Third 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

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Abstract:
The use of prescribed fire and mechanical thinning to reduce wildland fuels is a common practice 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. 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, 2020, and 2021 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). As documented in our first-year report, tree density at the Fawn Gulch (FG) site (85 trees/ha) was less than at either the Turkey Springs (TS) (128 trees/ha) or Jackson Mountain (JM) (132 trees/ha) sites. Gambel Oak dominated the shrub layer at all three sites, which was largely absent at the TS site after prescribed fire in 2019, but recovered by 2020; widely dispersed at FG; and notably most dense at JM. Data on bird species presence and individual bird counts by species were collected at 15 monitoring points at each site a minimum of ten times across a seven-week period beginning in late May of 2019, 2020 and 2021. Looking across the three years of the study, 82 bird species have been documented, with 37 species, common to all years, representing over 90% of sightings. Twelve species were observed at all three sites in all three years of the study, accounting for about 67% of all birds counted. There were 9 species unique to the 2019 season, 10 species found only in our 2020 sample season, and 10 species found only in 2021. The TS site, which had the fewest species and birds counted in 2019, showed noticeable recovery to 37 species and 688 individual birds in 2020, and 35 species accounting for 609 birds in 2021. The FG site, which had the greatest number of species of the three sites in 2019 (34 species), was surpassed in number of species by the JM site in 2020 (45 species and), but had more birds counted in 2020 compared to JM (856 vs. 683, respectively). In 2021, JM had slightly more bird species and birds counted compared to the other two sites. Summing across years, FG had a greater number of species observed (63 vs. 58 at JM and 49 at TS), and a greater number of birds counted (1936 vs. 1613 at JM and 1482 at TS). Grouping bird species into feeding guilds, and the application to our data of simple measures of species diversity, species evenness, and community similarity provide further insights that are discussed. 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 short-term negative impacts on bird communities, with relatively quick recovery within a year or so, followed by a net positive impact on bird communities over the long-term and at a regional/landscape scale.

Acknowledgments:
The data and information generated by this study is the work of many dedicated volunteers who collectively contributed more than 600 hours to the completion of this project in each of the three years of the study. Their names (in alphabetical order) are: (Note: a = 2019 participant; b = 2020 participant; c = 2021 participant)

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Bob Endres[a, b, c]
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Third 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 might be affected by mastication and/or prescribed fire treatments designed to reduce wildland fuel loads. The report for the first and second years of the study (Grover et. al., 2019; Grover et. al., 2020) can be downloaded from the Weminuche Audubon Society website at http://www.weminucheaudubon.org/bird-community-monitoring/. First and second year findings are also summarized in YouTube videos posted at https://www.youtube.com/watch?v=mfBiFN0gR6A and https://youtu.be/zI1QNo7qZBU, respectively. The results from the 2021 sample season for this project are the primary focus of this report, along with comparisons to earlier years of the study.

There is a vast literature detailing the consequences of livestock grazing and forest management practices on the 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), moderating the buildup of wildland fuel loads is receiving 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 (i.e., mowing). 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) by modifying forest composition and structure, thereby affecting habitat quality and food resources for a wide range of species.

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 initiated in 2019 (Grover et. al., 2019) that has continued with data collection in 2020 (Grover et. al. 2020), and 2021.

As a citizen science project, this study incorporates several objectives complementary to the scientific question that is being investigated. For example, volunteers participating in this study have become better informed regarding:

- 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 include 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,
- 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) – are 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 16 km (~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 for many decades 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, and 2020)
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 (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 and third seasons of this study, special precautions were taken to adhere to established CDC guidelines with regard to COVID-19 transmission. However, the majority of volunteers in 2021 were vaccinated, which minimized risk of infection. Regardless, volunteers 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 sampling protocols established in 2019 were followed in 2020 and 2021 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 the third week of May, and ending on or about the second week of July 11.
- 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 to gain from, or contribute to the birding experience of co-participants.
- Data collection consisted of visiting each point on each assigned 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.

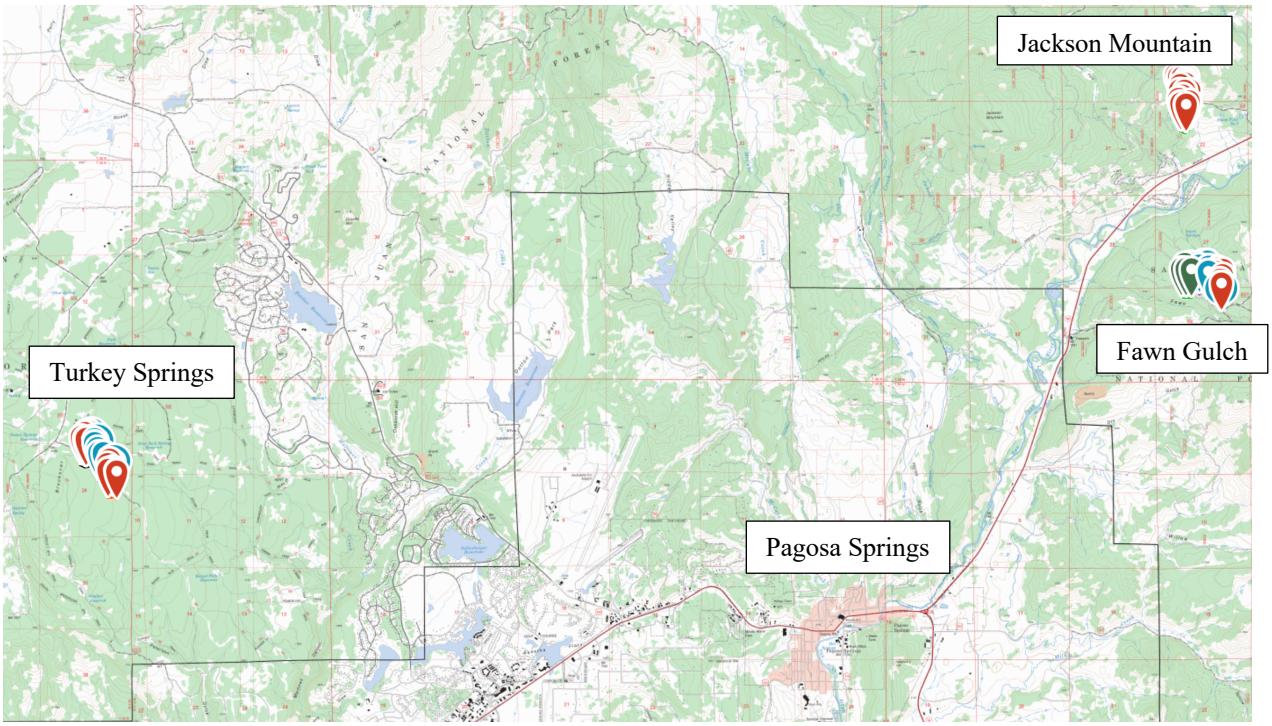

Figure 1. Map showing locations of Turkey Springs, Fawn Gulch, and Jackson Mountain study areas.

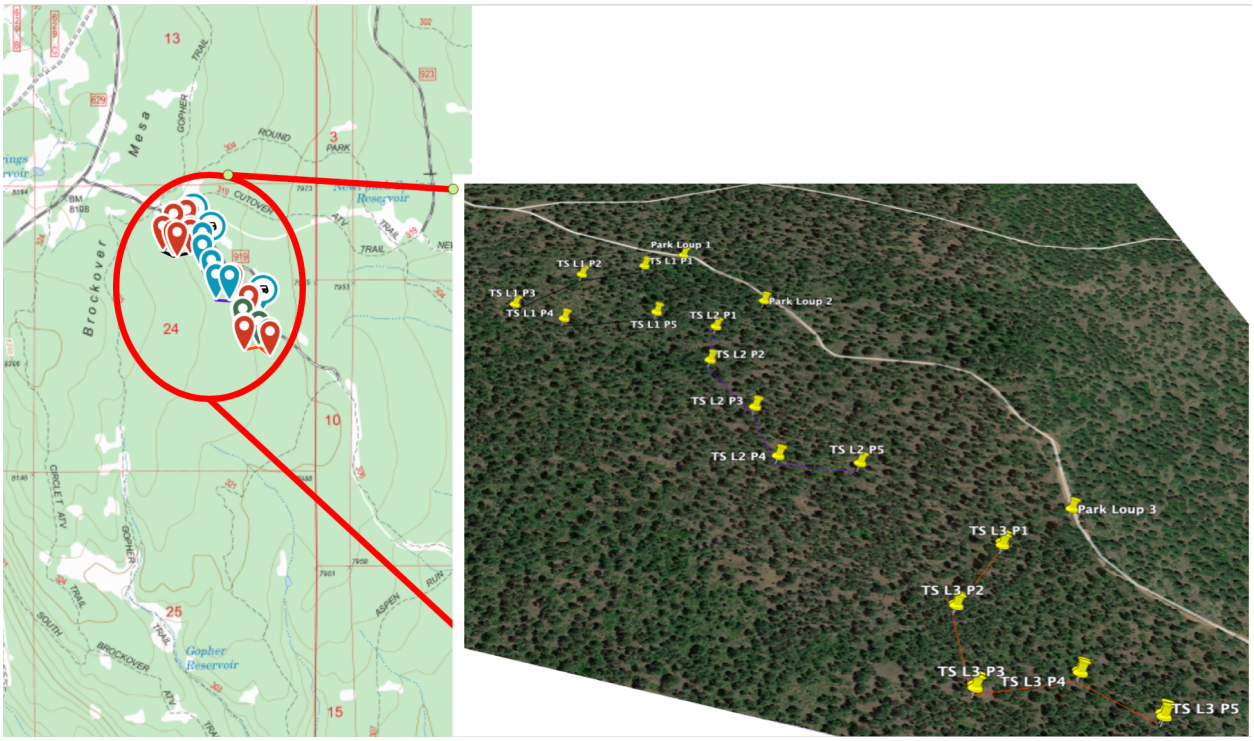

Figure 2. Map showing locations of monitoring points within Turkey Springs study area. TS = Turkey Springs; L # = Loop number; P # = Monitoring point number.

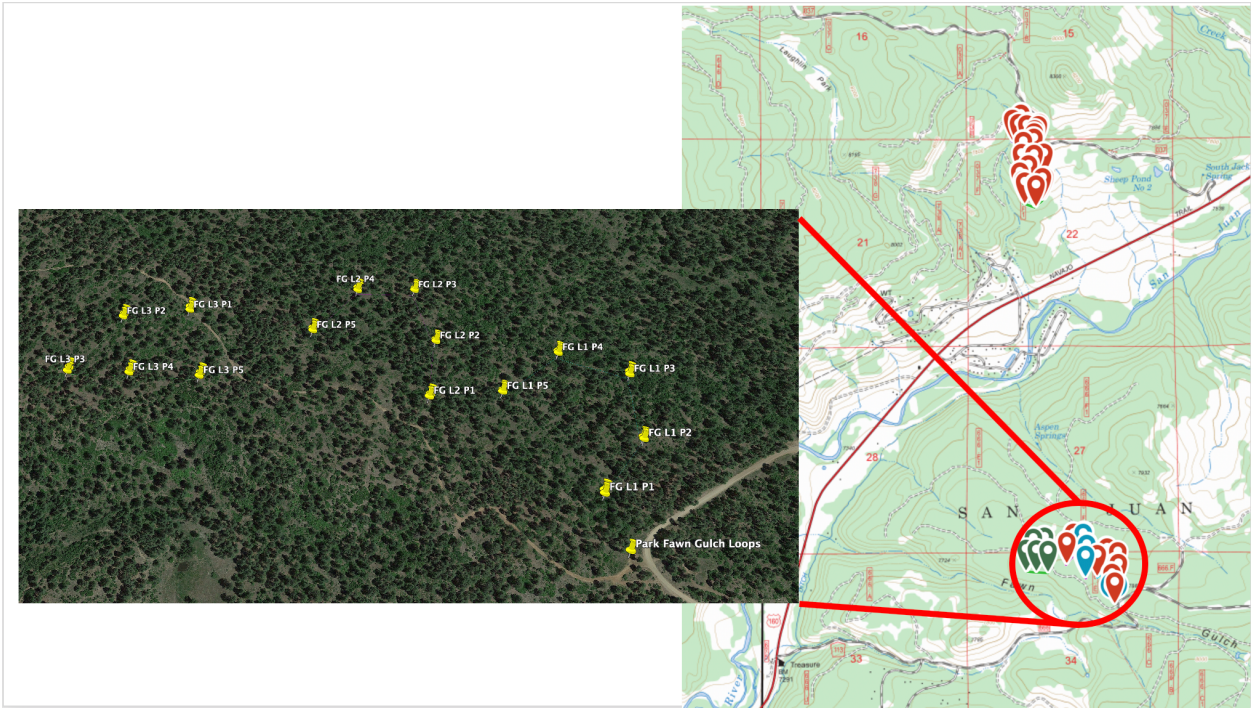

Figure 3. Map showing locations of monitoring points within Fawn Gulch study area. FG = Fawn Gulch; L # = Loop number; P # = Monitoring point number.

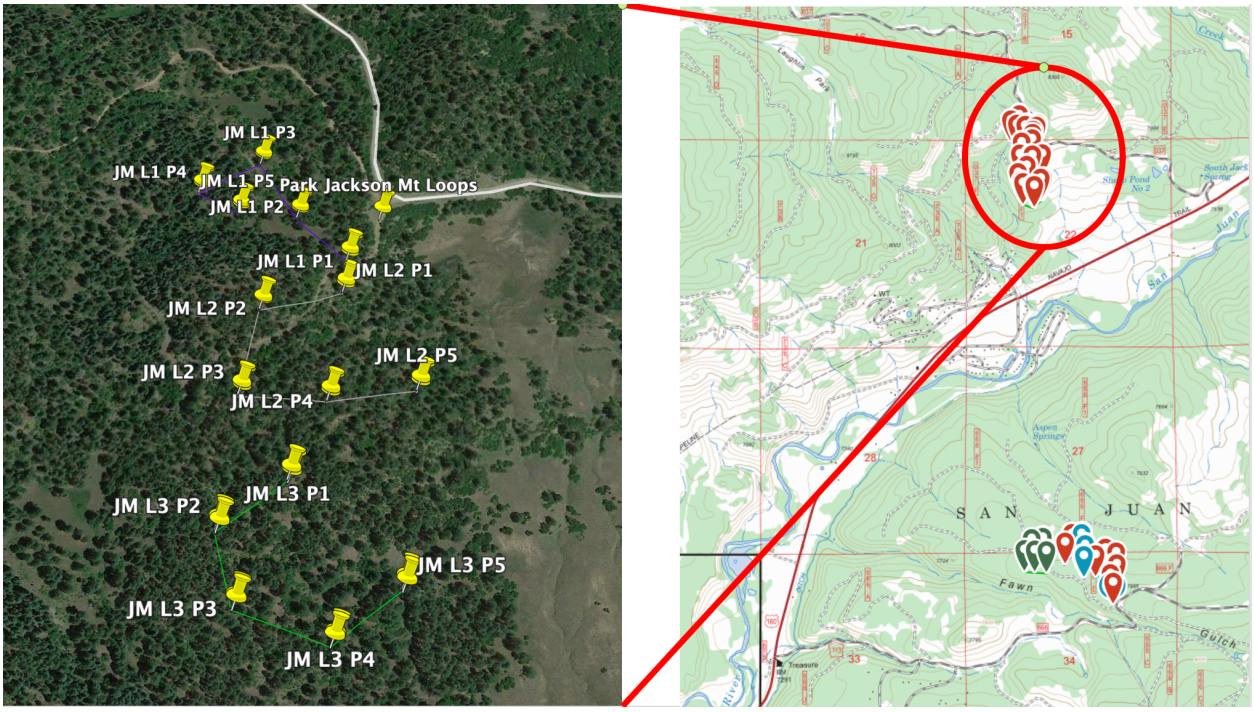

Figure 4. Map showing locations of monitoring points within Jackson Mountain study area. JM = Jackson Mountain; L # = Loop number; P # = Monitoring point number.

