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Title: 2022 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory

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2022 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, Technical Area 16 Burn Ground, and DARHT at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY

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Cover photo: A Violet-green Swallow (*Tachycineta thalissina*) captured during a Monitoring Avian Productivity and Survivorship (MAPS) banding session in Sandia Canyon June 2022. Photo credit: Elisa Abeyta.

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EXECUTIVE SUMMARY

Los Alamos National Laboratory (LANL) biologists in the Environmental Protection and Compliance Division initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property, with additional monitoring beginning in 2017 at a third firing site. In this annual report, we compare monitoring results from these efforts among years to assess trends in local migratory bird communities. The objectives of this study are

- to determine whether LANL operations impact bird abundance, species richness, or diversity; and
- to examine occupancy and nest success of secondary-cavity nesting birds that use nest boxes.

LANL biologists completed the tenth year of this effort in 2022.

Between May and July 2022, biologists completed three avian point count surveys at each of the treatment sites:

- Technical Area (TA)-36 Minie site,
- TA-39 Point 6,
- TA-16 Burn Ground, and
- Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT).

We recorded a total of 1,182 birds representing 63 species at the four treatment sites and compared these results with data from their associated control sites. We also compared occupancy and nest success data from nest boxes at treatment sites with the overall avian nest box monitoring network and against a subset of relevant control sites.

In 2022, abundance and species richness at treatment and control sites continued to trend similarly from year to year with minor random deviations, indicative of a stable avian community. Though richness remained stable across all sites, two new bird species were observed at the treatment sites—Bullock's Oriole and Painted Redstart. The species diversity at the TA-36 Minie site, TA-39, and DARHT were statistically higher than their associated controls. The species diversity at all three treatment sites has been consistently lower at control relative to treatment sites, likely due to subtle habitat differences. Annual diversity at treatment sites in 2022 remains stable relative to past years. Overall diversity remains high across all sites relative to similar habitats.

Nest box occupancy and success continue to fluctuate annually; however, a long-term discrepancy between occupancy and nest success at treatment sites in ponderosa pine habitat warrants further data collection and analyses.

The overall results from 2022 continue to suggest that operations at the four treatment sites are not negatively impacting bird populations. This long-term project will continue to monitor for any changes over time.

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1 Introduction

As part of the Resource Conservation and Recovery Act permit process, Los Alamos National Laboratory (LANL) started an annual avian monitoring program in 2013. The permit was for two open detonation sites—Technical Area (TA)-36 Minie site and TA-39 Point 6; and one open burn site—TA-16 Burn Ground (hereafter referred to as Minie, TA-39, and TA-16, respectively; or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock, Thompson, and Berryhill 2017; Hathcock, Bartlow, and Thompson 2018; Hathcock et al. 2019; Sanchez, Hathcock, and Thompson 2020; Rodriguez and Abeyta 2021). LANL biologists have been conducting point counts and monitoring nest boxes near an additional firing site, the Dual-Axis Radiographic Hydrodynamic Test Facility (DARHT) since 2017. Results for DARHT are included in this report. The objectives of this long-term monitoring program are

- to determine whether LANL operations impact bird abundance, species richness, or diversity; and
- to examine occupancy and nest success of secondary-cavity nesting birds that use nest boxes.

This effort involves comparing community and nest box metrics at treatment sites with control sites of similar habitat that LANL biologists have surveyed since 2011 (Hathcock, Zemlick, and Norris 2011).

LANL biologists used standard point count methodology to record avian abundance, richness, and diversity along transects at the three treatment sites and their associated control sites during the summer of 2022. Summer surveys provide information about which bird species could be breeding at each site. These surveys are most valuable when they are conducted over multiple years because they provide long-term trend data that can be compared with local, regional, or national trends in bird populations. These data can also be used to test for correlations between bird communities and the natural environment, including environmental changes at LANL.

Although point counts are a reliable way to assess community level metrics, their utility in detecting fine-scale landscape differences may be limited (Ralph, Sauer, and Droege 1995). Point counts cannot distinguish between birds that use the local habitat to breed versus itinerant individuals that migrate through or temporarily forage locally. Assessing the success of birds known to nest in close proximity to firing (treatment) sites and those that nest in similar habitats away from firing (control) sites provides increased power to connect local environmental disturbances with local biology. To perform this assessment, LANL biologists monitored nest boxes around all four treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success were compared with the overall avian nest box monitoring network, which was established in 1997 (Fair and Myers 2002), and a subset of sites of similar habitat type and nest box number.

2 Methods

2.1 Field Methods for Point Count Surveys

LANL biologists conducted the point count surveys along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 2-1 through 2-5). The habitat types around the sites are a pinyon (*Pinus edulis*)-juniper (*Juniperus monosperma*) woodland (PJ) at Minie (Figure 2-1) and TA-39 (Figure 2-2) and a ponderosa pine (*Pinus ponderosa*) forest (PIPO) at TA-16 (Figure 2-3) and DARHT (2-4). The habitat descriptions are based on the 1/4 ha physiognomic cover classes in the LANL land cover map (McKown et al. 2003). The treatment and control sites (5) are monitored annually. The control sites were originally established in 2011 (Hathcock, Zemlick, and Norris 2011). Each habitat type control contained two replicate transects that LANL biologists monitored in the same way as the treatment sites, with the same number of points and during the same time periods. In each survey month, all treatment and control site transects are surveyed in a random order. Note that due to fire restrictions in 2022, biologists were unable to survey PJ control transects in June.

The treatment sites at Minie and TA-39 are similar to the PJ control sites at TA-70 and TA-71 in elevation, vegetation, and proximity to developed areas; however, the transect at TA-39 is in the canyon bottom, whereas the controls are on mesa tops. The treatment sites at TA-16 and DARHT are similar in elevation and overstory vegetation to the PIPO control sites, and all are on mesa tops. One of the PIPO control transects is adjacent to development, and the other transect is in an undeveloped area.

Transects are approximately 2.0 to 2.5 km in length, with nine survey points spaced approximately 250 m apart. These survey routes and points can change slightly over time due to construction activities or access constraints. The timeframe for breeding bird surveys is May 11 through July 9. Ideally, the breeding bird surveys should take place during the second week of May, June, and July. This protocol requires a total of three surveys per site conducted between 0.5 hours before sunrise and 4 hours after sunrise.

The following steps apply to breeding bird surveys:

- Each survey consists of nine points along a transect spaced approximately 250 m apart.
- The surveyor looks and listens for 5 minutes, recording all birds encountered at each point on a data sheet. For each observation, the minimum data collected is point number, time, species, number of individuals, and distance from the point. The observation distance is considered as an "unlimited-distance circular plot"; however, surveyors record the distance to each bird out to an estimated 100 m. A range finder should be used if available. Surveyors avoid re-counting individuals between points.
- While walking between points, surveyors record any obvious species not recorded at the previous point that also would not be counted at the next point. Surveyors do not spend excess time looking for birds between points.
- Surveyors do not conduct surveys during rain events or during winds greater than 24 kph.
- Surveyors use the "NOTES" section to document additional information about the survey that may affect the data. Examples include excess noise from nearby equipment, vehicles, or aircraft that make it hard to hear the birds. Surveyors also record other wildlife or unusual sightings that could be useful for other projects.

