63	9.1	Pygmy Nuthatch	29	5.1	55	6.4	Steller's Jay	36	6.7	52	7.6
Yellow-rumped Warbler	35	7.2	53	7.6	Yellow-rumped Warbler	33	5.8	41	4.8	Western Tanager	34	6.3	49	7.2
Dark-eyed Junco	32	6.5	46	6.6	Violet-green Swallow	14	2.5	38	4.4	Violet-green Swallow	25	4.7	41	6.0
Mourning Dove	30	6.1	36	5.2	Western Tanager	28	4.9	36	4.2	Chipping Sparrow	25	4.7	37	5.4
Western Bluebird	19	3.9	30	4.3	Green-tailed Towhee	28	4.9	35	4.1	Green-tailed Towhee	24	4.5	29	4.2
Chipping Sparrow	20	4.1	23	3.3	House Wren	26	4.6	32	3.7	Western Wood-Pewee	27	5.0	29	4.2
White-breasted Nuthatch	21	4.3	23	3.3	Warbling Vireo	22	3.9	30	3.5	Plumbeous Vireo	23	4.3	25	3.7
Red Crossbill	4	0.8	17	2.4	White-breasted Nuthatch	18	3.2	29	3.4	Warbling Vireo	16	3.0	17	2.5
House Wren	12	2.5	15	2.2	Black-capped Chickadee	13	2.3	21	2.5	White-breasted Nuthatch	16	3.0	17	2.5
Northern Flicker	12	2.5	14	2.0	Cordilleran Flycatcher	15	2.6	19	2.2	Black-capped Chickadee	8	1.5	11	1.6
Hairy Woodpecker	9	1.8	10	1.4	Plumbeous Vireo	17	3.0	19	2.2	Broad-tailed Hummingbird	10	1.9	11	1.6
Western Tanager	9	1.8	10	1.4	Steller's Jay	13	2.3	16	1.9	Yellow-rumped Warbler	10	1.9	11	1.6
Steller's Jay	7	1.4	7	1.0	Western Bluebird	14	2.5	16	1.9	Turkey Vulture	9	1.7	10	1.5
American Crow	5	1.0	6	0.9	Chipping Sparrow	11	1.9	12	1.4	Mourning Dove	7	1.3	9	1.3
Broad-tailed Hummingbird	6	1.2	6	0.9	Northern Flicker	8	1.4	10	1.2	American Crow	8	1.5	8	1.2
Townsend's Solitaire	5	1.0	6	0.9	Red Crossbill	7	1.2	9	1.1	Dark-eyed Junco	8	1.5	8	1.2
Cordilleran Flycatcher	4	0.8	5	0.7	Dark-eyed Junco	6	1.1	8	0.9	House Wren	7	1.3	8	1.2
Green-tailed Towhee	4	0.8	5	0.7	Hairy Woodpecker	6	1.1	7	0.8	Mountain Chickadee	5	0.9	8	1.2
Black-capped Chickadee	4	0.8	4	0.6	Mountain Chickadee	5	0.9	6	0.7	Red Crossbill	1	0.2	8	1.2
Mountain Chickadee	2	0.4	4	0.6	Broad-tailed Hummingbird	3	0.5	3	0.4	Hairy Woodpiecker	5	0.9	5	0.7
Plumbeous Vireo	2	0.4	2	0.3	Turkey Vulture	3	0.5	3	0.4	Cordilleran Flycatcher	4	0.7	4	0.6
Turkey Vulture	1	0.2	1	0.1	American Crow	2	0.4	2	0.2	Townsend's Solitaire	1	0.2	1	0.1
Warbling Vireo	1	0.2	1	0.1	Townsend's Solitaire	1	0.2	1	0.1	Western Bluebird	1	0.2	1	0.1
Species Unique to Respective Sites (Sorted by Abundance)														
Pine Siskin	2	0.4	3	0.4										
European Starling	1	0.2	1	0.1										
Osprey	1	0.2	1	0.1										
White-crowned sparrow	1	0.2	1	0.1										
					Band-tailed Pigeon	6	1.1	34	4.0					
					Black-headed Grosbeak	8	1.4	9	1.1					
					Great Horned Owl	1	0.2	3	0.4					
					Black-chinned Hummingbird	1	0.2	1	0.1					
					Dusky Grouse	1	0.2	1	0.1					
					Evening Grosbeak	1	0.2	1	0.1					
					Song Sparrow	1	0.2	1	0.1					
					Williamson's Sapsucker	1	0.2	1	0.1					
										Virginia's Warbler	21	3.9	21	3.1
										Black-headed Grosbeak	7	1.3	7	1.0
										Say's Phoebe	4	0.7	4	0.6
										Hermit Thrush	2	0.4	3	0.4
										Brown Creeper	1	0.2	1	0.1
										Cooper's Hawk	1	0.2	1	0.1
										Dusky Flycatcher	1	0.2	1	0.1
										Northern Goshawk	1	0.2	1	0.1
										Gray Catbird	1	0.2	1	0.1
										Great Blue Heron	1	0.2	1	0.1
										Tree Swallow	1	0.2	1	0.1
Species Found At Two Respective Sites (Unsorted)														
Cassin's Finch	1	0.2	2	0.3	Cassin's Finch	4	0.7	6	0.7					
Spotted Towhee	3	0.6	3	0.4	Spotted Towhee	3	0.5	4	0.5					
					Grace's Warbler	11	1.9	11	1.3	Grace's Warbler	3	0.6	4	0.6
					Red-tailed Hawk	4	0.7	4	0.5	Red-tailed Hawk	4	0.7	4	0.6
					Orange-crowned Warbler	4	0.7	6	0.7	Orange-crowned Warbler	3	0.6	3	0.4
Brown-headed Cowbird	1	0.2	1	0.1						Brown-headed Cowbird	2	0.4	2	0.3
Collared Dove	2	0.4	3	0.4						Eurasian Collared Dove	1	0.2	1	0.1
Common Nighthawk	3	0.6	3	0.4						Common Nighthawk	1	0.2	1	0.1
Common Raven	5	1.0	14	2.0						Common Raven	9	1.7	12	1.8
Red-breasted Nuthatch	1	0.2	2	0.3						Red-breasted Nuthatch	1	0.2	3	0.4

Table 3. Summary of all bird species recorded for 2019 and 2020 sample years.

Year	2019		2020	
Total # Species	54		58	
Total Point Records	653		1578	
# Species Common Across Years	40			
Total Point Records By Year	621	95.1	1534	97.2
Species	Freq	Rel Freq	Freq	Rel freq
Species Recorded in 2019 And 2020 (= 40)				
American Crow	24	3.7	15	1.0
American Robin	151	23.1	215	13.6
Black-capped Chickadee	1	0.2	25	1.6
Black-headed Grosbeak	10	1.5	15	1.0
Broad-tailed Hummingbird	5	0.8	19	1.2
Brown-headed Cowbird	11	1.7	3	0.2
Cassin's Finch	3	0.5	5	0.3
Chipping Sparrow	10	1.5	56	3.5
Common Nighthawk	8	1.2	4	0.3
Common Raven	10	1.5	14	0.9
Cordilleran Flycatcher	2	0.3	23	1.5
Dark-eyed Junco	1	0.2	46	2.9
Green-yailed Towhee	21	3.2	56	3.5
Hairy Woodpecker	9	1.4	20	1.3
Hermit Thrush	1	0.2	2	0.1
House Wren	2	0.3	45	2.9
Mountain Chickadee	3	0.5	12	0.8
Mourning Dove	2	0.3	69	4.4
Northern Flicker	33	5.1	64	4.1
Orange Crowned Warbler	1	0.2	7	0.4
Osprey	1	0.2	1	0.1
Pine Siskin	1	0.2	2	0.1
Plumbeous Vireo	11	1.7	42	2.7
Pygmy Nuthatch	48	7.4	114	7.2
Red Crossbill	1	0.2	12	0.8
Red-tailed Hawk	5	0.8	8	0.5
Say's Phoebe	2	0.3	4	0.3
Steller's Jay	5	0.8	56	3.5
Townsend's Solitaire	3	0.5	7	0.4
Tree Swallow	4	0.6	1	0.1
Turkey Vulture	4	0.6	13	0.8
Violet-green Swallow	97	14.9	89	5.6
Virginia's Warbler	2	0.3	21	1.3
Warbling Vireo	8	1.2	39	2.5
Western Bluebird	9	1.4	34	2.2
Western Tanager	3	0.5	71	4.5
Western Wood-Pewee	54	8.3	171	10.8
White-breasted Nuthatch	31	4.7	55	3.5
Williamson's Sapsucker	5	0.8	1	0.1
Yellow-rumped Warbler	19	2.9	78	4.9