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 2021 to assign 3 teams to each site, with one additional 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 or beginner 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/beginner birders as much as possible.

Over the course of the study, there have been 42 different volunteer observers involved, with about 25 observers actively participating in the study each year (see Acknowledgements). Table 2 summarizes the number of loop visits per site by year. In the total dataset for 2019, FG received more site visits than TS and JM. To make the data comparable across sites in that year, 4 FG site visits were selectively removed to re-balance the project dataset. The details of that process are explained in our first-year project report (Grover et. al. 2019). Greater care was exercised in 2020 and 2021 to coordinate site visits to yield a dataset that was balanced across sites in terms of number of loop visits. In the process of analyzing our 2020 dataset, we determined that 10 visits to each loop was the most efficient strategy for our study – i.e., a greater number of loop visits did not yield additional information critical to our analysis.

Table 2. Summary of number of loops visited per site and total number of volunteer observers visiting each site by year. (see also Grover et. al. 2019 and 2020)

Site	Turkey Springs		Fawn Gulch*		Jackson Mountain	
	Loop Visits	**Observers**	**Loop Visits**	**Observers**	**Loop Visits**	**Observers**
2019	22	44	19	42	18	42
2020	34	108	35	114	36	100
2021	31	105	31	84	30	98

* 2019 data shown for FG are re-balanced. (See Grover et. al. 2019 for detailed explanation)

Multiplying the number of team members per visit times the number of visits and loops per visit reveals for 2020, 108 observer-visits at TS; 114 observer-visits at FG; and 100 observer-visits at JM, and 105 vs. 84, vs. 98 observer-visits, respectively, in 2021. With the benefit of the experience from the 2019 and 2020 field seasons, the bird identification skills of many of our observers were also markedly improved. It is worth noting that across all three years, between 50% and 75% of bird identifications were by sight; the remainder being by song. This is in contrast to other similar studies in which identification by song is more common than by sight.

We conservatively estimate that each observer-visit entails a minimum of 2.5 hours of volunteer time. Add to this estimated time involved in orientation sessions; site preparation; tree sampling visits (2019 only); and data analysis and report preparation yields estimates of over 500 volunteer hours in 2019; over 900 hours in 2020; and over 800 hours in 2021.

Results and Discussion:

Table 3 summarizes the bird species documented for 2021 that were common to all three sites; unique to each of the three sites; or documented at two of the three sites. Of the 60 total species recorded for 2021, 22 were found at all three sites this year. Comparing sites in 2021, 35 total species were recorded at TS, with 6 species unique to that site; 40 total species were recorded at FG, with 7 species unique to that site; and 43 total species were recorded at JM, with 11 species unique to that site.

In 2021, the number of birds counted across all three sites, totaling 1855, were evenly distributed across the three sites, with 33% at TS; 32% at FG; and 35% at JM (Tables 3 and 4). Corresponding data tables from our first- and second-year reports are included as Appendix A to this report (see also Grover et al., 2019, and 2020).

Definitions:
Common – bird species that have been reported at more than one study site or in more than one year, including those 37 species observed in all three years of the study, or those species ranked in the top 15 species by relative abundance.
Uncommon or rare – bird species observed in small numbers, typically fewer than 10, and observed at only one or two sites or in only one or two years of the study.
Unique – bird species observed at only one site or in only one year; typically, in small numbers (fewer than 5 birds).

Table 3. Summary of the 60 different bird species observed across the three study areas in 2021. 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 any one of the three sites, sorted by abundance within the respective sites; and those found at two of the three sites, unsorted

2021	Turkey Springs					Fawn Gulch					Jackson Mountain				
Number of Species	35				Number of Species	40				Number of Species	43				
# Point Records	438	# Birds	609		# Point Records	422	# Birds	594		# Point Records	467	# Birds	652		
	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)															
Pygmy Nuthatch	48	11.0%	92	15.1%	American Robin	81	19.2%	140	23.6%	Pygmy Nuthatch	50	10.7%	90	13.8%
Violet-green Swallow	42	9.6%	77	12.6%	Western Wood-Pewee	67	15.9%	94	15.8%	American Robin	61	13.1%	85	13.0%
American Robin	49	11.2%	59	9.7%	Green-tailed Towhee	42	10.0%	53	8.9%	Western Wood-Pewee	44	9.4%	59	9.0%
Western Wood-Pewee	43	9.8%	55	9.0%	Western Tanager	24	5.7%	37	6.2%	Northern Flicker	40	8.6%	49	7.5%
Yellow-rumped Warbler	37	8.4%	45	7.4%	Stellar's Jay	24	5.7%	33	5.6%	Western Tanager	35	7.5%	47	7.2%
Chipping Sparrow	24	5.5%	35	5.7%	Pygmy Nuthatch	19	4.5%	27	4.5%	Violet-green Swallow	24	5.1%	45	6.9%
White-breasted Nuthatch	30	6.8%	34	5.6%	White-breasted Nuthatch	19	4.5%	20	3.4%	Mourning Dove	27	5.8%	39	6.0%
Northern Flicker	20	4.6%	27	4.4%	Northern Flicker	19	4.5%	19	3.2%	Stellar's Jay	20	4.3%	30	4.6%
Dark-eyed Junco	13	3.0%	17	2.8%	Warbling Vireo	11	2.6%	19	3.2%	Warbling Vireo	15	3.2%	27	4.1%
Western Tanager	13	3.0%	17	2.8%	Yellow-rumped Warbler	14	3.3%	19	3.2%	Yellow-rumped Warbler	16	3.4%	18	2.8%
Plumbeous Vireo	15	3.4%	15	2.5%	Chipping Sparrow	13	3.1%	15	2.5%	Hairy Woodpecker	13	2.8%	15	2.3%
House Wren	5	1.1%	7	1.1%	Violet-green Swallow	8	1.9%	14	2.4%	White-breasted Nuthatch	12	2.6%	14	2.1%
Townsend's Solitaire	6	1.4%	7	1.1%	Mourning Dove	10	2.4%	11	1.9%	Green-tailed Towhee	10	2.1%	11	1.7%
Hairy Woodpecker	5	1.1%	6	1.0%	Hairy Woodpecker	5	1.2%	7	1.2%	Plumbeous Vireo	8	1.7%	10	1.5%
American Crow	4	0.9%	5	0.8%	Plumbeous Vireo	4	0.9%	5	0.8%	Common Raven	7	1.5%	8	1.2%
Common Raven	4	0.9%	4	0.7%	American Crow	3	0.7%	3	0.5%	House Wren	6	1.3%	7	1.1%
Green-tailed Towhee	4	0.9%	4	0.7%	Dark-eyed Junco	2	0.5%	3	0.5%	Chipping Sparrow	5	1.1%	6	0.9%
Mourning Dove	3	0.7%	3	0.5%	Mountain Chickadee	2	0.5%	3	0.5%	Turkey Vulture	5	1.1%	6	0.9%
Warbling Vireo	3	0.7%	3	0.5%	House Wren	2	0.5%	2	0.3%	Dark-eyed Junco	2	0.4%	5	0.8%
Mountain Chickadee	1	0.2%	1	0.2%	Townsend's Solitaire	2	0.5%	2	0.3%	American Crow	3	0.6%	3	0.5%
Stellar's Jay	1	0.2%	1	0.2%	Turkey Vulture	2	0.5%	2	0.3%	Mountain Chickadee	1	0.2%	2	0.3%
Turkey Vulture	1	0.2%	1	0.2%	Common Raven	1	0.2%	1	0.2%	Townsend's Solitaire	2	0.4%	2	0.3%
Species Unique to Respective Sites (Sorted by Abundance)															
Brown Creeper	1	0.2%	1	0.2%										
Great-Horned Owl	1	0.2%	1	0.2%										
Mallard	1	0.2%	1	0.2%										
Mountain Bluebird	1	0.2%	1	0.2%										
Sharp-shinned Hawk	1	0.2%	1	0.2%										
White-crowned Sparrow	1	0.2%	1	0.2%										
					Three-toed Woodpecker	2	0.5%	3	0.5%					
					Ash-throated Flycatcher	1	0.2%	1	0.2%					
					Cassin's Vireo	1	0.2%	1	0.2%					
					Olive-sided Flycatcher	1	0.2%	1	0.2%					
					Red-tailed Hawk	1	0.2%	1	0.2%					
					Red-winged Blackbird	1	0.2%	1	0.2%					
					Tree Swallow	1	0.2%	1	0.2%					
										Brown-headed Cowbird	2	0.4%	4	0.6%
										Lewis's Woodpecker	3	0.6%	3	0.5%
										Bullock's Oriole	2	0.4%	2	0.3%
										Bald Eagle	1	0.2%	1	0.2%
										Band-tailed Pigeon	1	0.2%	1	0.2%
										Collared Dove	1	0.2%	1	0.2%
										Downy Woodpecker	1	0.2%	1	0.2%
										Hermit Thrush	1	0.2%	1	0.2%
										Peregrine Falcon	1	0.2%	1	0.2%
										Western Meadowlark	1	0.2%	1	0.2%
										Williamson's Sapsucker	1	0.2%	1	0.2%
Species Found At Two Respective Sites (Unsorted)															
Cassin's Finch	2	0.5%	3	0.5%	Cassin's Finch	2	0.5%	2	0.3%					
Common Nighthawk	5	1.1%	7	1.1%	Common Nighthawk	8	1.9%	16	2.7%					
Spotted Towhee	5	1.1%	5	0.8%	Spotted Towhee	11	2.6%	13	2.2%					
Western Bluebird	34	7.8%	53	8.7%	Western Bluebird	6	1.4%	8	1.3%					
					Black-headed Grosbeak	4	0.9%	7	1.2%	Black-headed Grosbeak	10	2.1%	10	1.5%
					Cordilleran Flycatcher	2	0.5%	2	0.3%	Cordilleran Flycatcher	12	2.6%	18	2.8%
					Great Blue Heron	1	0.2%	1	0.2%	Great Blue Heron	1	0.2%	1	0.2%
					Orange-crowned Warbler	2	0.5%	2	0.3%	Orange-crowned Warbler	8	1.7%	9	1.4%
					Say's Phoebe	2	0.5%	2	0.3%	Say's Phoebe	2	0.4%	2	0.3%
					Turkey	1	0.2%	2	0.3%	Turkey	1	0.2%	1	0.2%
					Virginia's Warbler	1	0.2%	1	0.2%	Virginia's Warbler	4	0.9%	5	0.8%
Black-capped Chickadee	3	0.7%	3	0.5%						Black-capped Chickadee	3	0.6%	5	0.8%
Broad-tailed Hummingbird	2	0.5%	2	0.3%						Broad-tailed Hummingbird	3	0.6%	3	0.5%
Grace's Warbler	10	2.3%	15	2.5%						Grace's Warbler	2	0.4%	3	0.5%

The cumulative relative abundance for the 22 species common to all three sites totaled 87.4% of all sightings (Table 3; calculations not shown). At TS, the common bird species accounted for 84.6% of the birds documented at that site, with slightly greater cumulative relative abundances of 89.1% at FG, and 88.7% at JM.

Each of the species unique to a particular site were observed in small numbers (i.e., 1, 2, or 3 individuals), with cumulative relative abundances for unique species ranging from 9% at JM, to 5% at FG, and 3% at TS. For those species found at any two sites, the cumulative relative abundances were between 1.7% and 5.8%. This indicates that species common to all three sites represented the majority of bird sightings recorded, and that those common bird species were more-or-less evenly distributed across all three sites.

As shown in Table 4, 82 different species of birds have been recorded across the three years of this study, with a total of 5031 birds counted. The number of species unique to a site varied from 4 at TS in 2019, to 11 at FG in 2019

and JM in 2020 and 2021. These numbers are also summarized in detail in Table 3, and Appendix A. Note that the Hermit Thrush, a species unique to JM, was the only species observed at a single site across all three years of the study, as shown in Table 4 in the "All Years" column.

The number of species common to all sites within years is also shown in Table 4, ranging from 15 in 2019, to 26 in 2020. Twelve species were seen at all three sites in all three years (see also Table 6 below).

Table 4. Summary of total number of bird species and birds counted across years at all three sites. The heading "All Years" represents summations across all years of the study. Unique bird species refers to species observed only at a respective site in a given year or across multiple years. (see also Grover et al. 2019, and 2020)

Year	2019	2020	2021	All Years
Total # Different Species	54	58	60	82
Total # Birds Counted	949	2227	1855	5031
# Unique Bird Species by Site:				
Turkey Springs	4	4	6	0
Fawn Gulch	11	7	7	0
Jackson Mountain	8	11	11	1
Species Common to All Sites	15	26	22	12

Figure 5 further illustrates how the numbers of bird species identified per site differed across years. In particular, the number of bird species recorded for TS increased from 26 in 2019, to 37 and 35 species in 2020 and 2021, respectively. This likely reflects the response of the bird community to recovery of the understory following the prescribed fire treatment that was implemented on this site concurrent with the initiation of the study in 2019. At FG, the number of bird species ranged from 33 in 2019 to 40 species in 2021. However, referring back to the un-balanced data provided in our first-year report (Grover et. al. 2019) reveals that 39 species were identified at FG in 2019. This would suggest that, with increased sample density, the number of bird species at FG has been fairly uniform across years.

There was a notable increase in numbers of bird species observed at JM, from 33 in 2019, to 45, and 43 species in 2020 and 2021, respectively (Fig. 5). As noted previously, JM differs substantially from the other two sites in terms of shrub-layer height and density. This makes bird identification more challenging in that identification by song becomes more important as shrub-layer foliage density impairs sight identification. It is likely that, over the course of this study, the observers visiting JM on a regular basis improved their skills at identification by song, which, in addition to year-to-year variability, could account for the trend observed in numbers of species documented at JM. Another contributing factor to greater number of birds and bird species observed at JM in 2020 and 2021 is the continued thinning and logging activity taking place in the areas surrounding our study sites, which could make our study site a refuge area for some birds.

The numbers of birds counted at each site in each year of the study is summarized in Table 4, and illustrated by site in Figure 6. The lower number of birds counted in 2019 likely reflects fewer loop visits in 2019 compared to 2020 and 2021 (see Table 5). The inexperience of volunteers with data collection protocols in the first year of the study may have been a contributing factor as well. Notably, the number of monitoring points at which no birds were sighted (Table 5) is much higher in 2019 compared to the other years of the study across all three sites.

Table 5. Summary of total points monitored at each site (# loop visits x 5 points/loop), along with number points with no birds observed in each year. Note that percentages are rounded to the nearest whole number.