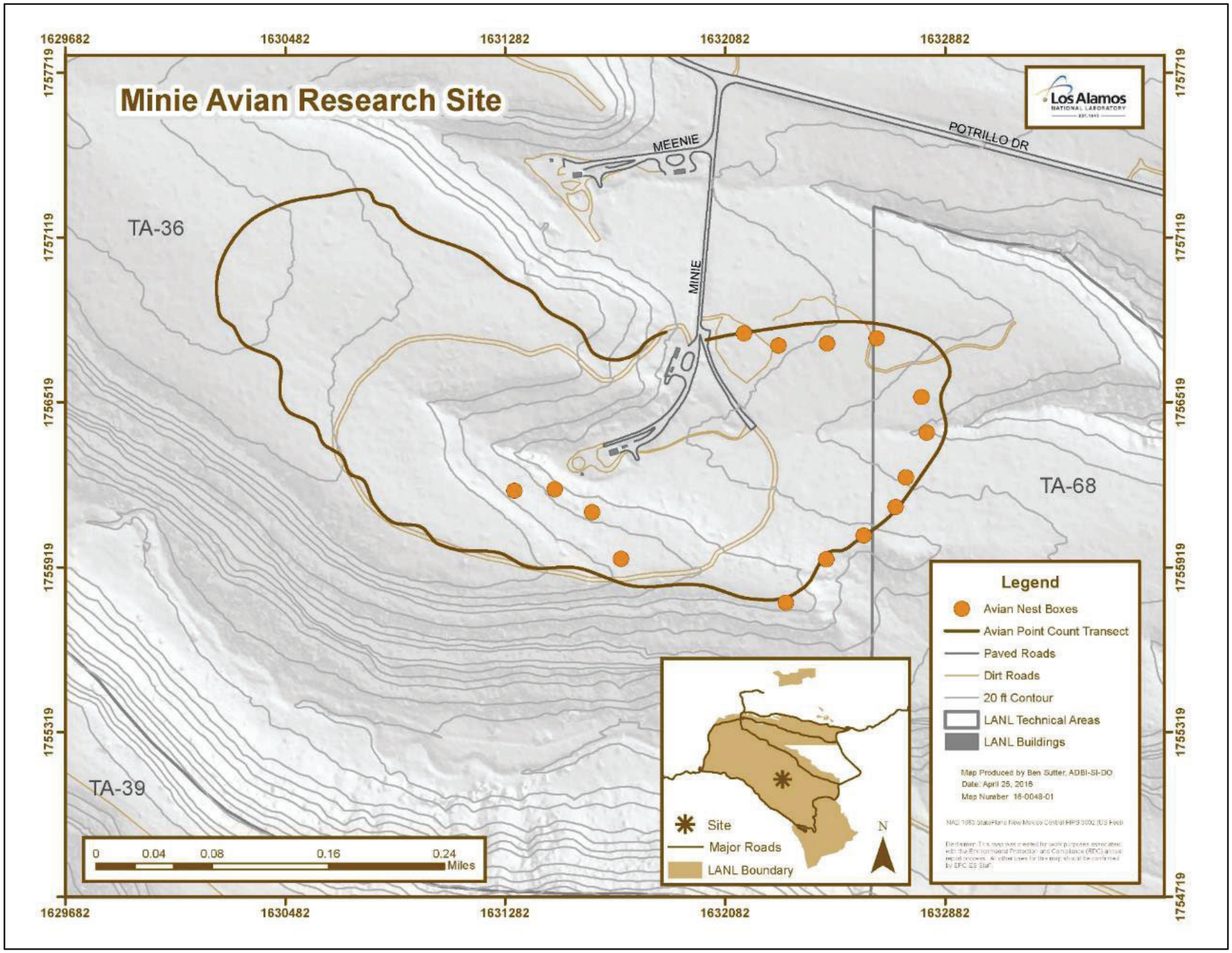

Figure 2-1. Breeding bird survey transect and nest box locations around TA-36 Minie Site.

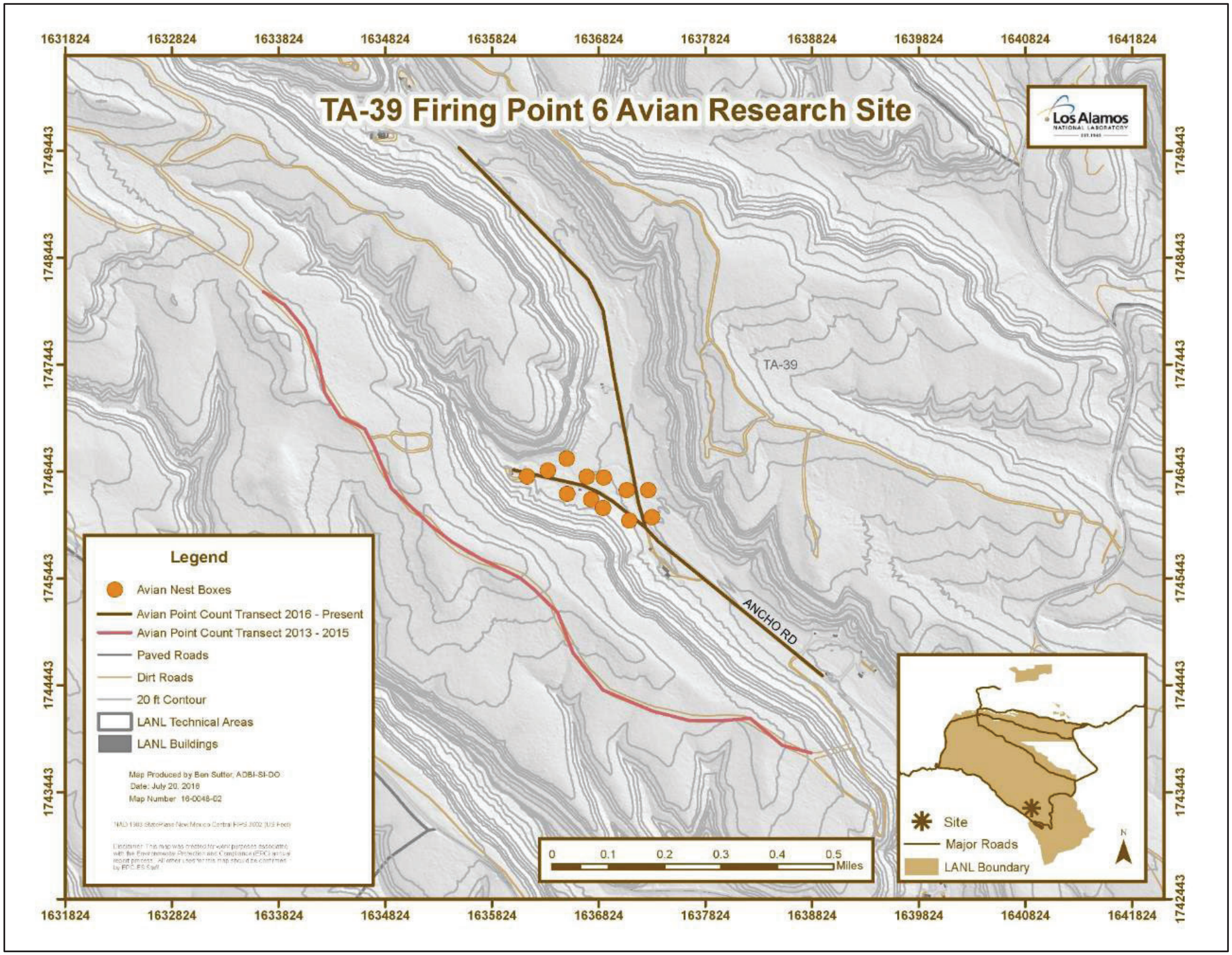

Figure 2-2. Breeding bird survey transect and nest box locations around TA-39 Point 6.

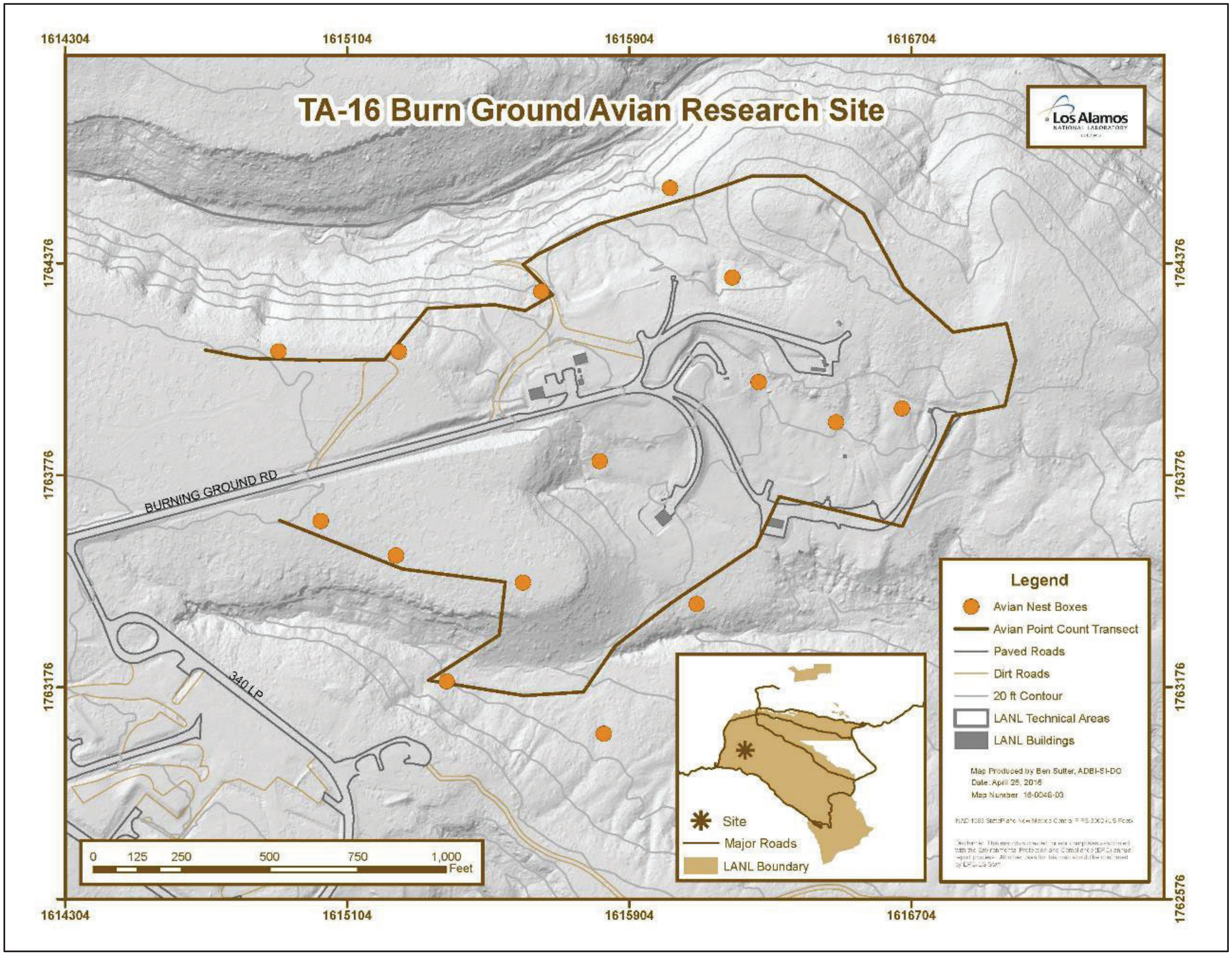

Figure 2-3. Breeding bird survey transect and nest box locations around TA-16 Burn Ground.

