LA-UR-21-30407

Approved for public release; distribution is unlimited.

Title:	2021 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory
Author(s):	Gadek, Chauncey Ryland Velardi, Milu Sue
Intended for:	Environmental Regulatory Document
Issued:	2021-10-29 (rev.1)

LA-UR-21-30407
October 2021
*Approved for public release;
distribution is unlimited.*

2021 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory

Los Alamos
NATIONAL LABORATORY

Prepared by: **Chauncey Gadek and Milu Velardi, Environmental Protection and Compliance Division, Environmental Stewardship Group, Los Alamos National Laboratory**

An Affirmative Action/Equal Opportunity Employer

Contents

Figures

Tables

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. 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 1) determine whether LANL operations impact bird abundance, species richness, or diversity, and 2) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. LANL biologists completed the ninth year of this effort in 2021.

Between May and July 2021, we completed three avian point count surveys at each of the treatment sites which are the Technical Area (TA)-36 Minie site, the TA-39 point 6, and the TA-16 burn ground. We recorded a total of 778 birds representing 58 species at the three treatment sites and compared these results to data from their associated control sites. We also compared occupancy and nest success data from nestboxes at treatment sites with the overall avian nestbox monitoring network.

In 2021, abundance and species richness at treatment and control sites continued to trend similarly from year to year with minor random deviations. Though richness remained stable across all sites, three new bird species were observed at the treatment sites: Blue Grosbeak, White-crowned Sparrow, and Willow Flycatcher indicative of a healthy avian community. The species diversity at the TA-36 Minie site and TA-39 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. The slightly elevated diversity at treatment sites in 2021 is not unexpected and shows no clear pattern of diverging with diversity at treatment sites. Overall diversity remains high across all sites relative to similar habitats.

Nestbox occupancy and success continue to fluctuate annually, though all three treatment sites experienced decreases in nest success between 2020 and 2021, likely driven by extremely low precipitation levels during winter of 2020.

The overall results from 2021 continue to indicate that operations at the three treatment sites are not negatively affecting bird populations. This long-term project will continue to monitor for any changes over time.

This page intentionally left blank.

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, or together as treatment sites) (Hathcock and Fair 2013; Hathcock 2014, 2015; Hathcock et al. 2017, 2018, 2019; Sanchez et al. 2020; Rodriguez and Abeyta 2021). The objectives of this long-term monitoring program are to (1) determine whether LANL operations impact bird abundance, species richness, or diversity, and (2) examine occupancy and nest success of secondary-cavity nesting birds using nestboxes. This involves comparing community and nestbox metrics at treatment sites with control sites of similar habitat that LANL biologists have surveyed since 2011 (Hathcock et al. 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 2021. Summer surveys provide information about which bird species are breeding at each site. These surveys are most valuable when they are conducted over multiple years since 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.

In addition to avian point counts, LANL biologists monitored nestboxes around all three treatment sites to investigate any potential impacts to occupancy rates and productivity of secondary cavity-nesting birds. Occupancy and nest success were compared to the overall avian nestbox monitoring network, which was established in 1997 (Fair and Myers 2002).

Methods

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 1–3). The habitat types around the sites are a pinyon (*Pinus edulis*) – juniper (*Juniperus monosperma*) woodland (PJ) for Minie (Figure 1) and TA-39 (Figure 2) and a ponderosa pine (*Pinus ponderosa*) forest (PIPO) at TA-16 (Figure 3). 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 (Figure 4) are monitored annually. The control sites were originally established in 2011 (Hathcock et al. 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 monitored randomly.

The treatment sites at Minie and TA-39 were 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 was in the canyon bottom while the controls were on mesa tops. The treatment site at TA-16 was similar in elevation and overstory vegetation to the PIPO control sites and all were on mesa tops. One of the PIPO control transects was adjacent to development and the other transect was in an undeveloped area.

Transects were 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 time frame for breeding bird surveys is May 11 through July 9. Ideally, the breeding bird surveys should take place the second week of May, June, and July. This protocol required a total of three surveys per site conducted between 0.5 hours before sunrise and four 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 five 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 wouldn’t be counted at the next point. Surveyors do not spend excess time looking for birds between points.
- Surveys are not conducted during rain events or winds greater than 24 kph.
- Surveyors use the “NOTES” section to indicate any 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 record other wildlife or unusual sightings that could be used for other projects.

