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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

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Executive Summary

Los Alamos National Laboratory biologists in the Environmental Compliance and Protection Division at Los Alamos National Laboratory (LANL) initiated a multi-year program in 2013 to monitor avifauna (birds) at two open detonation sites and one open burn site on LANL property. Monitoring results from these efforts were compared among years to monitor trends. The objectives of this study were to determine whether LANL operations impact bird species richness, diversity, abundance, or composition. Additionally, nesting success of secondary-cavity nesting birds was examined using nestboxes. LANL biologists completed the sixth year of this effort in 2018. The overall results from 2018 continue to indicate that operations are not negatively affecting bird populations; however, we are seeing some species turnover through time and that will continue to be monitored.

Three bird point count surveys were completed at each of the treatment sites at the Technical Area (TA) 36 Minie site, the TA-39 point 6, and the TA-16 burn ground between May and July 2018. A total of 842 birds representing 58 species were recorded at the three treatment sites. Three bird point count surveys were also completed at each of the control sites between May and July 2018. Occupancy and nest success data from nestboxes at treatment sites were compared with the overall avian nestbox monitoring network.

Species richness at the treatment sites was not statistically different from their associated controls; however, species diversity was. In all three cases, the diversity was higher at the treatment sites than at the control sites. Avian abundance showed more variability but treatment and controls were trending together year to year. Species composition seems to indicate some species turnover in the habitat types but very little difference between treatment and control sites.

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Introduction

An annual avian monitoring program was started in 2013 as part of the Resource Conservation and Recovery Act permitting process at Los Alamos National Laboratory (LANL) 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). The objectives of this study were to determine whether LANL operations impact bird species richness, diversity, abundance, or composition. Comparisons were made with control sites of similar habitat that have been surveyed since 2011 (Hathcock et al. 2011).

Biologists at LANL used standard point count methodology to record avian abundance and diversity along transects at the three treatment sites and associated control sites during the summer of 2018. Summer surveys provide information about what birds were 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 change at LANL.

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

Methods

Field Methods for Point Count Surveys

The point count surveys were conducted along single transects in the forested, undeveloped land surrounding the treatment sites (Figures 1–3). The habitat types around the sites are a pinyon-juniper woodland (PJ) for Minie and TA-39 and a ponderosa pine forest (PIPO) at TA-16. These habitat descriptions were 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) were monitored annually in ongoing surveys that have been conducted at LANL since 2011 as described in Hathcock et al. (2011). Each habitat type control contained two replicate transects that were 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 were randomized and surveyed according to the random order.

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 more natural.

Transects were approximately 2.0 to 2.5 km in length and allowed for 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 was May 1 through August 15. 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 and surveys must be 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 will look and listen for 5 minutes, noting any birds encountered at each point. The distance for observations is considered as an "unlimited-distance circular plot"; however, the distance to each bird out to 100 m should be noted. Ensure individual birds are not re-counted from point to point. Use a range finder when possible for measuring the distance.
- While walking between points, note any species encountered that have not otherwise been counted from a previous point or future point. The surveyor's main focus is counting birds from each point and not spending unnecessary time looking for additional birds between points.
- Do not conduct surveys during rain events or winds greater than 24 kph.
- Record all birds encountered on the data sheet. For each observation, the minimum data collected should be point number, time, species, number of individuals, and distance from the point.
- Use the "NOTES" section to indicate any potentially important aspects of 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. Other wildlife or evidence of wildlife that could be used for other projects should be recorded.

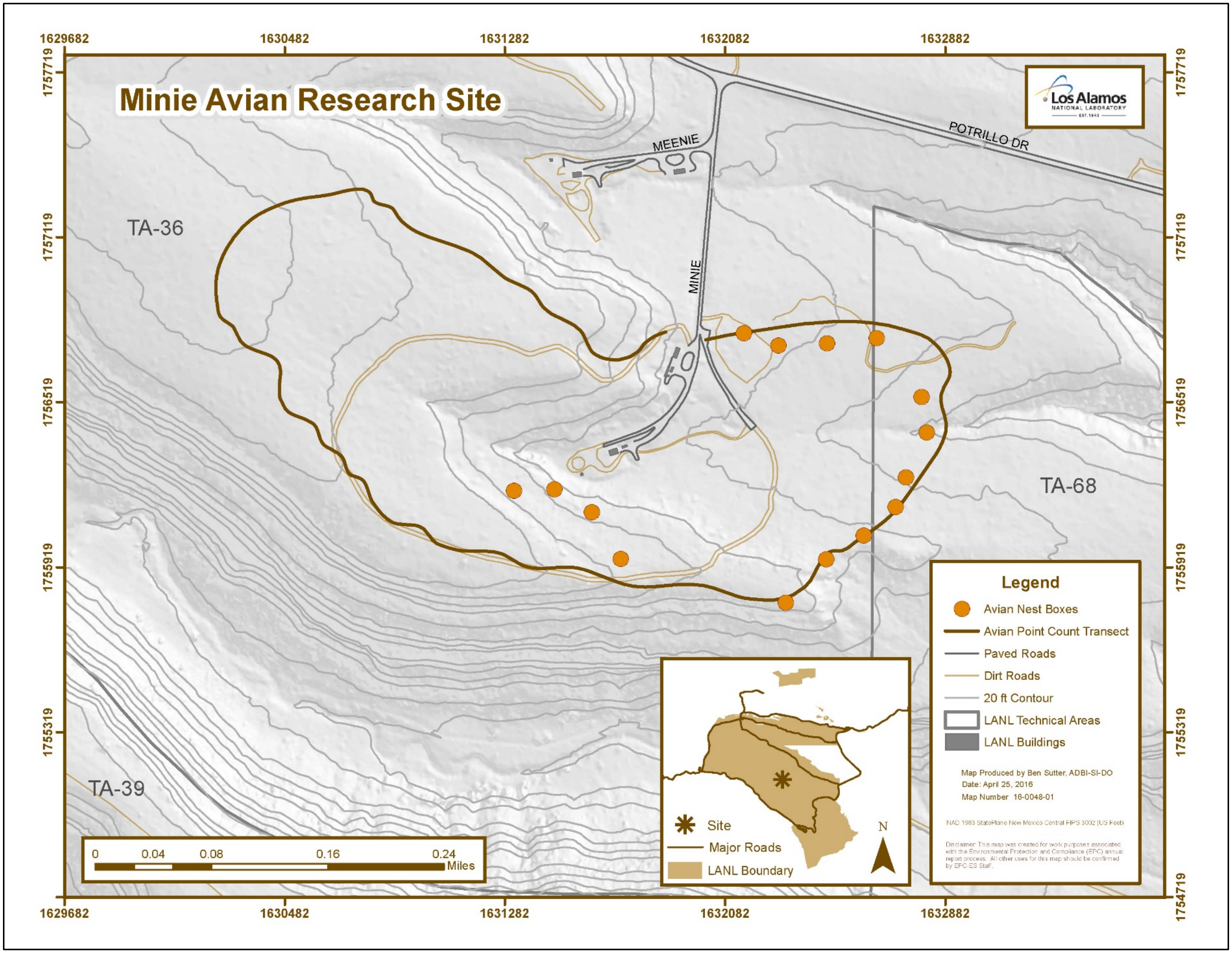

Figure 1. Breeding bird survey transect and nestbox locations around TA-36 Minie site