Year	2019		2020	
# Species by Year	14		18	
Total Point Records By Year	32	4.9	44	2.8
Species	Freq	Rel Freq	Freq	Rel freq
Species Recorded in 2019 Only (= 14)				
American Goldfinch	2	0.3		
American Kestrel	1	0.2		
Bald Eagle	2	0.3		
Bullock's Oriole	2	0.3		
Canada Goose	3	0.5		
Downy Woodpecker	2	0.3		
Lewis's Woodpecker	1	0.2		
MacGillvery's Warbler	1	0.2		
Black-billed Magpie	2	0.3		
Mountain Bluebird	1	0.2		
Northern Rough-winged Swallow	10	1.5		
Red-naped Sapsucker	2	0.3		
White-throated Swift	1	0.2		
Yellow Warbler	2	0.3		
Species Recorded in 2020 Only (= 18)				
Band-tailed Pigeon			6	0.4
Black-chinned Hummingbird			1	0.1
Brown Creeper			1	0.1
Eurasian Collared Dove			3	0.2
Cooper's Hawk			1	0.1
Dusky Flycatcher			1	0.1
Dusky Grouse			1	0.1
European Starling			1	0.1
Evening Grosbeak			1	0.1
Northern Goshawk			1	0.1
Grace's Warbler			14	0.9
Gray Catbird			1	0.1
Great Blue Heron			1	0.1
Great Horned Owl			1	0.1
Red-breasted Nuthatch			2	0.1
Song Sparrow			1	0.1
Spotted Towhee			6	0.4
White-crowned sparrow			1	0.1

Note that Virginia's Warbler sightings at JM, a species unique to that site, constituted 3.9% of bird sightings for that location in 2020. Although not recorded as frequently in 2019, Virginia's Warbler was also unique to JM in that dataset (Grover et. al. 2019).

The total number of points where birds were recorded in 2020 was highest at FG (571); second highest at JM (536); and lowest at TS (471) (Table 4). While the site rankings were the same in 2019, the frequencies were lower, with 300 total point records at FG; 209 point records at JM; and 144 point records at TS.

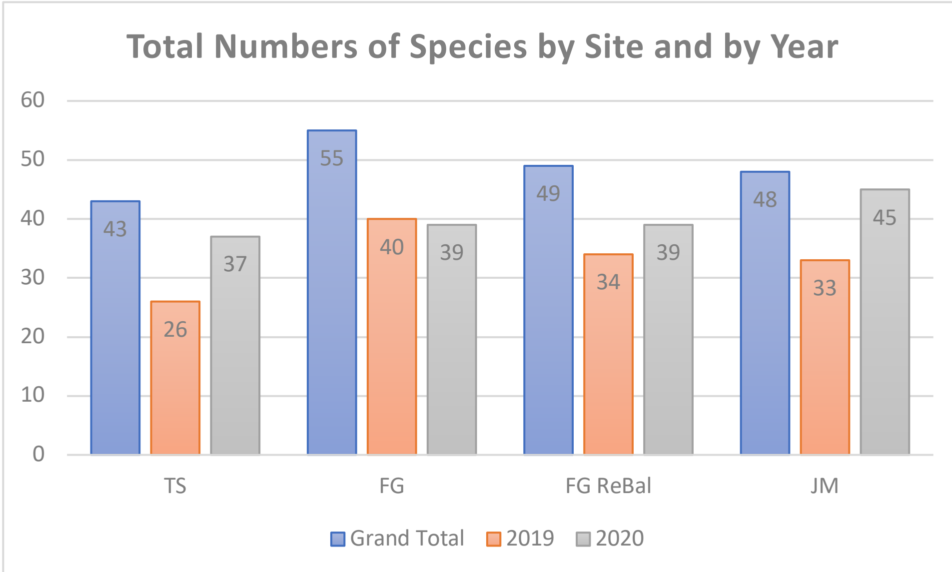

Figure 5. Comparison of bird species recorded by site across the two years of study. TS = Turkey Springs; FG = Fawn Gulch; FG ReBal = Fawn Gulch Rebalanced; and JM = Jackson Mountain. For an explanation of FG ReBal, see Grover et. al., 2019.

Figure 5 illustrates the total number of bird species identified at each of the three sites included in this study, with species counts by year of study shown as well. FG stands out as the site with the greatest number of different species at 55, and also had the greatest number of species recorded for 2019 compared to the other two sites. Also notable in these data is the increase in number of bird species recorded at TS in 2019 vs. 2020. Recall that the TS site was subject to prescribed fire at the outset of the study in 2019, which probably accounts for the lower number of species recorded at that site in that year. Year-to-year variations in other environmental factors may contribute to this finding as well.

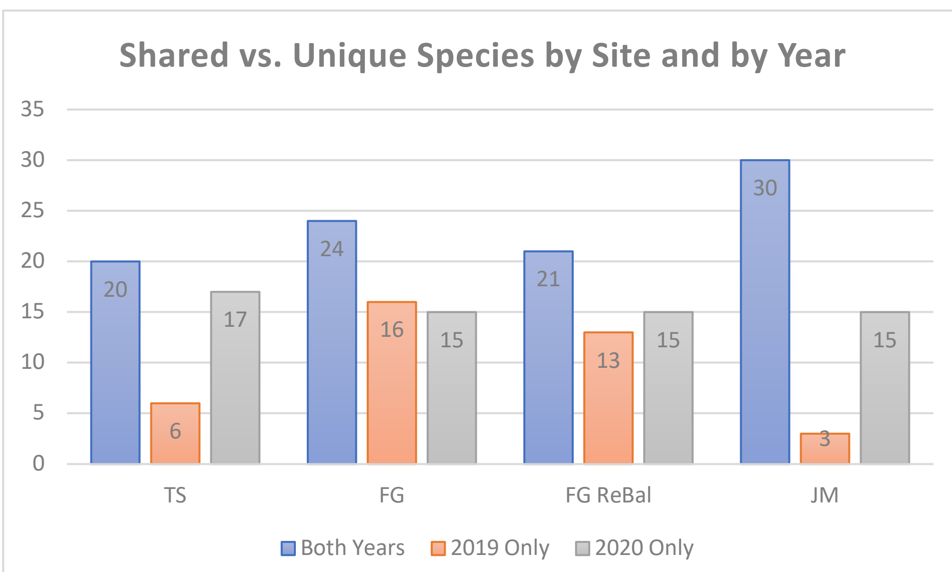

Figure 6. Comparison of bird species common to (blue bars) or unique to respective sites (orange or gray bars) over the two years of study. TS = Turkey Springs; FG = Fawn Gulch; FG ReBal = Fawn Gulch Rebalanced; and JM = Jackson Mountain. For an explanation of FG ReBal, see Grover et. al., 2019.

Considering the common vs. unique bird species observed at each site across 2019 and 2020 (Fig. 6), JM stands out as the site with the greatest number of shared species across years with 30 out of 48 total species recorded (see Fig. 5). By comparison, less than half of the bird species observed at TS and FG were common to both years. For both TS and JM, the 2020 dataset contained a greater number of bird species unique to that sample year compared to 2019 (17 and 15, respectively). In the case of TS, the simplest explanation for an increase in bird species unique to 2020 is that the site is undergoing recovery of the shrub layer following prescribed fire in 2019, although year-to-year variability and an increase in sample frequency and effectiveness may contribute to this result as well. The increased number of unique species to 2020 at the JM site more likely reflects increased sample frequency and effectiveness, with year-to-year variability another contributing factor.

Table 4. Comparison of top 15 ranked bird species among the 40 bird species common to both the 2019 and 2020 years of the study.

2019					2020			
Species	RANK	Freq	Rel Freq		Species	RANK	Freq	Rel freq
American Crow	7	24	3.7					
American Robin	1	151	23.1		American Robin	1	215	13.6
Black-headed Grosbeak	12	10	1.5					
Brown-headed Cowbird	10	11	1.7					
Chipping Sparrow	13	10	1.5		Chipping Sparrow	9	56	3.5
Common Raven	14	10	1.5					
					Dark-eyed Junco	13	46	2.9
Green-tailed Towhee	8	21	3.2		Green-tiled Towhee	10	56	3.5
Hairy Woodpecker	15	9	1.4					
					House Wren	14	45	2.9
					Mourning Dove	7	69	4.4
Northern Flicker	5	33	5.1		Northern Flicker	8	64	4.1
Plumbeous Vireo	11	11	1.7		Plumbeous Vireo	15	42	2.7
Pygmy Nuthatch	4	48	7.4		Pygmy Nuthatch	3	114	7.2
					Steller's Jay	11	56	3.5
Violet-green Swallow	2	97	14.9		Violet-green Swallow	4	89	5.6
					Western Tanager	6	71	4.5
Western Wood-Pewee	3	54	8.3		Western Wood-Pewee	2	171	10.8
White-breasted Nuthatch	6	31	4.7		White-breasted Nuthatch	12	55	3.5
Yellow-rumped Warbler	9	19	2.9		Yellow-rumped Warbler	5	78	4.9

Eleven bird species were found at two of the three study sites in 2020; 2 at TS and FG; 4 at FG and JM; and 5 at TS and JM (Table 2). In 2019, a total of 15 species were observed at two sites, with 4 species found at both TS and FG; 7 species at both FG and JM, and 4 species at both TS and JM (Grover et. al. 2019). Of the 11 bird species observed at two sites in 2020, the Spotted Towhee, Grace's Warbler, Eurasian Collared Dove, and Red-breasted Nuthatch were not documented in the 2019 dataset, and the Red-tailed Hawk and Brown-headed Cowbird were common to all three sites in the 2019 dataset. Of the remaining species, only the Common Nighthawk was observed at the same two sites – TS and JM – in 2020 as it was in 2019 (Grover et. al., 2019).