	Points Monitored			Points with no Birds		
Site	**2019**	**2020**	**2021**	**2019**	**2020**	**2021**
Turkey Springs	110	170	155	18 (16%)	10 (6%)	13 (8%)
Fawn Gulch	95	175	155	14 (15%)	3 (2%)	4 (3%)
Jackson Mountain	90	180	150	15 (17%)	12 (2%)	4 (3%)

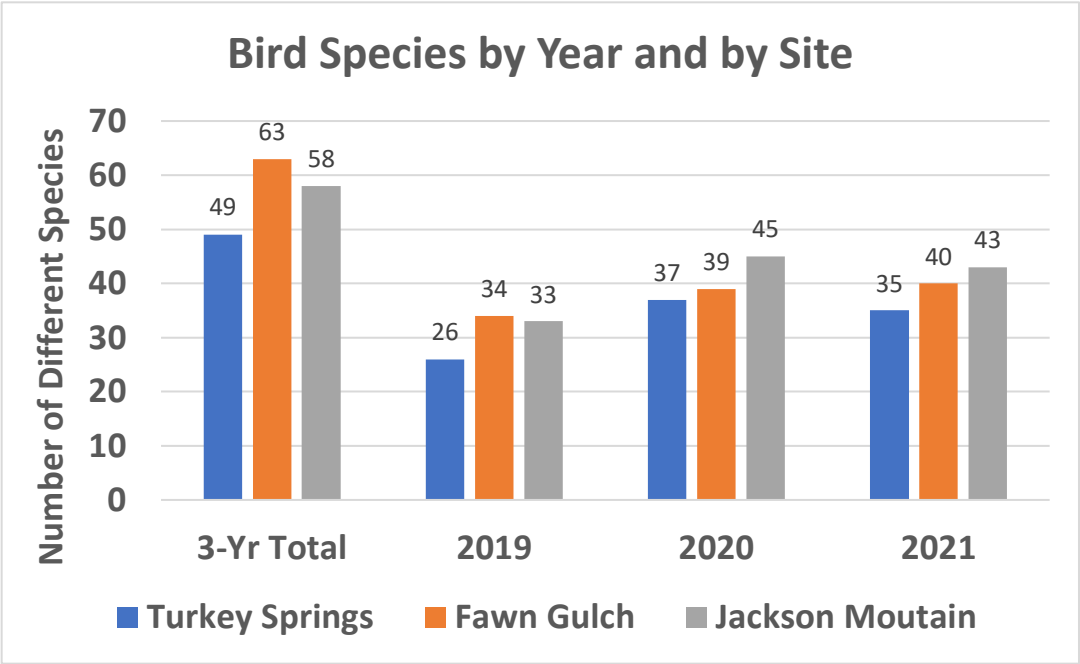

Figure 5. Summary of number of bird species observed by site and by year.

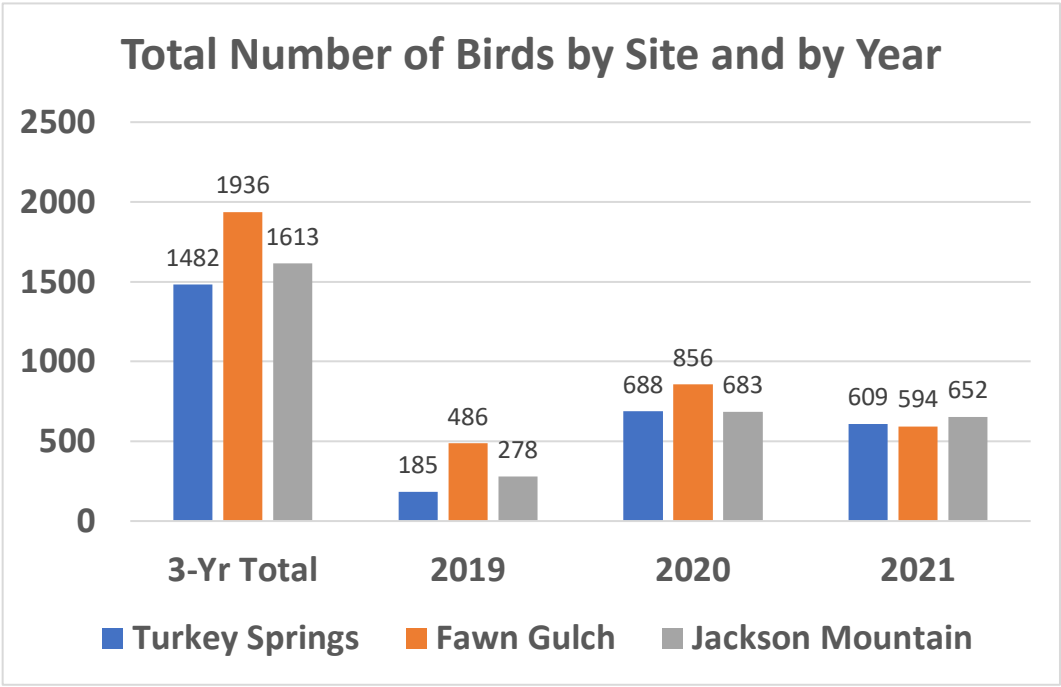

Figure 6. Summary of number of birds counted at each site by year.

The impacts of the 2019 prescribed fire on the TS bird community likely accounts for the lower number of bird species and lower number of birds observed there compared to other sites as well (Table 4). Bird counts at TS increased substantially in 2020 and 2021, corresponding to recovery of the understory shrub-layer (Fig. 6), but the number of points lacking bird sightings remains high at TS relative to the other sites across all years (Table 5),

suggesting that habitat quality (e.g., shrub layer density) remains less favorable for the bird community compared to the other sites.

At FG, there were substantially more birds counted in 2020 than in 2019 (a difference of 370 birds), or 2021 (a difference of 262 birds) (Fig. 6). Sample density may account for some proportion of this increase as the number of loops and points visited in 2020 (see Table 2 and Table 5) was greater at FG than in other years or at other sites, and the number of observer-visits (114; Table 2) was also greatest at FG in 2020 compared to the other sites.

Table 6 summarizes the distribution of the number of common or unique bird species observed at each site within and across years. For example, of the 82 total bird species recorded over the first three years of this study, 49 were recorded at TS; 63 at FG; and 58 at JM (see also Fig. 5). At TS and FG, 18 species were observed in all three years of the study (i.e., common), with 26 species common to all three years at JM. At TS and JM, the species common to all three years accounted for 85% and 86% of the birds counted at those sites, respectively. FG stands out as having 76% of the birds observed accounted for by species common to all three years, and a much higher proportion of birds unique to each year of the study (~ 9% at FG) compared to TS (~5%) and JM (~3%).

Table 6. Summary of bird species numbers and relative abundances grouped across or within years by site.

	Turkey Springs		Fawn Gulch		Jackson Mountain	
	# Species	Cum Rel Abund (%)	# Species	Cum Rel Abund (%)	# Species	Cum Rel Abund (%)
TOTAL Species	49		63		58	
All Years	18	85.3	18	76.3	26	86.1
2019+2020	2	0.3	2	0.8	3	2.4
2020+2021	11	10.5	8	12.3	7	7.9
2019+2021	0	0	4	1.4	1	0.5
2019	4	2.2	10	2.7	3	0.9
2020	4	1.1	11	4.9	9	1.3
2021	6	1.4	10	1.6	9	0.9

Tables 7, 8, 9, and Figure 7 contain summaries of the species-specific data across years for the TS, FG, and JM sites, respectively. As shown in the tables and in Figure 7, with one exception, the cumulative relative abundance of bird species shared across all years ranged from about 80% to a high of 95% (TS in 2019). The noted exception is a low of 69% reported for FG in 2020 (Table 8 and Fig. 7). The abundance of several species account for this disparity – sightings of House Wrens, Mourning Doves, Plumbeous Vireos, and Warbling Vireos, which were also reported at FG in 2021; and Band-tailed Pigeons, Black-capped Chickadees, and Grace's Warblers, which were reported at FG only in 2020, were all recorded in relatively high numbers in 2020 (Table 8 and Fig. 7). Although some other species were observed in lesser numbers at FG in 2020 compared to other years (e.g., Green-tailed towhee; Stellar's Jay; Northern Flicker), the number of species observed in greater numbers in 2020, and their abundances, exceeded those for species whose numbers were smaller across years. These results, coupled with the fact that FG had the highest number of different species observed across all three years (63 vs. 49 at TS, and 58 at JM; Table 6), and slightly higher numbers of bird species recorded in individual years compared to the other two sites (10 or more at FG vs. 9 or fewer at TS and JM; Table 6), suggests that a significant component of the bird community at FG varies more from year-to-year than has been observed for the other two sites.

Table 10 contains a listing of the 37 bird species observed in all three years. Within each year, the birds listed in Table 10 accounted for 92.6%; 94.7%; and 96.5% of birds counted in 2019, 2020, and 2021, respectively. Summing across years, there were a total of 5031 birds counted by observers in this study, with 4779 birds represented by the 37 common species listed in Table 10. Notably, the birds counted in the 37 species observed in all three years constitute 95% of all birds counted.

Of the 37 bird species common to all three years, 12 species were seen at all three sites in all three years (shaded rows in Table 10). Not surprisingly, 8 of those species were the top 8 ranked species by relative abundance.

Summing relative abundances of these 12 species reveals that about 67% of the birds counted were among those species found at all three sites in all three years of the study.

Table 7. Summary of bird species observed at Turkey Springs site across the three years of this study.

TURKEY SPRINGS											
2019			2020			2021			Three Year TOTALS	
Total Birds Counted	185		Total Birds Counted	688		Total Birds Counted	609		1482	
	Abund	Rel Abund		Abund	Rel Abund		Abund	Rel Abund	ABUND	REL ABUND
American Crow	10	5.41	American Crow	6	0.87	American Crow	5	0.82	21	1.42
American Robin	43	23.24	American Robin	77	11.19	American Robin	59	9.69	179	12.08
Broad Tailed Hummingbird	1	0.54	Broad-tailed Hummingbird	6	0.87	Broad-tailed Hummingbird	2	0.33	9	0.61
Chipping Sparrow	6	3.24	Chipping Sparrow	23	3.34	Chipping Sparrow	35	5.75	64	4.32
Common Nighthawk	6	3.24	Common Nighthawk	3	0.44	Common Nighthawk	7	1.15	16	1.08
Hairy Woodpecker	2	1.08	Hairy Woodpecker	10	1.45	Hairy Woodpecker	6	0.99	18	1.21
Mourning Dove	1	0.54	Mourning Dove	36	5.23	Mourning Dove	3	0.49	40	2.70
Northern Flicker	16	8.65	Northern Flicker	14	2.03	Northern Flicker	27	4.43	57	3.85
Plumbeous Vireo	2	1.08	Plumbeous Vireo	2	0.29	Plumbeous Vireo	15	2.46	19	1.28
Pygmy Nuthatch	17	9.19	Pygmy Nuthatch	81	11.77	Pygmy Nuthatch	92	15.11	190	12.82
Steller's Jay	1	0.54	Steller's Jay	7	1.02	Stellar's Jay	1	0.16	9	0.61
Turkey Vulture	1	0.54	Turkey Vulture	1	0.15	Turkey Vulture	1	0.16	3	0.20
Violet Green Swallow	29	15.68	Violet Green Swallow	109	15.84	Violet-green Swallow	77	12.64	215	14.51
Western Bluebird	5	2.70	Western Bluebird	30	4.36	Western Bluebird	53	8.70	88	5.94
Western Tanager	1	0.54	Western Tanager	10	1.45	Western Tanager	17	2.79	28	1.89
Western Wood Pewee	20	10.81	Western Wood-Pewee	63	9.16	Western Wood-Pewee	55	9.03	138	9.31
White Breasted Nuthatch	11	5.95	White-breasted Nuthatch	23	3.34	White-breasted Nuthatch	34	5.58	68	4.59
Yellow Rumped Warbler	4	2.16	Yellow-rumped Warbler	53	7.70	Yellow-rumped Warbler	45	7.39	102	6.88
Brown-headed Cowbird	2	1.08	Brown-headed Cowbird	1	0.15				3	0.20
Osprey	1	0.54	Osprey	1	0.15				2	0.13
			Black-capped Chickadee	4	0.58	Black-capped Chickadee	3	0.49	7	0.47
			Cassin's Finch	2	0.29	Cassin's Finch	3	0.49	5	0.34
			Common Raven	14	2.03	Common Raven	4	0.66	18	1.21
			Dark-eyed Junco	46	6.69	Dark-eyed Junco	17	2.79	63	4.25
			Green-tailed Towhee	5	0.73	Green-tailed Towhee	4	0.66	9	0.61
			House Wren	15	2.18	House Wren	7	1.15	22	1.48
			Mountain Chickadee	4	0.58	Mountain Chickadee	1	0.16	5	0.34
			Spotted Towhee	3	0.44	Spotted Towhee	5	0.82	8	0.54
			Townsend's Solitaire	6	0.87	Townsend's Solitaire	7	1.15	13	0.88
			Warbling Vireo	1	0.15	Warbling Vireo	3	0.49	4	0.27
			White-crowned sparrow	1	0.15	White-crowned Sparrow	1	0.16	2	0.13
Bullocks Oriole	1	0.54							1	0.07
Downy Woodpecker	1	0.54							1	0.07
Lewis Woodpecker	1	0.54							1	0.07
MacGillvery's Warbler	1	0.54							1	0.07
Red Tailed Hawk	1	0.54							1	0.07
Williamson's Sapsucker	1	0.54							1	0.07
										0.00
			Collared Dove	3	0.44				3	0.20
			Cordilleran Flycatcher	5	0.73				5	0.34
			European Starling	1	0.15				1	0.07
			Pine Siskin	3	0.44				3	0.20
			Red Crossbill	17	2.47				17	1.15
			Red-breasted Nuthatch	2	0.29				2	0.13
						Brown Creeper	1	0.16	1	0.07
						Grace's Warbler	15	2.46	15	1.01
						Great-Horned Owl	1	0.16	1	0.07
						Mallard	1	0.16	1	0.07
						Mountain Bluebird	1	0.16	1	0.07
						Sharp-shinned Hawk	1	0.16	1	0.07

Table 8. Summary of bird species observed at Fawn Gulch site across the three years of this study.