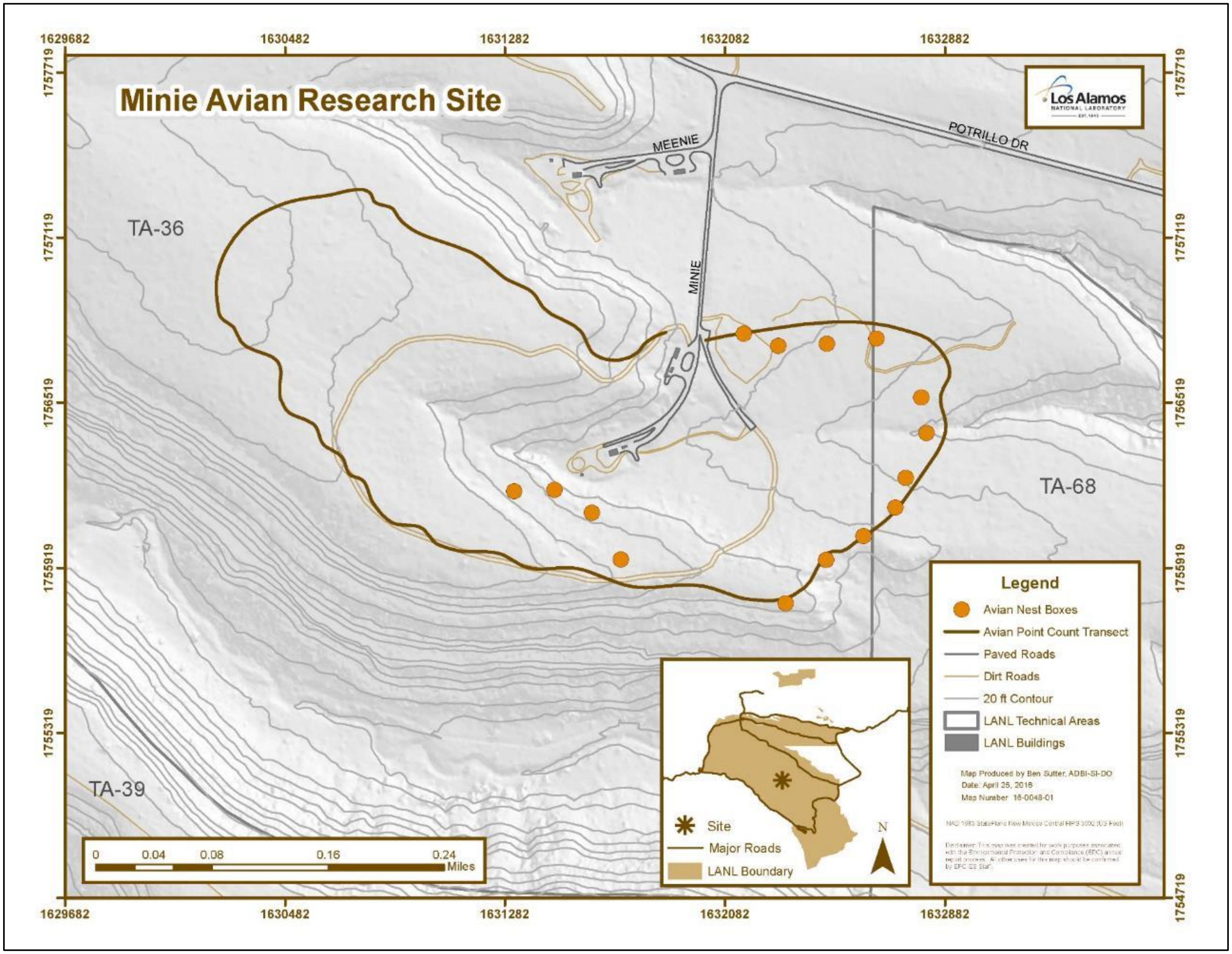

Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie Site

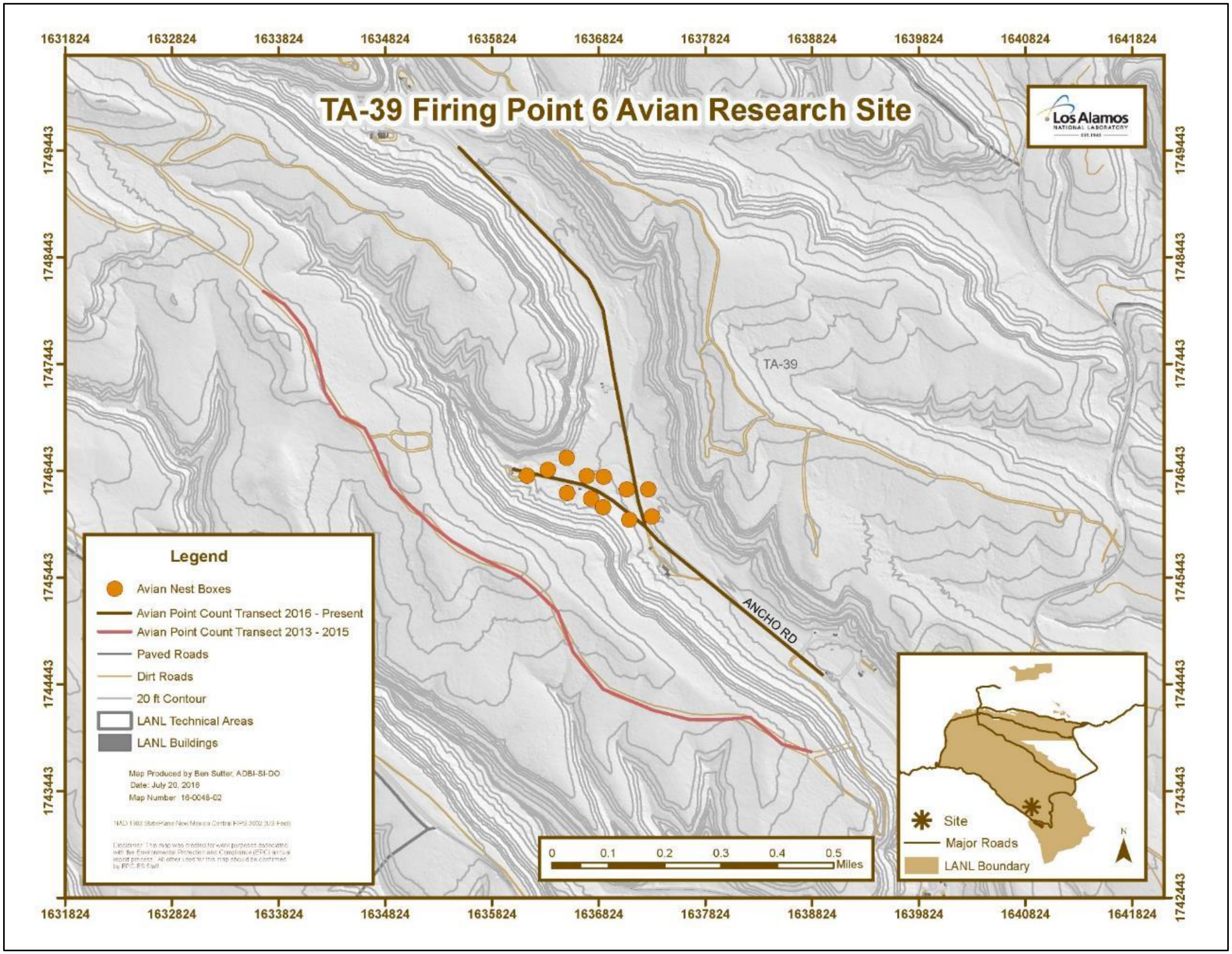

Figure 2. Breeding bird survey transect and nestbox locations around TA-39 Point 6