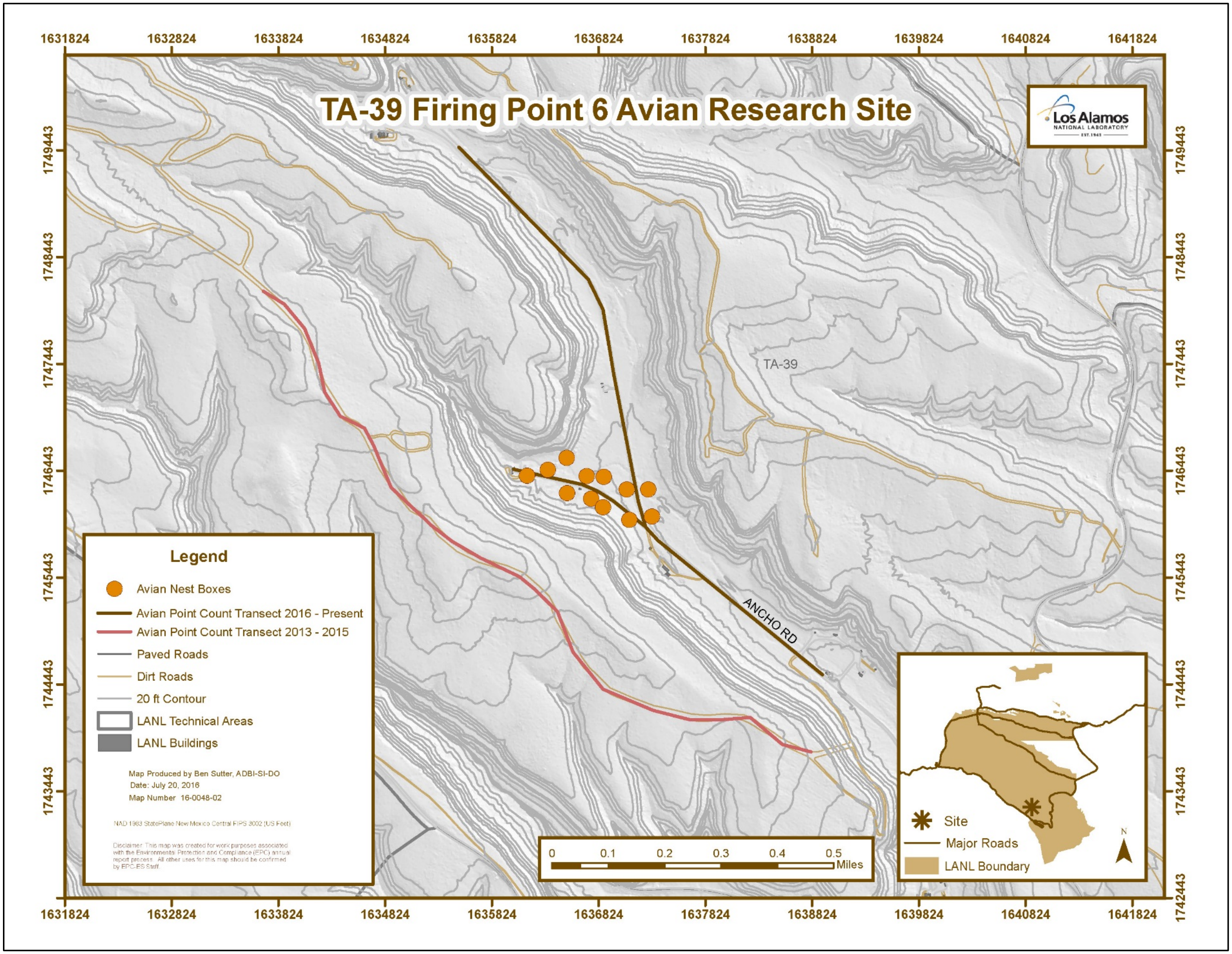

Figure 2. Breeding bird survey transect and nestbox locations around TA-39 point 6

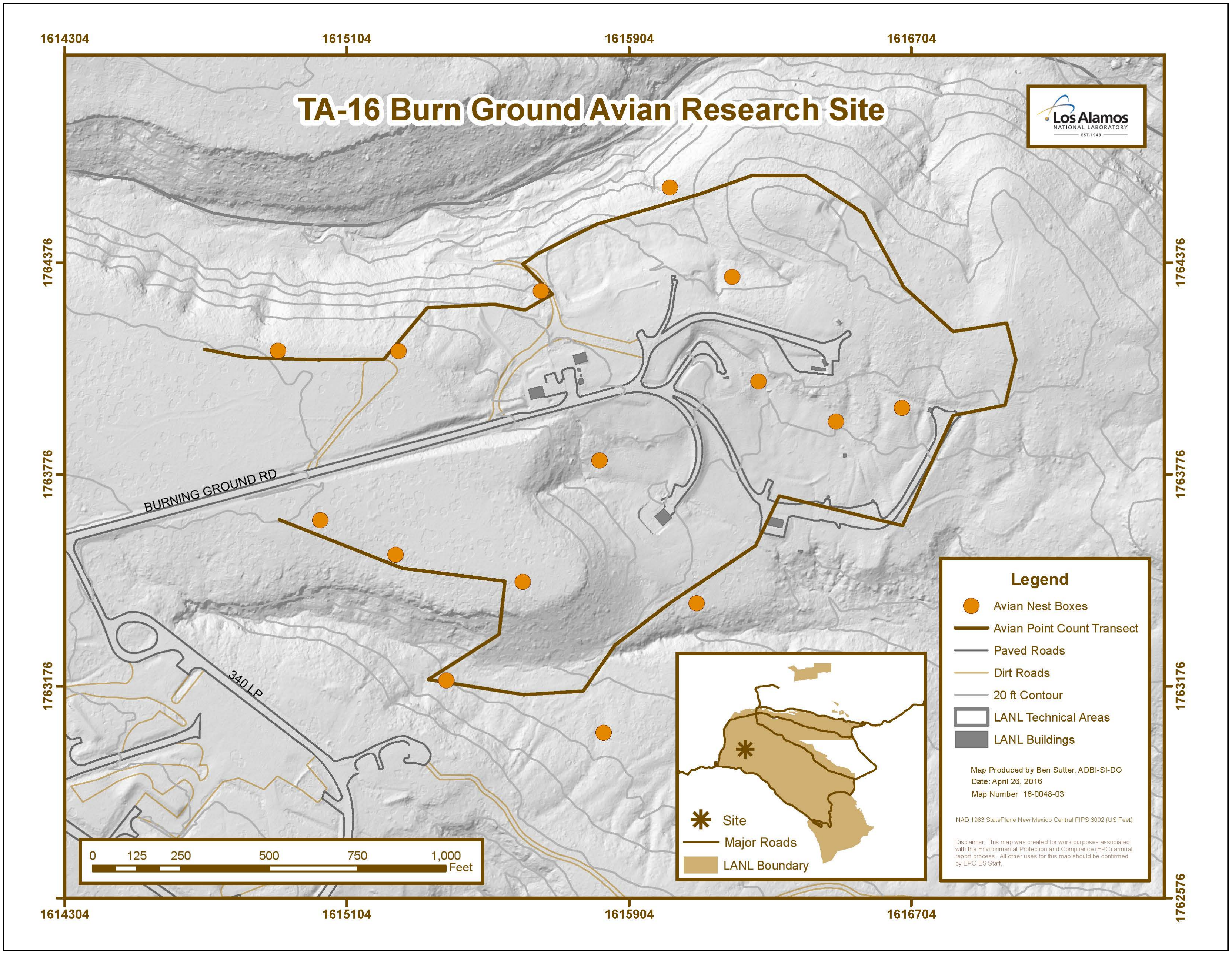

Figure 3. Breeding bird survey transect and nestbox locations around the TA-16 burn ground