FAWN GULCH											
2019			2020			2021			Three Year TOTALS	
Total Birds Counted	354		Total Birds Counted	856		Total Birds Counted	594		1804	
	Abund	Rel Abund		Abund	Rel Abund		Abund	Rel Abund	ABUND	REL ABUND
American Crow	4	1.13	American Crow	2	0.23	American Crow	3	0.51	9	0.50
American Robin	81	22.88	American Robin	110	12.85	American Robin	140	23.57	331	18.35
Cassins Finch	1	0.28	Cassin's Finch	6	0.70	Cassin's Finch	2	0.34	9	0.50
Chipping Sparrow	8	2.26	Chipping Sparrow	12	1.40	Chipping Sparrow	15	2.53	35	1.94
Cordilleran Flycatcher	3	0.85	Cordilleran Flycatcher	19	2.22	Cordilleran Flycatcher	2	0.34	24	1.33
Green Tailed Towhee	16	4.52	Green-tailed Towhee	35	4.09	Green-tailed Towhee	53	8.92	104	5.76
Hairy Woodpecker	1	0.28	Hairy Woodpecker	7	0.82	Hairy Woodpecker	7	1.18	15	0.83
Northern Flicker	35	9.89	Northern Flicker	10	1.17	Northern Flicker	19	3.20	64	3.55
Pygmy Nutatch	4	1.13	Pygmy Nuthatch	55	6.43	Pygmy Nuthatch	27	4.55	86	4.77
Red Tailed Hawk	1	0.28	Red-tailed Hawk	4	0.47	Red-tailed Hawk	1	0.17	6	0.33
Steller's Jay	5	1.41	Steller's Jay	16	1.87	Stellar's Jay	33	5.56	54	2.99
Turkey Vulture	3	0.85	Turkey Vulture	3	0.35	Turkey Vulture	2	0.34	8	0.44
Violet Green Swallow	7	1.98	Violet-green Swallow	38	4.44	Violet-green Swallow	14	2.36	59	3.27
Western Bluebird	4	1.13	Western Bluebird	16	1.87	Western Bluebird	8	1.35	28	1.55
Western Tanager	27	7.63	Western Tanager	36	4.21	Western Tanager	37	6.23	100	5.54
Western Wood Pewee	64	18.08	Western Wood-Pewee	153	17.87	Western Wood-Pewee	94	15.82	311	17.24
White Breasted Nuthatch	17	4.80	White-breasted Nuthatch	29	3.39	White-breasted Nuthatch	20	3.37	66	3.66
Yellow Rumped Warbler	8	2.26	Yellow-rumped Warbler	41	4.79	Yellow-rumped Warbler	19	3.20	68	3.77
Broad-tailed Hummingbi	1	0.28	Broad-tailed Hummingbi	3	0.35				4	0.22
Red Crossbill	1	0.28	Red Crossbill	9	1.05				10	0.55
			Dark-eyed Junco	8	0.93	Dark-eyed Junco	3	0.51	11	0.61
			House Wren	32	3.74	House Wren	2	0.34	34	1.88
			Mountain Chickadee	6	0.70	Mountain Chickadee	3	0.51	9	0.50
			Mourning Dove	63	7.36	Mourning Dove	11	1.85	74	4.10
			Plumbeous Vireo	19	2.22	Plumbeous Vireo	5	0.84	24	1.33
			Spotted Towhee	4	0.47	Spotted Towhee	13	2.19	17	0.94
			Townsend's Solitaire	1	0.12	Townsend's Solitaire	2	0.34	3	0.17
			Warbling Vireo	30	3.50	Warbling Vireo	19	3.20	49	2.72
Black-headed Grosbeak	5	1.41				Black-headed Grosbeak	7	1.18	12	0.67
Common Raven	1	0.28				Common Raven	1	0.17	2	0.11
Say's Phoebe	2	0.56				Say's Phoebe	2	0.34	4	0.22
Tree Swallow	7	1.98				Tree Swallow	1	0.17	8	0.44
American Goldfinch	3	0.85							3	0.17
Bald Eagle	2	0.56							2	0.11
Brown-headed Cowbird	3	0.85							3	0.17
Canada Goose	6	1.69							6	0.33
Downy Woodpecker	3	0.85							3	0.17
Magpie	1	0.28							1	0.06
Northern Rough Winged	25	7.06							25	1.39
Pine Siskin	2	0.56							2	0.11
Red Naped Sapsucker	1	0.28							1	0.06
Yellow Warbler	2	0.56							2	0.11
			Band-tailed Pigeon	34	3.97				34	1.88
			Black-capped Chickadee	21	2.45				21	1.16
			Black-chinned Hummingl	1	0.12				1	0.06
			Black-headed Grosbeak	9	1.05				9	0.50
			Dusky Grouse	1	0.12				1	0.06
			Evening Grosbeak	1	0.12				1	0.06
			Grace's Warbler	11	1.29				11	0.61
			Great Horned Owl	3	0.35				3	0.17
			Orange-crowned Warbler	6	0.70				6	0.33
			Song Sparrow	1	0.12				1	0.06
			Williamson's Sapsucker	1	0.12				1	0.06
						Ash-throated Flycatcher	1	0.17	1	0.06
						Cassin's Vireo	1	0.17	1	0.06
						Common Nighthawk	16	2.69	16	0.89
						Great Blue Heron	1	0.17	1	0.06
						Olive-sided Flycatcher	1	0.17	1	0.06
						Orange-crowned Warbler	2	0.34	2	0.11
						Red-winged Blackbird	1	0.17	1	0.06
						Three-toed Woodpecker	3	0.51	3	0.17
						Turkey	2	0.34	2	0.11
						Virginia's Warbler	1	0.17	1	0.06

Table 9. Summary of bird species observed at Jackson Mountain site across the three years of this study.

JACKSON MOUNTAIN											
2019			2020			2021				Three Year TOTALS	
Total Birds Counted	278		Total Birds Counted	683		Total Birds Counted	652			1613	
	Abund	Rel Abund		Abund	Rel Abund		Abund	Rel Abund		ABUND	REL ABUND
American Crow	2	0.7	American Crow	8	1.2	American Crow	3	0.5		13	0.8
American Robin	75	27.0	American Robin	103	15.1	American Robin	85	13.0		263	16.3
Black Capped Chickadee	1	0.4	Black-capped Chickadee	11	1.6	Black-capped Chickadee	5	0.8		17	1.1
Black Headed Grosbeak	5	1.8	Black-headed Grosbeak	7	1.0	Black-headed Grosbeak	10	1.5		22	1.4
Broad Tailed Hummingbird	2	0.7	Broad-tailed Hummingbird	11	1.6	Broad-tailed Hummingbird	3	0.5		16	1.0
Brown Headed Cowbird	1	0.4	Brown-headed Cowbird	2	0.3	Brown-headed Cowbird	4	0.6		7	0.4
Common Raven	11	4.0	Common Raven	12	1.8	Common Raven	8	1.2		31	1.9
Hairy Woodpecker	1	0.4	Hairy Woodpiecker	5	0.7	Hairy Woodpecker	15	2.3		21	1.3
Hermit Thrush	1	0.4	Hermit Thrush	3	0.4	Hermit Thrush	1	0.2		5	0.3
House Wren	4	1.4	House Wren	8	1.2	House Wren	7	1.1		19	1.2
Mountain Chickadee	4	1.4	Mountain Chickadee	8	1.2	Mountain Chickadee	2	0.3		14	0.9
Mourning Dove	1	0.4	Mourning Dove	9	1.3	Mourning Dove	39	6.0		49	3.0
Northern Flicker	29	10.4	Northern Flicker	52	7.6	Northern Flicker	49	7.5		130	8.1
Orange Crowned Warbler	2	0.7	Orange-crowned Warbler	3	0.4	Orange-crowned Warbler	9	1.4		14	0.9
Plumbeous Vireo	12	4.3	Plumbeous Vireo	25	3.7	Plumbeous Vireo	10	1.5		47	2.9
Pygmy Nuthatch	12	4.3	Pygmy Nuthatch	57	8.3	Pygmy Nuthatch	90	13.8		159	9.9
Steller's Jay	11	4.0	Steller's Jay	52	7.6	Stellar's Jay	30	4.6		93	5.8
Townsend's Solitaire	3	1.1	Townsend's Solitaire	1	0.1	Townsend's Solitaire	2	0.3		6	0.4
Turkey Vulture	8	2.9	Turkey Vulture	10	1.5	Turkey Vulture	6	0.9		24	1.5
Violet Green Swallow	3	1.1	Violet-green Swallow	41	6.0	Violet-green Swallow	45	6.9		89	5.5
Virginia's Warbler	3	1.1	Virginia's Warbler	21	3.1	Virginia's Warbler	5	0.8		29	1.8
Warbling Vireo	7	2.5	Warbling Vireo	17	2.5	Warbling Vireo	27	4.1		51	3.2
Western Tanager	16	5.8	Western Tanager	49	7.2	Western Tanager	47	7.2		112	6.9
Western Wood Pewee	14	5.0	Western Wood-Pewee	29	4.2	Western Wood-Pewee	59	9.0		102	6.3
White Breasted Nuthatch	4	1.4	White-breasted Nuthatch	17	2.5	White-breasted Nuthatch	14	2.1		35	2.2
Yellow Rumped Warbler	12	4.3	Yellow-rumped Warbler	11	1.6	Yellow-rumped Warbler	18	2.8		41	2.5
Common Nighthawk	2	0.7	Common Nighthawk	1	0.1					23	1.4
Red Tailed Hawk	6	2.2	Red-tailed Hawk	4	0.6					10	0.6
Tree Swallow	4	1.4	Tree Swallow	1	0.1					5	0.3
			Chipping Sparrow	37	5.4	Chipping Sparrow	6	0.9		43	2.7
			Collared Dove	1	0.1	Collared Dove	1	0.2		2	0.1
			Cordilleran Flycatcher	4	0.6	Cordilleran Flycatcher	18	2.8		22	1.4
			Dark-eyed Junco	8	1.2	Dark-eyed Junco	5	0.8		13	0.8
			Great blue heron	1	0.1	Great Blue Heron	1	0.2		2	0.1
			Green-tailed Towhee	29	4.2	Green-tailed Towhee	11	1.7		40	2.5
			Say's Phoebe	4	0.6	Say's Phoebe	2	0.3		6	0.4
Williamson's Sapsucker	7	2.5				Williamson's Sapsucker	1	0.2		8	0.5
Canada Goose	5	1.8								5	0.3
Green Tailed Towhee	7	2.5								7	0.4
White Throated Swift	3	1.1								3	0.2
			Brown Creeper	1	0.1					1	0.1
			Cooper's Hawk	1	0.1					1	0.1
			Dusky Flycatcher	1	0.1					1	0.1
			Goshawk	1	0.1					1	0.1
			Grace's Warbler	4	0.6					4	0.2
			Gray Catbird	1	0.1					1	0.1
			Red Crossbill	8	1.2					8	0.5
			Red-breasted Nuthatch	3	0.4					3	0.2
			Western Bluebird	1	0.1					1	0.1
						Bald Eagle	1	0.2		1	0.1
						Band-tailed Pigeon	1	0.2		1	0.1
						Bullock's Oriole	2	0.3		2	0.1
						Downy Woodpecker	1	0.2		1	0.1
						Grace's Warbler	3	0.5		3	0.2
						Lewis's Woodpecker	3	0.5		3	0.2
						Peregrine Falcon	1	0.2		1	0.1
						Wild Turkey	1	0.2		1	0.1
						Western Meadowlark	1	0.2		1	0.1

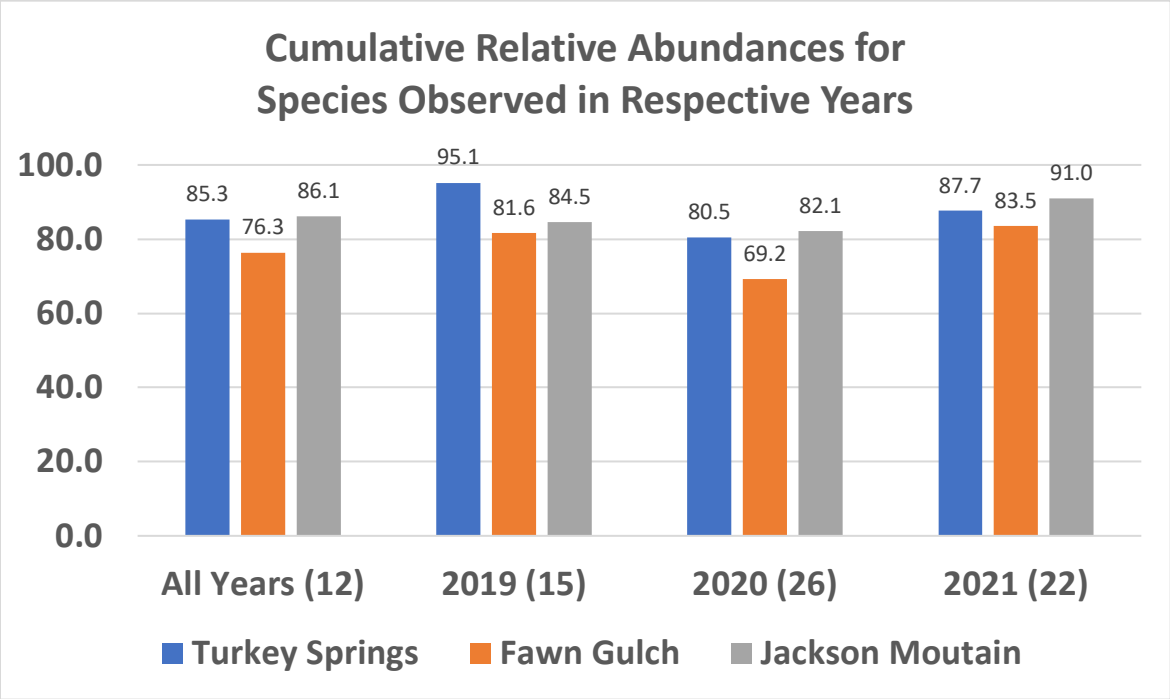

Figure 7. Summary of cumulative relative abundances for the bird species recorded in respective years at each site. Numbers in parentheses are the number of species common to all three sites in that respective year. (see also Tables 4, 6, 7, 8, and 9)

Table 11 contains a summary of the 15 top-ranked bird species by year according to relative abundance. In 2019, the top 15 species accounted for 82% of all birds counted; almost 79% in 2020; and 87.4% in 2021. Of the 15 top-ranked species shown for each year, 9 species were observed in all three years, to include the American Robin, Chipping Sparrow, Green-tailed Towhee, Northern Flicker, Pygmy Nuthatch, Violet-green Swallow, Western Wood-Pewee, White-breasted Nuthatch, and Yellow-rumped Warbler. Comparing this list to information in Table 7 reveals that the American Robin, Northern Flicker, Pygmy Nuthatch, Violet-green Swallow, Western Wood-Pewee, White-breasted Nuthatch, and Yellow-rumped Warbler were observed at all three sites in all three years of the study. Note also that the American Robin is ranked first in all three years; and that the Pygmy Nuthatch, Violet-green Swallow, and Western Wood-Pewee are all in the top 4 species by relative abundance in all three years of the study.

The majority of bird species observed in any single year of the study, or across two years of the study, were recorded as single bird sightings, or as three or fewer birds (Table 12). Sixteen bird species were observed in two of the three years of the study (Table 12). Notable among those species for their abundance were the Band-tailed Pigeon and Grace's Warbler, both observed in 2020 and 2021. All sightings of the Band-tailed Pigeon occurred at FG, with Grace's Warbler observed at FG and JM in 2020, and at TS and JM in 2021 (see Table 3, and Appendix A).

As shown in Table 12, nine species were seen only in 2019; 10 species only in 2020; and 10 species only in 2021. The most numerous species recorded only in 2019 were Canada Geese (17 birds) observed at FG and JM, and Northern Rough-winged Swallows (25 birds) observed at FG (see Table 3, and Appendix A). In 2020, a total of five Red- breasted Nuthatches were observed at TS and JM. In 2021, 3 birds each were observed for the Three-toed Woodpecker and the Wild Turkey. Notably, the Three-toed Woodpecker was documented as an incidental at TS in 2020, but was observed at our monitoring points at FG in 2021. Wild Turkeys were observed at both FG (2 birds) and JM (1 bird) in 2021 (see Table 3, and Appendix A).