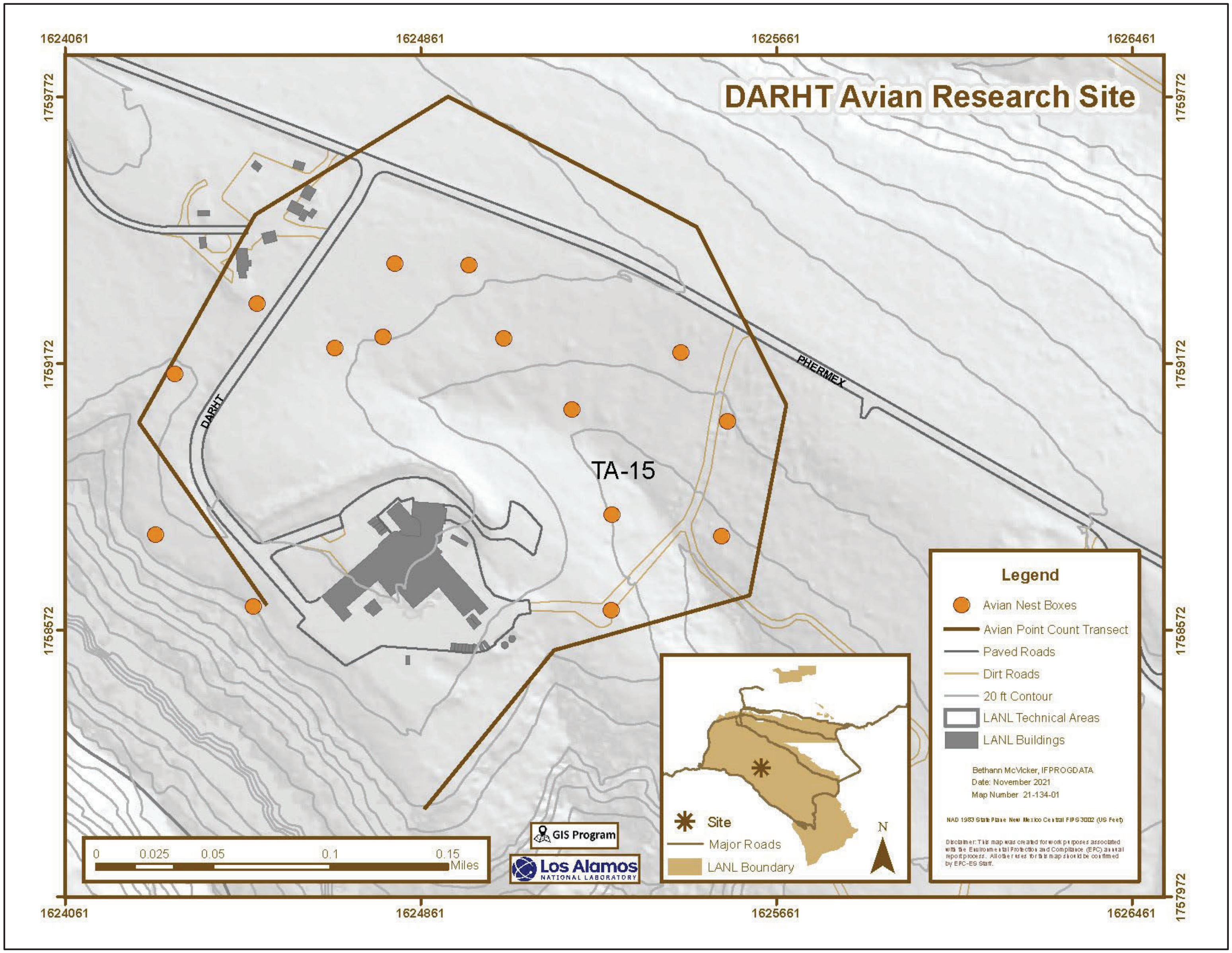

Figure 2-4. Breeding bird survey transect and nest box locations around DARHT.

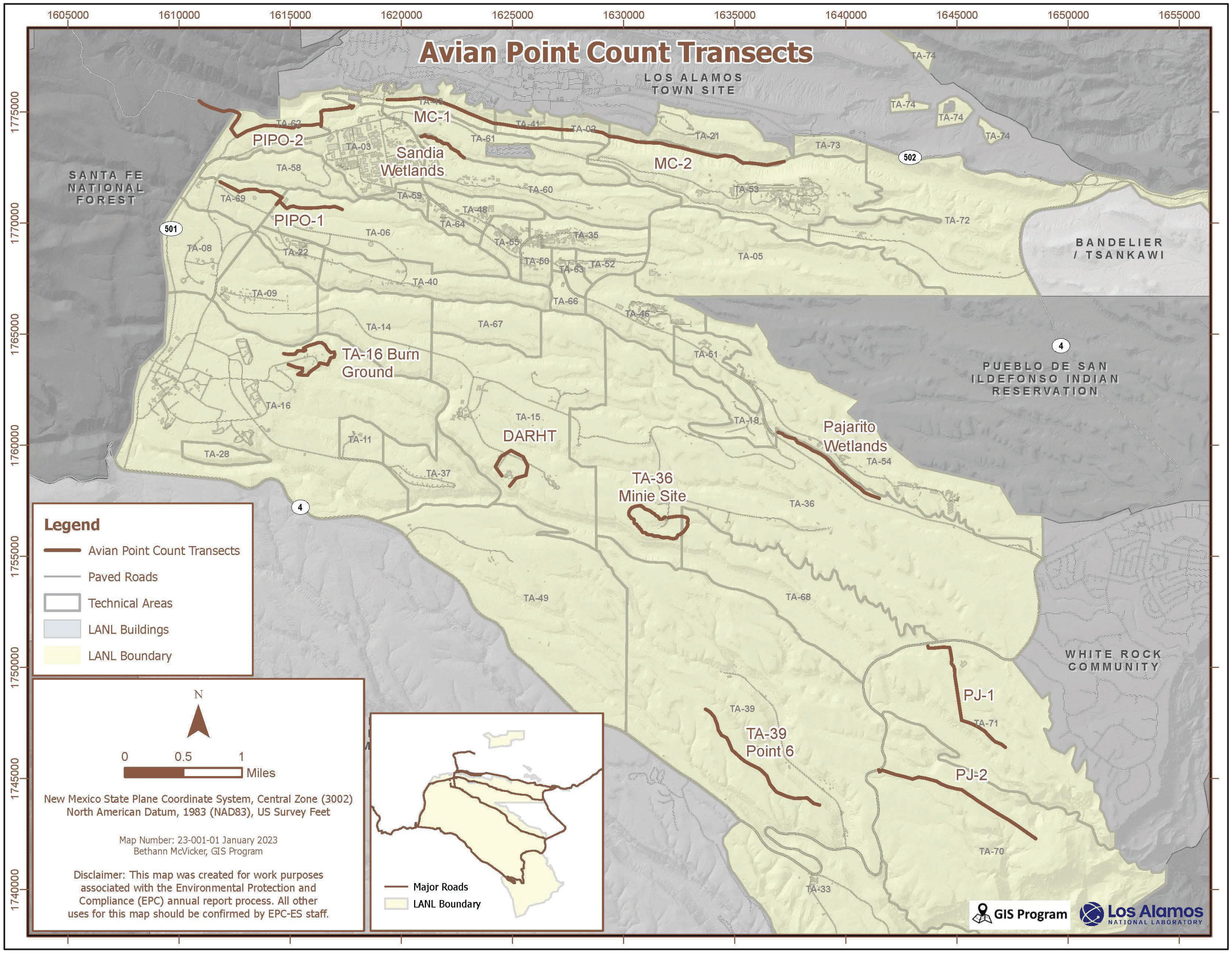

Figure 2-5. All avian point count transects around LANL ponderosa pine forest (PIPO); pinyon-juniper woodland (PJ).

2.2 Statistical Methods for Point Counts

We summarized breeding bird survey data to compare abundance, species richness, and diversity between treatment and control sites and over time. We considered each treatment site and control to be individual communities and compared averaged metrics by combining treatment and control sites within the same habitat class.