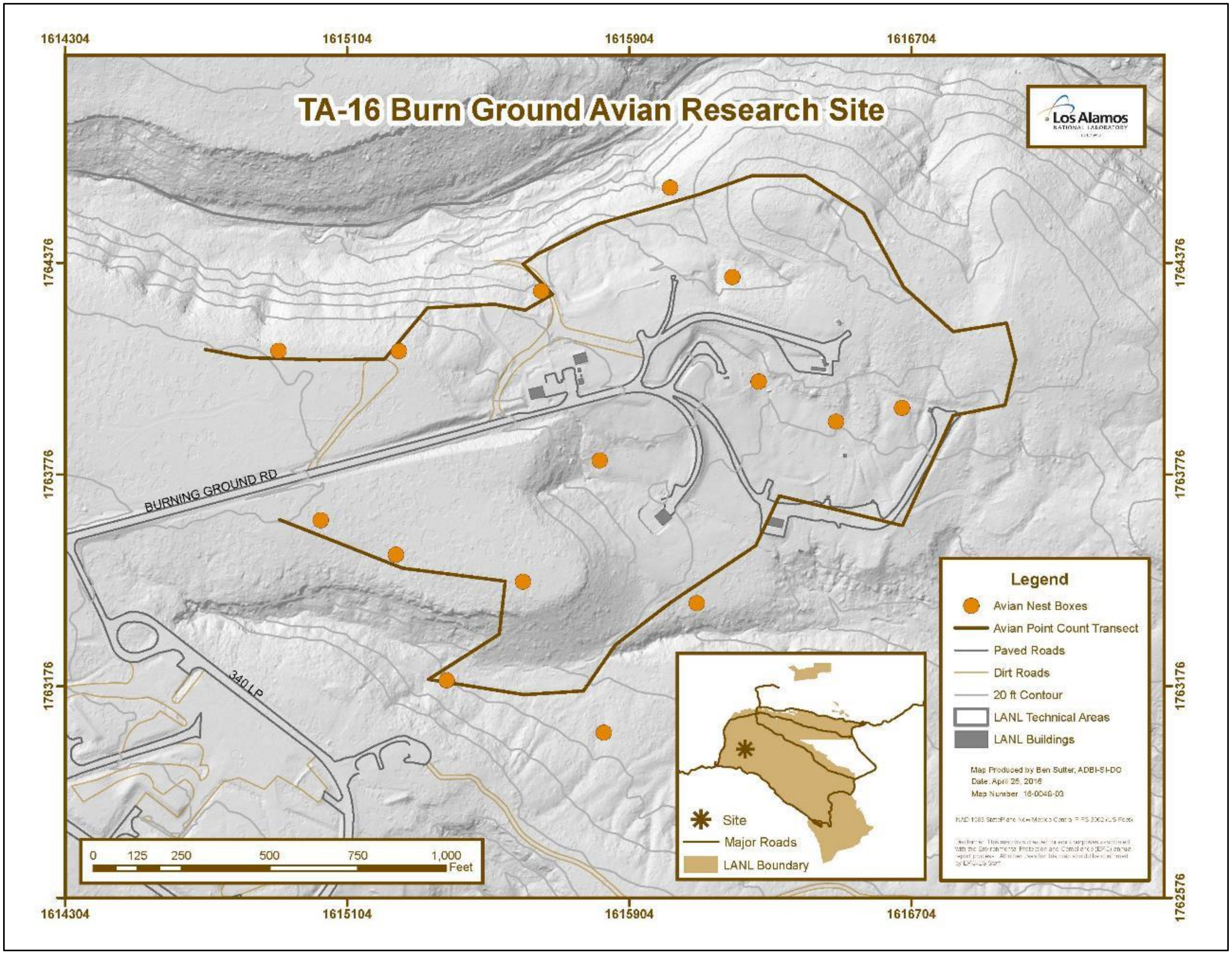

Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 Burn Ground

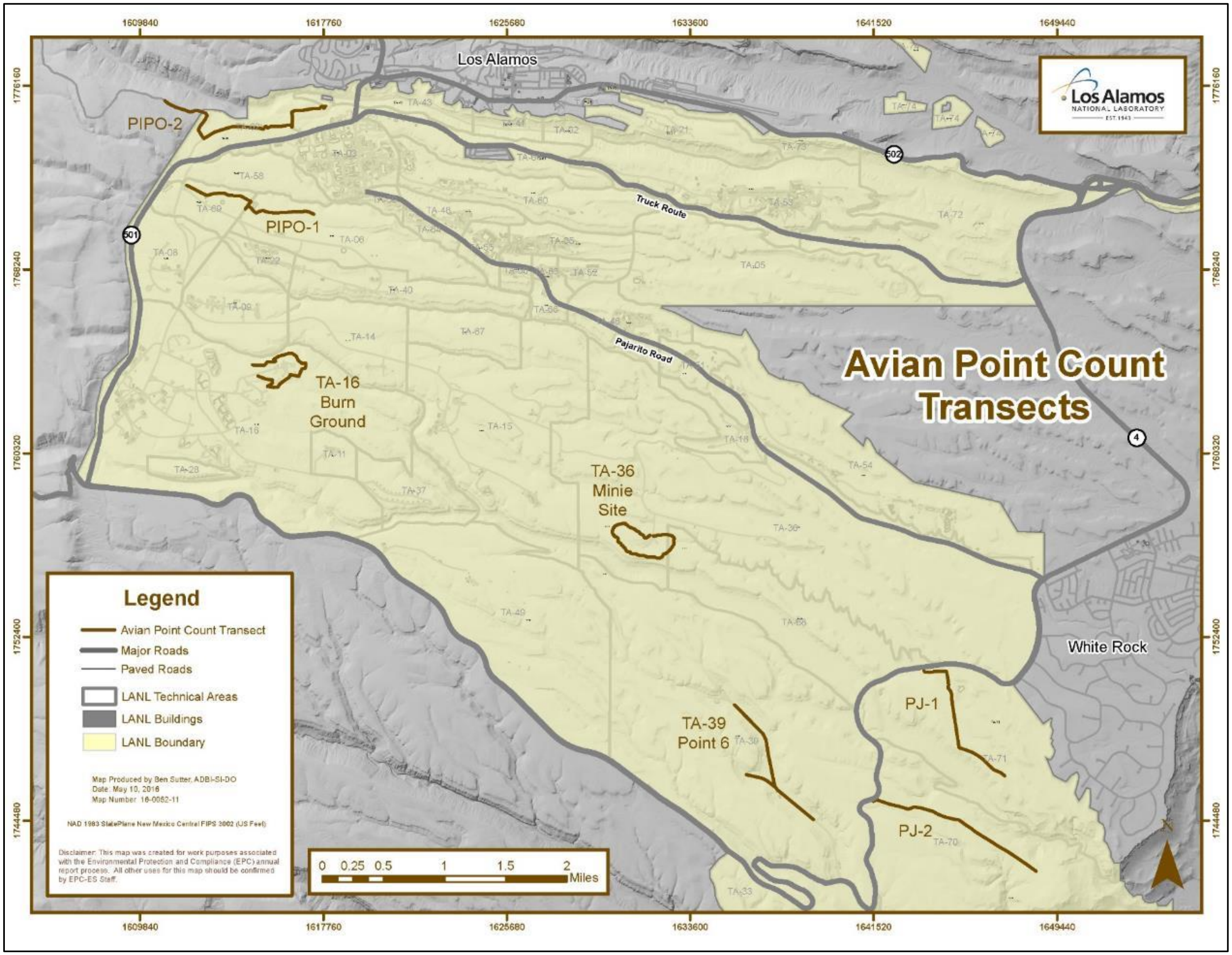

Figure 4. All avian point count transects around LANL

PIPO: ponderosa pine forest, PJ: pinyon-juniper woodland

Statistical Methods for Point Counts

We summarized these 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. 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 takes into account 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).

We calculated species richness, diversity, and abundance using the statistical software R (version 4.1.0; R Core Team 2021) and the package *vegan* (Dixon 2003). We used the Shannon's diversity index to compare diversity between habitats (Clarke et al. 2014). 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 used a Hutcheson's T-test in the R package *ecolTest* (Salinas and Ramirez-Delgado 2021) to test for differences between treatment and combined control site diversity each year.

In September of 2020, biologists and concerned citizens documented a large avian mortality event across New Mexico (NMDGF 2020). While researchers have yet to determine the causal factors of the die-off, an anomalous early cold front and record breaking wildfires along the Pacific coast coincided with the event. In 2021, LANL biologists predicted to see a decrease in species richness due to the mass mortality event in 2020. To test for a signal of the avian mortality event, we looked for differences in richness and abundance between 2020 and 2021 using a repeated measures ANOVA framework with transect as a repeated measurement in the R package *lme4* (Bates et al. 2015). Because bird species recovered from the 2020 mortality event tended to be insectivores (D'Ammassa 2020), we also binned all species in two major summer feeding guilds (insectivores and omnivores) in the ANOVAs.

Field Methods for Nestbox Monitoring

In 2011, LANL biologists added nestboxes to Minie and TA-39 (Figures 1 and 2). In 2015, biologists added nestboxes to TA-16 (Figure 3). We monitored nestboxes every one to two 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. We compared the data from the nestboxes at the treatment sites to the data from the overall nestbox network at LANL.

Statistical Methods for Nestboxes

We calculated occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network. For any single site or overall, the occupancy rate was the number of active nestboxes divided by the total number of nestboxes. Similarly, the nest success rate was the number of nestboxes that successfully fledged young divided by the number of active nestboxes. We compared the 2021 data from the three treatment sites with the overall avian nestbox network at LANL which was established in 1997 (Fair and Myers 2002).

Results and Discussion

Point Count Surveys-Year 2021

LANL biologists completed three surveys at each of the three treatment sites and the associated control sites between May and July 2021. Table 1 summarizes the species richness, diversity, and abundance for 2021 for each treatment and control site. A total of 778 birds representing 58 species were recorded at the three treatment sites. A full account of the 2013 – 2021 data is detailed in Appendix 1.

Table 1. The species richness, diversity, and abundance recorded at all treatment and control sites in 2021

	Minie	*TA-39*	*PJ Control 1*	*PJ Control 2*	*TA-16*	*PIPO Control 1*	*PIPO Control 2*
Richness	33	38	33	25	37	36	44
Diversity	3.00	3.03	2.82	2.54	3.20	3.01	3.22
Abundance	209	286	225	159	283	349	448

Abundance

Overall bird abundance has trended similarly for both treatment and control sites (Figure 5 & Table 2). Overall abundance has tended to increase since 2013 with minor fluctuations. The fluctuations in bird abundances were not alarming, and abundances at treatment sites and control sites have continued to trend together (Figure 5). Bird abundances seems to partially track winter precipitation levels with 2015-2017 representing the wettest winters in our dataset (NOAA 2021). Abundance values marginally decreased in 2021, with the exception of Minie and PIPO-2 sites, potentially driven by extreme drought conditions during winter 2020 and spring 2021 (NOAA 2021).