We also reviewed the records of incidental species for each year to determine whether there were any species identified between sample points that were not recorded during point visits. All of the 31 incidental species recorded in 2019 were included in the dataset generated by sample point visits. In 2020, 45 incidental species were recorded. All but four of those species were identified at sample points. Those not included in the sample point dataset were Lewis's Woodpecker, Meadowlark (presumably Western), Mountain Bluebird, and Sharp-shinned Hawk. In 2019, the Lewis's Woodpecker was one of the bird species unique to the TS site, but in 2020 it was an incidental at the JM site. The Mountain Bluebird was sighted in 2020 at TS; this species was one of the unique species at FG in 2019. The [Western] Meadowlark was sighted at JM in 2020 but was not seen in 2019. Finally, there were sightings of Sharp-shinned Hawks at TS and JM in 2020, with no records of this bird species in 2019.

Discussion:
The scientific question that served as the focus of this study concerned the potential effects of wildland fuel reduction treatments on bird community composition. The other complementary objectives of the study included raising awareness among participants of the principles of fire ecology and forest management, particularly with regard to wildland fuel management practices; engaging participants in the planning and conduct of field studies research; improving the birding skills of participants through interactions of novice birders with skilled birders; and strengthening the sense of community among conservation-minded birders in our area. We viewed the achievement of these complementary objectives as equally important to investigating the scientific question we posed, and consequently some confounding variables were introduced into the study. In particular, the frequency of site visits increased substantially in the second year of the study, many observers were more skilled in bird identification as a result of a year of field experience, and participants were encouraged to join other teams during their respective site visits, resulting in a much more thorough canvassing of the study areas in 2020 vs. 2019. As we move forward with our discussion and interpretation of our results, the impact of increased sampling frequency and sampling effectiveness (what we will often refer to moving forward as sampling density) on our data is difficult to ascertain. None-the-less, our findings offer important insights into how bird communities respond to changes in forest structure following wildland fuel reduction treatments.

Community -level response: Because the TS site was subject to prescribed fire at the outset of this study in 2019, data from this site offered an ideal opportunity to address the central scientific question of this study. From 2019 to 2020, the number of bird species at TS increased from 26 in the 2019 dataset to 37 in 2020 (Fig. 5). Interestingly, the number of species recorded at FG was about stable across the two years of this study, with the number of species at JM increasing from 33 in 2019 to 45 in 2020 (Fig. 5).

The number of species unique to a site in 2019 vs. 2020 (see Fig. 6) was very similar for FG (16 vs. 15, respectively), with greater differences observed for TS (6 vs. 17, respectively) and JM (3 vs. 15, respectively). In most cases the bird species that were unique to a site were observed in very low numbers (< 5 % of birds counted), with a few notable exceptions – the Dark-eyed Junco at TS in 2020; Northern Rough-winged Swallow at FG in 2019; Mourning Dove at FG in 2019; and the Chipping Sparrow at JM in 2020.

The increased number of species and unique species at TS and JM are likely due to a combination of factors, the first being recovery of the shrub layer at TS from prescribed fire in 2019. While year-to-year variability in bird community composition and increased sample density in 2020 compared to 2019 are important contributing factors as well, we think these had a more important impact on the JM dataset than TS.

Interpreting patterns in numbers of bird species and numbers of birds within species between sites and across years can be aided by the use of a couple of standard indices – the Shannon Index (H'), also known as the Shannon-Weaver or Shannon-Wiener Index, and the Simpson Index (Ds) (Cox, 2002). The Shannon Index is derived from information theory and describes the degree of uncertainty in predicting the species of the next individual picked at random from a community. This index, known as H', increases as the number of species increases (species richness), and is also affected by how individuals are distributed across species (species evenness), which is represented by Ds.

For this report, we used $\log_2$ of p_i in the equation for $H' = -\sum p_i \log p_i$, where p_i is the relative abundance of individuals of the i^{th} species, (see Cox, 2002). Although $\log_{10}$ was used for our calculations in the 2019 report, $\log_2$ is recommended in the literature, yielding uniformly higher values of H' in 2020 compared to those reported in the 2019 report. For 2020, H' values for JM > FG = FG ReBal > TS (Fig. 8), whereas in our 2019 report, FG had the highest value for H'. As shown in Figure 8, the same trend is found in the 2020 data with H' for JM > FG > TS.

As noted earlier, H' convolves both species richness (number of different species recorded), and species evenness (numbers of individual birds distributed to each species). The Simpson Index is used to represent species evenness (Cox, 2002), and is calculated by the equation: $Ds = \frac{N(N-1)}{\Sigma n(n-1)}$, where N = the total number of individuals of all species; and n = the number of individuals of each species. Higher values of Ds indicate that individuals are more evenly distributed among species; lower values indicate greater dominance by a subset of species. Re-calculation of Ds for this report (Fig. 9) yielded different values than contained in our 2019 project report (Grover et. al., 2019), reflecting our probable inappropriate use of frequency values in the 2019 calculations.

The Ds values calculated for this report are shown in Fig. 9, comparing species evenness between sites and across years. As shown in Fig. 9, Ds values are greatest at JM > FG ReBal > TS > FG for 2019, but shift to JM >> FG = FG ReBal > TS.

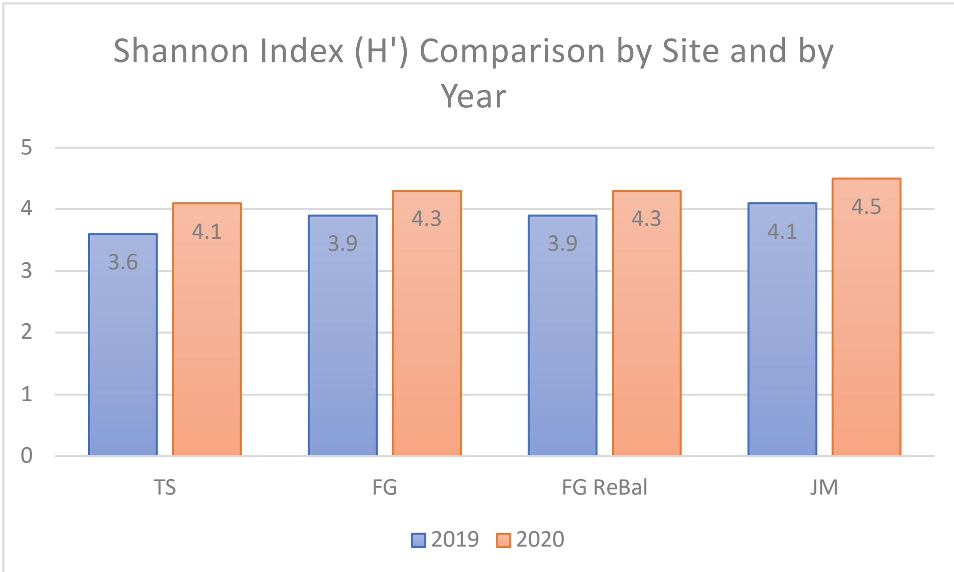

Figure 8. Comparison of the Shannon Index, H', between sites and across years. The equation for H' is: H' = $-\sum p_i \log p_i$; where p_i = the relative abundance of individuals of the ith species. We used $\log_2$ for our calculations. (Note that calculations in the 2019 report used $\log_{10}$) TS = Turkey Springs; FG = Fawn Gulch; FG ReBal = Fawn Gulch Rebalanced; and JM = Jackson Mountain. For an explanation of FG ReBal, see Grover et. al., 2019.

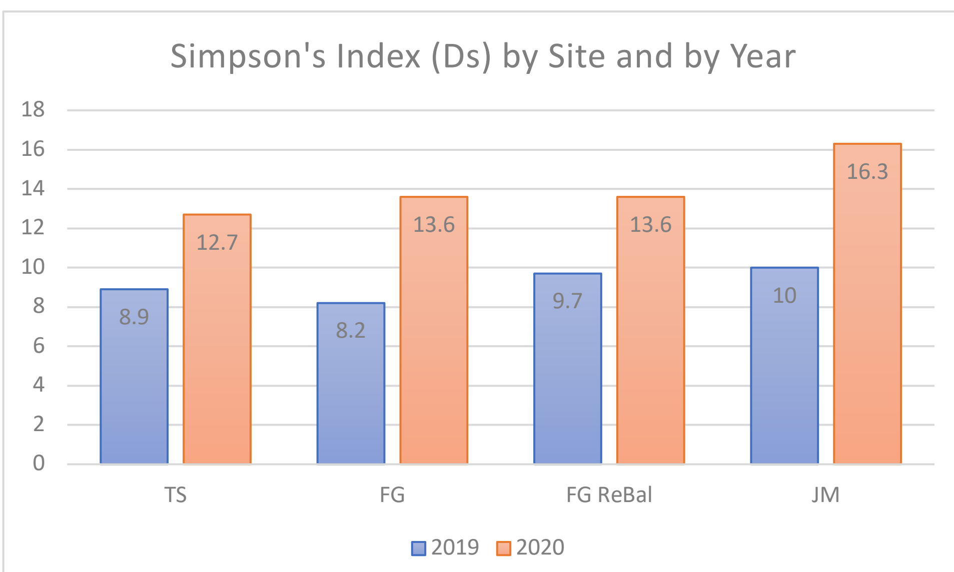

Figure 9. Comparison of Simpson's Index (Ds) by site and by year. The equation for Ds is discussed in the text. TS = Turkey Springs; FG = Fawn Gulch; FG ReBal = Fawn Gulch Rebalanced; and JM = Jackson Mountain. For an explanation of FG ReBal, see Grover et. al., 2019.