Abundance is the total number of individuals recorded of a given species (Gotelli and Colwell 2011). Species richness is the number of different species represented in an ecological community and is simply a count of species (Boulinier et al. 1998). Species diversity is a measure that considers species richness and the overall abundance to compare evenness across a community (Tramer 1969). As a species diversity metric, we used Shannon's diversity index, which measures the probability that two individuals randomly selected from a sample will belong to different species (Shannon and Weaver 1949; Clarke et al. 2014). We used the diversity index to compare diversity between treatment and control sites. Shannon's diversity ranges for most ecological systems are between 1.5 and 3.5 and are rarely greater than 4.5, where high values indicate high diversity.

We calculated all community metrics using the statistical software R (version 4.2.2; R Core Team 2022 and the package *Vegan* (Dixon 2003) and used simple linear models to estimate coarse trends across the study period. We used Hutcheson's t-tests in the R package *ecolTest* (Salinas and Ramirez-Delgado 2021) to test for differences between treatment and combined (averaged species abundances) control site diversity for each year from 2013 to 2022.

2.3 Field Methods for Nest Box Monitoring

In 2011, we added nest boxes to Minie and TA-39 (Figure 2-1 and Figure 2-2). In 2015, we added nest boxes to TA-16 (Figure 2-3). In 2017, we added 15 nest boxes to DARHT (Figure 2-4). Beginning in May, we monitored nest boxes every 1 to 2 weeks for active nests. When an active nest was found, we monitored it more frequently to determine whether the nest failed or successfully fledged young. We also banded nestlings and determined the sex after the age of 10 days.

2.4 Statistical Methods for Nest Boxes

We calculated occupancy and nest success rates of the nest boxes at the four treatment sites and in the overall network. For any single site or overall, the occupancy rate was the number of active nest boxes divided by the total number of nest boxes. Similarly, the nest success rate was the number of nest boxes that successfully fledged young divided by the number of active nest boxes. We compared the 2022 data from the four treatment sites with the overall avian nest box network at LANL, which was established in 1997 (Fair and Myers 2002). Because the overall nest box network comprises habitats and conditions not present at treatment sites, we also selected control sites that closely matched habitat type and nest box number of comparable treatment sites to examine nesting success metrics in a more balanced design. We calculated and plotted mean nest occupancy and success estimates by treatment and control sites between habitats across all study years.

3 Results and Discussion: Point Count Surveys for Year 2022

LANL biologists completed three surveys at each of the three treatment sites and PIPO control sites between May and July 2022. Because of fire restrictions, the PJ habitat was not surveyed in June 2022. Table 3-1 summarizes the species richness, diversity, and abundance for 2022 for each treatment and control site. A total of 1,182 birds representing 63 species were recorded at the treatment sites. A full account of the 2013–2022 data is detailed in Appendix A.

Table 3-1. Species Richness, Diversity, and Abundance Recorded during 2022 at All Treatment and Control Sites

	Minie	TA-39	PJ Control 1	PJ Control 2	TA-16	DARHT	PIPO Control 1	PIPO Control 2
Richness	37	36	36	22	41	45	36	37
Diversity	3.31	3.11	2.96	2.27	3.18	3.33	2.86	3.06
Abundance	229	339	209	142	340	274	337	334

3.1 Abundance

Overall bird abundance has trended similarly for both treatment and control. Figure 3-1 and Table B-1 detail abundance measured across all years for all sites. Overall abundance has tended to increase since 2013, with minor fluctuations. These fluctuations show no clear pattern that indicates bird numbers are reduced at treatment sites (Figure 3-1, Table 3-1, and Table B-1). Although mean annual abundance estimates trended higher at PIPO control sites than the comparable firing sites, there was substantial overlap in many years when considering per-survey variation in abundances. Mean annual abundance estimates at PJ controls and treatment sites have trended together across the study period, with treatment sites showing a modest but significant increase over time ($t = 3.31$, $p = 0.01$) (Figure 3-1).

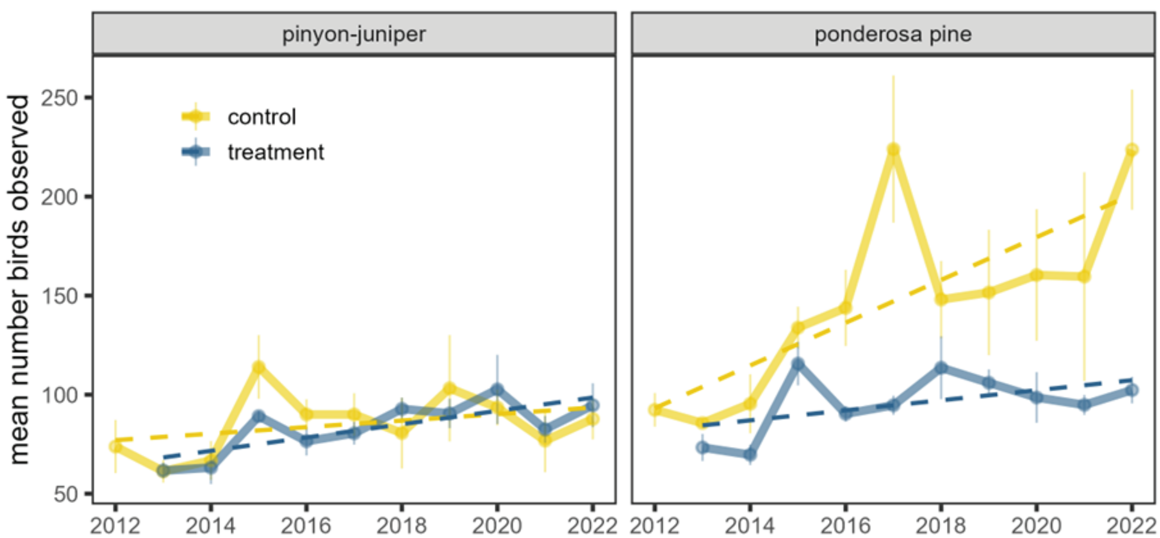

Figure 3-1. Mean bird abundances across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean abundance from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.2 Species Richness

Figure 3-2 and Table B-2 illustrate changes in species richness over time at the treatment and individual control sites. Overall, the mean richness at treatment sites has marginally increased with annual fluctuations since monitoring began (Figure 3-2 and Table B-2). The only significant increase across all years occurred at PJ treatment sites ($t = 2.81$, $p = 0.02$). Species richness at both treatment and control sites has partially trended together with average richness slightly higher than at control sites for most years. Per-survey species richness has markedly diverged between treatment and control sites since 2020 in PIPO habitat (Figure 3-2). Though slight increasing trends seem promising, it cannot be ruled out that survey effort and detectability has changed across the study period, leading to increased identification ability. Future data collection should include surveyors' names to control surveyor variability in ongoing analyses.

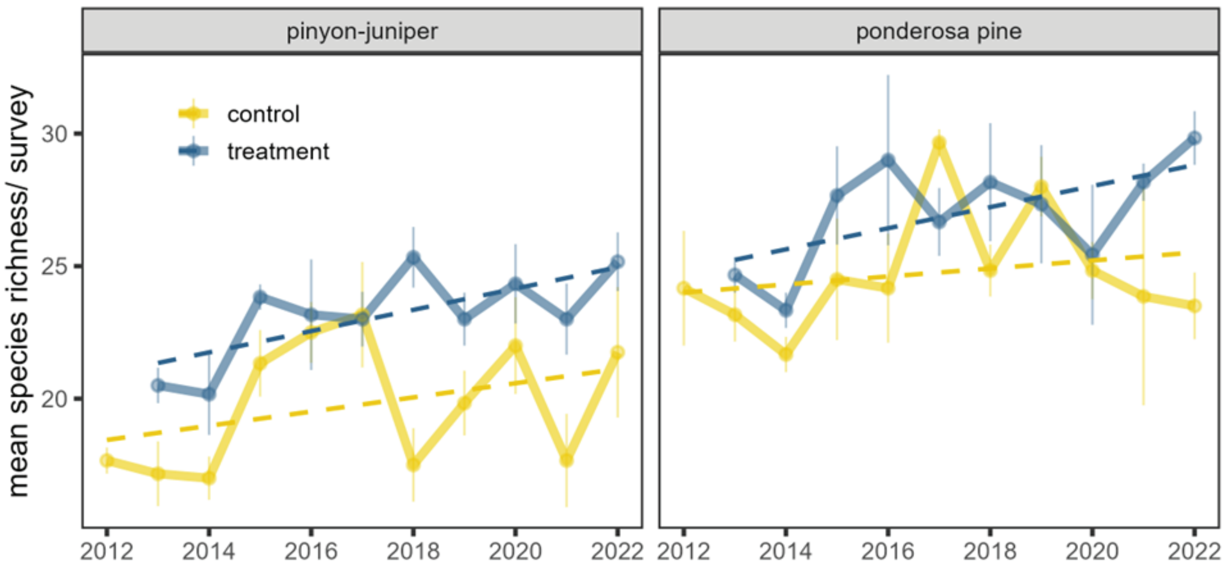

Figure 3-2. Mean bird species richness across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean richness from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.3 Diversity

Figure 3-3 and Table B-3 through Table B-10 illustrate variation in species diversity over time between the treatment and control sites. Both treatment sites in PJ habitat and DARHT in PIPO habitat had significantly higher total diversity than the comparable control sites in 2022 (Table B-3 through Table B-10). Across the entire study window in all significantly different comparisons, the diversity was significantly higher at the treatment site than the combined controls (Table B-3 through Table B-10). Though we see significant differences, the total bird diversity at all sites has remained stable at around 3. Per-survey diversity indices between treatment and control sites in ponderosa pine habitat clearly diverge in 2017, likely driven by the addition of DARHT surveys (Figure 3-3). The generally low ambient disturbance conditions at Weapons Facilities Operations relative to control sites may be driving the higher diversity we observed at treatment sites.