Table 13 lists the bird species observed as "incidentals only" in the respective years of this study. For example, the American Kestrel was noted as an incidental in 2019, but was not observed at any of the established monitoring sites in that year, or in 2020 or 2021 either. Similarly, at least one Western Meadowlark was noted as an incidental in

Table 10. Summary of bird species observed in all three years sorted by total relative abundance. (Notes: shading indicates bird species observed at all three sites in all three years; * a total of 82 different species were observed across all three years)

Year	2019		2020		2021		TOTAL ACROSS YEARS	
Total # Species	54		58		60		82*	
Total # Birds Counted	949		2227		1855		5031	
	Abund	Rel Abund	Abund	Rel Abund	Abund	Rel Abund	Abund	Rel Abund
Species Recorded in All Three Years = 37								
American Robin	248	26.1	290.0	13.0	284.0	15.3	822	16.34
Western Wood Pewee	80	8.4	245.0	11.0	208.0	11.2	533	10.59
Pygmy Nuthatch	63	6.6	193.0	8.7	209.0	11.3	465	9.24
Violet-green Swallow	141	14.9	188.0	8.4	136.0	7.3	465	9.24
Northern Flicker	51	5.4	76.0	3.4	95.0	5.1	222	4.41
Yellow-rumped Warbler	22	2.3	105.0	4.7	82.0	4.4	209	4.15
Western Tanager	3	0.3	95.0	4.3	101.0	5.4	199	3.96
White Breasted Nuthatch	36	3.8	69.0	3.1	68.0	3.7	173	3.44
Green-tailed Towhee	26	2.7	69.0	3.1	68.0	3.7	163	3.24
Mourning Dove	2	0.2	108.0	4.8	53.0	2.9	163	3.24
Chipping Sparrow	16	1.7	72.0	3.2	56.0	3.0	144	2.86
Steller's Jay	5	0.5	75.0	3.4	64.0	3.5	144	2.86
Western Bluebird	10	1.1	47.0	2.1	61.0	3.3	118	2.35
Warbling Vireo	8	0.8	48.0	2.2	49.0	2.6	105	2.09
Plumbeous Vireo	14	1.5	46.0	2.1	30.0	1.6	90	1.79
Dark-eyed Junco	1	0.1	62.0	2.8	25.0	1.3	88	1.75
House Wren	4	0.4	55.0	2.5	16.0	0.9	75	1.49
Hairy Woodpecker	12	1.3	22.0	1.0	28.0	1.5	62	1.23
American Crow	32	3.4	16.0	0.7	11.0	0.6	59	1.17
Common Raven	12	1.3	26.0	1.2	13.0	0.7	51	1.01
Cordilleran Flycatcher	3	0.3	28.0	1.3	20.0	1.1	51	1.01
Black-capped Chickadee	1	0.1	36.0	1.6	8.0	0.4	45	0.89
Black Headed Grosbeak	10	1.1	16.0	0.7	17.0	0.9	43	0.85
Common Nighthawk	8	0.8	4.0	0.2	23.0	1.2	35	0.70
Broad-tailed Hummingbird	8	0.8	20.0	0.9	5.0	0.3	33	0.66
Virginia's Warbler	3	0.3	21.0	0.9	6.0	0.3	30	0.60
Mountain Chickadee	5	0.5	18.0	0.8	6.0	0.3	29	0.58
Turkey Vulture	4	0.4	14.0	0.6	9.0	0.5	27	0.54
Brown-headed Cowbird	15	1.6	3.0	0.1	4.0	0.2	22	0.44
Orange-crowned Warbler	2	0.2	9.0	0.4	11.0	0.6	22	0.44
Townsend's Solitaire	3	0.3	8.0	0.4	11.0	0.6	22	0.44
Cassins Finch	3	0.3	8.0	0.4	5.0	0.3	16	0.32
Red Tailed Hawk	6	0.6	8.0	0.4	1.0	0.1	15	0.30
Tree Swallow	11	1.2	1.0	0.0	1.0	0.1	13	0.26
Say's Phoebe	2	0.2	5.0	0.2	4.0	0.2	11	0.22
Williamson's Sapsucker	8	0.8	1.0	0.0	1.0	0.1	10	0.20
Hermit Thrush	1	0.1	3.0	0.1	1.0	0.1	5	0.10

Table 11. Comparison of top 15 ranked bird species among the 37 bird species common to all three years of the study.

2019				2020				2021			
Cumulative Rel Abund			82.1	Cumulative Rel Abund			78.6	Cumulative Rel Abund			87.4
Bird Species	Rank	Abund	Rel Abund	Bird Species	Rank	Abund	Rel Abund	Bird Species	Rank	Abund	Rel Abund
American Crow	7	32	3.4								
American Robin	1	248	26.1	American Robin	1	290	13.0	American Robin	1	284	15.9
Brown-headed Cowbird	11	15	1.6								
Chipping Sparrow	10	16	1.7	Chipping Sparrow	10	72	3.2	Chipping Sparrow	12	56	3.1
Common Raven	13	12	1.3								
				Dark-eyed Junco	13	62	2.8				
Green-tailed Towhee	8	26	2.7	Green-tailed Towhee	11	69	3.1	Green-tailed Towhee	8	68	3.8
Hairy Woodpecker	14	12	1.3								
				House Wren	14	55	2.5				
				Mourning Dove	5	108	4.8	Mourning Dove	13	53	3.0
Northern Flicker	5	51	5.4	Northern Flicker	8	76	3.4	Northern Flicker	6	95	5.3
Plumbeous Vireo	12	14	1.5					Plumbeous Vireo	15	30	1.7
Pygmy Nuthatch	4	63	6.6	Pygmy Nuthatch	3	193	8.7	Pygmy Nuthatch	2	209	11.7
				Steller's Jay	9	75	3.4	Stellar's Jay	10	64	3.6
Tree Swallow	15	11	1.2								
Violet-green Swallow	2	141	14.9	Violet-green Swallow	4	188	8.4	Violet-green Swallow	4	136	7.6
				Warbling Vireo	15	48	2.2	Warbling Vireo	14	49	2.7
								Western Bluebird	11	61	3.4
				Western Tanager	7	95	4.3	Western Tanager	5	101	5.6
Western Wood Pewee	3	80	8.4	Western Wood-Pewee	2	245	11.0	Western Wood-Pewee	3	208	11.6
White Breasted Nuthatch	6	36	3.8	White-breasted Nuthatch	12	69	3.1	White-breasted Nuthatch	9	68	3.8
Yellow-rumped Warbler	9	22	2.3	Yellow-rumped Warbler	6	105	4.7	Yellow-rumped Warbler	7	82	4.6

Table 12. Summary of bird species abundances recorded in any two years, or any single year of the study.

Year	2019		2020		2021	
	Abund	Rel Abund	Abund	Rel Abund	Abund	Rel Abund
Species Recorded in 2019 and 2020 Only = 3						
Osprey	1	0.1	1	0.0		
Pine Siskin	2	0.2	3	0.1		
Red Crossbill	1	0.1	34	1.5		
Species Recorded in 2019 and 2021 Only = 5						
Bald Eagle	2	0.2			1	0.1
Bullocks Oriole	2	0.2			2	0.1
Downy Woodpecker	4	0.4			1	0.1
Lewis's Woodpecker	1	0.1			3	0.2
Mountain Bluebird	1	0.1			1	0.1
Species Recorded in 2020 and 2021 Only = 8						
Band-tailed Pigeon			34.0	1.5	1.0	0.1
Brown Creeper			1.0	0.0	1.0	0.1
Collared Dove			4.0	0.2	1.0	0.1
Grace's Warbler			15.0	0.7	18.0	1.0
Great Blue Heron			1.0	0.0	2.0	0.1
Great Horned Owl			3.0	0.1	1.0	0.1
Spotted Towhee			7.0	0.3	18.0	1.0
White-crowned sparrow			1.0	0.0	1.0	0.1
Species Recorded in 2019 Only = 9						
American Goldfinch	3	0.3				
American Kestrel	1	0.1				
Canada Goose	17	1.8				
MacGillivray's Warbler	1	0.1				
Magpie	2	0.2				
Northern Rough-winged Sw	25	2.6				
Red-naped Sapsucker	2	0.2				
White-throated Swift	3	0.3				
Yellow Warbler	2	0.2				
Species Recorded in 2020 Only = 10						
Black-chinned Hummingbird			1.0	0.0		
Cooper's Hawk			1.0	0.0		
Dusky Flycatcher			1.0	0.0		
Dusky Grouse			1.0	0.0		
European Starling			1.0	0.0		
Evening Grosbeak			1.0	0.0		
Goshawk			1.0	0.0		
Gray Catbird			1.0	0.0		
Red-breasted Nuthatch			5.0	0.2		
Song Sparrow			1.0	0.0		
Species Recorded in 2021 Only = 10						
Ash-throated Flycatcher					1.0	0.1
Cassin's Vireo					1.0	0.1
Mallard					1.0	0.1
Olive-sided Flycatcher					1.0	0.1
Peregrine Falcon					1.0	0.1
Red-winged Blackbird					1.0	0.1
Sharp-shinned Hawk					1.0	0.1
Three-toed Woodpecker					3.0	0.2
Wild Turkey					3.0	0.2
Western Meadowlark					1.0	0.1

Table 13. List of bird species identified as incidental in respective years that were not observed at monitoring points in those years. INC ONLY = incidental only that year; none = no sightings; TS = Turkey Springs site; FG = Fawn Gulch site; JM = Jackson Mountain site.

Species	2019	2020	2021
American Kestrel	INC ONLY	none	none
Dark-eyed Junco	INC ONLY	TS, FG, JM	TS, FG, JM
Mountain Bluebird	INC ONLY	none	TS
Western Meadowlark	none	INC ONLY	JM
Sharp-shinned Hawk	none	INC ONLY	TS
Wild Turkey	none	INC ONLY	FG, JM
Canada Goose	FG, JM	none	INC ONLY
Pine Siskin	FG	TS	INC ONLY
Red Crossbill	FG	TS, FG, JM	INC ONLY
Red-naped Sapsucker	none	none	INC ONLY

2020, was not seen in 2019, but was observed at JM monitoring points in 2021. Pine Siskins and Red Crossbills were observed at monitoring points in 2019 and 2020, but recorded only as incidentals in 2021. Wild Turkeys were encountered during routine monitoring in 2021, but only noted as incidentals in 2020. Canada Geese were also observed from monitoring points in 2019, but were not seen in 2020, and were documented as incidentals in 2021.

The small number of birds noted as "incidentals only" compared to the total number of bird species documented in this study reinforces our confidence that our sampling protocol was effective in representing the composition of the bird communities in our three study areas.

Community -level observations-

The fields of population and community ecology have, for over a century of field research, addressed questions concerning the causes and consequences of the distribution and abundance of various species' populations or groups of species. Regardless of the taxonomic group of interest, one uniform outcome of these studies is that a relatively small number of species tend to be very common, with a greater number of species found to be uncommon or rare in a region surveyed (e.g., Flather and Sieg, 2007; Gaston, 2011). The results of our study are consistent with this general pattern. As already noted, of the 82 different bird species observed over the three years of this study, 37 species, representing about 95% of the birds counted, were observed in all three years. Moreover, 12 of those species were observed at all three sites over the course of the study, representing about 67% of the birds counted (Tables 4 and 6; Figs. 5 and 6). This means that about 7% of the birds counted, or about 352 birds, were distributed across 45 species of birds observed infrequently or in small numbers in only one or two years of the study. This raises an important question – should conservationists be more concerned about patterns in the distribution and abundance of common species, or focus their attention on the uncommon or rare species? We will address this issue further in the Summary and Conclusions section of this report.

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 document potential impacts of wildland fuel reduction treatments on the bird community, which is the central scientific question of this study. From 2019 to 2021, the number of bird species at TS increased from 26 in the 2019 dataset, to 37 in 2020, and 35 in 2021 (Fig. 5). Interestingly, the number of species recorded at FG ranged from 34 in 2019, to 39 in 2020, and 40 in 2021. The number of species at JM increased from 33 in 2019 to 45 in 2020, and 43 species in 2021 (Fig. 5). Of the 82 different bird species observed across the three years of this study, 49 species were documented at TS, 63 species at FG, and 58 species at JM (see Fig. 5). We also counted a greater number of birds at FG and JM compared to TS over the course of the study (Fig. 6). FG emerges as not only having the greatest proportion of bird species (Fig. 5), but also the largest proportion of birds observed, with about 38% of the total number of birds counted, compared to 29% at TS and 32 % at JM, (Fig. 6).

These results point to recovery of the TS site from prescribed fire, even by the second year of the study. Although the number of bird species encountered at FG appears stable across years, the distribution of birds across species varies more at FG than at either of the other two sites (see discussion of species diversity and species evenness

below). The greater year-to-year variability at FG is also indicated by the lower cumulative relative abundance among the 18 species recorded at FG in all three years (76.3%; Table 6) compared to the other two sites.

Species Diversity-

Ecologists for many decades have debated the proper application of diversity indices to compare two or more ecological communities. The Shannon Index (H`), also known as the Shannon-Weaver or Shannon-Wiener 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 (see Morris et al., 2014). The Shannon Index increases as the number of species increases (species richness), and is also increases as individuals are distributed more evenly across species (species evenness).

The equation for the Shannon Index is: $H` = -\sum p_i \ln p_i$, where $p_i$ is the relative abundance of individuals of the $i^{th}$ species, (see Cox, 2002; Jost, 2006; Jost, 2009). Note that ln (natural logarithm) is typically used in calculating H`, although some researchers have used $\log_2$ or $\log_{10}$. In our 2019 report, we used $\log_{10}$, then recalculated H` using $\log_2$ in 2020. For this report, all H` values have been recalculated using ln.

Figure 8 illustrates H` values calculated for each site by year. Higher values are obtained for JM in each year of the study, followed by FG, then TS in 2021 and 2019, with FG and TS very similar in 2020. As noted by many authors (e.g., Jost 2006, 2009; Morris et al., 2014), interpretation of H` is complicated by the fact that it is a unitless index that convolves both species richness (number of different species recorded), and species evenness (numbers of individual birds distributed to each species).

The Simpson Index (Ds) 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.

As shown in Fig 9, Ds values were uniformly higher for JM compared to FG or TS in all three years of the study. Species evenness increased and stabilized for TS from 2019 to 2020 and 2021; and was substantially higher for FG in 2020 compared to 2019 or 2021. Referring to species abundance values shown in Tables 7, 8, and 9, and Fig. 7, helps explain these patterns in Ds. For example, FG has the lowest cumulative relative abundances for species observed across sites in all three years (Fig. 7). This indicates that a greater number of birds at FG were observed for species not seen in at least one of the sample years (e.g., see data in Table 8 for House Wren; Mourning Dove; Plumbeous Vireo; and Warbling Vireo).

As pointed out in several reviews (e.g., Jost 2006, 2009), H` is a measure of entropy or uncertainty in a system, which is a representation of diversity in a system, but the index as calculated is non-linear. Jost (2009) illustrates this point by comparing two hypothetical communities in which individuals were evenly distributed across 5 species, yielding an H` of 1.609 in case 1, compared to case 2 in which a community of 10 species yielded an H` of 2.305. In his model, doubling the number of species did not result in a doubling of the value for H`, illustrating the difficulties in using H` to draw comparisons between ecological communities.

In his synthesis of the mathematical basis for diversity indices, Jost (2006, 2009) proposes a new index – Effective Number of Species (ENS), which is calculated as: exp(H`). Jost shows that ENS varies proportionally to the number of species in his demonstration model, offering a more intuitive index for comparing ecological communities. Several other authors have proposed indices of diversity that purportedly represent species diversity more effectively than H` or D_s, or similar indices reported in the literature (e.g., Morris et. al., 2014; Augousti 2021), most of which are mathematically more complicated than ENS. We, therefore, opted to use ENS in our analysis.

Figure 10 illustrates the ENS indices we calculated from H` values for our dataset. Not surprisingly, the patterns shown parallel those observed for H` in Fig. 8, but the ENS index allows quantitative comparisons that are not applicable using H`. For example, based on ENS values, we can infer that in 2020 the bird community at JM was almost 24% more diverse than for TS in that year, but only about 12% more diverse compared to FG. Remember, because ENS is based on H`, both species richness and species evenness affect this result as well.