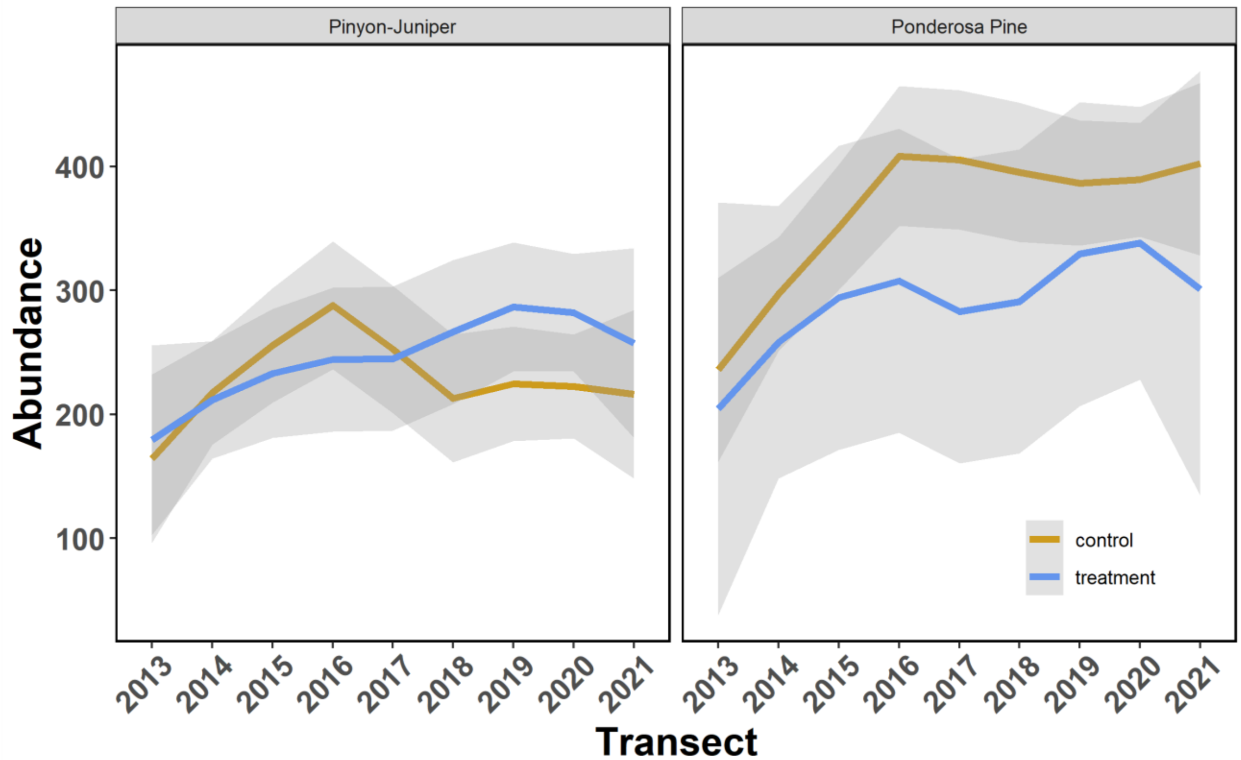

Figure 5. Abundance values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% CI.

Table 2. Changes in species abundance over time for all treatment and control sites

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

Species Richness

Figure 6 & Table 3 illustrate changes in species richness over time at the treatment and individual control sites. Overall the mean richness at treatment sites has remained stable with small annual fluctuations since monitoring began (Figure 6 & Table 3). Species richness at both treatment and control sites have largely trended together with average richness at treatment sites slightly increasing in 2015- 2017, similar to abundance values, suggesting richness may also be influenced by winter precipitation.

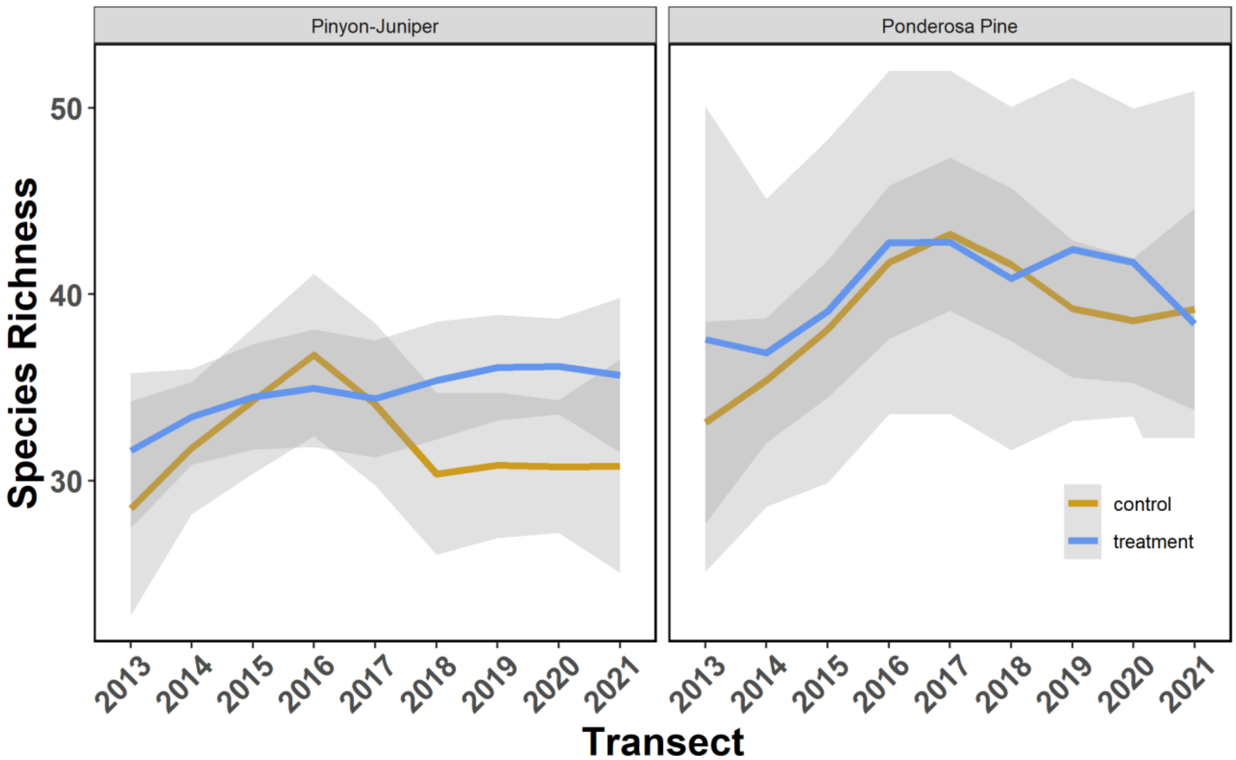

Figure 6. Species richness values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% CI.

Table 3. Changes in species richness over time for all treatment and control sites

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

PIPO Control 1	34	34	30	40	46	40	41	33	36
PIPO Control 2	33	36	43	43	44	39	40	40	44

Diversity

Figure 7 and Tables 4 – 6 compare the species diversity over time between the treatment site and the combined controls. We combined the two control sites to analyze diversity because we were interested in the relative abundances among species. Significant differences in diversity between sites by year are indicated in bold font with a darker shading. In these cases, the diversity was significantly higher at the treatment site than the combined controls. Even though we see significant differences, the bird diversity at all sites is around 3, which—compared with ecological systems in general—is very high.