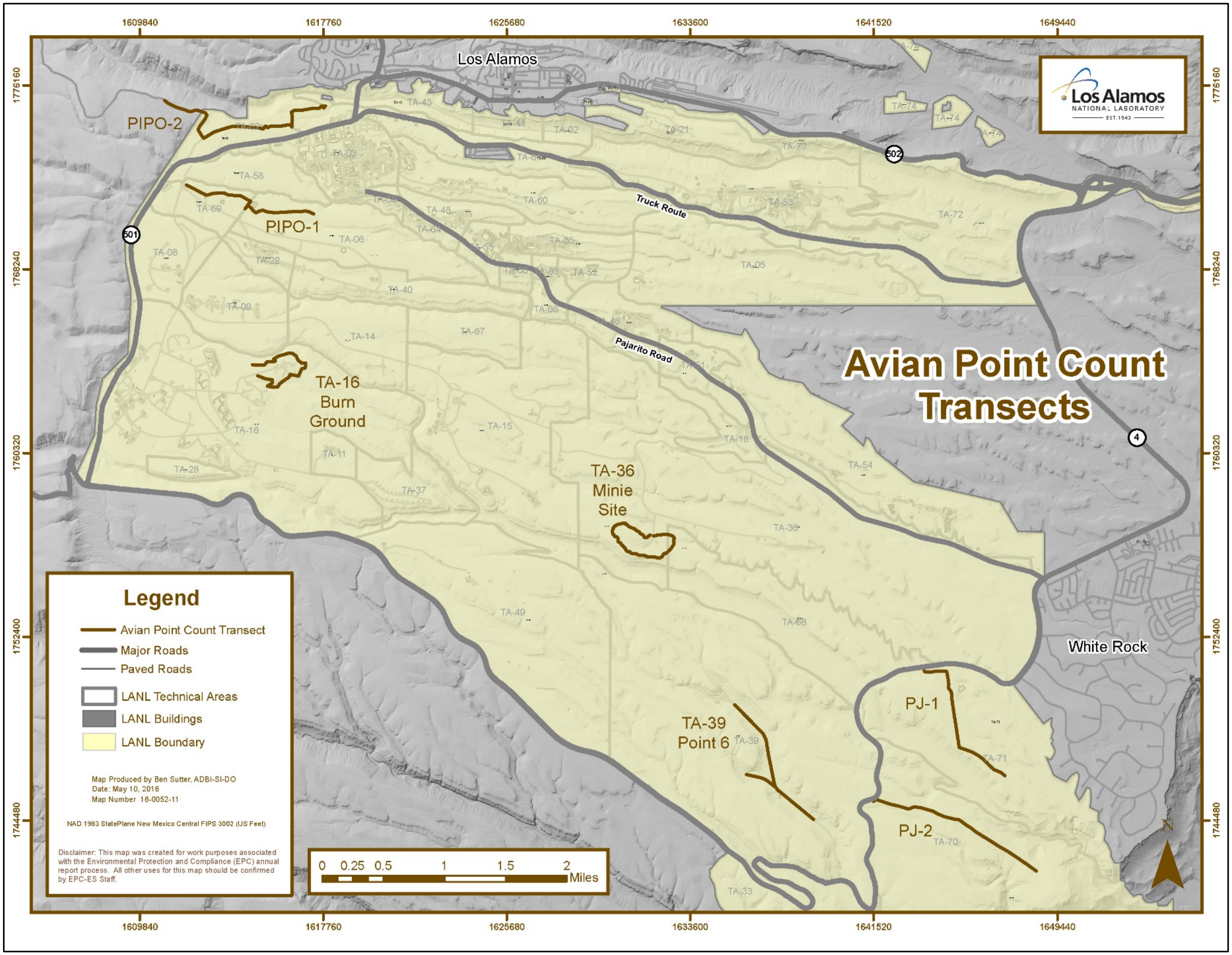

Figure 4. All avian point count transects around LANL

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

Field Methods for Nestbox Monitoring

In 2011, nestboxes were added to Minie and TA-39 (Figures 1 and 2). In 2015, nestboxes were added to TA-16 (Figure 3). Nestboxes were monitored every 1 to 2 weeks for active nests. When an active nest was found, it was monitored more frequently to determine whether the nest failed or successfully fledged young. Nestlings were also banded and the sex determined after the age of 10 days.

Statistical Methods for Point Counts

The data were summarized to compare species richness, diversity, abundance, and composition between sites and among years using the statistical software R (version 3.4.1; R Core Team 2017). Species richness and diversity were computed using the R-package 'iNEXT' (Hsieh et al. 2016; Chao et al. 2014) and plotted with bootstrap confidence intervals around the mean for rarefied/extrapolated samples, facilitating the comparisons of richness and diversity. The estimated asymptote along with a confidence interval were also provided. The Simpson's diversity index was calculated using the following formula: $D = 1 – (\sum n(n-1) / N(N-1))$, where n = the total number of organisms of a particular species and N = the total number of organisms of all species. The value of D ranges between 0 and 1. With this index, 1 represents infinite diversity and 0 represents no diversity. Species diversity was also computed using the statistical software PAST (Hammer et al. 2001) and a t-test was used to test for differences between treatment and control sites each year. Comparisons of Simpson diversity in two samples are described by Hutcheson (1970) and is an alternative to the permutation test. To examine species composition, non-metric multidimensional scaling (NMDS) was used to determine dissimilarity among sites. To compare species composition between treatments and years, an analysis of similarity (ANOSIM) was conducted using 1000 permutations. These analyses were completed using the community ecology R-package 'vegan' (Oksanen et al. 2017).

Statistical Methods for Nestboxes

Occupancy and nest success rates of the nestboxes at the three treatment sites and in the overall network were calculated. 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. Annually, data from the three treatment sites were compared with the overall avian nestbox network at LANL that was established in 1997.

In 2019 a nest survival model (Dinsmore et al. 2002) in Program MARK was generated to estimate nest survival (S) for Western Bluebirds during a 22-year period (1997-2018). The nesting period spanned 21 April to 16 August (118 days) across all years of the study. Data for each nest were subdivided into the incubation and nestling periods and formatted as groups for analyses in Program MARK (Dinsmore and Dinsmore 2007). There was also an interest in survival estimates for the three treatment sites. Because there were not enough data to fit models specific to each site, a simple constant survival model was used, by nest stage. These estimates are presented for planning purposes only and are not meant to be directly comparable to estimates generated from the entire dataset (Unpublished data 2019).

Results and Discussion

Year 2018

Three surveys were completed at each of the three treatment sites and the associated control sites between May and July 2018. A total of 842 birds representing 58 species were recorded at the three treatment sites. A full account of the 2013–2018 data is detailed in Appendix 1.

Species richness is the number of different species represented in an ecological community and is simply a count of species. In this case, each treatment site and control are individual communities. Species diversity is a measure that takes into account the species richness and the overall abundance to compare evenness across a community. Here we used the Simpson's diversity index, which measures the probability that two individuals randomly selected from a sample will belong to different species. The abundance is the total number recorded of a given species. Table 1 details the species richness, diversity, and abundance for 2018 for each treatment site.

Table 1. The species richness, diversity, and abundance recorded at each site in 2018

2018	*Minie Site*	*TA-39*	*TA-16*
Richness	35	39	43
Diversity	0.9494	0.9405	0.9541
Abundance	242	315	285

To further analyze species richness and diversity, species rarefaction and extrapolation plots were developed with the control sites being combined. Species rarefaction and extrapolation from 2018 show no differences between treatment and control sites for species richness. There were overlapping 95% confidence intervals for species richness (Figures 5A–6A) for all three treatments and their controls. Simpson's diversity (Figures 5B–6B) was significantly different since the 95% confidence intervals did not overlap. In these cases, the treatment sites were higher in diversity than the controls.