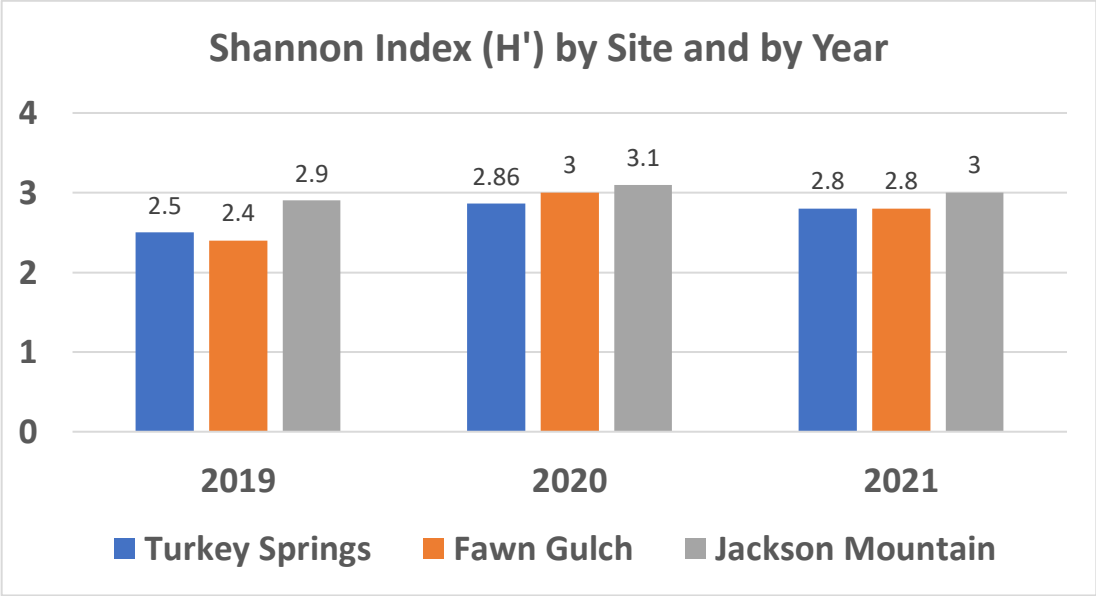

Figure 8. Comparison of the Shannon Index, H', between sites and across years. The equation for H' is: $H' = -\sum p_i \ln p_{i,}$ where p_i = the relative abundance of individuals of the i^{th} species. TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

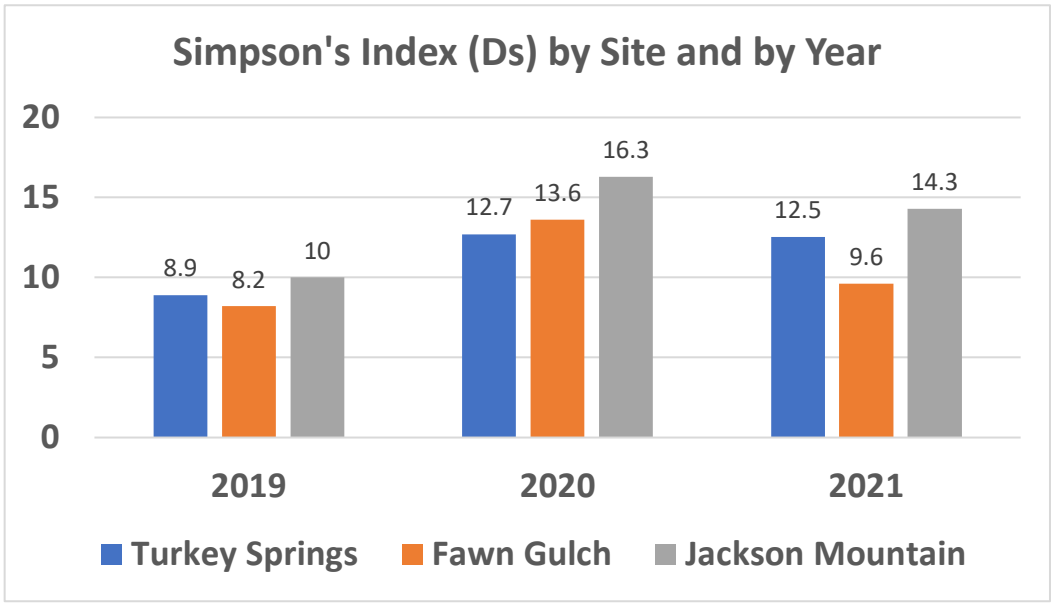

Figure 9. Comparison of Simpson's Index (Ds) by site and by year. The equation for Ds is discussed in the text. TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

Looking further at ENS values reveals that index values for species diversity increased to their highest values in 2020 for all sites, from their lowest values in 2019, and intermediate values in 2021. JM exhibits the highest ENS values for all three sites across all three years. FG shows the greatest inter-annual variability in bird species diversity, nearly doubling from 2019 to 2020, then falling by about 20% from 2020 to 2021.

These findings corroborate and extend inferences made from our analysis of numbers of bird species and numbers of birds distributed across species at our three sites across the term of this study. For example, increasing ENS values

for TS are consistent with recovery of that site following prescribed fire in 2019 (see also Table 3 and 4; and Figs 5 and 6). Lower values for FG in 2019, followed by increased numbers in 2020 and 2021 reflect lower species evenness (i.e., Ds; see Fig. 9), even though FG had the highest or second highest number of species in each year of the study (see also Table 4; and Figs. 5 and 6), a likely consequence of inter-annual variability in bird community composition. Finally, JM had consistently higher Ds values than the other two sites (Fig. 9), and also had the highest or second highest species richness values in each year of the study (see also Table 4; and Figs. 5 and 6). As noted earlier, these results may reflect improved bird identification skills of observers, but may also be a consequence of bird movement into the area of the JM study site in response to nearby thinning and logging activities.

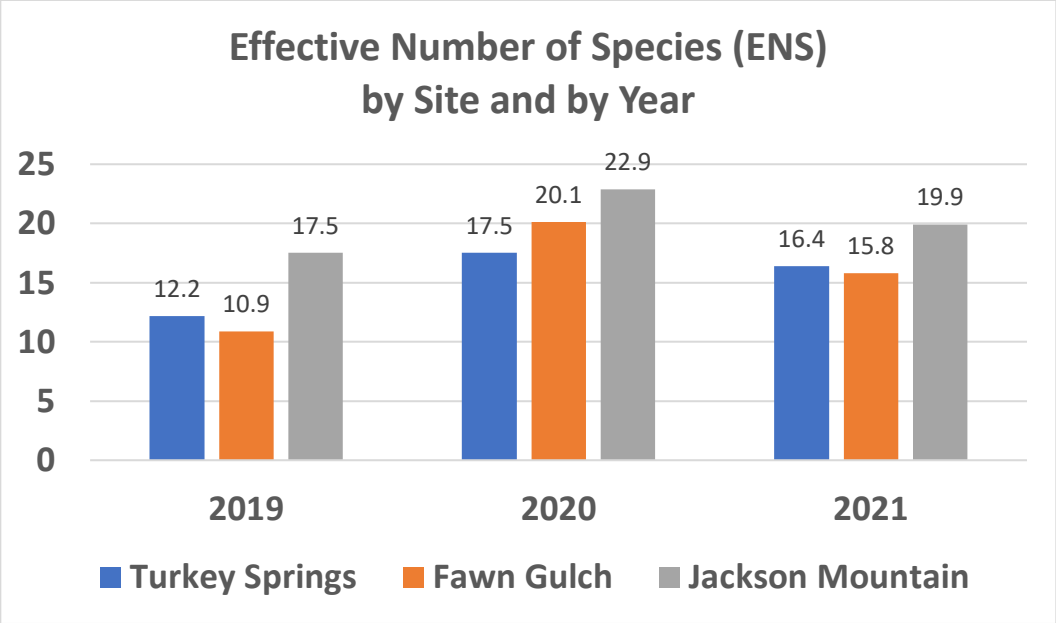

Figure 10. Comparison of Effective Number of Species (ENS) by site and by year. The equation for ENS is exp (H') as developed by L. Jost (2006 and 2009). TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

Community Similarity-

A simplified index for comparing ecological communities when relative abundance values (in percent) are available is the Coefficient of Communities (C%): where C% = ∑ (lower % relative abundance values for shared species between 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.

Year-by-year calculations of C% shown in Fig. 11 reveal that JM and FG are least similar across the course of this study, with C% values ranging from 58% to 72%. TS, by comparison, is 64% similar in 2019 vs. 2020 and vs. 2021, but is 77% similar between 2020 vs. 2021. These patterns reflect the proportions of shared vs. unique species by year shown for each site in Table 6. The data shown in Table 6 reveals that JM had 26 species common to all three years, out of a total of 58 different species observed at that site; TS had 18 shared species out of a total of 49 different species observed across all three years; and FG also had 18 shared species out of a total of 63 different species observed. 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 for 2019 vs. 2021. At both JM and TS, there were greater similarities in bird community composition in 2020 vs. 2021 (77% and 72%, respectively) than observed in any other year-by-year comparisons.

A similar approach was used within years to reveal site-by-site similarities, as shown in Fig. 12. These calculations indicate notably less similarity across sites in the 2019 dataset compared to 2020. For example, C% values ranged

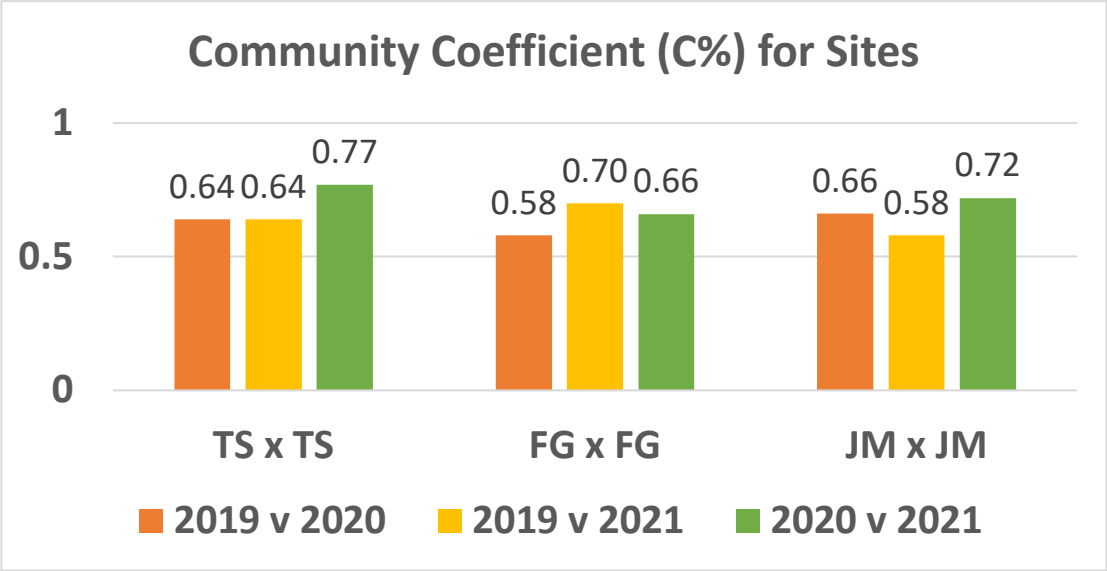

Figure 11. Year by year comparison of Community Coefficient (C%) values calculated based on bird relative abundances across species. TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

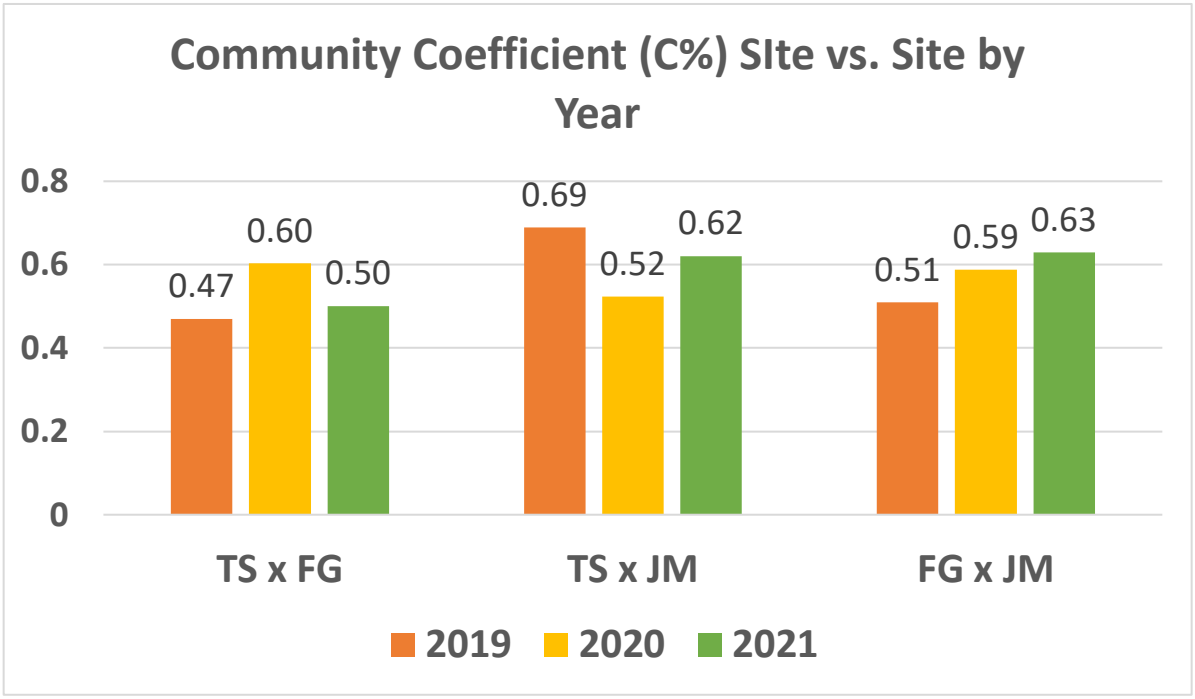

Figure 12. Community Coefficient (C%) values calculated based on bird relative abundances within years and across sites for 2019 vs. 2020. TS = Turkey Springs; FG = Fawn Gulch; and JM = Jackson Mountain.

from 69% for TS compared to JM in 2019; to 47% for FG compared to JM in that year. The range of values in the 2020 dataset was much narrower – 60% for TS x FG, to 52% for TS x JM, while JM is equally similar to TS and FG in 2021. These differences 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 3).

Looking across years, there was greater similarity across sites in 2021 and 2020 compared to 2019 (Fig. 12). This pattern seems to be driven by the TS site bird community recovering to numbers more similar to FG from 2019 to 2020. The increasing trend in C% shown for FG x JM comparisons across years may reflect improved bird identification skills among observers at JM, resulting in a more accurate representation of the bird community at that site through time.

Tropic-level Impacts: Effects of Bird Predation on Herbivorous Invertebrates-

Studies elucidating the role of birds in controlling foliovorous arthropod populations consistently find a reduction in herbivorous invertebrates in many different ecosystem types (e.g., Atlegrim, 1992; Holmes, 1990, Heyman and Gunnarsson, 2011). In view of the difficulties associated with quantifying bird predation on arthropods (see Dahlsten et. al., 1990), the most compelling findings come from studies in which various methods are used to exclude bird predation from vegetation (i.e., netting exclosures; Bridgeland et al. 2010; Heyman and Gunnarsson, 2010), coupled in some cases with insecticide applications to additionally suppress arthropod populations (e.g., Marquis and Whelan, 1994). The general consensus from these and other studies is that bird predation may effectively limit prey population densities when at endemic levels, especially during bird breeding season, but insect outbreaks often overwhelm the ability of bird populations to control such irruptions (Holmes, 1990). Venier and others (2009), however, were able to quantify enhanced breeding success in several warbler species common to the eastern boreal forests when spruce budworm outbreaks occurred.

The indirect consequences of bird predation on plant growth has also been demonstrated for sugar maple seedlings in the eastern deciduous forest (Strong et. al., 2000), and white oak in hardwood forests of Missouri (Marquis and Whelan, 1994). Finally, experimental work by Heyman and Gunnarsson (2010) in suburban deciduous forests in Sweden confirms that removal of the forest understory, through impacts on various arthropod populations, significantly reduces bird population densities as well.