In order to put H' and Ds indices into context, we ran a model in which we calculated these indices for extreme scenarios based on a community of 37 species of 688 total birds, which is the number of species and birds found at TS in 2020. In the first scenario, depicting minimal evenness, 652 individuals were attributed to species 1, with one individual each attributed to each of the remaining 36 species. In Scenario 2, depicting maximal evenness, the 688 individuals were distributed evenly across all 37 species. H' for Scenario 1 was 0.57; and for Scenario 2, H' was 5.2, with this range of values strongly reflecting species evenness on this index. Applying the same scenarios to calculations for Ds yields values ranging from 1.1 for Scenario 1 (minimum evenness) to 39.1 for Scenario 2 (maximum evenness).

Comparing these model results to the calculations obtained from our 2019 and 2020 datasets indicates that the bird communities at our study sites lean toward moderately diverse, largely because the number of birds within individual species relative to the total number of birds recorded are distributed fairly evenly across more than half of the species recorded at the sites. For example, the 26 shared species in the 2020 dataset accounted for 94% of the birds counted at TS; 90% of the birds counted at FG; and 89.5% of the birds counted at JM (see Table 2). In the 2019 dataset, the 15 shared species accounted for about 70% of the cumulative relative abundance of species across the three sites, which is reflected in the uniformly lower values for H' and Ds for the 2019 dataset.

A simplified index for comparing ecological communities when relative abundance values (in percent) are available is the Coefficient of Communities (C%) – where C% = $\sum$ (lower % relative abundance values for shared species between the two sites) (Cox, 2002). Values for this index range from 0 for communities with the least similarity, to 1 for communities that are identical to one another.

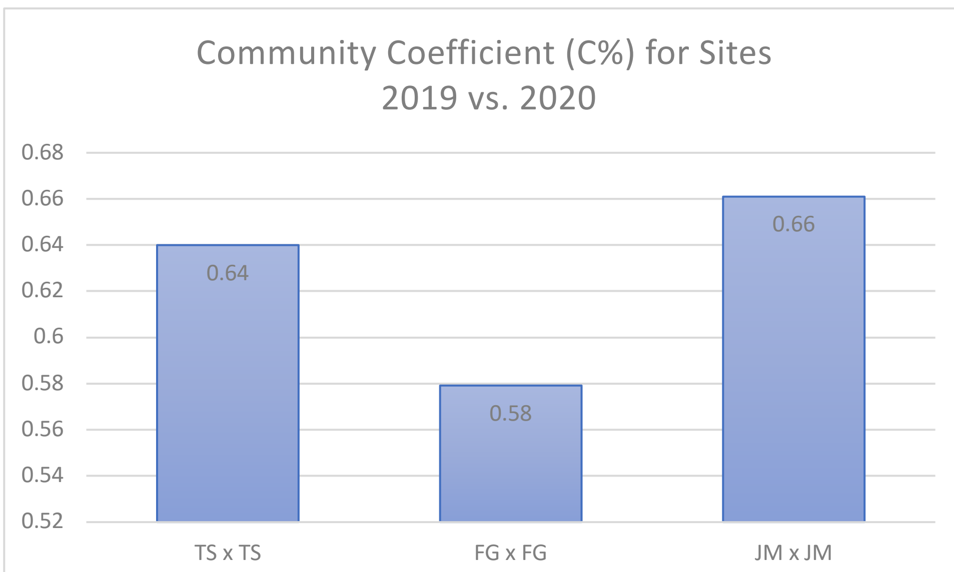

Figure 10. Community Coefficient (C%) values calculated based on bird relative abundances across species for 2019 vs. 2020. TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

Calculations of C% shown in Fig. 10 reveal that JM is most similar across years, with TS nearly as similar across years as JM, and FG least similar from 2019 to 2020. These patterns reflect the proportions of shared vs. unique species by year shown for each site in Fig. 6. The data shown in Fig. 6 reveals that JM had 30 species common to both years out of a total of 48 different species observed at that site; TS had 20 shared species out of a total of 43 different species observed across both years; and FG had 24 shared species (21 in FG ReBal) out of a total of 55 different species observed (or 49 total in FG ReBal). Using C%, we can infer that year-to-year differences across 2019 vs. 2020 is less at JM; with similar year-to-year differences at TS; and greatest year-to-year differences at FG.

A similar approach can be used within years to reveal site-by-site differences, as shown in Fig. 11. These calculations indicate notably greater disparities in the 2019 dataset compared to 2020. For example, C% values ranged from 0.69 for TS compared to JM in 2019; to 0.47 for FG compared to JM in that year. The range of values in the 2020 dataset was much narrower: 0.60 for TS x FG to 0.52 for TS x JM. These difference between years are driven in part by the greater diversity of bird species observed at FG in 2019 compared to either TS or JM. In 2020, JM had a greater number of species, but many of those new species were observed in very low numbers (see Table 2).

Analysis of C% indices suggest that there was greater similarity across sites in 2020 compared to 2019. This pattern seems to be driven by the TS site bird community recovering to numbers more similar to FG from 2019 to 2020. However, as noted earlier, the increase in sampling density in 2020 compared to 2019 may contribute to these shifts as well.

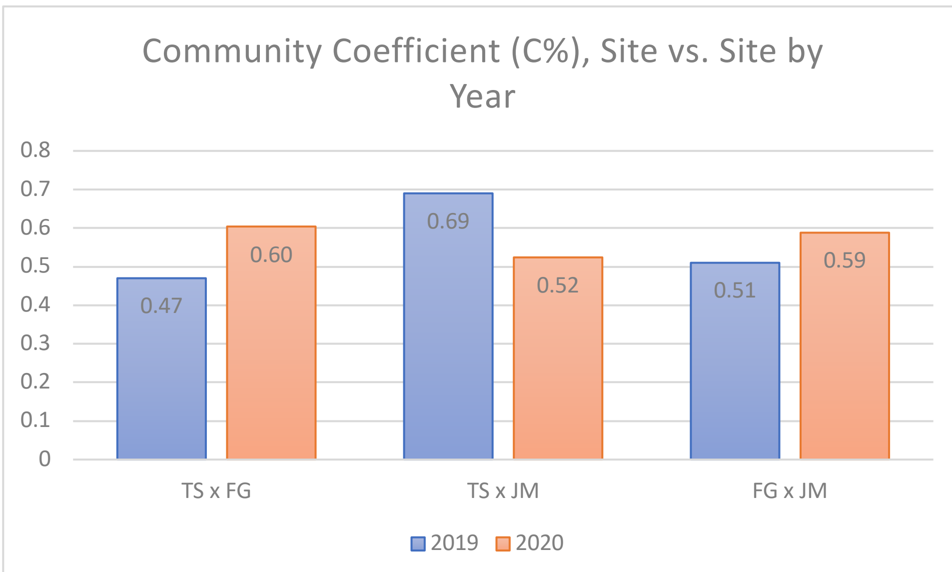

Figure 11. Community Coefficient (C%) values calculated based on bird relative abundances within years and across sites for 2019 vs. 2020. TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

Taken together, our analysis of numbers of bird species and abundances across species and between sites suggests the following:

- There was a much greater number of points where birds were recorded and a much greater abundance of birds observed in 2020 compared to 2019 (Tables 2 and 3);
- The increase in numbers of bird species recorded at TS from 2019 to 2020 increased to a number similar to FG, suggesting recovery of that site from prescribed fire in 2019 (Tables 2 and 3; and Figs. 5 and 6)
- The 40 bird species common to both years across all three sites represent the majority of birds making up the bird community in this region (Tables 2, 3, and 4; and Fig. 5);
- The greatest number of bird species were recorded for FG in 2019, with JM achieving that rank in 2020 (Fig. 6)
- The bird community was more diverse in 2020 compared to 2019, largely due to a more even distribution of birds observed across species (Figs 7 and 8);
- Intra-site comparisons across years indicates that FG exhibited the greatest difference in bird community composition from 2019 to 2020 (Fig. 9); and
- There was greater similarity in bird community composition between sites in 2020 compared to 2019 (Fig. 11).