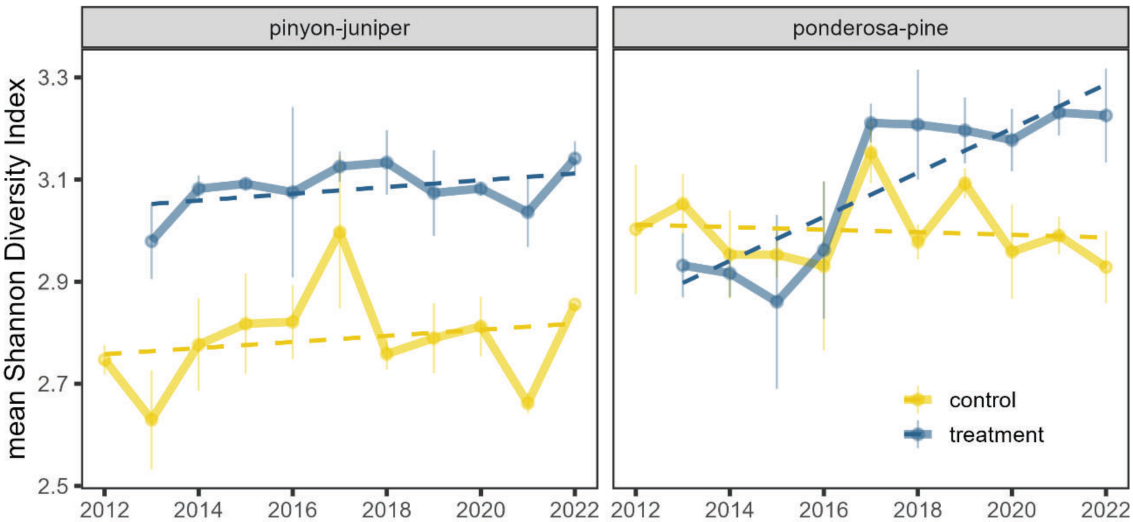

Figure 3-3. Mean Shannon Diversity Index across all years of data collection for control (gold) and treatment (blue) compared by habitat type. Points indicate mean diversity from three annual surveys per site. Vertical lines show standard error among surveys and sites. Thick solid lines connect annual means to show variability in trends. Dashed lines show simple linear model fits.

3.4 Nest Boxes

During the 2022 nesting season, LANL biologists actively monitored 15 nest boxes at each treatment site and a total of 333 nest boxes throughout the overall avian nest box network. Of those, 110 contained active nests, and 49 of those nests fledged young successfully, for an overall occupancy rate of 41 percent and a success rate of 42 percent. Though occupancy rate increased from a historic low in 2021, nesting success rate for 2022 continued to drop to a new recorded low since data collection began in 2015 (Table B-11 and Table B-12). Figure 3-4, Table B-11, and Table B-12 compare the occupancy and nest success rates for each treatment site and the overall nest box network since 2015.

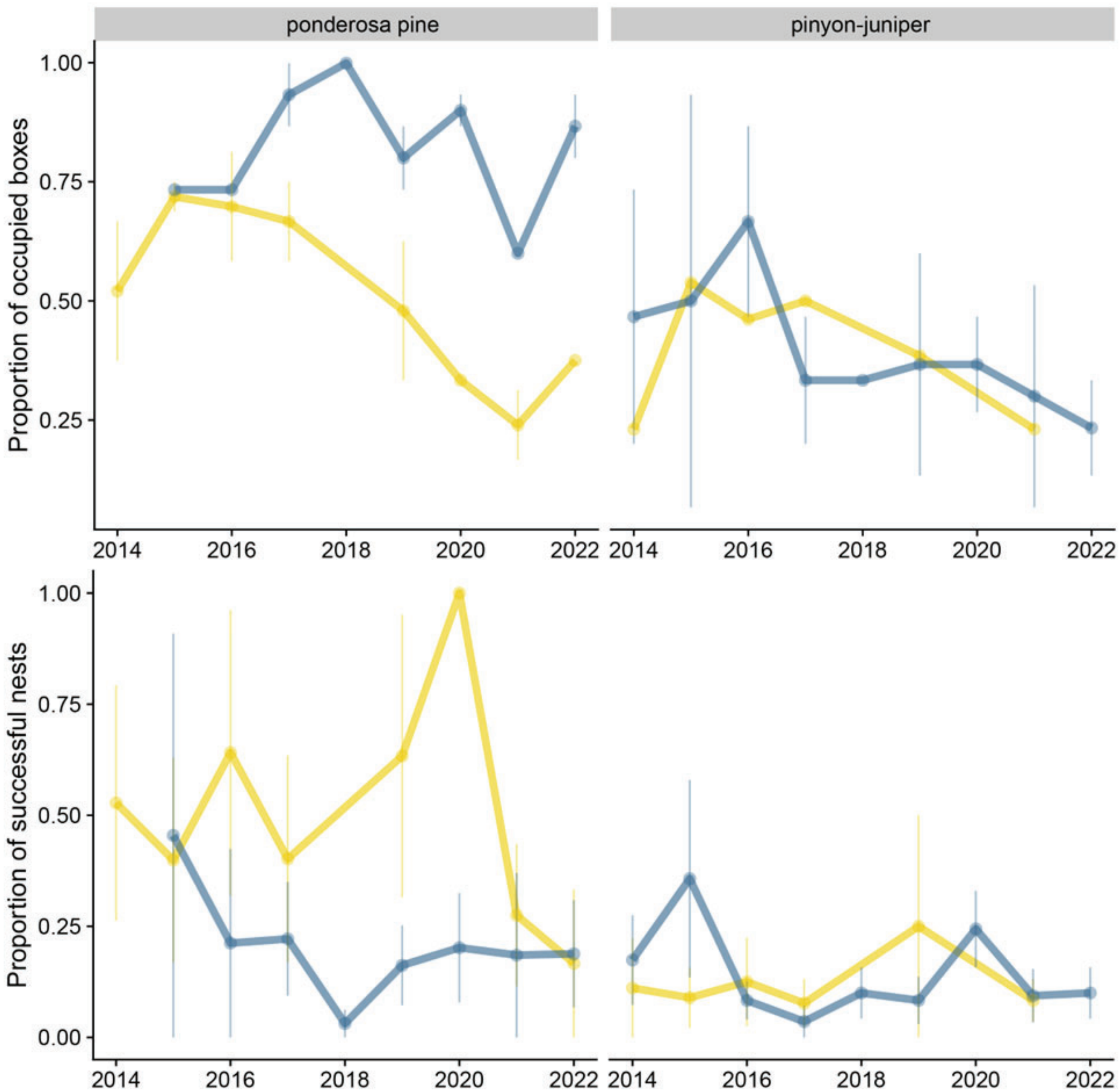

Figure 3-4. Mean proportion occupancy and success across study period for treatment sites (blue) and control sites (yellow) in ponderosa pine habitat (left panels) and pinyon-juniper habitat (right panels). Lines connecting sequential year's values to illustrate trends. Vertical lines represent standard error around mean values.

In 2022, two successful nests fledged young at Minie, five at TA-16, and zero at TA-39. Occupancy at TA-39 continues to be low relative to the other treatment sites and the overall network. The nest success rate at TA-39 has been highly variable since monitoring began in 2015, ranging between 0 percent and 100 percent. TA-39 is the lowest elevation treatment site, and occupancy has been decreasing over time at this site and surrounding areas of the avian nest box network (Table B-11). Wysner et al. (2019) found that Western Bluebirds, one of the target species of the network, have increased their nesting elevation over time in the study area. Western Bluebirds have the highest occupancy rates throughout the nest box network, and shifts in nesting elevation could be driving the lower occupancy rates at TA-39. Occupancy and success rates at the Minie treatment site have fluctuated annually and have not displayed a decreasing trend over time, though the success rate dropped substantially after 2020 and does not appear to have recovered (Table B-12). While occupancy has been relatively high and naturally fluctuating at TA-16, the success rate has shown a decreasing trend since 2017, with the largest decrease in success occurring in 2021 (Table B-12). These decreases are likely driven by low precipitation values from winter 2020 through spring 2022 (NOAA 2022). Decreases in precipitation have been linked to declines in body mass, which could indirectly impact reproductive success (Smith, Reitsma, and Marra 2010).