The results of our study are consistent with research showing that understory removal reduces bird densities (e.g., Heyman and Gunnarsson 2010). Simplifying forest understory structure, as was accomplished with prescribed fire at the TS site at the onset of our study, resulted in at least a short-term reduction in bird abundance (see Figs. 5 and 6). and bird community diversity (see Figs. 8, 9, and 10). Mastication at FG, however, which occurred at least 2 years before our study began, did not have prolonged impacts on bird species richness (Fig. 5); apparent abundance (Fig. 6); evenness (Fig. 9); or diversity (Figs. 8 and 10). Spruce budworm and bark beetle infestations that have significantly impacted forests across the western states, and in particular in higher elevation forests surrounding our area, do not seem to be a problem in the vicinity of our study sites. Although difficult to confirm, bird predation may be a contributing factor to the apparent absence of insect outbreaks in dry-mixed conifer forests in our area.

Species-level response – Feeding Guilds-

Table 14 summarizes the categorization of bird species encountered in our study according to their feeding habits using lists 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, and 2020). The relative abundances of species in the most common of these feeding guilds are illustrated in Fig. 13. Bird species categorized as ground-brush foraging (GBF) (e.g., American Robin, Green-tailed Towhee; Northern Flicker; see Table 14) are most common at all three sites, with timber-foliage searching (TFS) (e.g., Plumbeous Vireo, Warbling Vireo, Yellow-rumped Warbler; see Table 14) second most common at JM. Aerial flycatchers (AF) (e.g., Violet-green Swallow; see Table 14)) and timber-drilling/gleaning species (TDG) (e.g., Hairy Woodpecker, Pygmy Nuthatch, White-breasted Nuthatch; see Table 14) were notably abundant at TS, with TDG species demonstrating modest increasing trends across years at both TS and JM. The relative abundance of aerial flycatchers (AF) at TS remained notably consistent across years, due largely to the presence of Violet-green Swallows (Table 14; Fig. 13).

Notably, the increase in TFS species (led by increases in Plumbeous Vireos; Western Tanagers; and Yellow-rumped Warblers) and TDG species (led by Pygmy Nuthatches and White-breasted Nuthatches) at TS from 2019 to 2021 is consistent with the recovery of the shrub layer following the prescribed fire at that site in 2019 (Table 14; and Fig. 13). The number of species in the GBF guild at TS increased from 7 to 18 species across years, led largely by the return of Dark-eyed Juncos, Mourning Doves, Western Bluebirds, House Wrens, and Red Crossbills. 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 and 2021, due in part to increased sample density, but the scale of response in these species exceeds the increase in sample density, indicating a substantial contribution of shrub layer recovery to this finding.

At JM, the decreasing trend in the relative abundance of GBF species shown in Fig. 13 does not reflect a decrease in numbers of birds representing species in this category, which actually increased, but rather a concurrent increase in abundance and relative abundance of TDG species (Table 14). Indeed, numbers of American Robins, Chipping Sparrows, Green-tailed Towhees, and Northern Flickers (all GBF species) increased substantially across years at JM, with a concurrent increase in numbers of Hairy Woodpeckers, Pygmy Nuthatches, and White-breasted Nuthatches (all TDG species) at that site. This result may reflect, at least in part, year-to-year variability, but as discussed earlier, improved birding skills of observers may partially account for this result as well.

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). Using information from the Cornell Lab (www.allaboutbirds.org; see also Coe, 2014), we categorized birds as tree/shrub nesters; ground/cliff, or "other," nesters (where "other" refers to use of crevices or ledges on buildings or other structures); and cavity nesters. 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 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 to 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 (e.g., Hairy Woodpecker, Northern Flicker) 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 82 species encountered through the three years of our study, we identified 42 tree/shrub nesting species; 19 ground/cliff/other species; and 20 cavity nesting species (see Table 15; only data for cavity nesters is shown). Among the 20 cavity nesting species, 5 are categorized as primary nesting species (Downy Woodpecker, Hairy Woodpecker, Northern Flicker, Three-toed Woodpecker, and Williamson's Sapsucker); 10 species fall into the secondary nesting category (American Kestrel, Ash-throated Flycatcher, 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 15). Notably, cavity nesting species made up about 30% of bird sightings in each year of the study (35% in 2019; 27% in 2020; and 31% in 2021). In terms of relative abundance across all years, 45% of birds counted at TS were cavity nesters, predominantly Violet-green Swallows and Pygmy Nuthatches; with 21% of birds counted at FG; and 29% of birds counted at JM falling into this category. Northern Flickers, White-breasted Nuthatches, and Pygmy Nuthatches were the most widespread cavity nesting species at all three sites, with House Wrens observed most frequently at JM.

In our study, Hairy Woodpeckers and Northern Flickers were the most abundant primary cavity nesters seen at all three sites in each year of the study, along with Violet-green Swallows and White-breasted Nuthatches as abundant secondary cavity nesters, and Pygmy Nuthatches the most common species fulfilling either category (Table 15). It is notable that each of these species increased in numbers, some markedly, from 2019 to 2021. These increases are consistent with recovery of the TS site from prescribed fire, as well as year-to-year variability in bird species abundance, with an increase in sample density across years a potential contributing factor to this outcome as well.

Table 14. 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		2021		2019		2020		2021		2019		2020		2021	
	ABUND	REL ABUND	ABUND	REL ABUND	ABUND	REL ABUND	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	59	9.7	130	25.9	110	12.9	140	23.6	75	26.2	103	15.1	85	13.0
Band-tailed Pigeon									34	4							1	0.2
Black-capped Chickadee			4	0.6	3	0.5			21	2.5			1	0.3	11	1.6	5	0.8
Black-headed Grosbeak							5	1	9	1.1	1	0.2	5	1.8			10	1.5
Brown-headed Cowbird	2	0.9	1	0.1			3	0.6					1	0.001	2	0.3	4	0.6
Bullock's Oriole	1	0.4					1	0.2									2	0.3
Canada Goose							12	2.4					5	1.75				
Cassin's Finch			2	0.3	3	0.5	3	0.6	6	0.7	2	0.3						
Chipping Sparrow	6	2.6	23	3.3	35	5.7	10	2	12	1.4	15	2.5			37	5.4	6	0.9
Collared Dove			3	0.4											1	0.1	1	0.2
Dark-eyed Junco			46	6.6			1	0.2	8	0.9	3	0.5			8	1.2	5	0.8
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	4	0.7	19	3.8	35	4.1	53	8.9	7	2.5	29	4.2	11	1.7
Hermit Thrush													1	0.4	3	0.4	1	0.2
House Wren			15	2.2	7	1.1			32	3.7	2	0.3	1	1.4	8	1.2	7	1.1
Mountain Bluebird					1	0.2	1	0.2										
Mourning Dove	1	0.4	36	5.2	3	0.5			63	7.4	11	1.9	1	0.4	9	1.3	39	6.0
Northern Flicker	16	6.9	14	2	27	4.4	44	8.8	10	1.2	19	3.2	29	10.1	52	7.6	49	7.5
Pine Siskin			3	0.4			2	0.4										
Red Crossbill			17	2.4			1	0.2	9	1.1					8	1.2		
Red-winged Blackbird											1	0.2						
Song Sparrow									1	0.1								
Spotted Towhee			3	0.4	5	0.8			4	0.4	13	2.2						
Townsend's Solitaire			6	0.9	7	1.1			1	0.1	2	0.3	3	1.1	1	0.1	2	0.3
Western Bluebird	5	2.2	30	4.3	53	8.7	5	1	16	1.9	8	1.3			1	0.1		
Western Meadowlark																	1	0.2
White-crowned sparrow			1	0.1	1	0.2												
Wild Turkey											2	0.34					1	0.2
TOTALS	**74**	**31.9**	**287**	**41.1**	**208**	**34.2**	**240**	**47.9**	**373**	**43.7**	**272**	**45.8**	**129**	**45.951**	**274**	**39.9**	**229**	**35.2**
Timber-Foliage Searching																		
Cassin's Vireo											1	0.20						
MacGillvery's Warbler	1	0.4																
Mountain Chickadee			4	0.6	1	0.2	1	0.2	6	0.7	3	0.5	4	1.4	8	1.2	2	0.3
Orange-crowned Warbler									5	0.7	2	0.3	2	0.7	3	0.4	9	1.4
Plumbeous Vireo	2	0.9	2	0.3	15	2.5			19	2.2	5	0.8	12	4.2	25	3.7	10	1.5
Red-breasted Nuthatch			2	0.3											3	0.4		
Steller's Jay	1	0.4	7	1	1	0.2	10	2	16	1.9	33	5.6	11	3.9	52	7.6	30	4.6
Virginia's Warbler											1	0.2	3	1	21	3.1	5	0.8
Warbling Vireo			1	0.1	3	0.5	1	0.2	30	3.5	19	3.2	7	2.5	17	2.5	27	4.1
Western Tanager	1	0.4	10	1.4	17	2.8	32	6.4	36	4.2	37	6.2	16	5.6	49	7.2	47	7.2
Yellow-rumped Warbler	4	1.7	53	7.6	45	7.4	13	2.6	41	4.8	19	3.2	12	4.2	11	1.6	18	2.8
TOTALS	**9**	**3.8**	**79**	**11.3**	**82**	**13.5**	**57**	**11.4**	**153**	**18**	**119**	**20.0**	**67**	**23.5**	**189**	**27.7**	**148**	**22.7**
Aerial Flycatcher																		
Common Nighthawk	6	2.6	3	0.4	7	1.1					16	2.7	2	0.7	1	0.1		
Northern Rough-winged Swallow							25	5										
Olive-sided Flycatcher											1	0.2						
Tree Swallow							7	1.4			1	0.2	4	1.4	1	0.1		
Violet-green Swallow	29	12.5	109	15.7	77	12.6	11	2.2	38	4.4	14	2.4	3	1.1	41	6	45	6.9
White-throated Swift													3	1.1				
TOTALS	**35**	**15.1**	**112**	**16.1**	**84**	**13.8**	**43**	**8.6**	**38**	**4.4**	**32**	**5.4**	**12**	**4.3**	**43**	**6.2**	**45**	**6.90**
Flycatcher																		
Cordilleran Flycatcher			5	0.7			3	0.6	19	2.2	2	0.3			4	0.6	18	2.8
Dusky Flycatcher															1	0.1		
Grace's Warbler					15	2.5			11	1.3					4	0.6	3	0.5
Lewis's Woodpecker	1	0.4															3	0.5
Say's Phoebe							2	0.4			2	0.3			4	0.6	2	0.3
Western Wood-Pewee	20	8.6	63	9.1	55	9.0	83	16.6	153	17.9	94	15.8	14	4.9	29	4.2	59	9.0
Yellow Warbler							2	0.4										
TOTALS	**21**	**9**	**68**	**9.8**	**70**	**11.5**	**90**	**18**	**183**	**21.4**	**98**	**16.5**	**14**	**4.9**	**42**	**6.1**	**85**	**13.0**
Timber Drilling / Gleaning																		
Brown Creeper					1	0.2									1	0.1		
Downy Woodpecker	1	0.4					3	0.6									1	0.2
Hairy Woodpecker	2	0.9	10	1.4	6	1.0	2	0.4	7	0.8	7	1.2	1	0.4	5	0.7	15	2.3
Pygmy Nuthatch	17	7.3	81	11.6	92	15.1	7	1.4	55	6.4	27	4.5	12	4.2	57	8.3	90	13.8
Red-naped Sapsucker							2	0.4										
Three-toed Woodpecker											3	0.5						
White-breasted Nuthatch	11	4.7	23	3.3	34	5.6	23	4.6	29	3.4	20	3.4	4	1.4	17	2.5	14	2.1
Williamson's Sapsucker	1	0.4							1	0.1	1	0.1	7	2.45			1	0.2
TOTALS	**32**	**13.7**	**114**	**16.3**	**133**	**21.8**	**37**	**7.4**	**92**	**10.7**	**58**	**9.7**	**24**	**8.45**	**80**	**11.6**	**121**	**18.6**
Corvid																		
American Crow	10	4.3	6	0.9	5	0.8	4	0.8	2	0.2	3	0.5	2	0.7	8	1.2	3	0.5
Common Raven			14	2			1	0.2			1	0.2	11	3.9	12	1.8	8	1.2
Black-billed Magpie							2	0.4										
TOTALS	**10**	**4.3**	**20**	**2.9**	**5**	**0.82**	**7**	**1.4**	**2**	**0.2**	**4**	**0.67**	**13**	**4.6**	**20**	**3**	**11**	**1.7**
Raptor																		
American Kestrel							1	0.2										
Bald Eagle							2	0.4									1	0.2
Cooper's Hawk															1	0.1		
Goshawk															1	0.1		
Great Horned Owl					1	0.2			3	0.4								
Osprey	1	0.4	1	0.1														
Peregrine Falcon																	1	0.2
Red-tailed Hawk	1	0.4					1	0.2	4	0.5	1	0.2	6	2.1	4	0.6		
Sharp-shinned Hawk																	1	0.2
Turkey Vulture	1	0.4	1	0.1	1	0.2	6	1.2	3	0.4	2	0.3	8	2.8	10	1.5	6	0.9
TOTALS	**3**	**1.2**	**2**	**0.2**	**2**	**0.33**	**10**	**2**	**10**	**1.3**	**3**	**0.51**	**14**	**4.9**	**16**	**2.3**	**9**	**1.5**
Nectar Feeding																		
Black-chinned Hummingbird									1	0.1								
Broad-tailed Hummingbird	1	0.43	6	0.9	2	0.3	2	0.4	3	0.4			2	0.7	11	1.6	3	0.5
TOTALS	**1**	**0.43**	**6**	**0.9**	**2**	**0.33**	**2**	**0.4**	**4**	**0.5**	**0**	**0.00**	**2**	**0.7**	**11**	**1.6**	**3**	**0.46**
Other																		
Great Blue Heron											1	0.2			1	0.2	1	0.2
Mallard																	1	0.2

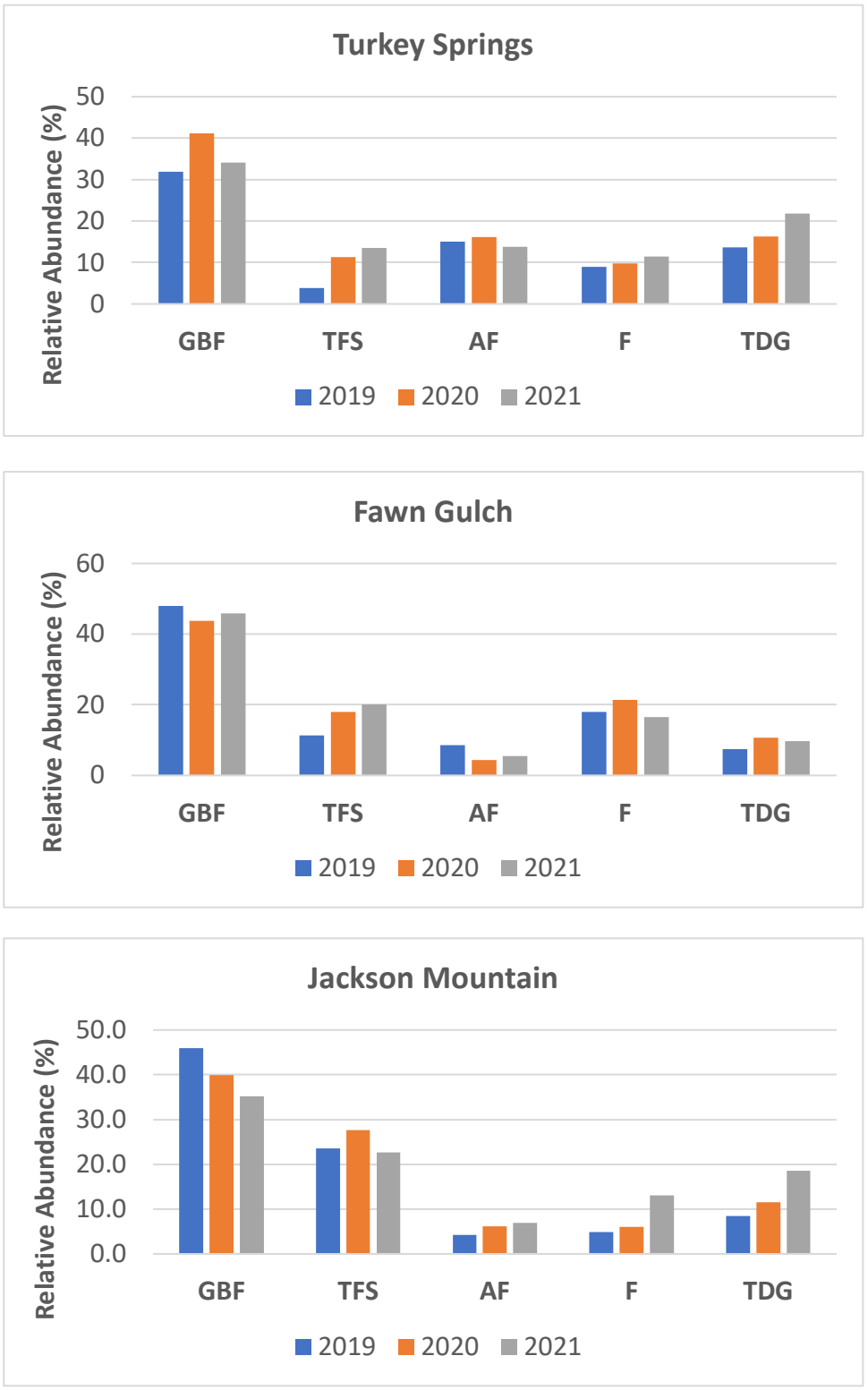

Figure 13. Relative abundances of bird species feeding guilds at Turkey Springs; Fawn Gulch; and Jackson Mountain study sites. GBF = Ground/Brush Foraging; TFS = Timber Foliage Searching; AF = Aerial Flycatcher; F = Flycatcher; and TDG = Timber Drilling/Gleaning.