Species-level response – Feeding Guilds: Table 5 summarizes the categorization of species according to their feeding habits using schemes contained in Lowe et al., (1978); Bock and Lynch (1970); and life history characteristics published by the Cornell Laboratory of Ornithology (www.allaboutbirds.org; see also Grover et. al., 2019). The relative abundances of species in these feeding guilds are illustrated in Fig. 12. Bird species categorized as ground-brush foraging (GBF) are most common at all three sites, with timber-drilling/gleaning (TDG) second most common at TS; timber-foliage searching (TFS) species and flycatchers (F) second most common at FG; and TFS second most common at JM. Note that the relative importance (i.e., ranking) of each of these feeding guilds is the same in 2020 compared to 2019 (see also Grover et. al., 2019).

Notably, we observed a substantial increase in GBF species and TFS species at TS in 2020 compared to 2019, likely reflecting the recovery of the shrub layer following the prescribed fire at that site in 2019 (Table 5; Fig. 12). The number of species in the GBF guild at TS increased from 8 to 18 species across years, with the appearance (return?) of Dark-eyed Juncos; House Wrens; and Red Crossbills in 2020. American Robins, Chipping Sparrows, Mourning Doves, and Western Bluebirds were observed at TS in 2019, but were recorded in substantially higher numbers at that site in 2020, due in part to increased sample density, but the scale of response in these species exceed the increase in sample density, indicating a substantial contribution of shrub layer recovery to this finding.

A substantial increase in the number of Yellow-rumped Warblers, and lesser increases in Western Tanagers, and the appearance of Mountain Chickadees in 2020 contributed to the increase in TFS species at TS in 2020 compared to 2019 (Table 5; Fig. 12). TFS species showed a marginal increase in abundance at FG and JM (Fig. 12). These patterns reflect the appearance of Orange-crowned Warblers and Plumbeous Vireos at FG, and Virginia's Warblers at JM, that were lacking in the 2019 dataset (Table 5). There were also increases in the number of Warbling Vireos and Yellow-rumped Warblers at FG; and similar marked increases in the numbers of Plumbeous Vireos, Stellar's Jays, and Western Tanagers at JM (Table 5).

Two interesting patterns emerge regarding aerial flycatchers (AF) and flycatchers (F) (Fig. 12). First, the relative abundances of flycatcher species is remarkably similar across years at all three sites. This is in contrast to a reduction in the relative abundance of aerial flycatchers at FG from 2019 to 2020, and an increase birds exhibiting this feeding habit at JM over the course of this study.

The timber-drilling/gleaning (TDG) guild increased at all three sites from 2019 to 2020 (Table 5; Fig. 12). This pattern was driven largely by increases in Pygmy Nuthatches and White-breasted Nuthatches at all three sites. This is another pattern in our data that reflects, at least in part, increased sample density in 2020 compared to 2019. However, while sampling density less than doubled, increases in the numbers of Pygmy Nuthatches increased by factors of about 5 at TS and JM, and by a factor of 8 at JM. This indicates an influence of other factors affecting year-to-year variability in bird community composition, including recovery from prescribed fire at the TS site.

Species-level response – Nesting Behaviors:
The availability of nesting sites is expected to have a significant influence on bird species present at a site (see Coe, 2014). For purposes of our study, we categorized birds as tree/shrub nesters; ground/cliff or other, where other refers to use of crevices or ledges on buildings or other structures; and cavity nesters using information from the Cornell Lab (www.allaboutbirds.org; see also Coe, 2014). Using these information resources, we categorized cavity nesters into primary (species that excavate or enlarge nest cavities each breeding season); secondary (species that use existing cavities from primary excavators); or primary or secondary nesters (species that may be weak excavators and may use existing cavities if available).

Cavity nesting species are of great interest in the conservation community because of the potentially limited availability of sites amenable to cavity excavation (e.g., standing dead trees or "snags", or living trees with soft or decaying areas on branches or boles); important interdependencies that exist between primary and secondary cavity nesters; and the implications of this group on ecosystem function (Bednarz et. al., 2004; Coe, 2004; Ibarra et. al., 2017; Martin and Li, 1992). In this context, the concept of "nest-webs" and the role of primary nest cavity excavators as keystone species (see Bednarz et. al., 2004; Coe, 2014; and Ibarra et. al., 2017) has particular relevance for forest managers. Primary cavity excavators are keystone species in the sense that they are essential to the reproductive success of weak nest excavator species (e.g., Lewis's Woodpeckers; many Chickadee species) and bird species that rely exclusively on pre-existing cavities for reproduction. Cavity nest excavators also play a role in other ecosystem functions, in particular wood decomposition, through the dispersal of fungal spores during nest excavation and foraging (Farris et. al., 2004). The work of Ibarra et. al., (2017) provides compelling evidence that cavity nesters are also important determinants of forest ecosystem resilience in the context of forest management practices.

Looking across all 72 species encountered through both years of our study, we identified 39 tree/shrub nesters; 15 ground/cliff/other species; and 18 cavity nesting species (Table 6, only data for cavity nesters is shown). Among the 18 cavity nesting species, 4 are categorized as primary nesting species (Downy Woodpecker, Hairy Woodpecker, Northern Flicker, and Williamson's Sapsucker); 9 species fall in to the secondary nester category (American Kestrel, European Starling, House Wren, Mountain Bluebird, Mountain Chickadee, Tree Swallow, Violet-green Swallow, Western Bluebird, White-breasted Nuthatch); with 5 species capable of either excavating new cavities or using existing cavities for their nests (Table 6). In our study, Hairy Woodpeckers and Northern Flickers were the most abundant primary cavity nesters, seen at all three sites, along with Violet-green Swallows and White-breasted Nuthatches as abundant secondary cavity nesters, and Pygmy Nuthatches fulfilling either category (Table 6). It is notable that each of these species increased in numbers, some markedly, from 2019 to 2020. These increases reflect recovery of the TS site, as well as year-to-year variability and increase in sample density across years as noted previously. Other less common species that increased across years were Black-capped Chickadees, House Wrens, Mountain Chickadees, and Western Bluebirds. Williamson's Sapsuckers and Tree Swallows were uncommon in our study and in very low numbers, along with Downy Woodpeckers and Lewis's Woodpeckers. The observation that these uncommon species decreased from 2019 to 2020, or were observed only in one of the two years of study, suggests that their presence or absence was a consequence of year-to-year variability and was not affected by sample density.

<u>Comparative Studies:</u> Previous studies in Ponderosa Pine forests across the American southwest reported increases in populations of GBF and AF species, and decreases in TFS 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 TDG 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 at the recently burned TS site and FG site, but absent from the non-treated JM site. Notably, Western Bluebirds increased in numbers at TS and FG from 2019 to 2020 (Table 5). 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 in 2019, but returned in 2020 (Table 5). Their numbers also increased at FG and JM in 2020 compared to 2019.

Brawn and Balda (1988) noted a positive impact of increased tree density and canopy cover on the Western Wood-Pewee and Black-headed Grosbeak. Dickson et al., (2009) also noted a short-term decline in Western Wood-Pewee in response to prescribed fire across several Ponderosa Pine sites in Arizona and New Mexico. These patterns are not consistent with our findings, in which the Western Wood-Pewee is among the 5 most abundant species at TS and FG in both 2019 and 2020 (Tables 2 and 4), but drops to the third most abundant species at JM in 2019, and the ninth most abundant species at that site in 2020, where tree density and canopy cover is greatest (Tables 2 and 4).

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 TFS feeding guild (e.g., Yellow-rumped Warbler and Steller's Jay). Timber-Drilling/Gleaning (TDG) 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

Table 5. Summary of bird species by feeding habit (i.e., feeding guilds) across sites. Categorization of bird species based on Lowe et al., 1978; Bock and Lynch, 1970; and Cornell Lab of Ornithology (www.allaboutbirds.org)