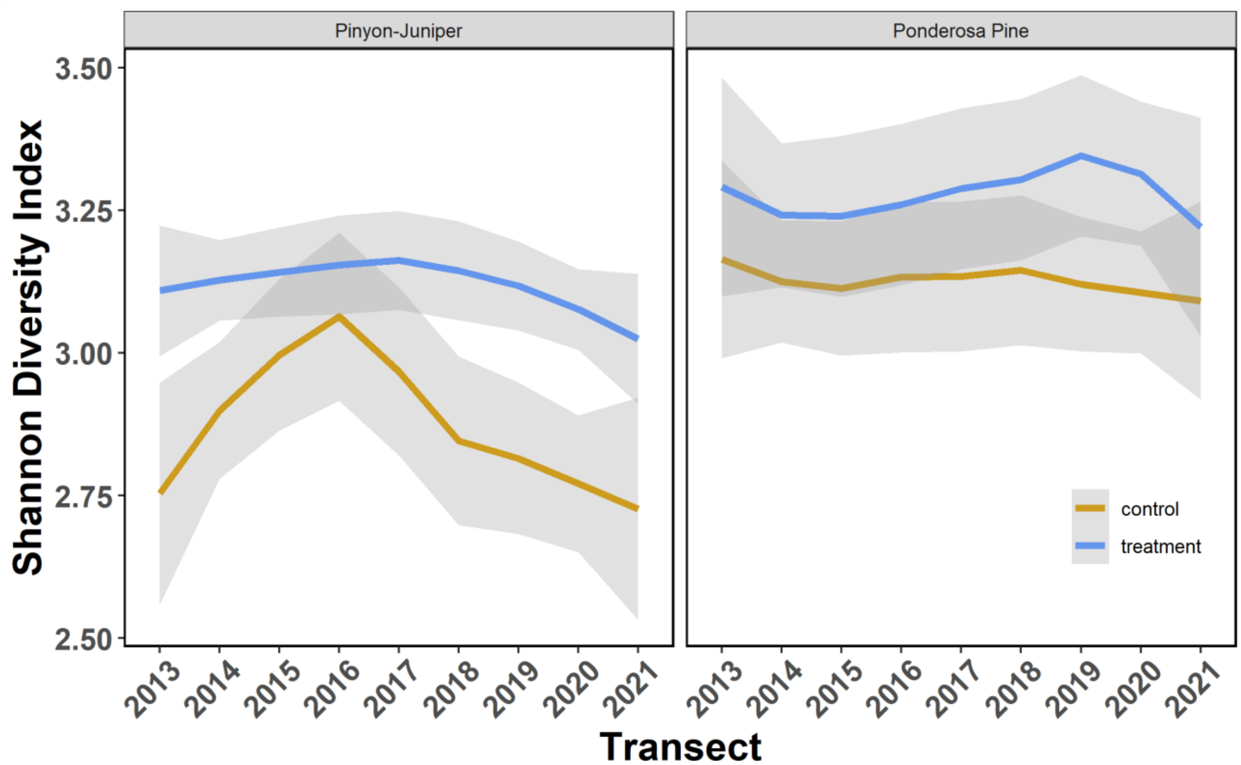

Figure 7. Shannon diversity index values by year averaged across treatment (blue line) and control sites (orange line). Shaded gray areas represent local smoothed 95% CI.

Table 4. Changes in species diversity over time comparing Minie Site with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Minie	3.14	3.14	3.19	2.97	3.13	3.21	3.06	3.13	3.00
PJ Control	2.88	2.99	3.16	3.07	3.24	2.94	2.97	2.98	2.80
Hutcheson's t-test	**t = 3.34 df = 523 p < 0.001**	t = 1.97 df = 468 p = 0.05	t = 0.55 df = 683 p = 0.58	t = -1.34 df = 473 p = 0.18	t = -1.53 df = 515 p = 0.13	**t = 4.07 df = 599 p < 0.0001**	t = 1.29 df = 634 p = 0.20	**t = 2.23 df = 528 p = 0.03**	**t = 2.41 df = 532 p = 0.02**

Table 5. Changes in species diversity over time comparing TA-39 with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
TA-39	3.09	3.07	3.13	3.32	3.18	3.13	3.08	3.07	3.03
PJ Control	2.88	2.99	3.16	3.07	3.24	2.94	2.97	2.97	2.80
Hutcheson's t-test	**t = 2.64 df = 481 p < 0.01**	t = 1.08 df = 488 p = 0.28	t = -0.28 df = 492 p = 0.78	**t = 3.91 df = 690 p < 0.00001**	t = -1.00 df = 693 p = 0.32	**t = 2.83 df = 702 p < 0.01**	t = 1.46 df = 673 p = 0.15	t = 1.49 df = 945 p = 0.14	**t = 2.73 df = 644 p < 0.01**

Table 6. Changes in species diversity over time comparing TA-16 with the PIPO controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
TA-16	3.30	3.21	3.23	3.29	3.24	3.36	3.29	3.36	3.20
PIPO-Control	3.26	3.22	3.16	3.21	3.20	3.17	3.31	3.18	3.22
Hutcheson's t-test	t = 0.71 df = 419 p = 0.48	t = -0.28 df = 517 p = 0.78	t = 1.30 df = 702 p = 0.20	t = 1.18 df = 524 p = 0.24	t = -0.91 df = 549 p = 0.36	**t = 3.07 df = 598 p < 0.005**	t = -0.46 df = 659 p = 0.65	**t = 3.42 df = 842 p < 0.001**	t = -0.24 df = 583 p = 0.81

Detecting 2020 Mass Mortality Event

Though upwards of 100,000 birds are thought to have died in the mass mortality event last September (NMDGF 2020), repeated measures ANOVAs between years and foraging guilds, controlled for transect, showed no significant difference in abundance or richness between 2020 and 2021 (Figure 8). It is likely that most of the birds involved in the die-off, were migrants flying through New Mexico and therefore did not contribute to local breeding populations.

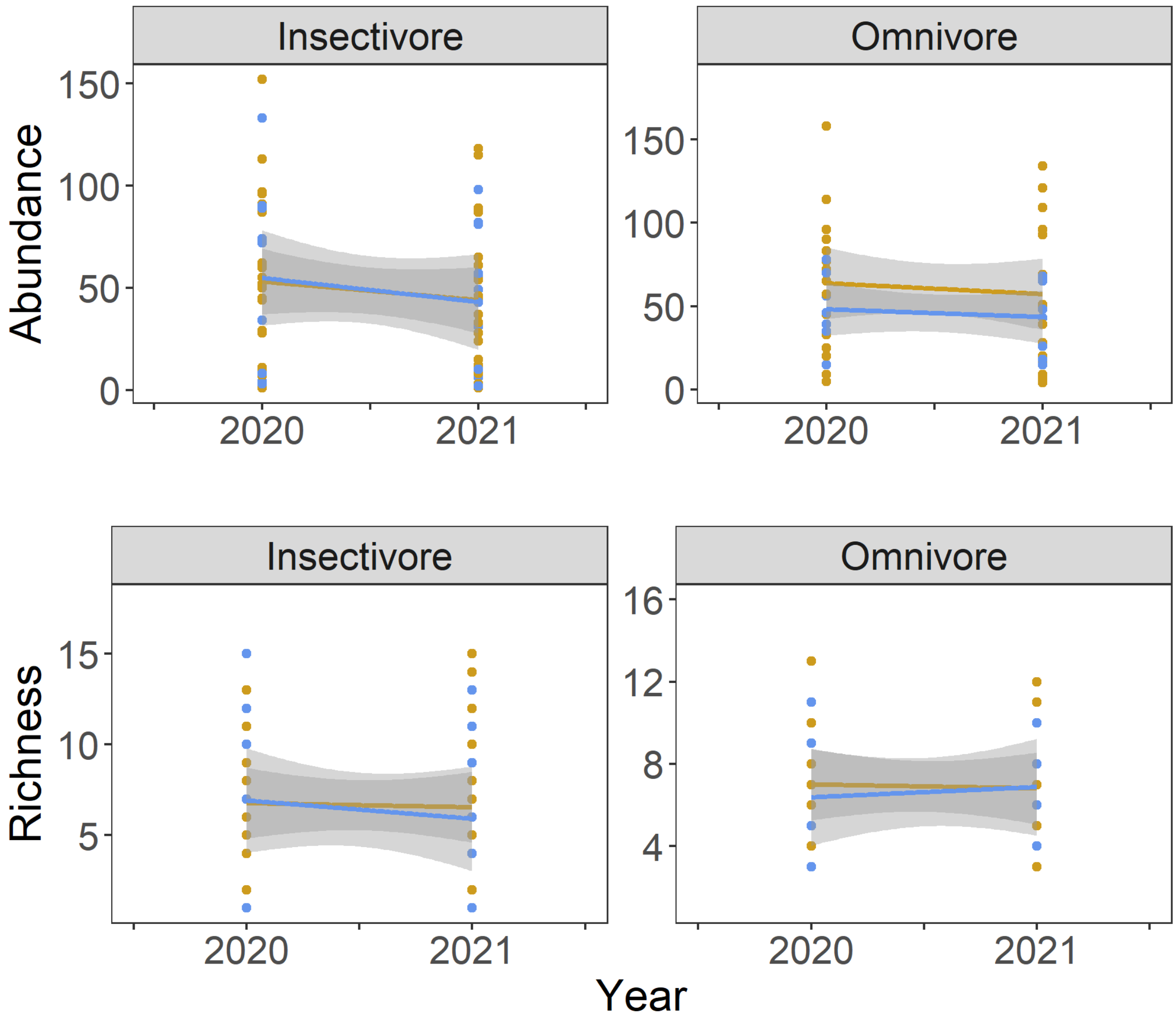

Figure 8. Richness compared between 2020 and 2021 for two major summer foraging guilds between control sites (orange) and treatment sites (blue).