Cavity Nesting Species										
	2019			2020			2021			Conservation
Species	Sites	Freq	Rel Freq	Sites	Freq	Rel freq	Sites	Freq	Rel freq	Score
Species Recorded in both 2019 And 2020										
Primary Cavity Nesters										
Downy Woodpecker	TS, FG	2	0.3	none	none	none	JM	1	0.08	7
Hairy Woodpecker	TS, FG, JM	9	1.4	TS, FG, JM	20	1.3	TS, FG, JM	23	1.73	6
Northern Flicker	TS, FG, JM	33	5.1	TS, FG, JM	64	4.1	TS, FG, JM	79	5.95	10
Three-toed Woodpecker	none	none	none	none	none	none	FG	2	0.15	10
Williamson's Sapsucker	TS, JM	5	0.8	FG	1	0.1	JM	1	0.08	12
Primary or Secondary Cavity Nesters										
Black-capped Chickadee	JM	1	0.2	TS, FG, JM	25	1.6	TS, JM	6	0.45	7
Lewis's Woodpecker	TS	1	0.2	none	none	none	JM	3	0.23	15
Red-breasted Nuthatch	none	none	none	TS, JM	2	0.1	none	none	none	6
Red-naped Sapsucker	FG	2	0.3	none	none	none	none	none	none	9
Pygmy Nuthatch	TS, FG, JM	48	7.4	TS, FG, JM	114	7.2	TS, FG, JM	117	8.82	11
Secondary Cavity Nesters										
American Kestrel	FG	1	0.2	none	none	none	none	none	none	11
Ash-throated Flycatcher	none	none	none	none	none	none	FG	1	0.08	8
European Starling	none	none	none	TS	1	0.1	none	none	none	5
House Wren	JM	2	0.3	TS, FG, JM	45	2.9	TS, FG, JM	13	0.98	5
Mountain Bluebird	FG	1	0.2	none	none	none	TS	1	0.08	12
Mountain Chickadee	FG, JM	3	0.5	TS, FG, JM	12	0.8	none	none	none	10
Tree Swallow	FG, JM	4	0.6	JM	1	0.1	none	none	none	8
Violet-green Swallow	TS, FG, JM	97	14.9	TS, FG, JM	89	5.6	TS, FG, JM	74	5.58	9
Western Bluebird	TS, FG	9	1.4	TS, FG, JM	34	2.2	TS, FG	40	3.01	9
White-breasted Nuthatch	TS, FG, JM	31	4.7	TS, FG, JM	55	3.5	TS, FG, JM	61	4.60	6

Table 15. Summary of cavity nesting species identified across all three years of the study. 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 16 and 17)

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 were present in very low numbers, along with Downy Woodpeckers and Lewis's Woodpeckers. The observation that these uncommon species decreased from 2019 to 2021, or were observed only in one or two of the three years of study, suggests that their presence or absence was a consequence of year-to-year variability in bird community composition and was not affected by sample density.

Most notable among the cavity nester are those exhibiting conservation scores of 12 or higher, indicating some concern for the sustainability of their populations. These include Williamson's Sapsucker, Lewis's Woodpecker, and the Mountain Bluebird. Regardless of conservation status, cavity nesting bird species fulfill a critical role in forest ecosystems through their consumption of insects and other invertebrates that, if their population numbers are left unchecked, can have significant impacts on other measures of ecosystem function.

Comparative Studies:

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, and at TS through 2021 (see Tables 7 and 8). 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 and 2021 (see Tables 7 and 8). Their numbers also increased at FG and JM in 2020 compared to 2019, but decreased at these two sites in 2021.

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 species found at 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 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 (untreated) sites (see Table 14). 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, and at TS in 2020 and 2021 as the oak shrub layer recovered from prescribed fire.

Consistent with the findings of Lowe et al., (1978), TDG species show a pattern of decline in relative abundance across our study sites within years with TS > JM > FG (see Fig. 13). One reason reported in the literature 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). Findings reported in the literature regarding TDG bird species is consistent with the increasing trend in relative abundance of TDG species noted for the TS site in our study from 2019 to 2021.

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 16, 17, and 18). 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 82 bird species documented over the course of this study, 29 species have shown population declines since the late 1960's, and 32 species have CC scores of 10 or greater (Tables 16, 17, and 18). Six of the species we recorded over the three years of our study – Lewis's Woodpecker, Virginia's Warbler, Cassin's Finch, Band-tailed pigeon, Grace's Warbler, and Olive-sided Flycatcher – 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, noted as an incidental in 2020, with three Lewis's Woodpecker sightings at JM in 2021. Similarly, Virginia's Warbler was documented only at the JM site in 2019 and 2020, but recorded at FG and JM in 2021. Cassin's Finch was one of the unique species at the FG site in 2019, but occurred at the TS site in 2020, and was seen at both TS and FG in 2021. The recurring sightings of Band-tailed Pigeons at the FG site was one of the most exciting observations of 2020, complemented by a single siting at JM in 2021. Grace's Warbler was noted as an incidental in 2019, but was sighted much more commonly at both FG and JM in 2020 and at TS and JM in 2021. Finally, an Olive-sided Flycatcher was recorded at FG in 2021.

Of the remaining bird species with CC scores > 10, four were found at all three of our study sites in 2019 (Tables 16, 17, and 18). 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. 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 10 and 11. Overall, FG stands out as the site with the greatest number of sightings of bird species with CC scores > 10, with 14 species in 2019, 4 in 2020, and 3 in 2021, and is the site where most of the species with the highest CC scores were observed.

One of the most exhilarating sightings across all three years of our study was that of a nesting pair of Common Nighthawks at the TS site in 2019 (Grover et. al., 2019), and another siting at FG in 2021. 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. In 2021, a Common Nighthawk nest was identified at both the FG and TS sites, and we were able to document fledgling success for both nests.

The Pine Siskin, another species in steep decline, was observed at the FG site in 2019 (Table 14). In 2020, Pine Siskins were observed in small numbers at TS (see Appendix A), but were not recorded at any of our study sites in 2021. 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, Warbling Vireo, Williamson's Sapsucker, and House Wren nests at the JM site, and the cavity nest for Northern Flickers at the TS, FG, and JM sites in 2019, 2020, and 2021. 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 17), 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 time, underscoring the significance of 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 17, 18, and19) reveals several species that could 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 16. 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 17. 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. = 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
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	

Table 18. Summary of conservation status of bird species recorded in this study in 2021. Conservation status categories, concern scores, and estimates of population status are taken from Cornell Laboratory of Ornithology website – www.allaboutbirds.org. = unique to one site.

		Abundance by Site			Conservation	Concern	Population		Estimated	
Common Name	Scientific Name	TS	FG	JM	Status	Score	Status	% decline	Population	Notes
American Three-toed Woodpecker	Picoides dorsalis		3		Low	10	increasing		1.6M	favors mature forests, vulnerable to habitat fragmentation
Ash-throated Flycatcher	Myiarchus cinerascens		1		Low	8	increasing		7.4M	
Cassin's Vireo	Vireo cassinii		1		Low	10	increasing		5M	vulnerable to logging activities
Mallard	Anas platyrhynchos	1			Low	7	increasing		11.6M	
Olive-sided Flycatcher	Contopus cooperi		1		Watch	13	decline	79%	1.9M	vulnerable to loss of wintering habitat
Peregrine Falcon	Falco peregrinus			1	Low	10	stable		140,000	vulnerable to pesticides, especially DDT
Sharp-shinned Hawk	Accipiter striatus	1			Low	7	stable		700,000	vulnerable to pesticides, especially DDT

Summary and Conclusions:
The scientific question examined by this study concerned the potential effects of wildland fuel reduction treatments (i.e., prescribed fire or shrub layer mastication) on bird community composition in the dry, mixed-conifer forests of southwestern Colorado. As a citizen science project, other complementary objectives of the study included raising awareness among participants regarding 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; 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 (e.g., bird species mis-identification, uneven sampling frequencies, etc.) are embedded in the study, as may be the case with any citizen science project. Nonetheless, the dataset we have generated by returning to the same sites and monitoring points at the same time of year over a three-year period represents an invaluable resource for understanding year-to-year variability in bird community composition in our area; the response of the bird community to wildland fuel reduction treatments; and other factors that should be accounted for when considering alternative forest management practices.

Bird Community Response to Prescribed Fire and Mastication-
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 untreated, old-growth site. Our data revealed a reduction in bird species richness, abundance, and overall diversity at the TS site immediately following prescribed fire treatments in early June, 2019. Recovery of the shrub layer at the TS site was clearly evident by 2021, with subsequent changes in the bird community to render this site more like FG and JM in species composition and feeding guilds.

Comparing 2019, 2020 and 2021 datasets reveal that increased sampling frequency and involvement of more observers per site visitation (i.e., sampling density; see Tables 2 and 5) in 2020 and 2021 contributed to a substantial increase in the number of birds recorded, but had a marginal impact on the increased number of species recorded. 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 song.

Commonness vs. Rarity of Bird Species-
Patterns in commonness vs. rarity that have been noted in ecological studies over the past century of ecological research was revealed by the findings of our study. Of the 82 bird species observed across the three years of this study, 37 were observed in all three years, and 12 of those bird species were observed at all three sites in all three years (Tables 10, 11, and 12). Notably, 8 of the 12 species observed at all three sites across years were among the most abundant species counted (Table 10). The 37 bird species observed in all three years accounted for over 95% of all birds counted, and 67% of the 5031 birds observed in this study were accounted for by the 12 species seen at all three sites in all three years.

The commonness vs rarity issue begs the question: Which species are more important to focus on when considering management options or when monitoring forest health – common species, or uncommon/rare species? Certainly, the most common and most abundant bird species are likely to have the greatest quantitative impact on populations of insects and other invertebrates that they feed upon, and which could potentially impair forest health through defoliation, tree death, or spread of disease. But the absence of uncommon or apparently rare species may have inordinate consequences for ecosystem functionality as well (e.g., Leitao et. al., 2016). Flather and Sieg (2007), and Gaston (2011) provide a thorough analysis of issues concerning uncommon/rare species contributions to ecosystem function (e.g., functional complementarity, redundancy, and asynchrony), concluding that protection of uncommon species deserves our full attention in order to enhance ecosystem resilience in response to changing environments.

Certainly, issues surrounding the ecological roles of uncommon/rare species are superseded by the ethical precept that all species possess intrinsic value and that protecting biodiversity has value in and of itself (e.g., Sandler, 2012; Palmer et. al., 2014). Many writers, citing the life's work of icons such as Aldo Leopold; Stephen J. Gould; E.O.

Wilson; and others, underscore the significance of the intrinsic value of species as foundational to the field of conservation biology (e.g., Piccolo, 2017; Schweiger, 2009). There is also a substantial literature produced by accomplished scientists invoking a theological basis for protecting species based on intrinsic value (e.g., DeWitt, 2000; Van Dyke, 2010). Hence, we conclude that evaluating and categorizing forest management practices based on potential impacts on common vs. uncommon/rare species is a false dichotomy – the potential impacts of management practices on all species must be carefully considered, regardless of their relative abundances.

Nesting vs. Feeding Behaviors and Ecosystem Resilience-
Ibarra et al. (2017) address complementary issues to the commonness/rarity topic in the context of forest resilience, with a focus on forest management practices that interfere with the success of tree cavity nesting bird species (e.g., logging; thinning; and fire). Indeed, the cavity nesting species identified across the three years of this study accounted for almost 30% of all birds counted, with the 6 most common cavity nesting species (Hairy Woodpecker, Northern Flicker, Pygmy Nuthatch, Violet-green Swallow, Western Bluebird, and White-breasted Nuthatch) accounting for about 27.5% of all birds counted (see Tables 14 and 15). Moreover, looking across the range of cavity nesting species found at our sites, several feeding guilds are represented. Of the 20 cavity nesting species observed in our study (see Table 15), 7 belong to the TDG feeding guild; 6 to the GBF guild; 2 to the TFS guild; 3 to the AF guild; 1 to the F guild; and 1 is a raptor (American Kestrel) (see Table 14). Of the 6 most common cavity nesting species, 3 belong to the TDG guild (Hairy Woodpecker, Pygmy Nuthatch, and White-breasted Nuthatch); 2 to the GBF guild (Northern Flicker, Western bluebird); and 1 belongs to the AF guild (Violet-green Swallow). The distribution of cavity nesting bird species across feeding guilds, along with their numerical importance in this study, affirms that forest management practices that are protective of potential cavity nesting sites (e.g., dead snags) are critical to enhancing forest resilience to changing environmental conditions that might promote population growth in potentially harmful insect or invertebrate species.

Secondary Objectives-
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 in each year of the study 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.

Recommendations for Future Work:
In response to the enthusiasm shared by participants in the 2019 and 2020 field seasons, we continued the project into 2021 with increased participation by first and second-year observers and the addition of several new volunteers. A fourth 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 10 visits to each loop would provide adequate data for our analysis. Continued engagement of participants in bird identification workshops, particularly identification by song, would also prove valuable.

As noted in our 2019 and 2020 reports (Grover et. al., 2019, and 2020), the need for more detailed data on plant community structure is essential for understanding the response of the bird community to wildland fuel reduction treatments. 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.

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Appendix A
Data Summaries from First and Second Year Reports:

Table 3 (from Grover et. al., 2019). 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

Table 2 (from Grover et. al., 2020). 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