	Turkey Springs				Fawn Gulch				Jackson Mountain			
	2019		2020		2019		2020		2019		2020	
	ABUND	REL ABUND	ABUND	REL ABUND	ABUND	REL ABUND	ABUND	REL ABUND	ABUND	REL ABUND	ABUND	REL ABUND
Ground-Brush Foraging												
American Goldfinch					3	0.6						
American Robin	43	18.5	77	11.1	130	25.9	110	12.9	75	26.2	103	15.1
Band-tailed Pigeon							34	4				
Black-capped Chickadee			4	0.6			21	2.5	1	0.3	11	1.6
Black-headed Grosbeak					5	1	9	1.1	5	1.8		
Brown-headed Cowbird	2	0.9	1	0.1	3	0.6			1	0.001	2	0.3
Bullock's Oriole	1	0.4			1	0.2						
Canada Goose					12	2.4			5	1.75		
Cassin's Finch			2	0.3	3	0.6	6	0.7				
Chipping Sparrow	6	2.6	23	3.3	10	2	12	1.4			37	5.4
Collared Dove			3	0.4							1	0.1
Dark-eyed Junco			46	6.6	1	0.2	8	0.9			8	1.2
Dusky Grouse							1	0.1				
European Starling			1	0.1								
Evening Grosbeak							1	0.1				
Gray Catbird											1	0.1
Green-tailed Towhee			5	0.7	19	3.8	35	4.1	7	2.5	29	4.2
Hermit Thrush									1	0.4	3	0.4
House Wren			15	2.2			32	3.7	1	1.4	8	1.2
Mountain Bluebird					1	0.2						
Mourning Dove	1	0.4	36	5.2			63	7.4	1	0.4	9	1.3
Northern Flicker	16	6.9	14	2	44	8.8	10	1.2	29	10.1	52	7.6
Pine Siskin			3	0.4	2	0.4						
Red Crossbill			17	2.4	1	0.2	9	1.1			8	1.2
Song Sparrow							1	0.1				
Spotted Towhee			3	0.4			4	0.4				
Townsend's Solitaire			6	0.9			1	0.1	3	1.1	1	0.1
Western Bluebird	5	2.2	30	4.3	5	1	16	1.9			1	0.1
White-crowned sparrow			1	0.1								
TOTALS	**74**	**31.9**	**287**	**41.1**	**240**	**47.9**	**373**	**43.7**	**129**	**45.951**	**274**	**39.9**
Timber-Foliage Searching												
MacGillvery's Warbler	1	0.4										
Mountain Chickadee			4	0.6	1	0.2	6	0.7	4	1.4	8	1.2
Orange-crowned Warbler							5	0.7	2	0.7	3	0.4
Plumbeous Vireo	2	0.9	2	0.3			19	2.2	12	4.2	25	3.7
Red-breasted Nuthatch			2	0.3							3	0.4
Steller's Jay	1	0.4	7	1	10	2	16	1.9	11	3.9	52	7.6
Virginia's Warbler									3	1	21	3.1
Warbling Vireo			1	0.1	1	0.2	30	3.5	7	2.5	17	2.5
Western Tanager	1	0.4	10	1.4	32	6.4	36	4.2	16	5.6	49	7.2
Yellow-rumped Warbler	4	1.7	53	7.6	13	2.6	41	4.8	12	4.2	11	1.6
TOTALS	**9**	**3.8**	**79**	**11.3**	**57**	**11.4**	**153**	**18**	**67**	**23.5**	**189**	**27.7**
Aerial Flycatcher												
Common Nighthawk	6	2.6	3	0.4					2	0.7	1	0.1
Northern Rough-winged Swallow					25	5						
Tree Swallow					7	1.4			4	1.4	1	0.1
Violet-green Swallow	29	12.5	109	15.7	11	2.2	38	4.4	3	1.1	41	6
White-throated Swift									3	1.1		
TOTALS	**35**	**15.1**	**112**	**16.1**	**43**	**8.6**	**38**	**4.4**	**12**	**4.3**	**43**	**6.2**
Flycatcher												
Cordilleran Flycatcher			5	0.7	3	0.6	19	2.2			4	0.6
Dusky Flycatcher											1	0.1
Grace's Warbler							11	1.3			4	0.6
Lewis's Woodpecker	1	0.4										
Say's Phoebe					2	0.4					4	0.6
Western Wood-Pewee	20	8.6	63	9.1	83	16.6	153	17.9	14	4.9	29	4.2
Yellow Warbler					2	0.4						
TOTALS	**21**	**9**	**68**	**9.8**	**90**	**18**	**183**	**21.4**	**14**	**4.9**	**42**	**6.1**
Timber Drilling/Gleaning												
Brown Creeper											1	0.1
Downy Woodpecker	1	0.4			3	0.6						
Hairy Woodpecker	2	0.9	10	1.4	2	0.4	7	0.8	1	0.4	5	0.7
Red-naped Sapsucker					2	0.4						
Williamson's Sapsucker	1	0.4					1	0.1	7	2.45		
Pygmy Nuthatch	17	7.3	81	11.6	7	1.4	55	6.4	12	4.2	57	8.3
White-breasted Nuthatch	11	4.7	23	3.3	23	4.6	29	3.4	4	1.4	17	2.5
TOTALS	**32**	**13.7**	**114**	**16.3**	**37**	**7.4**	**92**	**10.7**	**24**	**8.45**	**80**	**11.6**
Corvid												
American Crow	10	4.3	6	0.9	4	0.8	2	0.2	2	0.7	8	1.2
Common Raven			14	2	1	0.2			11	3.9	12	1.8
Black-billed Magpie					2	0.4						
TOTALS	**10**	**4.3**	**20**	**2.9**	**7**	**1.4**	**2**	**0.2**	**13**	**4.6**	**20**	**3**
Raptor												
American Kestrel					1	0.2						
Bald Eagle					2	0.4						
Cooper's Hawk											1	0.1
Goshawk											1	0.1
Great Horned Owl							3	0.4				
Osprey	1	0.4	1	0.1								
Red-tailed Hawk	1	0.4			1	0.2	4	0.5	6	2.1	4	0.6
Turkey Vulture	1	0.4	1	0.1	6	1.2	3	0.4	8	2.8	10	1.5
TOTALS	**3**	**1.2**	**2**	**0.2**	**10**	**2**	**10**	**1.3**	**14**	**4.9**	**16**	**2.3**
Nectar Feeding												
Black-chinned Hummingbird							1	0.1				
Broad-tailed Hummingbird	1	0.43	6	0.9	2	0.4	3	0.4	2	0.7	11	1.6
TOTALS	**1**	**0.43**	**6**	**0.9**	**2**	**0.4**	**4**	**0.5**	**2**	**0.7**	**11**	**1.6**
Other												
Great Blue Heron											1	0.2

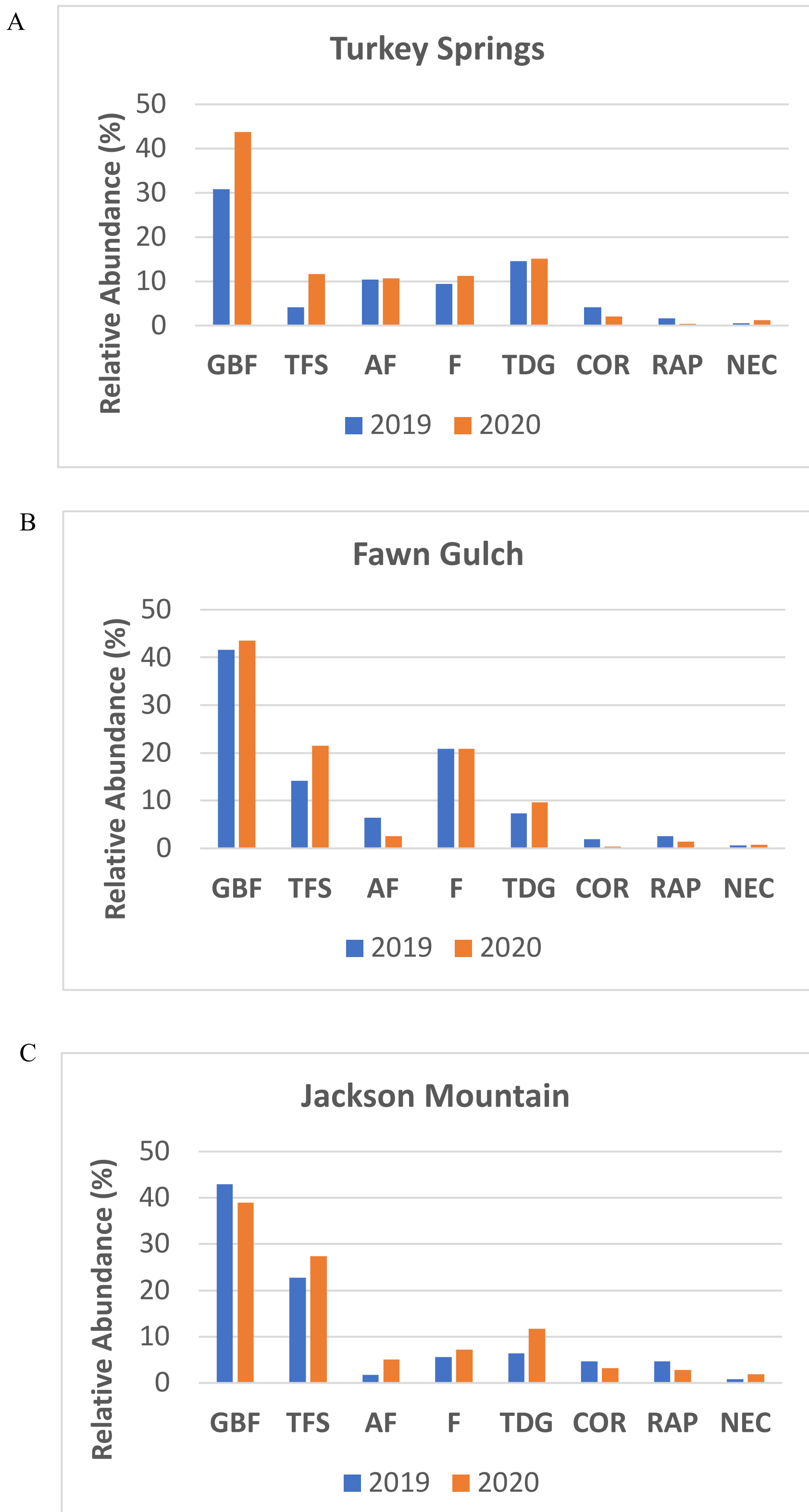

Figure 12. Relative abundances of bird species feeding guilds at Turkey Springs (A); Fawn Gulch (B); and Jackson Mountain (C) study sites. GBF = Ground Brush Foraging; TFS = Timber Foliage Searching; AF = Aerial Flycatcher; F = Flycatcher; TDG = Timber Drilling/Gleaning; COR = Corvids; RAP = Raptors; and NEC = Nectar Feeders.