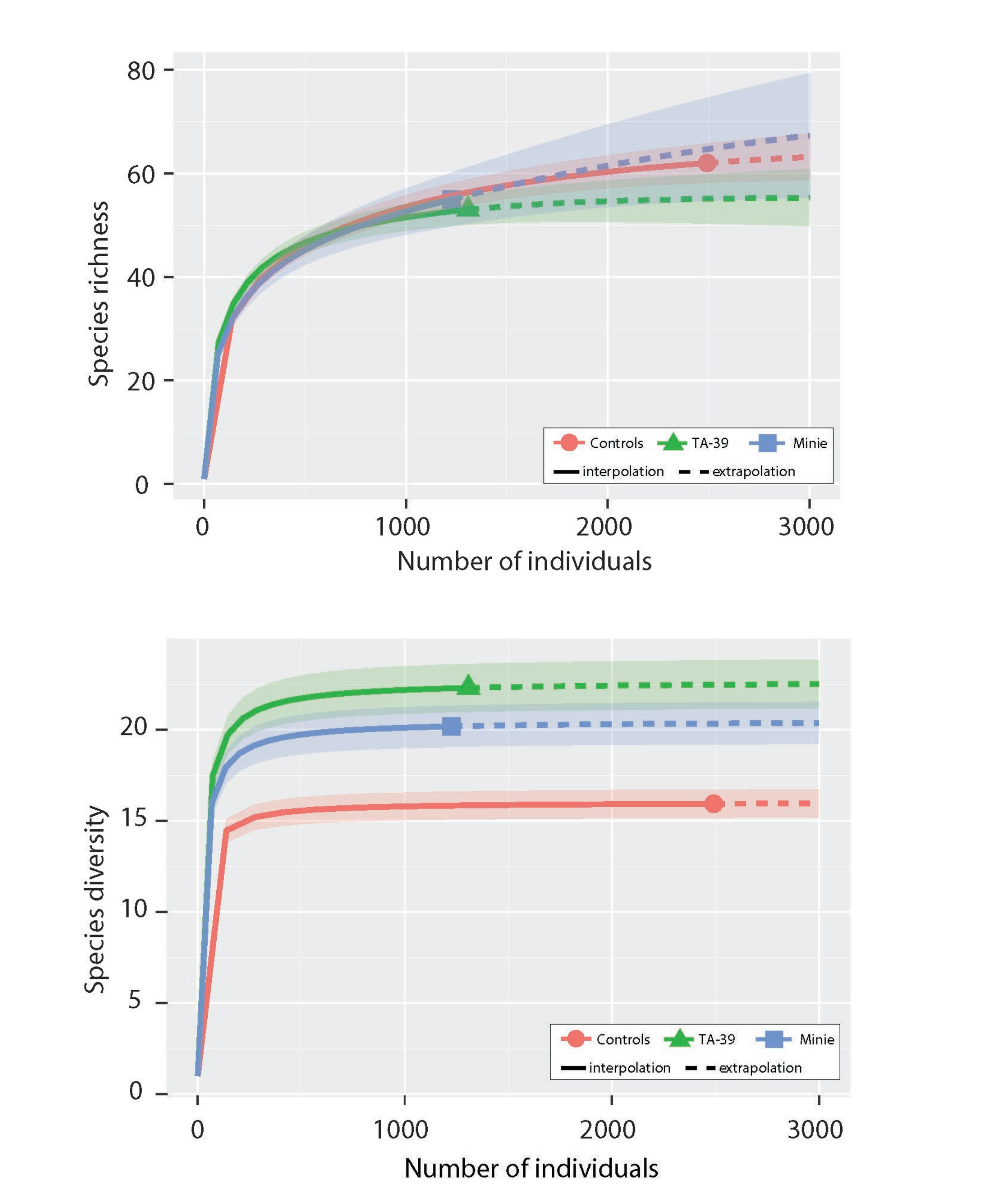

Figure 5. Species rarefaction and extrapolation for species richness and diversity comparing Minie and TA-39 with the PJ controls

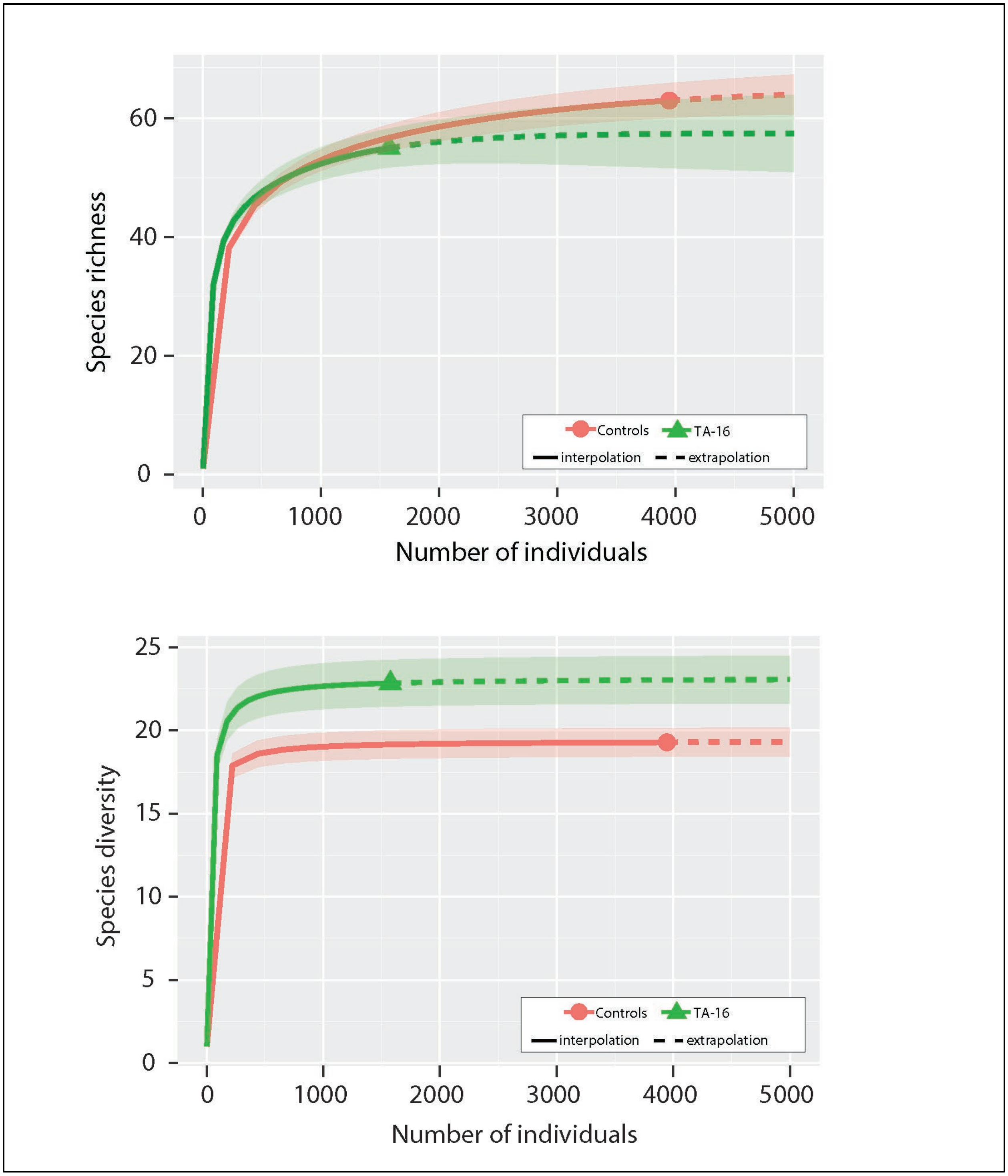

Figure 6. Species rarefaction and extrapolation for species richness and diversity comparing TA-16 with the PIPO controls

Multivariate analysis with ordination was used to explore the data further to look for patterns that may be explained by a multitude of other environmental factors not assessed directly. We used non-metric multidimensional scaling (NMDS) (Gardener 2014). NMDS is a method used to collapse data from multiple dimensions–such as several communities in different sites–into just a few dimensions. A measure of ‘stress’ (mismatch between the rank order of distances in the actual data, and the rank order of distances in the ordination) is calculated according to the number of dimensions (k). Lower stress values (typically < 0.1) mean greater conformity of the ordinated distances to the actual multivariate distances. Using this method, the samples are moved slightly in a direction that decreases the stress until stress reaches a minimum. More dimensions can be added when high stress is produced from too few dimensions. The final configuration of points for 2018 is represented in Figure 7 where the treatments and controls are plotted (k = 3, stress = 0.002). The different species composition between the left and right and the upper and lower part of the graph (dotted lines = the reference lines) correlate with the associated habitat types. Here, the PJ sites are grouped on the left and PIPO sites on the right. In the plot it is clear that the PJ-2 control transect is slightly different that the other control and the two treatments. The species that seem to be driving the PJ-2 control are the Black-throated Gray Warbler, American Kestrel, Black-chinned Hummingbird, and Juniper Titmouse. There must be some subtle habitat differences between the two controls for PJ. The PIPO controls and treatment site are more closely aligned with one another. In 2018, even with some variation, the treatments were not statistically different than the controls overall (ANOSIM: R = -0.15, P = 0.67) and the two habitat types were different as one would expect (ANOSIM: R = 0.96, P = 0.037).