Nestboxes

During the 2021 nesting season, LANL biologists actively monitored 15 nestboxes at each treatment site and a total of 365 nestboxes throughout the overall avian nestbox network. Of those, 110 contained active nests and 49 of those nests fledged young successfully for an overall occupancy rate of 30% and a 45% success rate. Both the occupancy and success rates for 2021 were the lowest recorded since the start of the nestbox monitoring at firing sites in 2015 (Tables 7 & 8). Figure 9 and Tables 7 and 8 compare the occupancy and nest success rates for each treatment site and the overall nestbox network since 2015.

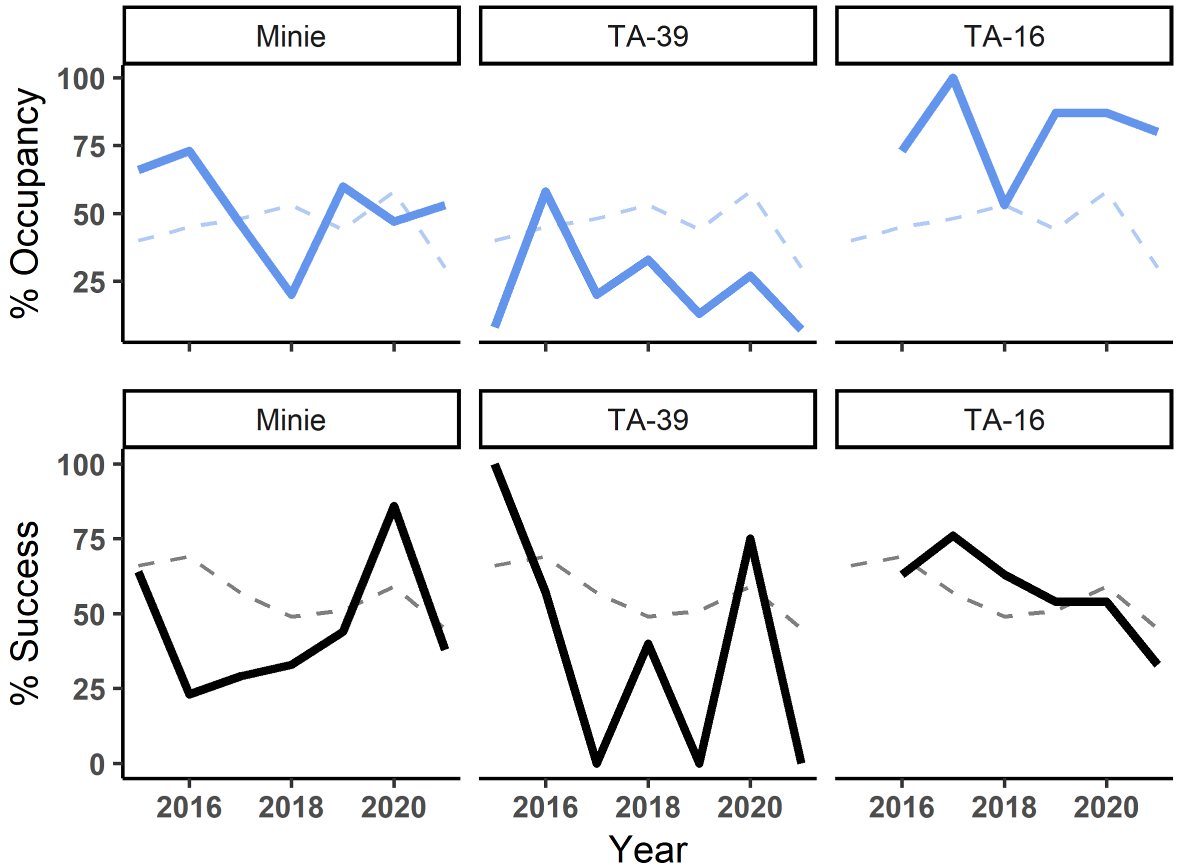

Figure 9. Nestbox occupancy (blue line; top) and success (black line; bottom) plotted by year for the three treatment sites. Dashed lines are global yearly mean for occupancy and success combined across all sites.

Table 7. Comparison of occupancy for the treatment sites and the overall nestbox network over time

	2015	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Overall Network	40%	45%	48%	53%	44%	58%	30%
Minie	66%	73%	46%	20%	60%	47%	53%
TA-39	8%	58%	20%	33%	13%	27%	7%

TA-16	-	73%	100%	53%	87%	87%	80%

Table 8. Comparison of nest success for the treatment sites and the overall nestbox network over time

	2015	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*
Overall Network	66%	69%	57%	49%	51%	59%	45%
Minie	64%	23%	29%	33%	44%	86%	38%
TA-39	100%	57%	0%	40%	0%	75%	0%
TA-16	-	63%	76%	63%	54%	54%	33%

In 2021, there were three successful nests that fledged young at Minie, four at TA-16, and zero at TA-39. Occupancy at TA-39 was also 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% and 75%. TA-39 is the lowest elevation treatment site and occupancy has been decreasing over time at this site and surrounding areas of the avian nestbox network (Figure 9 & Table 7). 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 nestbox 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 between 2020 and 2021 (Figure 9 & Table 8). While occupancy has been relatively high and naturally fluctuating at TA-16, the success rate has been decreasing since 2017 with the largest decrease in success occurring in 2021.

Decreases in occupancy and nest success were pervasive across both control and treatment sites between 2020 and 2021 with 79% of all nestbox sites showing a decrease in occupancy and 86% showing a decrease in nesting success (Figure 10 & Table 9). These decreases are likely driven by extreme low precipitation values winter 2020 and spring 2021 (NOAA 2021). Decreases in precipitation have been linked to declines in body mass which may indirectly impact reproductive success (Smith et al. 2010).

In 2021, LANL biologists submitted nonviable eggs collected from nestboxes at the treatment sites and the rest of the nestbox network to an analytical lab for chemical analyses. These data will be presented in a separate report.