After establishing more appropriate control sites for productivity comparisons, an interesting trend emerged. Comparative site occupancy patterns varied between habitat types (Figure 3-4). Proportion site occupancy across all years was substantially higher in PIPO treatment sites than controls ($t = 4.84$, $df = 21.7$, $p < 0.001$), representing a difference of 31 percent mean proportion occupancy. Conversely, PJ habitat showed no difference in occupancy combined across all years ($t = 0.12$, $df = 17.9$, $p = 0.92$) (Figure 3-4).

Proportion nest success also varied between habitat types but contradicted the within-habitat-type nest success patterns (Figure 3-4). In PIPO habitat, the proportion of nest success across all years compared with reduced and relevant control sites was significantly lower at treatment sites (TA-16 and DARHT; $t = -2.59$, $df = 37.6$, $p = 0.01$). There was no discernable difference across all years in PJ habitat ($t = 0.68$, $df = 49.5$, $p = 0.50$). The pattern suggests that in PIPO treatment sites, the local habitat is attractive to cavity nesting birds, but their success rates are substantially lower—roughly equivalent to those in the PJ habitats.

In 2022, LANL biologists submitted nonviable eggs and nestlings collected from nest boxes at the treatment sites and the rest of the nest box network to an analytical lab for chemical analyses. These data will be presented in a separate report. A total of 7 nonviable eggs and 1 nestling were collected from treatment sites compared with 18 nonviable eggs and 2 nestlings across all control sites in 2022.

4 Management Recommendations

In addition to supporting federally protected bird species such as the Mexican Spotted Owl and the Southwestern Willow Flycatcher, LANL lands are important for migratory bird conservation. Over the 10-year study period, LANL biologists have documented sensitive species from the Sensitive Species Best Management Practices Source Document (Berryhill et al. 2020) and the Birds of Management Concern and Focal Species list (USFWS 2021) at the treatment sites. Those species are Cassin's Finch, Juniper Titmouse, Grace's Warbler, Virginia's Warbler, Black-throated Gray Warbler, Evening Grosbeak, Peregrine Falcon, and Mourning Dove. The Gray Vireo is the only sensitive species documented in only control sites. Of the 81 species detected at the three treatment sites, the Migratory Bird Treaty Act protects all but one species. The Eurasian Collared-Dove is not native and is therefore not protected under the Migratory Bird Treaty Act.

Overall comparisons provide mixed evidence for and against firing sites' potential negative impact on birds. Through further data collection and refining analyses to appropriately control for uneven sampling and site-specific variation, we gain to sharpen our understanding of differences between bird communities and productivity at treatment and control sites. For example, is it valid to compare TA-16 Burn Site, where noise disturbances could be relatively minimal to open firing sites like Minie and TA-39? It is likely that a complex interaction of local habitat, climate trends, and disturbance levels interact in ways that might obscure signals in the absence of large, long-term datasets. Continuing to document migratory bird occurrences and nest success among treatment and control sites will only increase our ability to uncover such signals should they exist, allowing LANL biologists to assess the ecological health of avifauna at the three firing sites and one open burn site at LANL.

Anthropogenic noise variation has been documented to affect bird behavior (Derryberry et al. 2020; Bernat-Ponce, Gil-Delgado, and López-Iborra 2021). Because a primary disturbance of concern at the open firing sites is intermittent noise, we suggest measuring sound metrics of the local bird communities between and during firing operations and compare those levels against appropriate controls using passive acoustic recording devices.

This research contributes to meeting the Department of Energy's commitments under the Migratory Bird Treaty Act and associated memorandum of understanding with the U.S. Fish and Wildlife Service. It also allows LANL to contribute to national goals in avian conservation monitoring and research.

5 Acknowledgments

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7 Acronyms and Abbreviations

Acronym	Definition
DARHT	Dual-Axis Radiographic Hydrodynamic Test Facility
LANL	Los Alamos National Laboratory
PIPO	ponderosa pine (forest)
PJ	pinyon-juniper (woodland)
TA	Technical Area

Appendix A Tables of 2013–2022 Species Abundances among Firing Sites

Table A-1. Detected Species Abundances at TA-36 Minie Site (Pinyon-Juniper Woodland Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acorn Woodpecker										
American Crow										
American Kestrel				1				1	1	
American Robin	1	1	2		2					5
Ash-throated Flycatcher	11	5	14	13	13	10	17	12	12	7
Audubon's Warbler		2				5				1
Bewick's Wren	4	8	9	9	14	14	5	10	4	5
Black-chinned Hummingbird		1	1				1	2	1	2
Black-headed Grosbeak	1	3				1	1	2	1	
Black-throated Gray Warbler			1		2			2		
Blue-gray Gnatcatcher	3	14	16	8	10	9	8	11	8	14
Blue Grosbeak										
Broad-tailed Hummingbird	2	1	3		1		3	2		5
Brown Creeper										
Brown-headed Cowbird	1								1	
Bullock's Oriole										
Bushtit		2		2		11				12
Canada Goose										
Canyon Towhee	2		5	3	6	2	3	5	3	
Canyon Wren					1					
Cassin's Finch						4				
Cassin's Kingbird	6	13	13	5	2	5	6	5	4	
Chipping Sparrow	3	16	17	29	6	22	10	10	10	
Clark's Nutcracker										
Common Nighthawk	6		5	2	4	4	1	5		
Common Raven	2	5	1		1	2	3			12

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cooper’s Hawk					1					
Cordilleran Flycatcher										
Dark-eyed Junco										
Downy Woodpecker				1						
Dusky Flycatcher				1						
Eurasian Collared-Dove	3									
Evening Grosbeak	3		4						1	
Grace’s Warbler							1			
Gray Flycatcher	12	6	5	7	3	6	3	2	4	8
Great Horned Owl		3								
Green-tailed Towhee	3	1								1
Hairy Woodpecker			2	1		1		1	1	1
Hammond’s Flycatcher										
Hepatic Tanager									2	
Hermit Thrush						1				
House Finch	16	17	26	17	12	18	17	11	11	17
House Wren										
Juniper Titmouse	12		7	6	9	3	26	8	20	3
Lark Sparrow										2
Lesser Goldfinch	2	6	7	4	9	12	8	4	4	8
MacGillivray’s Warbler										0
Mountain Bluebird		2	20	10	11	1	9	3	2	5
Mountain Chickadee	5	2	1	2						5
Mourning Dove	17	17	13	5	8	8	11	9	7	9
Northern Mockingbird					2		1	4		8
Northern Rough-winged Swallow						3				
Olive-sided Flycatcher										
Orange-crowned Warbler										
Painted Redstart										
Peregrine Falcon									1	
Pine Siskin	10	2		5	1			1		
Plumbeous Vireo	10	10	7	3	9	9	15	3	3	7

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Pygmy Nuthatch				2		2	3		1	
Red Crossbill					1					
Red-shafted Flicker	3	1	3	2	5	2	1		1	1
Red-tailed Hawk							1	2	1	
Rock Wren	3	3	4		2	10	11	10	4	5
Ruby-crowned Kinglet										
Savannah Sparrow										
Say's Phoebe	2	1	2		2	5	1	1	2	2
Scaled Quail			1							
Spotted Towhee	17	8	19	27	32	24	19	20	17	18
Steller's Jay							1			
Townsend's Solitaire	1									1
Turkey Vulture					1			2		2
Vesper Sparrow										
Violet-green Swallow		5	7	1	3	2	1	6		3
Virginia's Warbler					1	3	1			
Warbling Vireo						2				
Western Bluebird	15	11	18	17	16	19	21	23	8	11
Western Tanager		2	3		1					
Western Wood-Pewee	10	8	18	11	10	7	18	14	10	13
White-breasted Nuthatch	1	4	9	10	13	5	2	1	2	1
White-crowned Sparrow										
White-throated Swift										
White-winged Dove	1	5	9	2		3	2	1	1	
Willow Flycatcher										
Wilson's Warbler										
Woodhouse's Scrub-Jay	5	1	3	4	8	7	14	10	10	7

Table A-2. Detected Species Abundances at TA-39 Point 6 (Pinyon-Juniper Woodland Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acorn Woodpecker										
American Crow										
American Kestrel	1			2					2	
American Robin	1	1		2		4	2			
Ash-throated Flycatcher	19	11	30	12	8	8	6	11	4	7
Audubon's Warbler				2				5		3
Bewick's Wren	3	10	15	9	2	8	1	2		1
Black-chinned Hummingbird	3	2				1	2	3		
Black-headed Grosbeak		2	4	1		3	2	1	1	1
Black-throated Gray Warbler	5	6	4							
Blue-gray Gnatcatcher	2		7	5	4	2	13	5	2	13
Blue Grosbeak									1	
Broad-tailed Hummingbird	3	1	2		3	1	2	9	3	2
Brown Creeper										
Brown-headed Cowbird			2			3	2	10	3	12
Bullock's Oriole										1
Bushtit	2	14			1	12		2		
Canada Goose			16				2			
Canyon Towhee	1	1	2	10	13	19	6	3	9	5
Canyon Wren			2	3	8	6	2	4		
Cassin's Finch										
Cassin's Kingbird	7	6	2	21	21	32	37	49	14	41
Chipping Sparrow	6	6	5	8	15	25	27	24	16	20
Clark's Nutcracker										
Common Nighthawk	5	1	3	2	7	5	7	3	1	6
Common Raven	1		2	1		1	2	5		2
Cooper's Hawk										
Cordilleran Flycatcher										
Dark-eyed Junco						1	1			
Downy Woodpecker				1	2		1	2	1	
Dusky Flycatcher			1		1					1