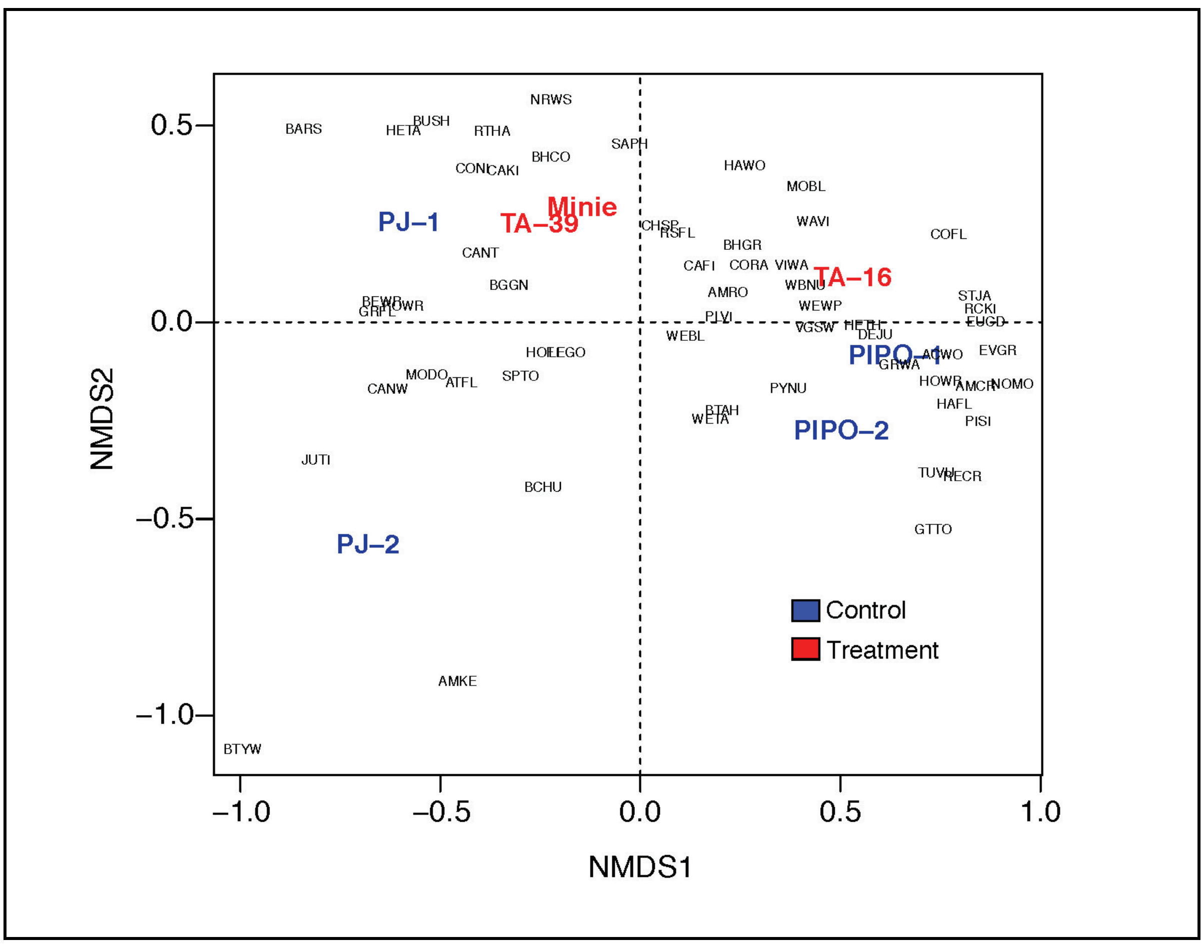

Figure 7. Non-metric multidimensional scaling of bird species and sites in 2018

Trends Over Time

Table 2 outlines the species richness over time at the treatment and individual control sites. The three treatment sites were maintaining a steady species richness over time with almost all indicating a slight increase in the number of species in 2015. Precipitation at LANL from January through July 2015 was the most precipitation since 1949 (Weather Machine 2015). The increases in richness, diversity, and abundance in 2015 were most likely attributed to the increased precipitation. Links between moisture and habitat quality for a migratory birds have been documented (Smith et al. 2010) and may be a causal factor. In addition, the winter of 2015 and into early 2016 was drier. The fluctuations in bird abundances are not alarming, and the differences between the treatment sites and control sites are not biologically significant. The winter moisture for the winter of 2018-2019 was at or slightly above normal (personal communication B. Parmenter) so it will be interesting to see what the effects will be to bird numbers in 2019.

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

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

Tables 3–5 compare the species diversity over time between the treatment site and the combined control. The two control sites were combined to analyze diversity because we were interested in the relative abundances among species and not the actual numbers. There have been some significant differences at times over the course of the study. 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 greater than 0.90, which compared with ecological systems in general, is very high.

The overall abundance of birds is trending the same for all treatment sites compared with the controls. At TA-16, the overall abundance is lower, but the percent abundance is similar year to year when compared with the control sites. Darker shading indicates a significant difference.

Table 3. Changes in species diversity over time comparing Minie Site with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
Minie	0.9464	0.9463	0.9502	0.9315	0.9429	0.9494
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419	0.9255
t-test	t = 3.9572 df = 501.3 p = <0.01	t = 2.5469 df = 510.42 p = 0.01	t = 1.5902 df = 644.91 p = 0.11	t = 0.4385 df = 499.33 p = 0.66	t = 0.1504 df = 448.66 p = 0.88	t = 3.577 df = 644.09 p < 0.01

Table 4. Changes in species diversity over time comparing TA-39 with the PJ controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
TA-39	0.9425	0.9427	0.9396	0.9559	0.9486	0.9405
PJ Control	0.9065	0.9285	0.9436	0.9279	0.9419	0.9255
t-test	t = 3.3636 df = 538 p <0.01	t = 1.9703 df = 509.25 p = 0.05	t = -0.6751 df = 401.58 p = 0.50	t = 4.5611 df = 783.86 p <0.01	t = 1.2234 df = 705.5 p = 0.22	t = 2.085 df = 717.79 p = 0.03

Table 5. Changes in species diversity over time comparing TA-16 with the PIPO controls

	2013	*2014*	*2015*	*2016*	*2017*	*2018*
TA-16	0.9542	0.9509	0.9454	0.9463	0.9429	0.9541
PIPO Control	0.9528	0.9462	0.9414	0.9417	0.9468	0.9431
t-test	t = 0.3323 df = 378.91 p = 0.73	t = 0.9236 df = 472.24 p = 0.35	t = 0.748 df = 633.26 p = 0.45	t = 0.7438 df = 475.6 p = 0.45	t = -0.6903 df = 444.95 p = 0.49	t = 2.52 df = 570.39 p = 0.01

Species composition was analyzed over time according to whether sites were controls or treatments for PJ sites and ponderosa sites separately (Figures 8 and 9 respectively). Figure 8 shows the species composition for PJ sites for each year (k = 4, stress = 0.09). Four dimensions were used to decrease the stress and get a better representation of the data. As expected, the difference in species composition was significant between treatment sites and control sites for PJ habitats (ANOSIM: R = 0.64, P = 0.001). In the figure, the species closest to each site were the species most important in separating those sites from the rest. An early versus late analysis was done where the years 2013 – 2015 were compared to 2016 – 2018. The differences in species composition was not significantly different (ANOSIM: R = 0.108, P = 0.11).

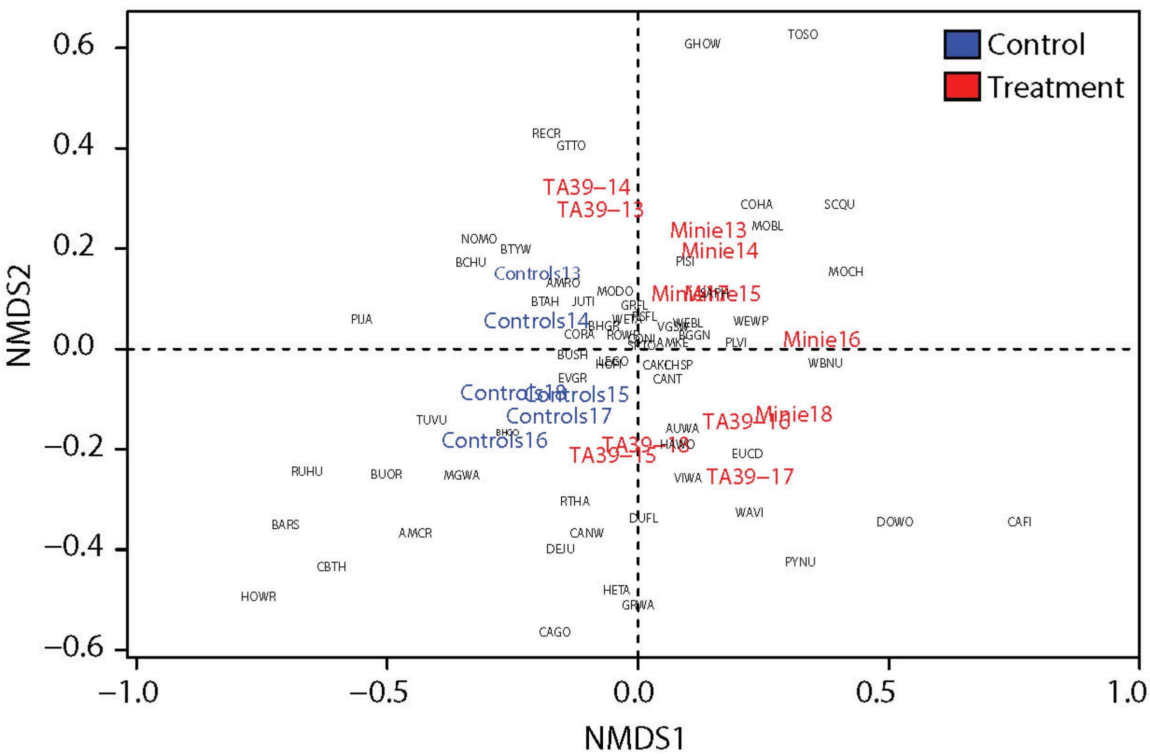

Figure 8. Non-metric multidimensional scaling of bird species from 2013 to 2018 by treatment for PJ sites