Cavity Nesting Species							
	2019			2020			Conservation
Species	Sites	Freq	Rel Freq	Sites	Freq	Rel freq	Score
Species Recorded in both 2019 And 2020							
Primary Cavity Nesters							
Hairy Woodpecker	TS, FG, JM	9	1.4	TS, FG, JM	20	1.3	6
Northern Flicker	TS, FG, JM	33	5.1	TS, FG, JM	64	4.1	10
Williamson's Sapsucker	TS, JM	5	0.8	FG	1	0.1	12
Primary or Secondary Cavity Nesters							
Black-capped Chickadee	JM	1	0.2	TS, FG, JM	25	1.6	7
Pygmy Nuthatch	TS, FG, JM	48	7.4	TS, FG, JM	114	7.2	11
Secondary Cavity Nesters							
House Wren	JM	2	0.3	TS, FG, JM	45	2.9	5
Mountain Chickadee	FG, JM	3	0.5	TS, FG, JM	12	0.8	10
Tree Swallow	FG, JM	4	0.6	JM	1	0.1	8
Violet-green Swallow	TS, FG, JM	97	14.9	TS, FG, JM	89	5.6	9
Western Bluebird	TS, FG	9	1.4	TS, FG, JM	34	2.2	9
White-breasted Nuthatch	TS, FG, JM	31	4.7	TS, FG, JM	55	3.5	6
Species Recorded in 2019 Only							
Primary Cavity Nesters							
Downy Woodpecker	TS, FG	2	0.3	none	none	none	7
Primary or Secondary Cavity Nesters							
Lewis's Woodpecker	TS	1	0.2	none	none	none	15
Red-naped Sapsucker	FG	2	0.3	none	none	none	9
Secondary Cavity Nesters							
American Kestrel	FG	1	0.2	none	none	none	11
Mountain Bluebird	FG	1	0.2	none	none	none	12
Species Recorded in 2020 Only							
Primary or Secondary Cavity Nesters							
Red-breasted Nuthatch	none	none	none	TS, JM	2	0.1	6
Secondary Cavity Nesters							
European Starling	none	none	none	TS	1	0.1	5

Table 6. Summary of cavity nesting species identified in 2019 vs. 2020. Primary cavity nesters are those species that actively excavate new cavities in each breeding season; secondary cavity nesters occupy existing cavities left by primary excavators. (categorizations based on data obtained from www.allaboutbirds.org; and Coe, 2014) (Conservation Scores are from Tables 7 and 8)

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 5). 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), TDG species show a consistent decline across our study sites from TS > FG > JM (Table 5 and Fig. 12), a pattern that was particularly evident for the Pygmy Nuthatch in 2019, but the abundance of this species increased markedly in 2020. One reason for TDG 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 TDG species noted for the TS site in our study in 2019 may be sustained through the coming winter and into next year. This pattern, however, was not evident in our 2020 data, in which TDG species increased at all three sites compared to 2019 (Table 5; Fig. 12). This finding reflects, in part, the increased sample density in our study noted for 2020 compared to 2019. However, as noted earlier, the total numbers of birds in the TDG guild increased by factors exceeding the proportional increase in sample density.

Conservation Notes: 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 (Tables 7 and 8). 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 72 bird species documented over the course of this study, 28 species have shown population declines since the late 1960's, and 28 species have CC scores of 10 or greater (Tables 7 and 8). Five of the species we recorded over the two years of our study – Lewis's Woodpecker, Virginia's Warbler, Cassin's Finch, Band-tailed pigeon, and Grace's Warbler – 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 in 2019, and noted as an incidental in 2020. Similarly, Virginia's Warbler was documented only at the JM site in both years, and Cassin's Finch was one of the unique species at the FG site in 2019, but occurred at the TS site in 2020. The recurring sightings of Band-tailed Pigeons at the FG site was one of the most exciting observations of 2020. Finally, Grace's Warbler was noted as an incidental in 2019, but was sighted at both FG and JM in 2020 in reasonable numbers.

Of the remaining bird species with CC scores > 10, four were found at all three of our study sites in 2019 (Tables 7 and 8). 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 2). The Northern Rough-winged Swallow, another species with a CC score > 10, was notably abundant at the FG site. The Northern Rough-winged Swallow is the only one of these 4 species that was not observed in 2020. However, in 2020 we documented the presence of single individuals of Dusky Grouse and Northern Goshawk at FG; and Dusky Flycatcher and Black-chinned Hummingbird at JM, each of which has conservation scores of between 10 and 11 (Table 7).

One of the most exhilarating sightings in our study in 2019 was that of a nesting pair of Common Nighthawks at the TS site (Grover et. al., 2019). 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, 2019, 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. This species was documented at TS and JM in 2019, and again in 2020 Common Nighthawks were observed at the TS and JM sites (Table 2).

The Pine Siskin, another species in steep decline, was observed at the FG site in 2019 (Table 6). In 2020, Pine Siskins were observed in small numbers at TS. 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 (Table 1), 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 in 2019 and 2020. 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 6), 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 6), 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. Violet-green Swallow nests were present in several standing dead trees at both the TS and JM sites in 2020. These same "snags" also housed House Wrens at the same .

Table 7. Summary of conservation status of bird species recorded in this study in 2019 (from Grover et. al., 2019). Conservation status categories, concern scores, and estimates of population status are taken from Cornell Laboratory of Ornithology website – www.allaboutbirds.org. = common to all sites; = unique to one site; = 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	

Table 8. Summary of conservation status of bird species recorded in this study in 2020. 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; [peach box] = unique to one site; [empty 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**
Band-tailed Pigeon	*Patagioenas fasciata*		34		Watch	13	decline	63	2M	decline due to hunting and habitat destruction
Grace's Warbler	*Setophaga graciae*		11	4	Watch	13	declining	52	3M	decline due to loss of habitat
Dusky Flycatcher	*Empidonax oberholseri*			1	Low	11	stable		8.8M	
Dusky Grouse	*Dendragapus obscurus*		1		Low	11	stable		not given	
Northern Goshawk	Accipiter gentilis			1	Low	11	stable		400k	
Black-chinned Hummingbird	*Archilochus alexandri*		1		Low	10	increasing	na	5M	recovery due to habitat gardens
Brown Creeper	*Certhia americana*			1	Low	8	stable		9.3M	
Gray Catbird	*Dumetella carolinensis*			1	Low	8	stable		27M	
Great Horned Owl	*Bubo virginianus*		3		Low	8	decline/common	33	6M	
Song Sparrow	*Melospiza melodia*				Low	8	decline/common	30	130M	
Spotted Towhee	*Pipilo maculatus*				Low	8	stable		33M	
White-crowned Sparrow	Zonotrichia leucophrys				Low	8	decline	29	60M	
Cooper's Hawk	*Accipiter cooperii*			1	Low	7	stable		700k	
European Starling	*Sturnus vulgaris*	1			Low	7	decreasing		150M	
Great Blue Heron	*Ardea herodias*			1	Low	7	stable		83k	
Red-breasted Nuthatch	*Sitta canadensis*	2		3	Low	6	increasing/common		20M	
Collared Dove	*Streptopelia decaocto*	3		1	Low	5	increasing		8M	

time, underscoring the significance or preserving standing dead trees as critical nesting habitat for several bird species.

Scanning the conservation notes from SONAB (Cornell, 2019) regarding the species encountered in our study (Tables 6 and 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.

Recommendations for Future Work:

In response to the enthusiasm shared by participants in the 2019 portion of this study, we continued the project into 2020 with increased participation by first-year observers and the addition of several new volunteers. A third year of data would be helpful in understanding year-to-year variability in bird community composition in our region and would also improve our understanding of successional recovery from wildland fuel reduction treatments.

What we have learned from continuation of this study is that 15 or 16 visits to each loop would likely provide adequate data for our analysis. Continued engagement of participants in bird identification workshops, particularly identification by ear, would also prove valuable.

As noted in our 2019 report (Grover et. al., 2019), the need for more detailed data on plant community structure is essential for understanding the response of the bird community. 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 revealed a reduction in bird species richness, abundance and overall diversity on the TS site immediately following prescribed fire treatments in early June, 2019. Recovery of the shrub layer at the TS site was clearly evident, with subsequent changes in the bird community to render this site more like FG and JM in species composition and feeding guilds.