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Eurasian Collared-Dove					4			2		
Evening Grosbeak			8							
Grace’s Warbler						2	4	1	6	3
Gray Flycatcher	10	10	11	10	5	8	3	14	5	6
Great Horned Owl	1									
Green-tailed Towhee	1									
Hairy Woodpecker			5	3			1	1	4	
Hammond’s Flycatcher										
Hepatic Tanager			1	2	1	2			1	
Hermit Thrush										
House Finch	21	4	23	9	30	44	50	53	22	41
House Wren							1			
Juniper Titmouse	11	13	18	6	1			3	2	3
Lark Sparrow										
Lesser Goldfinch	4	12	9	10	14	19	15	27	8	31
MacGillivray’s Warbler										
Mountain Bluebird		4						2	1	
Mountain Chickadee				1	1		1			
Mourning Dove	13	22	10	3	15	11	8	10	9	16
Northern Mockingbird		1							2	19
Northern Rough-winged Swallow										
Olive-sided Flycatcher										
Orange-crowned Warbler										
Painted Redstart										
Peregrine Falcon			1						1	
Pine Siskin	6		3	3						1
Plumbeous Vireo	1		1	6	6	5	5	12	4	9
Pygmy Nuthatch			2	4	12	9	11	10	1	8
Red Crossbill		2						1		
Red-shafted Flicker	3	2	4	8		3	2	2		4
Red-tailed Hawk			1	1	1	1				
Rock Wren	7	10	4	12	14	14	12	20	15	14

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ruby-crowned Kinglet										
Savannah Sparrow										
Say's Phoebe	2	1		5	2	4		6	5	
Scaled Quail										
Spotted Towhee	12	6	33	16	12	16	15	20	14	20
Steller's Jay										
Townsend's Solitaire										
Turkey Vulture								1		
Vesper Sparrow										
Violet-green Swallow	6	4	1	9	6	6	9	47	5	
Virginia's Warbler			1	2	4		5		2	3
Warbling Vireo										
Western Bluebird	5	19	12	21	13	6	7	17	3	4
Western Tanager		2	1	1	2	2	6	1	2	4
Western Wood-Pewee		4	2	10	8	11	12	18	12	16
White-breasted Nuthatch			2	4	4	2	6	3	2	3
White-crowned Sparrow									1	
White-throated Swift		1						2		
White-winged Dove	7	5	6	16	15	15	5	2	5	7
Willow Flycatcher									1	
Wilson's Warbler										
Woodhouse's Scrub-Jay	8	10	4	8	6	4	5		2	3

Table A-3. Detected Species Abundances at TA-16 Burn Grounds (Ponderosa Pine Forest Habitat)

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acorn Woodpecker	5		3	2	3	5	3	5	1	
American Crow					1	1		1	1	5
American Kestrel										
American Robin	7		9	4	4	6	12	6	14	
Ash-throated Flycatcher	3	5	6	2	3	8	4	6	6	11
Audubon's Warbler	6	5	1	6		1	11	14	9	5
Bewick's Wren										
Black-chinned Hummingbird	1		1		1		1	12	1	
Black-headed Grosbeak			1	2		2		1	1	1
Black-throated Gray Warbler										
Blue-gray Gnatcatcher		6	2	1	3	6	4	9	3	9
Blue Grosbeak										
Broad-tailed Hummingbird	5	11	11	5	7	10	8			11
Brown Creeper	1									
Brown-headed Cowbird	4	1			4	2	8	4	4	3
Bullock's Oriole										
Bushtit										
Canada Goose										
Canyon Towhee	1			1		1				
Canyon Wren			2							
Cassin's Finch									1	
Cassin's Kingbird				1				2		1
Chipping Sparrow	1	5	3	10	5	21	8	32	6	19
Clark's Nutcracker		4		1						
Common Nighthawk			1	2	2			1		
Common Raven	5	6	2	2	5	5	7	4	2	9
Cooper's Hawk	1			1			1			
Cordilleran Flycatcher	5	10	6	3	3	1	2	4		2
Dark-eyed Junco	6	2	4		5	2		2	3	3
Downy Woodpecker		1		1	1	1				
Dusky Flycatcher								2	1	1

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Eurasian Collared-Dove						1				
Evening Grosbeak	5		29			1				
Grace's Warbler	6	4	4	8	5	8	22	12	17	11
Gray Flycatcher										
Great Horned Owl										
Green-tailed Towhee								1		
Hairy Woodpecker	1	1		1	1	2	1	1		
Hammond's Flycatcher	8	9	12	5	7	5	10	5	7	1
Hepatic Tanager				1						
Hermit Thrush		4	6	1	2	2	5	5	2	2
House Finch	16	2	5	5	12	7	12	18	11	20
House Wren	1	1		2	2	6	8	2	1	2
Juniper Titmouse										
Lark Sparrow										
Lesser Goldfinch	3		8	9	4	8	5	6	2	9
MacGillivray's Warbler				1	3			1		1
Mountain Bluebird			4	4	4	7	4	5		
Mountain Chickadee	5	8	9	6	8	9	1	4	6	6
Mourning Dove	4		1	3	17	3	5	17	5	2
Northern Mockingbird										
Northern Rough-winged Swallow										
Olive-sided Flycatcher										
Orange-crowned Warbler								1		1
Painted Redstart										1
Peregrine Falcon										
Pine Siskin	12	4	5		4	2		6		1
Plumbeous Vireo	11	16	15	14	11	18	16	24	17	19
Pygmy Nuthatch	11	13	26	29	41	20	16	23	5	21
Red Crossbill		2	9	13	9		6	26	1	
Red-shafted Flicker	3	4	11	11	5	5	2	7	5	7
Red-tailed Hawk										1
Rock Wren	1	2	2	6			4	1		

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ruby-crowned Kinglet						2			1	
Savannah Sparrow								1		
Say's Phoebe	1		1	3	3	4	1	1	4	
Scaled Quail										
Spotted Towhee	11	18	16	14	21	22	34	24	16	23
Steller's Jay	3	2	5	6	3	4	4	2	1	
Townsend's Solitaire					1					
Turkey Vulture	1					1				
Vesper Sparrow							1			
Violet-green Swallow		2	19	2	2	4	2	7	6	7
Virginia's Warbler	17	11	21	13	7	5	5	8	3	4
Warbling Vireo	2	9	7	6	5	4	6	3	7	7
Western Bluebird	20	20	49	37	32	27	20	27	8	32
Western Tanager	2	3	7	2	4	6	16	10	7	
Western Wood-Pewee	15	10	16	14	22	20	24	28	25	47
White-breasted Nuthatch	9	8	7	9	20	10	10	8	10	9
White-crowned Sparrow										
White-throated Swift										
White-winged Dove			1	2			1			
Willow Flycatcher										
Wilson's Warbler										
Woodhouse's Scrub-Jay	1									

Table A-4. Detected Species Abundances at Dual-Axis Radiographic Hydrodynamic Test Facility (Ponderosa Pine Forest Habitat)

Species	2017	2018	2019	2020	2021	2022
Acorn Woodpecker		1	1	1		2
American Crow						
American Kestrel						1
American Robin	1		9	2	6	3
Ash-throated Flycatcher	7	2	2	5	4	2
Audubon's Warbler		4	12	2	3	2
Bewick's Wren						
Black-chinned Hummingbird		1				1
Black-headed Grosbeak		3	1			3
Black-throated Gray Warbler						
Blue-gray Gnatcatcher	5	8	16	17	4	9
Blue Grosbeak						
Broad-tailed Hummingbird	3	4	5	10	1	7
Brown Creeper						
Brown-headed Cowbird		5	2	7	6	8
Bullock's Oriole						
Bushtit						
Canada Goose						
Canyon Towhee						
Canyon Wren						
Cassin's Finch						
Cassin's Kingbird	9	14	13	1	15	10
Chipping Sparrow	16	31	21	17	30	18
Clark's Nutcracker		1				
Common Nighthawk						
Common Raven	10	1	5	5	6	4
Cooper's Hawk						
Cordilleran Flycatcher		1	1			3
Dark-eyed Junco						
Downy Woodpecker						
Dusky Flycatcher						2