Species composition over time for ponderosa sites are shown in Figure 9 (k = 3, stress = 0.06). As expected, the difference in species composition was significant between treatment sites and control sites for ponderosa habitats (ANOSIM: R = 0.88, P = 0.003). The species closest to each site were the species most important in separating those sites from the rest. An early versus late analysis was done where the years 2013 – 2015 were compared to 2016 – 2018. The differences in species composition was not significantly different (ANOSIM: R = -0.026, P = 0.46).

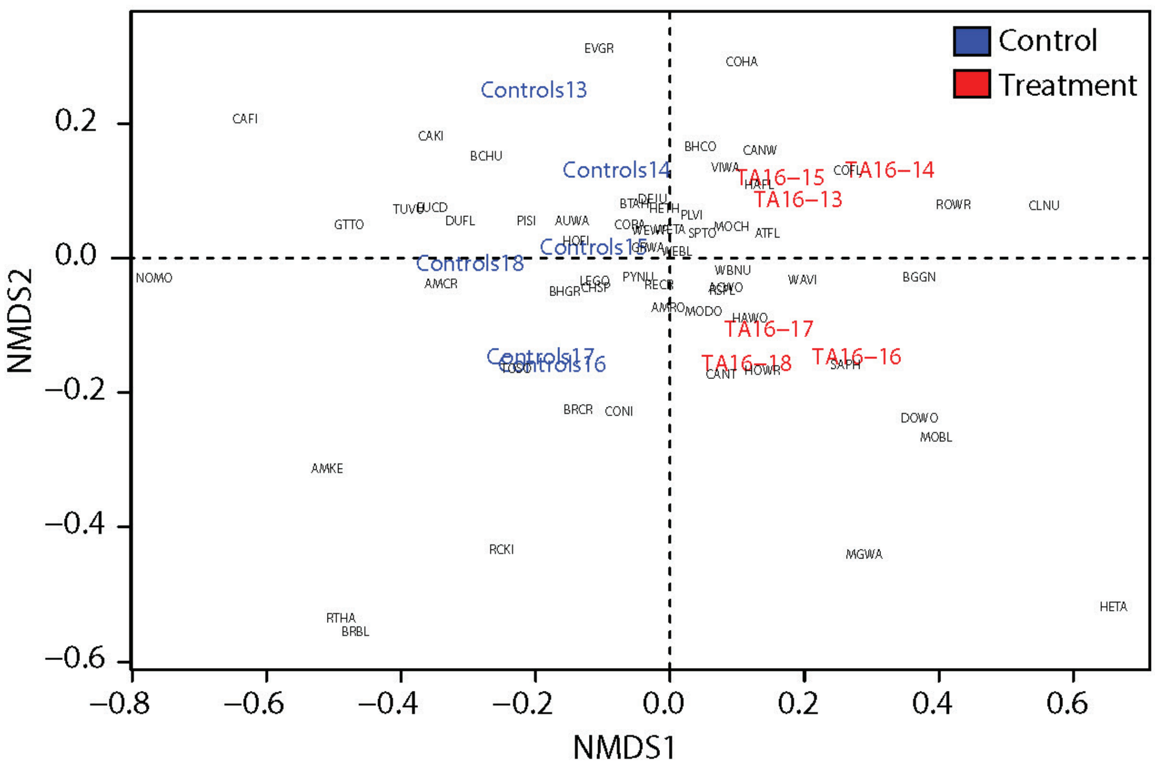

Figure 9. Non-metric multidimensional scaling of bird species from 2013 to 2018 by treatment for ponderosa sites

Collectively, Figures 8 and 9 suggest that the control sites have slightly different species composition than treatment sites over the course of the study.

Species in a community align themselves in ways similar to those described by MacArthur and Wilson (1967) in *The Theory of Island Biogeography*, which hypothesized how distance and area could combine to regulate the balance between immigration and extinction in an island population. Immigration is the appearance of a new species in a community, while extinction is the disappearance of a species from a community. This relationship is known as species turnover. The concept of species turnover is what drives the changes in composition over time.

More study is needed to better understand these patterns and to determine the mechanism for species turnover in these areas. The subtle changes in composition over time may be normal fluctuations, but if the gap widens then it may be indicative of a larger process at work. This and similar questions can be answered by continuing to monitor these sites and to analyze bird community data in other areas on the Pajarito Plateau.

Nestboxes

During the 2018 season, the overall avian nestbox network was managed at lower levels than previously. The treatment sites were maintained at previous years' effort, but site-specific constraints from increased fire restrictions in 2018 limited the overall network management.

During the 2018 nesting season, 15 nestboxes each at Minie, Burn Grounds, and TA-39 were actively monitored. The overall avian nestbox network, without the three treatment sites, only contained 177 nestboxes in 2018. Of those, 94 contained active nests and 46 of those nests fledged young successfully. This was an overall occupancy rate of 53% with a 49% success rate.

Tables 6 and 7 compare the occupancy and success rates for each treatment site and the overall nestbox network since 2015.

Table 6. Comparison of occupancy for the treatment sites and the overall nestbox network over time.

	2015	*2016*	*2017*	*2018*
Overall Network	40%	45%	48%	53%
Minie	66%	73%	46%	20%
TA-39	8%	58%	20%	33%
TA-16	-	73%	100%	53%

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

	2015	*2016*	*2017*	*2018*
Overall Network	66%	69%	57%	49%
Minie	64%	23%	29%	33%
TA-39	100%	57%	0%	40%
TA-16	-	63%	76%	63%

In 2018 there were three successful nests that fledged young at Minie, five at TA-39, and eight at TA-16. The occupancy rate at Minie is lower and stands out in comparison to previous years.

Precipitation was low, possibly contributing to reduced nesting attempts and lower box occupancy rates. Success rates at the three treatment sites were not very different in comparison to the overall network and did not display decrease over time.

In 2018, nonviable eggs collected from nestboxes at Minie, TA-16, and TA-39 were submitted to an analytical lab for chemical analyses. Eggs collected from two of the firing sites (Minie and TA-39) contained higher concentrations of copper when compared with background concentrations from samples on nearby public lands. The source of elevated copper found in two western bluebird egg samples collected near the firing sites could be from some high-explosives testing; copper has historically been detected above soil screening levels at Technical Area 39 (Juarez and Vigil-holterman 2011). Yet, copper soil levels at Minie, near the firing site were below the regional statistical reference level (RSRL) in 2018. However, it has been suggested that birds are relatively resistant to copper toxicity when compared with other taxa (Eisler 1998). Although magnesium, potassium, and sodium concentrations were higher compared with background egg concentrations, these elements are macronutrients which are required by living organisms in large quantities. Eggs collected from TA-16 contained higher concentrations of antimony, mercury, and selenium and exceeded regional RSRLs, but were all below the known lowest observable adverse effects levels (LOAELs). Eggs collected from TA-39 contained higher concentrations of mercury and selenium compared to the RSRLs, but were below the LOAEL. Most chemical concentrations that were detected at all of the sites were below RSRLs and all were below the LOAELs. These data suggest that egg element concentrations observed here are not of ecological concern. As these data are preliminary, more samples are needed to make a robust assessment, including additional background samples.

Nest survival estimates for the three treatment sites for the incubation and nestling periods of the Western Bluebird are in figures 10 and 11. Nest survival is comprised of two phases for this analysis, the incubation phase and the nestling phase. Due to low sample sizes for this type of analysis, confidence intervals are large and these results should be considered only for possible pattern analyses. During incubation, survival at Burn Grounds and TA-39 Point 6 did not differ from all other sites while survival at Minie Site was lower than that at all other sites pooled (Figure 10). During the nestling period survival at the three sites did not differ from that at all other sites pooled together (Figure 11).