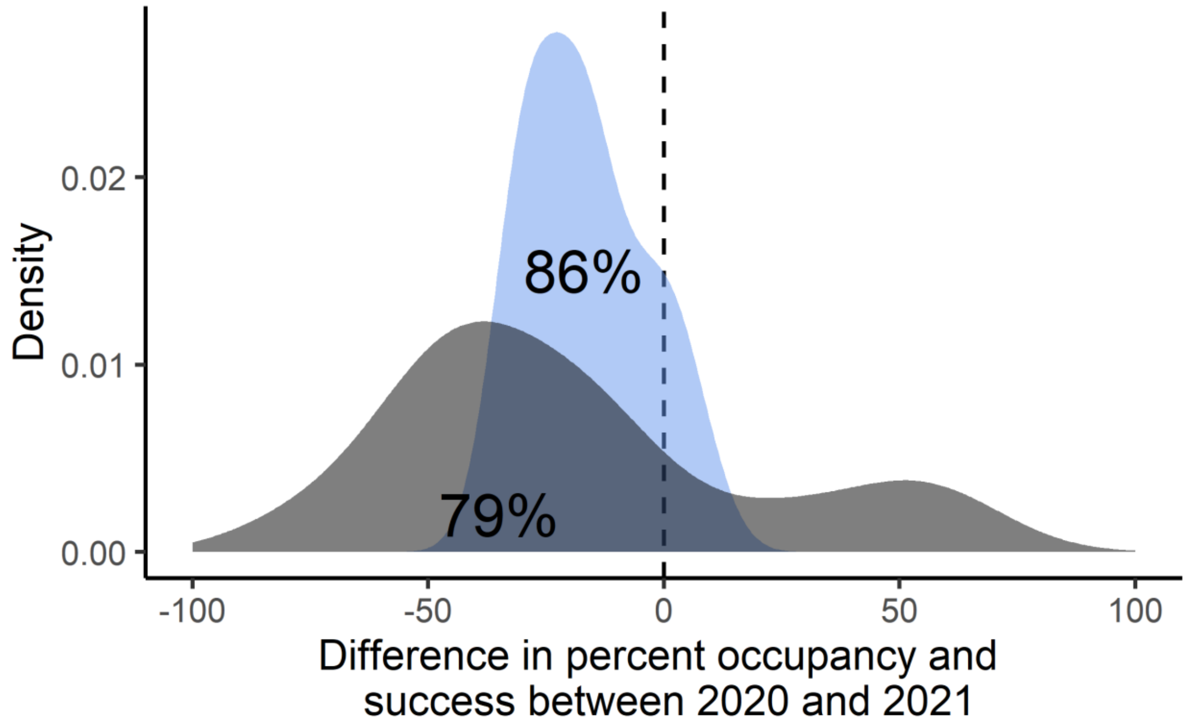

Figure 10. Distribution of between-year comparisons of percent occupancy (grey) and success (blue) between 2020 and 2021. Shaded area to left of dashed line illustrates number of sites that had a reduction in percent occupancy or success in 2021 compared to 2020. Percentages indicate number of comparisons falling below zero.

Table 9. Results from best fit repeated measures ANOVA for comparison between 2020 and 2021 abundance and richness binned by foraging guild and using transect as repeated measure.

Insectivore			
Abundance ~ Year + Site Cat	**df**	**t**	**P value**
Year	20	-1.320	0.20
Site Category (Treatment/Control)	12	0.823	0.43
Richness ~ Year + Site Cat	**df**	**t**	**P value**
Year	21	-0.728	0.48

Site Category (Treatment/Control)	13	0.780	0.45
Omnivore			
Abundance ~ Year + Site Cat	**df**	**t**	**P value**
Year	12	-1.532	0.15
Site Category (Treatment/Control)	12	0.036	0.97
Richness ~ Year + Site Cat	**df**	**t**	**P value**
Year	12	-0.628	0.54
Site Category (Treatment/Control)	12	0.674	0.51

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 9 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 the Cassin's Finch, Juniper Titmouse, Grace's Warbler, Virginia's Warbler, Black-throated Gray Warbler, Evening Grosbeak, Peregrine Falcon, and the Mourning Dove. The Gray Vireo is the only sensitive species documented in only control sites. Of the 79 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 therefore not protected under the Migratory Bird Treaty Act.

Continuing to document migratory bird occurrences and nest success across treatment and control sites, provides a long-term dataset to assess the ecological health of avifauna at the three treatment sites at LANL. In addition, 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, and it allows LANL to contribute to national goals in avian conservation monitoring and research.

Acknowledgments

Thanks to the following individuals for technical and field support work in 2021: Andrew Bartlow, Jesse Berryhill, Chuck Hathcock, Audrey Sanchez, Jenna Stanek, Brent Thompson, Luciana Vigil-Holterman, and former staff and interns that helped in previous years.

Literature Cited

Bates, D., M. Mächler, B. Bolker, and S. Walker. 2015. Fitting linear mixed-effects models using lme4. Journal of Statistical Software 67(1). https://doi.org/10.18637/jss.v067.i01

Berryhill, J.T., J.E. Stanek, E.J. Abeyta, and C.D. Hathcock. 2020. Sensitive Species Best Management Practices Source Document, Revision 5. Los Alamos National Laboratory report number LA-UR-20-24514, Los Alamos, New Mexico.

Boulinier, T., J.D. Nichols, J.R. Sauer, J.E. Hines, and K.H. Polluck. 1998. Estimating species richness: the importance of heterogeneity in species detectability. Ecology 79(3):1018–1028.

Clarke, K.R., R.N. Gorley, P.J. Somerfield, and R. Warwick. 2014. Change in marine communities; an approach to statistical analysis and interpretation, 3rd edition. Primer-E: Plymouth Marine Laboratory, Auckland, New Zealand. 262pp.

D'Ammassa, A. 2020. 'Hundreds of thousands, if not millions': New Mexico sees massive migratory bird deaths. Las Cruces Sun News.

Dixon, P. 2003. VEGAN, a package of R functions for community ecology. Journal of Vegetation Science 14(6):927–930.

Fair, J.M., and O.B. Myers. 2002 Early reproductive success of western bluebirds and ash-throated flycatchers: a landscape-contaminant perspective. Environmental Pollution 118:321–330.

Gotelli, N.J. and R.K. Colwell. 2011. Estimating species richness. Biological diversity: Frontiers in Measurement and Assessment 12:39–54.

Hathcock, C.D., K. Zemlick, and B. Norris. 2011. Winter and Breeding Bird Surveys at Los Alamos National Laboratory Progress Report for 2010 to 2011. Los Alamos National Laboratory report number LA-UR-11-05054, Los Alamos, New Mexico.

Hathcock, C.D. and J.M. Fair. 2013. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Grounds. Los Alamos National Laboratory report number LA-UR-13-27825, Los Alamos, New Mexico.

Hathcock, C.D. 2014. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-14-28161, Los Alamos, New Mexico.

Hathcock, C.D. 2015. Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-15-28296, Los Alamos, New Mexico.

Hathcock, C.D., B.E. Thompson, and J.T. Berryhill. 2017. 2016 Results for Avian Monitoring at the TA-36 Minie Site, TA-39 Point 6, and TA-16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-17-20359, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow and B.E. Thompson. 2018. 2017 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-18-22897, Los Alamos, New Mexico.

Hathcock, C.D., A.W. Bartlow, A.A. Sanchez, J. Stanek, and B.E. Thompson. 2019. 2018 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-19-24156, Los Alamos, New Mexico.

McKown, B., S.W. Koch, R.G. Balice, and P. Neville. 2003. Land cover classification map for the Eastern Jemez Region. Los Alamos National Laboratory report number LA-14029, Los Alamos, New Mexico.

New Mexico Department of Game and Fish (NMDGF). 2020. Starvation, unexpected weather to blame in mass migratory songbird mortality. http://www.wildlife.state.nm.us/starvation-unexpected-weather-to-blame-in-mass-migratory-songbird-mortality/. Accessed February 2021.

NOAA (National Oceanic and Atmospheric Administration). September 2021. Climate at a Glance: Global Mapping, retrieved on September 14, 2021 from https://www.ncdc.noaa.gov/cag/

R Core Team. 2021. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

Rodriguez, J.M. and E.J. Abeyta. 2021. 2020 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los

Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-21-22304, Los Alamos, New Mexico.

Salinas, H. and D. Ramirez-Delgado. 2021. ecolTest: Community Ecology Tests. URL https://cran.r-project.org/web/packages/ecolTest/index.html.

Sanchez, A.A., C.D. Hathcock, and B.E. Thompson. 2020. 2019 Results for Avian Monitoring at the Technical Area 36 Minie Site, Technical Area 39 Point 6, and Technical Area 16 Burn Ground at Los Alamos National Laboratory. Los Alamos National Laboratory report number LA-UR-20-20436, Los Alamos, New Mexico.

Shannon, C.E. and W. Weaver. 1949. The mathematical theory of communication. University of Illinois Press, Urbana, IL, USA. 127pp.

Smith, J.A.M., L.R. Reitsma, and P.P. Marra. 2010. Moisture as a determinant of habitat quality for a nonbreeding Neotropical migratory songbird. Ecology 91(10):2874–2882.

Tramer, E.J. 1969. Bird species diversity: components of Shannon’s formula. Ecology 50(5):927–929.

U.S. Fish and Wildlife Service (USFWS). 2021. Birds of conservation concern. United States Department of Interior, Fish and Wildlife Service, Migratory Bird Program, Arlington, Virginia. 48 pp.