Comparing 2019 to 2020 datasets revealed that increased sampling frequency and involvement of more observers per site visitation (i.e., sampling density) in 2020 contributed to a substantial increase in the number of birds recorded, but only a marginal impact on increased number of species. Regardless, patterns in the increased number of birds within species at TS were interpreted to indicate recovery of that site from prescribed fire in 2019. Although the numbers of birds counted at FG increased from 2019 to 2020, there was not a substantial change in numbers of species observed. Increased sampling density at JM, however, yielded both an increase in bird numbers and a notable increase in the number of bird species documented for that site. We attribute that finding to improved birding skills by observers assigned to that site, particularly with regard to identification by ear.

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 at the end of the 2019 field season, and again in 2020, affirms that we have been very successful in accomplishing these objectives.

Finally, through the conduct of this project we anticipated that participants would benefit from 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 in both years of this study affirm that our study has been overwhelmingly 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 in coming years.

Works Cited:

Ager, Alan A., P. Palaiologou, C.R. Evers, M.A. Day, C. Ringo, and K. Short. 2019. Wildfire exposure to the wildland urban interface in the western US. *Applied Geography*, 111:102059

American Bird Conservancy. 2019. Accessed November 6, 2019. Retrieved from American Bird Conservancy: https://abcbirds.org/bird/common-nighthawk/

Baker, W.L. 2018. Historical Fire Regimes in Ponderosa Pine and Mixed-Conifer Landscapes of the San Juan Mountains, Colorado, USA, from Multiple Sources. *Fire*, 1, 23; doi:10.3390/fire1020023.

Bednarz, J.C., D. Ripper, and P.M. Radley. 2004. Emerging Concepts and Research Direction in the Study of Cavity-Nesting Birds: Keystone Ecological Processes. The Condor, 106:1-4

Blake, J. 1982. Influence of fire and logging on nonbreeding bird communities of ponderosa pine forests. *Journal of Wildlife Management*, 46:404-415.

Block, W. M., and L.M. Conner (eds.) 2016. *Effects of Prescribed Fire on Wildlife and Wildlife Habitat in Selected Ecosystems of North America.* The Wildlife Society, Technical Review 16-01.

Bloom, S. A. 1981. Similarity Indices in Community Studies: Potential Pitfalls. *Marine Ecology - Progress Series*, (5):125-128.

Bock, C. E., and J.F. Lynch. 1970. Breeding bird populations of burned and unburned conifer forest in the Sierra Nevada. *Condor*, 72:182-189.

Brawn, J.D., and R.P. Balda. 1988. The influence of silvicultural activity on ponderosa pine forest bird communities in the southwestern United States. *Bird Conservation*, 3:3-21.

Coe, F.C. 2014. Cavity-Nesting Birds and Small Woodlands. Woodland Fish and Wildlife, Oregon Forest Resources Institute.

Cornell. 2019. Cornell Laboratory of Ornithology. Accessed November 30, 2019. http://www.mountainstudies.org

Covert-Bratland, K. A., W.M. Block, and T.C. Theimer. 2006. Hairy Woodpecker Winter Ecology in Ponderosa Pine Forests Representing Different Ages Since Wildfire. *Journal of Wildlife Management*, 70(5):1379-1392.

Covington, W.W., and M.M. Moore. 1994. Post settlement changes in natural fire regimes and forest structur: ecological restoration of old-growth ponderosa pine forests. *J. Sustain. For.*, (2) 153-181.

Cox, G. W. 2002. *General Ecology Laboratory Manual, 8th edition.* McGraw-Hill, NY.

eBird. 2019. Accessed May 15, 2019. Retrieved from eBird Archuleta County, CO: https://ebird.org/subnational2/US-CO-007?yr=all&m=&rank=mrec

Dickson, Brett G., B.R. Noon, C.H. Flather, S. Jentsch, and W.M. Block. 2009. Quantifying the multi-scale response of avifauna to prescribed fire experiments in the southwest United States. *Ecological Applications*, 19(5):608-621

Farris, K.L., M.J. Huss, and S. Zack. The Role of Foraging Woodpeckers in the Decomposition of Ponderosa Pine Snags. The Condor, 106:50-59

Gillihan, S. W. 1997. *The Influence of White Fir Invasion and Road Presence on Ponderosa Pine Bird Communities in the San Juan National Forest.* Brighton, Colorado: Colorado Bird Observatory for the USFS Pagosa Ranger District.

Grover, H., J. Zirnhelt, and K. Bruno. 2019. The Effects of Prescribed Fire and Shrub-layer Mastication on Bird Communities in Ponderosa Pine Forests of the San Juan Mountains, CO. Report can be accessed at http://www.weminucheaudubon.org/bird-community-monitoring/

Harrington, M.G., and S.S. Sackett. 1990. Using fire as a management tool in southwestern ponderosa pine. *Proceedings of Effects of Fire Management on Southwestern Natural Resources* (pp. 122-133). Tucson, AZ: Gen Tech Rep RM-191, USDA, Forest Service, Rocky Mountain Forest Range and Experiment Station, Fort Collins, CO, USA.

Hurteau, S.T., T.D. Sisk, W.M. Block, and B.G. Dickson. 2008. Fuel-Reduction Treatment Effects on Avian Community Structure and Diversity. *Journal of Wildlife Management,* 72(5):1168-1174

Hurteau, S. T., T. Sisk, B. Dickson, and W. Block. 2010. Variability in Nest Density, Occupancy, and Home Range Size of Western Bluebirds after Forest Treatments. *Forest Science 56(1)*, 131-138.

Ibarra, J.T., M. Martin, K.L. Cockle, and K. Martin. 2017. Maintaining Ecosystem Resilience: Functional Responses of Tree Cavity nesters to Logging in Temperate Forests of the Americas. Sci Rep. 7:4467. (doi: 10.1038/s41598-017-04733-2). (PMID: 28667282)

Jentsch, S. R., R.W. Mannan, B.G. Dickson, and W.M. Block. 2008. Associations Among Breeding Birds and Gambel Oak in Southwestern Ponderosa Pine Forests. *Journal of Wildlife Management*, 72(4):994-1000.

Kalies, E. L., C. L. Chambers, and W.W. Covington. 2010. Wildlife responses to thinning and burning treatments in southwestern conifer forests: a meta-analysis. *Forest Ecology and Management.*, 259:333-342.

Kalies, E. L., and S.S. Rosenstock. 2013. Stand Structure and Breeding Birds: Implications for Restoring Ponderosa Pine Forests. *The Journal of Wildlife Management.*, 77(6):1157-1165.

Korb, J.E., P.Z. Fule, and R. Wu. 2013. Variability of warm/dry mixed conifer forests in southwestern Colorado. *Forest Ecology and Management*, 304:182-191.

Lowe, P. O., P.F. Ffolliot, J.H. Dieterich, and D.R. Patton. 1978. *Gen Tech Rep RM-52; Determining Potential Wildlife Benefits from Wildfire in Arizona Ponderosa Pine Forests.* Rocky Mountain Forest and Range Experiment Station.

Martin, T.E., and P. Li. 1992. Life History Traits of Open vs. Cavity-Nesting Birds. Ecology, 73(2):579-592

McWethy, D.B., T. Schoennagel, P.E. Higuera, M. Krawchuk, B.J. Harvey, E.C. Metcalf, C. Schultz, C. Miller, A.L. Metcalf, B. Buma, A. Virapongse, J.C. Kulig, R.C. Stedman, Z. Ratajczak, C.R. Nelson, and C. Kolden. 2019. Rethinking resilience to wildfire. *Nature Sustainability*, https://doi.org/10.1038/s41893-019-0353-8 .

Mitchell, K. 2015. Quantitative Analysis by the Point-Centered Quarter Method. http://people.hws.edu/mitchell/PCQM.pdf

MSI. Unpublished data. Mountain Studies Institute. http://www.mountainstudies.org

Ornithology, C. L. 2019. Accessed November 6, 2019. Retrieved from All About Birds - Common Nighthawk: https://www.allaboutbirds.org/guide/Common_Nighthawk/overview

Pope, T. L., W.M. Block, and P. Beier. 2009. Prescribed Fire Effects on Wintering, Bark-Foraging Birds in Northern Arizona. *Journal of Wildlife Management*, 73(5):695-700.

Pope, T. L., and W.M. Block. 2010. Effects of Prescribed Fire on Winter Assemblages of Birds in Ponderosa Pine Forests of Northern Arizona. *The Southwestern Naturalist*, 55(1):22-28.

Romme, W.H., M.R. Crist, M.L. Floyd, and H. Grissino-Mayer. 2009. Historical Range of Variability and Current Landscape Condition Analysis: South Central Highlands Section, Southwestern Colorado and Northwestern New Mexico. *ResearchGate*, https://www.researchgate.net/publication/264884775 .

Technosylva Inc., La Jolla, CA. December, 2018. *2017 Colorado Wildfire Risk Assessment Update.* Colorado State Forest Service.

USDA. 1974. *Soil Survey of Piedra Area, Colorado.* USDA.

van Boer, A. N. 2018. *Monitoring the Effects of Restoration on Riparian Birds: 2017 Field Season.* Brighton, Colorado: Technical Report. Bird Conservancy of the Rockies.