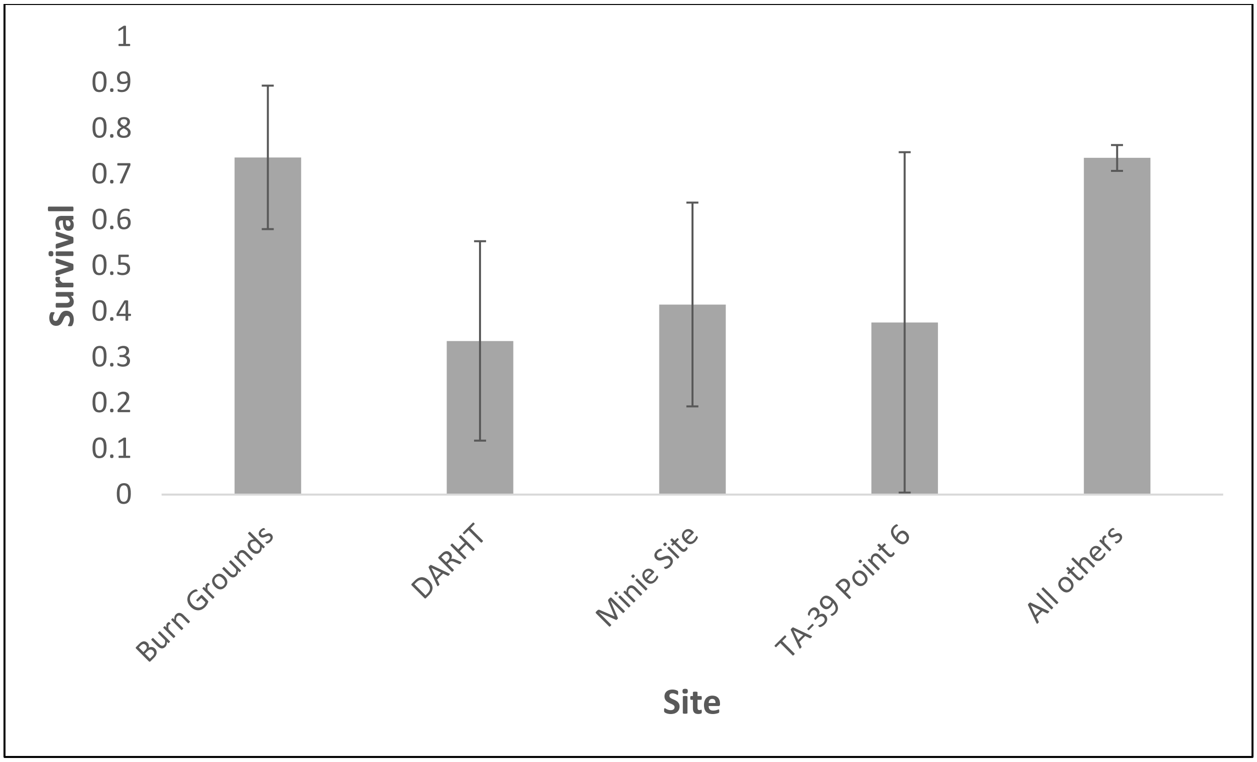

Figure 10. Estimated probability of surviving the 14-day incubation period for Western Bluebird nests at selected sites. Estimates (±95% CI) were generated using a constant survival model with no covariates.

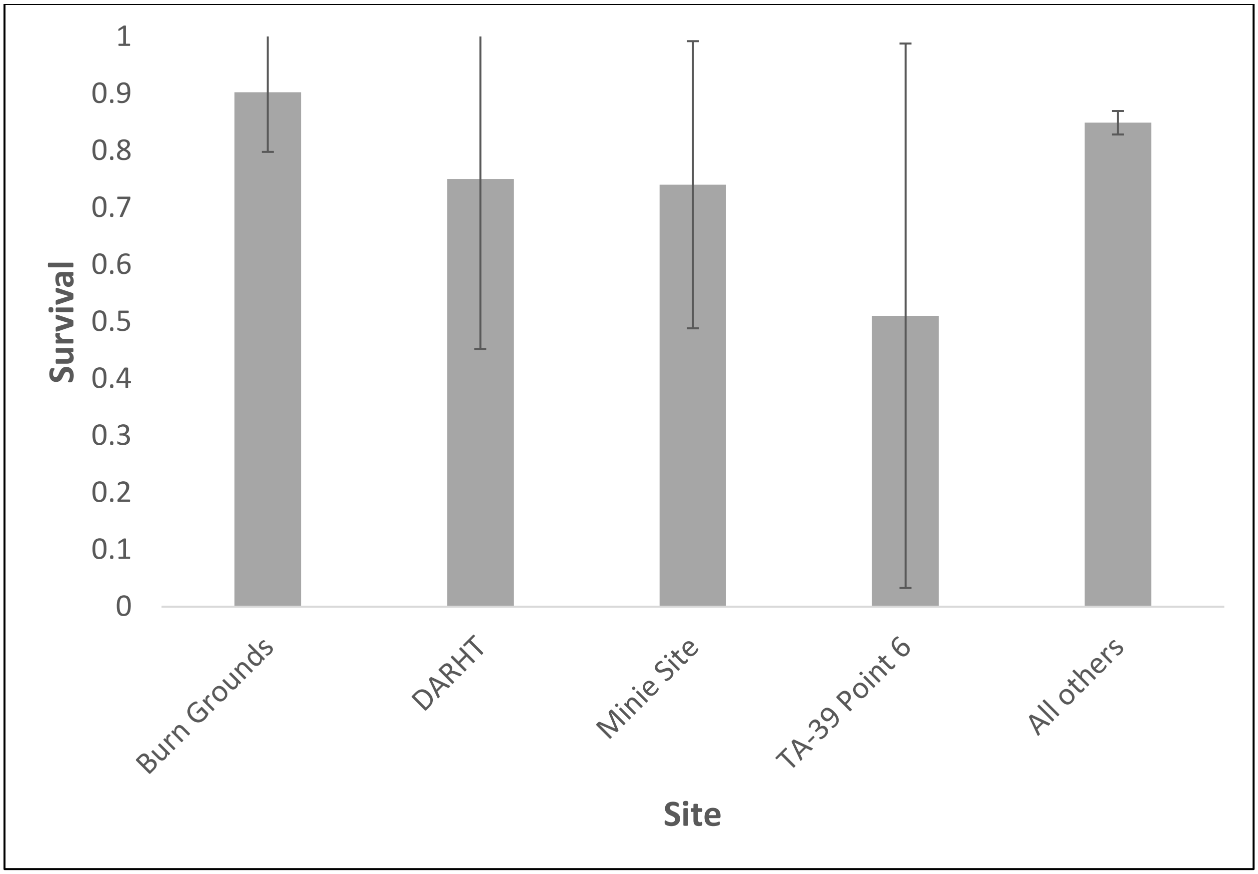

Figure 11. Estimated probability of surviving the 18-day nestling period for Western Bluebird nests at selected sites. Estimates (±95% CI) were generated using a constant survival model with no covariates.

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. Of the 59 species detected at the three treatment sites, all are protected under the Migratory Bird Treaty Act. Additionally, two of the species detected at the three treatment sites are on the Birds of Conservation Concern Region 16 list, the Southern Rockies/Colorado Plateau region (USFWS 2008). Those two species are the Juniper Titmouse and Grace's Warbler. The primary statutory authority for Birds of Conservation Concern is the Fish and Wildlife Conservation Act of 1980 (16 United States Code § 2901). Another conservation tool used in migratory bird management is the Birder's Conservation Handbook (Wells 2007), which lists the top 100 birds most at risk in North America. Two species detected at the three treatment sites are on the top 100 list. They are the Virginia's Warbler and Grace's Warbler.

Continuing the research reported herein will provide a long-term dataset on the ecological health of LANL's avifauna at the three treatment sites, contribute 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 allow LANL to contribute to national goals in avian conservation monitoring and research.

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Literature Cited

Chao, A., N.J. Gotelli, T.C. Hsieh, E.L. Sander, K.H. Ma, R.K. Colwell, and A.M. Ellison 2014. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. *Ecological Monographs* 84:45–67.