Wysner, T.E., A.W. Bartlow, C.D. Hathcock, and J.M. Fair. 2019. Long-tern phenology of two North American secondary cavity-nesters in response to changing climate conditions. The Science of Nature 106:54. doi:10.1007/s00114-019-1650-9.

Appendix 1. All birds recorded at the three treatment sites from 2013–2021

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021
	TA-36 Minie Site									TA-39 Point 6									TA-16 Burn Grounds								
	Pinyon-Juniper Woodland									Pinyon-Juniper Woodland									Ponderosa Pine Forest								
Acorn Woodpecker																			5		3	2	3	5	3	5	1
American Crow																							1	1		1	1
American Kestrel				1				1	1	1			2					2									
American Robin	1	1	2		2					1	1		2		4	2			7		9	4	4	6	12	6	14
Ash-throated Flycatcher	11	5	14	13	13	10	17	12	12	19	11	30	12	8	8	6	11	4	3	5	6	2	3	8	4	6	6
Audubon's Warbler		2				5							2				5		6	5	1	6		1	11	14	9
Bewick's Wren	4	8	9	9	14	14	5	10	4	3	10	15	9	2	8	1	2										
Black-chinned Hummingbird		1	1				1	2	1	3	2				1	2	3		1		1		1		1	12	1
Black-headed Grosbeak	1	3				1	1	2	1		2	4	1		3	2	1	1			1	2		2		1	1
Black-throated Gray Warbler			1		2			2		5	6	4															
Blue-gray Gnatcatcher	3	14	16	8	10	9	8	11	8	2		7	5	4	2	13	5	2		6	2	1	3	6	4	9	3
Blue Grosbeak																		1									
Broad-tailed Hummingbird	2	1	3		1		3	2		3	1	2		3	1	2	9	3	5	11	11	5	7	10	8		
Brown Creeper																			1								
Brown-headed Cowbird	1								1			2			3	2	10	3	4	1			4	2	8	4	4
Bushtit		2		2		11				2	14			1	12		2										
Canada Goose												16				2											
Canyon Towhee	2		5	3	6	2	3	5	3	1	1	2	10	13	19	6	3	9	1			1		1			
Canyon Wren					1							2	3	8	6	2	4				2						
Cassin's Finch						4																					1
Cassin's Kingbird	6	13	13	5	2	5	6	5	4	7	6	2	21	21	32	37	49	14				1				2	
Chipping Sparrow	3	16	17	29	6	22	10	10	10	6	6	5	8	15	25	27	24	16	1	5	3	10	5	21	8	32	6
Clark's Nutcracker																				4		1					
Common Nighthawk	6		5	2	4	4	1	5		5	1	3	2	7	5	7	3	1			1	2	2			1	
Common Raven	2	5	1		1	2	3			1		2	1		1	2	5		5	6	2	2	5	5	7	4	2
Cooper's Hawk					1														1			1			1		
Cordilleran Flycatcher																			5	10	6	3	3	1	2	4	
Dark-eyed Junco															1	1			6	2	4		5	2		2	3
Downy Woodpecker				1									1	2		1	2	1		1		1	1	1			
Dusky Flycatcher				1								1		1												2	1
Eurasian Collared-Dove	3													4			2							1			
Evening Grosbeak	3		4						1			8							5		29			1			
Grace's Warbler							1								2	4	1	6	6	4	4	8	5	8	22	12	17
Gray Flycatcher	12	6	5	7	3	6	3	2	4	10	10	11	10	5	8	3	14	5									

Species	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021
	TA-36 Minie Site									TA-39 Point 6									TA-16 Burn Grounds								
	Pinyon-Juniper Woodland									Pinyon-Juniper Woodland									Ponderosa Pine Forest								
Great Horned Owl		3								1																	
Green-tailed Towhee	3	1								1																1	
Hairy Woodpecker			2	1		1		1	1			5	3			1	1	4	1	1		1	1	2	1	1	
Hammond's Flycatcher																			8	9	12	5	7	5	10	5	7
Hepatic Tanager									2			1	2	1	2			1				1					
Hermit Thrush						1														4	6	1	2	2	5	5	2
House Finch	16	17	26	17	12	18	17	11	11	21	4	23	9	30	44	50	53	22	16	2	5	5	12	7	12	18	11
House Wren																1			1	1		2	2	6	8	2	1
Juniper Titmouse	12		7	6	9	3	26	8	20	11	13	18	6	1			3	2									
Lesser Goldfinch	2	6	7	4	9	12	8	4	4	4	12	9	10	14	19	15	27	8	3		8	9	4	8	5	6	2
MacGillivray's Warbler																						1	3			1	
Mountain Bluebird		2	20	10	11	1	9	3	2		4						2	1			4	4	4	7	4	5	
Mountain Chickadee	5	2	1	2									1	1		1			5	8	9	6	8	9	1	4	6
Mourning Dove	17	17	13	5	8	8	11	9	7	13	22	10	3	15	11	8	10	9	4		1	3	17	3	5	17	5
Northern Mockingbird					2		1	4			1							2									
Northern Rough-winged Swallow						3																					
Orange-crowned Warbler																										1	
Peregrine Falcon									1			1						1									
Pine Siskin	10	2		5	1			1		6		3	3						12	4	5		4	2		6	
Plumbeous Vireo	10	10	7	3	9	9	15	3	3	1		1	6	6	5	5	12	4	11	16	15	14	11	18	16	24	17
Pygmy Nuthatch				2		2	3		1			2	4	12	9	11	10	1	11	13	26	29	41	20	16	23	5
Red Crossbill					1						2						1			2	9	13	9		6	26	1
Red-shafted Flicker	3	1	3	2	5	2	1		1	3	2	4	8		3	2	2		3	4	11	11	5	5	2	7	5
Red-tailed Hawk							1	2	1			1	1	1	1												
Rock Wren	3	3	4		2	10	11	10	4	7	10	4	12	14	14	12	20	15	1	2	2	6			4	1	
Ruby-crowned Kinglet																								2			1
Savannah Sparrow																										1	
Say's Phoebe	2	1	2		2	5	1	1	2	2	1		5	2	4		6	5	1		1	3	3	4	1	1	4
Scaled Quail			1																								
Spotted Towhee	17	8	19	27	32	24	19	20	17	12	6	33	16	12	16	15	20	14	11	18	16	14	21	22	34	24	16
Steller's Jay							1												3	2	5	6	3	4	4	2	1
Townsend's Solitaire	1																						1				
Turkey Vulture					1			2									1		1					1			
Vesper Sparrow																									1		
Violet-green Swallow		5	7	1	3	2	1	6		6	4	1	9	6	6	9	47	5		2	19	2	2	4	2	7	6
Virginia's Warbler					1	3	1					1	2	4		5		2	17	11	21	13	7	5	5	8	3

	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021	2013	2014	2015	2016	2017	2018	2019	2020	2021
Species	TA-36 Minie Site									TA-39 Point 6									TA-16 Burn Grounds								
	Pinyon-Juniper Woodland									Pinyon-Juniper Woodland									Ponderosa Pine Forest								
Warbling Vireo						2													2	9	7	6	5	4	6	3	7
Western Bluebird	15	11	18	17	16	19	21	23	8	5	19	12	21	13	6	7	17	3	20	20	49	37	32	27	20	27	8
Western Tanager		2	3		1						2	1	1	2	2	6	1	2	2	3	7	2	4	6	16	10	7
Western Wood-Pewee	10	8	18	11	10	7	18	14	10		4	2	10	8	11	12	18	12	15	10	16	14	22	20	24	28	25
White-breasted Nuthatch	1	4	9	10	13	5	2	1	2			2	4	4	2	6	3	2	9	8	7	9	20	10	10	8	10
White-crowned Sparrow																		1									
White-throated Swift											1						2										
White-winged Dove	1	5	9	2		3	2	1	1	7	5	6	16	15	15	5	2	5			1	2			1		
Willow Flycatcher																		1									
Woodhouse's Scrub-Jay	5	1	3	4	8	7	14	10	10	8	10	4	8	6	4	5		2	1								