Species	2017	2018	2019	2020	2021	2022
Eurasian Collared-Dove						
Evening Grosbeak						
Grace's Warbler	6	8	12	4	7	6
Gray Flycatcher			1		3	
Great Horned Owl			2		2	
Green-tailed Towhee						
Hairy Woodpecker		1				
Hammond's Flycatcher	1					1
Hepatic Tanager	1		1			2
Hermit Thrush	1	1				1
House Finch	30	20	25	27	23	17
House Wren						
Juniper Titmouse						2
Lark Sparrow	1	2			1	
Lesser Goldfinch	19	12	20	25	5	9
MacGillivray's Warbler						
Mountain Bluebird	7	8	7	7	4	1
Mountain Chickadee	3		7	7	4	1
Mourning Dove	1	1	5	5	7	6
Northern Mockingbird		1		1	2	5
Northern Rough-winged Swallow			1			
Olive-sided Flycatcher		1	1		3	
Orange-crowned Warbler						
Painted Redstart						
Peregrine Falcon						
Pine Siskin	1				3	
Plumbeous Vireo	11	14	19	14	9	12
Pygmy Nuthatch	9	13	13	3	4	6
Red Crossbill	4					4
Red-shafted Flicker	8	10	3	1	3	2
Red-tailed Hawk	1		1			1
Rock Wren	2	1		1	2	

Species	2017	2018	2019	2020	2021	2022
Ruby-crowned Kinglet						
Savannah Sparrow						
Say's Phoebe	8	1	5	2	2	1
Scaled Quail						
Spotted Towhee	28	22	22	27	31	27
Steller's Jay	1					
Townsend's Solitaire		1				1
Turkey Vulture	2	1		1		
Vesper Sparrow						
Violet-green Swallow	9	12	32	20	28	15
Virginia's Warbler	12	8	4	1	8	2
Warbling Vireo						
Western Bluebird	15	24	25	32	12	26
Western Tanager	2	1	4	6	6	3
Western Wood-Pewee	14	19	22	14	17	25
White-breasted Nuthatch	5	7	7	4	6	3
White-crowned Sparrow						
White-throated Swift	8					3
White-winged Dove		4	1	2		1
Willow Flycatcher						
Wilson's Warbler		2				
Woodhouse's Scrub-Jay	3					7

Appendix B Supplemental Tables

Table B-1. Changes in Species Raw Abundance over Time for All Treatment and Control Sites

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie	193	186	275	210	222	242	245	203	209	229
TA-39	177	193	260	249	261	315	298	413	286	339
PJ Control 1	187	157	269	312	240	235	226	292	225	209
PJ Control 2	181	177	301	228	300	168	187	269	159	142
TA-16	220	209	347	271	302	285	310	389	283	340
PIPO Control 1	258	223	432	323	447	374	364	373	349	337
PIPO Control 2	256	254	371	396	449	366	394	429	448	334

Table B-2. Changes in Raw Species Richness over Time for All Treatment and Control Sites

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie	33	33	34	30	35	35	34	33	33	37
TA-39	31	31	39	38	34	36	38	40	38	36
PJ Control 1	29	30	33	36	37	30	30	37	33	40
PJ Control 2	30	29	37	33	39	23	33	32	25	30
TA-16	39	33	40	44	41	43	39	46	37	40
PIPO Control 1	34	34	30	40	46	40	41	33	36	37
PIPO Control 2	33	36	43	43	44	39	40	40	44	39

Table B-3. Changes in Species Diversity over Time Comparing Minie Site with PJ Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie		3.14	3.14	3.19	2.97	3.13	3.21	3.06	3.13	3.00	3.31
PJ Control 1		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98
Hutcheson's t-test	t	−3.93	−3.06	−2.10	−0.68	−1.73	−4.38	−3.31	−2.99	−1.87	−3.59
	df	327	272	534	511	450	458	392	493	419	331
	p-value	<0.01	<0.01	0.04	0.50	0.08	<0.01	<0.01	<0.01	0.06	<0.01

Table B-4. Changes in Species Diversity over Time Comparing Minie Site with PJ Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Minie		2.81	2.87	3.05	3.03	3.20	2.59	2.90	2.86	2.54	2.69
PJ Control 2		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98
Hutcheson's t-test	t	−3.64	−2.94	−2.06	0.81	0.88	−7.20	−1.81	−3.42	−4.46	−7.49
	df	337	328	563	436	490	312	346	471	299	252
	p-value	<0.01	<0.01	<0.01	0.42	0.38	<0.01	0.07	<0.01	<0.01	<0.01

Table B-5. Changes in Species Diversity over Time Comparing TA-39 with PJ Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-39		3.09	3.07	3.14	3.32	3.18	3.13	3.08	3.09	3.03	3.11
PJ Control 1		2.76	2.83	3.05	2.91	2.98	2.88	2.75	2.87	2.82	2.98
Hutcheson's t-test	t	−3.36	−2.42	−1.12	−5.34	−2.40	−3.27	−3.37	−2.52	−2.15	−1.31
	df	330	268	509	540	425	497	444	561	462	361
	p-value	<0.01	0.02	0.26	0.00	0.02	<0.01	<0.01	0.01	0.03	0.19

Table B-6. Changes in Species Diversity over Time Comparing TA-39 with PJ Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-39		3.09	3.07	3.14	3.32	3.18	3.13	3.08	3.09	3.03	3.11
PJ Control 2		2.81	2.87	3.05	3.03	3.20	2.59	2.90	2.86	2.54	2.69
Hutcheson's t-test	t	−3.04	−2.22	−1.13	−3.89	0.31	−6.21	−1.94	−2.92	−4.70	−4.90
	df	337	325	542	440	561	325	396	578	319	279
	p-value	<0.01	0.03	0.26	<0.01	0.76	<0.01	0.05	<0.01	<0.01	<0.01

Table B-7. Changes in Species Diversity over Time Comparing TA-16 with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-16		3.30	3.21	3.24	3.29	3.24	3.36	3.29	3.37	3.20	3.18
PIPO Control 1		3.14	3.12	2.91	3.14	3.13	3.04	3.13	2.90	3.01	2.96
Hutcheson's t-test	t	−2.42	−1.21	−5.22	−2.01	−1.41	−4.55	−2.38	−6.95	−2.85	−3.12
	df	470	424	742	574	706	644	668	725	632	668
	p-value	0.02	0.23	<0.01	0.04	0.16	<0.01	0.02	<0.01	<0.01	<0.01

Table B-8. Changes in Species Diversity over Time Comparing TA-16 with PIPO Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
TA-16		3.30	3.21	3.24	3.29	3.24	3.36	3.29	3.37	3.20	3.18
PIPO Control 2		3.20	3.16	3.26	3.11	3.23	3.10	3.29	3.18	3.22	3.05
Hutcheson's t-test	t	−1.58	−0.67	0.43	−2.40	−0.11	−3.85	−0.08	−3.15	0.18	−1.98
	df	445	463	714	621	630	634	661	817	664	667
	p-value	0.11	0.50	0.67	0.02	0.91	<0.01	0.94	<0.01	0.86	0.05

Table B-9. Changes in Species Diversity over Time Comparing DARHT with PIPO Control 1

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
DARHT		-	-	-	-	3.18	3.24	3.14	3.17	3.26	3.33
PIPO Control 1		-	-	-	-	3.13	3.04	3.13	2.90	3.01	2.96
Hutcheson's t-test	t	-	-	-	-	−0.72	−2.73	−0.24	−3.59	−3.40	−4.85
	df	-	-	-	-	687	621	679	665	613	599
	p-value	-	-	-	-	0.47	0.01	0.81	0.00	0.00	0.00

Table B-10. Changes in Species Diversity over Time Comparing DARHT with PIPO Control 2

		2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
DARHT		-	-	-	-	3.18	3.24	3.14	3.17	3.26	3.33
PIPO Control2		-	-	-	-	3.23	3.10	3.29	3.18	3.22	3.05
Hutcheson's t-test	t	-	-	-	-	−2.05	2.43	0.16	−0.70	−3.86	−2.05
	df	-	-	-	-	609	686	640	593	572	609
	p-value	-	-	-	-	0.04	0.02	0.87	0.49	<0.01	0.04

Table B-11. Comparison of Occupancy for Treatment Sites and Overall Nest Box Network over Time

	2015	2016	2017	2018	2019	2020	2021	2022
Overall Network	40%	45%	48%	53%	44%	58%	30%	41%
Minie	66%	73%	46%	20%	60%	47%	53%	33%
TA-39	8%	58%	20%	33%	13%	27%	7%	13%
TA-16	-	73%	100%	53%	87%	87%	80%	93%
DARHT	-	-	87%	99%	73%	93%	64%	80%

Table B-12. Comparison of Nest Success for Treatment Sites and Overall Nest Box Network over Time

	2015	2016	2017	2018	2019	2020	2021	2022
Overall Network	66%	69%	57%	49%	51%	59%	45%	42%
Minie	64%	23%	29%	33%	44%	86%	38%	40%
TA-39	100%	57%	0%	40%	0%	75%	0%	0%
TA-16	-	63%	76%	63%	54%	54%	33%	36%
DARHT	-	-	62%	6.3%	45%	31%	56%	58%