Dinsmore, S.J., G.C. White, and F.L. Knopf. 2002. Advanced techniques for modeling avian nest survival. *Ecology* 83:3476-3488.

Dinsmore, S.J., and J.J. Dinsmore. 2007. Modeling avian nest survival in Program MARK. *Studies in Avian Biology* 34:73-83.

Eisler, R. 1998. Copper hazards to fish, wildlife, and invertebrates: a synoptic review. U.S. Geological Survey, Biological Resources Division, Biological Science Report.

Gardener, M. 2014. *Community Ecology: Analytical Methods Using R and Excel.* Pelagic Publishing. Exeter, United Kingdom. 556 pp.

Hammer, Ø., D.A.T. Harper, and P. D. Ryan 2001. PAST: Paleontological Statistics Software Package for Education and Data Analysis. *Palaeontologia Electronica* 4(1): 9pp.

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. LA-UR-11-05054. Los Alamos National Laboratory, 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. LA-UR-13-27825. Los Alamos National Laboratory, 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. LA-UR-14-28161. Los Alamos National Laboratory, 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. LA-UR-15-28296. Los Alamos National Laboratory, 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. LA-UR-17-20359. Los Alamos National Laboratory, 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. LA-UR-18-22897. Los Alamos National Laboratory, Los Alamos, New Mexico.

Hsieh, T.C., K.H. Ma, and A. Chao 2016. iNEXT: iNterpolation and EXTrapolation for species diversity. R package version 2.0.12 URL: http://chao.stat.nthu.edu.tw/blog/software-download/.

Hutcheson, K. 1970. A test for comparing diversities based on the Shannon formula. *Journal of Theoretical Biology* 29:151–154.

Juarez, C.L., and L.R. Vigil-holterman. 2011. Soil Sampling Results Summary Report for the Open Detonation Units at Technical Area (TA) 36-08 and TA-39-6. LA-UR-11-03156. Los Alamos National Laboratory, Los Alamos, New Mexico.

MacArthur, R.H. and E.O. Wilson 1967. *The Theory of Island Biogeography*. Princeton University Press, Princeton, N.J. 215pp.

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

Oksanen, J., F.G. Blanchet, M. Friendly, R. Kindt, P. Legendre, D. McGlinn, P.R. Minchin, R.B. O'Hara, G.L. Simpson, P. Solymos, M.H. Stevens, E. Szoecs and H. Wagner 2017. vegan: Community Ecology Package. R package version 2.4-4. https://CRAN.R-project.org/package=vegan.

R Core Team 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/.

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.

U.S. Fish and Wildlife Service (USFWS) 2008. *Birds of Conservation Concern 2008.* United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia. 85 pp.

Weather Machine 2015. Weather Machine Climatological Monthly Summary, September 2015, http://weather.lanl.gov/climo_monthly_summary.asp.

Wells, J.V. 2007. *Birder's Conservation Handbook: 100 North American Birds at Risk.* Princeton University Press. Princeton, New Jersey. 452 pp.

Appendix 1. All birds recorded at the three treatment sites from 2013–2018

Species	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
	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
American Crow																	1	1
American Kestrel				1			1			2								
American Robin	1	1	2		2		1	1		2		4	7		9	4	4	6
Ash-throated Flycatcher	11	5	14	13	13	10	19	11	29	12	8	8	3	5	6	2	3	8
Audubon's Warbler		2				5				2			6	5	1	6		1
Bewick's Wren	4	8	9	9	14	14	3	10	15	9	2	8						
Black-chinned Hummingbird		1	1				3	2				1	1		1		1	
Black-headed Grosbeak	1	3				1		2	4	1		3			1	2		2
Black-throated Gray Warbler			1		2		5	6	4									
Blue-gray Gnatcatcher	3	14	16	8	10	9	2		7	5	4	2		6	2	1	3	6
Broad-tailed Hummingbird	2	1	3		1		3	1	2		3	1	5	11	11	5	7	10
Brown Creeper													1					
Brown-headed Cowbird	1								2			3	4	1			4	2
Bushtit		2		2		11	2	14			1	12						
Canada Goose									16									
Canyon Towhee	2		5	3	6	2	1	1	2	10	13	19	1			1		1
Canyon Wren					1				2	3	8	6			2			
Cassin's Finch						4												
Cassin's Kingbird	6	13	13	5	2	5	7	6	2	21	21	32				1		

	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Chipping Sparrow	3	16	17	29	6	22	6	6	5	8	15	25	1	5	3	10	5	21
Clark's Nutcracker														4		1		
Common Nighthawk	6		5	2	4	4	5	1	3	2	7	5			1	2	2	
Common Raven	2	5	1		1	2	1		2	1		1	5	6	2	2	5	5
Cooper's Hawk					1								1			1		
Cordilleran Flycatcher													5	10	6	3	3	1
Dark-eyed Junco												1	6	2	4		5	2
Downy Woodpecker				1						1	2			1		1	1	1
Dusky Flycatcher				1					1		1							
Eurasian Collared-Dove	3										4							1
Evening Grosbeak	3		4						8				5		29			1
Grace's Warbler												2	6	4	4	8	5	8
Gray Flycatcher	12	6	5	7	3	6	10	10	11	10	5	8						
Great Horned Owl		3					1											
Green-tailed Towhee	3	1					1											
Hairy Woodpecker			2	1		1			5	3			1	1		1	1	2
Hammond's Flycatcher													8	9	12	5	7	5
Hepatic Tanager									1	2	1	2				1		
Hermit Thrush						1								4	6	1	2	2
House Finch	16	17	26	17	12	18	21	4	23	9	30	44	16	2	5	5	12	7
House Wren													1	1		2	2	6
Juniper Titmouse	12		7	6	9	3	11	13	18	6	1							
Lesser Goldfinch	2	6	7	4	9	12	4	12	9	10	14	19	3		8	9	4	8
MacGillivray's Warbler																1	3	

	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018	2013	2014	2015	2016	2017	2018
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Mountain Bluebird		2	20	10	11	1		4							4	4	4	7
Mountain Chickadee	5	2	1	2						1	1		5	8	9	6	8	9
Mourning Dove	17	17	13	5	8	8	13	22	10	3	15	11	4		1	3	17	3
Northern Mockingbird					2			1										
Peregrine Falcon									1									
Pine Siskin	10	2		5	1		6		3	3			12	4	5		4	2
Plumbeous Vireo	10	10	7	3	9	9	1		1	6	6	5	11	16	15	14	11	18
Pygmy Nuthatch				2		2			2	4	12	9	11	13	26	29	41	20
Red Crossbill					1			2						2	9	13	9	
Red-shafted Flicker	3	1	3	2	5	2	3	2	4	8		3	3	4	11	11	5	5
Red-tailed Hawk									1	1	1	1						
Rock Wren	3	3	4		2	10	7	10	4	12	14	14	1	2	2	6		
Ruby-crowned Kinglet																		2
Say's Phoebe	2	1	2		2	5	2	1		5	2	4	1		1	3	3	4
Scaled Quail			1															
Spotted Towhee	17	8	19	27	32	24	12	6	33	16	12	16	11	18	16	14	21	22
Steller's Jay													3	2	5	6	3	4
Townsend's Solitaire	1																1	
Turkey Vulture					1								1					1
Violet-green Swallow		5	7	1	3	2	6	4	1	9	6	6		2	19	2	2	4
Virginia's Warbler					1	3			1	2	4		17	11	21	13	7	5
Warbling Vireo						2							2	9	7	6	5	4
Western Bluebird	15	11	18	17	16	19	5	19	12	21	13	6	20	20	49	37	32	27
Western Tanager		2	3		1			2	1	1	2	2	2	3	7	2	4	6

	2013	**2014**	**2015**	**2016**	**2017**	**2018**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Species	TA-36 Minie Site						TA-39 Point 6						TA-16 Burn Grounds					
	Pinyon-Juniper Woodland						Pinyon-Juniper Woodland						Ponderosa Pine Forest					
Western Wood-Pewee	10	8	18	11	10	7		4	2	10	8	11	15	10	16	14	22	20
White-breasted Nuthatch	1	4	9	10	13	5			2	4	4	2	9	8	7	9	20	10
White-throated Swift								1										
White-winged Dove	1	5	9	2		3	7	5	6	16	15	15			1	2		
Woodhouse's Scrub-Jay	5	1	3	4	8	7	8	10	4	8	6	4	1					
Northern Rough-winged Swallow						3												