Habitat Use by Pinyon-Juniper Birds in Farmington BLM Resource Area

2013 Final Report

Pinyon Jays at Tank Mountain II guzzler, 7-22-2013. Photo courtesy John Hansen.

Kristine Johnson, Jacqueline Smith & Nathan Petersen
UNM Biology Department

Lynn Wickersham & John Wickersham
Animas Biological Studies

Natural Heritage New Mexico Publication # GTR-13-380
December 2013

Table of Contents

Table of Figures

List of Tables

Abstract

In 2013, we conducted the first year of a study to investigate habitat use by pinyon-juniper birds in the Bureau of Land Management Farmington, NM Resource Area. We investigated nest-scale habitat use by Pinyon Jays and Gray Vireos at multiple study sites for each species. Pinyon Jays nested in pinyon-juniper habitat in three colonies, one on Crow Mesa and two at Rawhide Canyon. Conditional logistic regression models yielded no significant topographic predictors of nest site use. Of the vegetation measures, no ground cover estimate or tree count variable was significant. The only competitive nest-scale model for Pinyon Jays included tree diameter and tree height. Parameter estimates indicated that Pinyon Jays nested in trees that were taller and had larger diameters than random trees within the colony. For Pinyon Jays, we recommend no net loss of mature Colorado pinyon or juniper (especially Utah juniper) trees in pinyon-juniper nesting habitat at Farmington BLM. Size distributions on areas maintained for Pinyon Jay nesting colonies should be similar to those measured on colonies in this study, leaving all mature trees for nesting and, in the case of pinyon, cone production.

Gray Vireos nested at five sites: Aztec, Crow Mesa, Mesa Mountains, Pump Canyon, and Pump Mesa. We found 23 nests in habitat dominated by juniper trees, except at Crow Mesa, where pinyons are the dominant tree. Conditional logistic regression models yielded no significant infrastructure or topographic predictors of Gray Vireo nest site selection. The best model discriminating Gray Vireo nest from random plots was the two-variable model including both tree density and tree foliage diameter. Parameter estimates indicated that Gray Vireos nested in areas with slightly more trees than available habitat but selected nest trees with slightly smaller foliage diameter than randomly selected trees. We recommend no net loss of juniper trees, especially in juniper-dominated woodlands, to support populations of nesting Gray Vireos. In addition, Gray Vireos should be considered where tree removal is proposed in pinyon-dominated landscapes in the BLM Farmington Resource Area. Where tree removal activities may occur, we recommend maintaining similar tree densities as reported in this study.

Introduction

Continued climate warming and associated vapor-pressure deficits in the Southwestern US are predicted to cause drought stress more severe than the strongest megadroughts since at least CE 1000 (Williams et al. 2012). Drought impacts to the widespread pinyon-juniper ecosystems in the Southwest are already being recorded. Since 2001, dramatic, rapid, large-scale mortality of pinyon pine trees has occurred due to “global change-type drought” and associated insect and disease outbreaks (Allen-Reid et al. 2005, Breshears et al. 2005). A 2002-2004 drought in northern Arizona pinyon-juniper woodlands reduced canopy cover by 55% (Clifford et al. 2011). Increased temperatures in the decades between 1974 and 2008 have been associated with declines in pinyon cone production in New Mexico and Oklahoma (Redmond et al. 2012). In central New Mexico, mast production of juniper, pinyon, and oak decreased from 1997-2004 during drought (Zlotin and Parmenter 2008). The range of pinyon-juniper is predicted to contract significantly in southern New Mexico, Utah, and Arizona under climate change (Thompson et al. 1998, Cole et al. 2007) and expand in northern New Mexico and Colorado (Cole et al. 2007), as pinyon-juniper habitats move to higher elevations and replace ponderosa pine and mixed conifer.

Although pinyon-juniper habitats are still abundant in the southwestern US, climate stress is currently impacting the wildlife species that depend on them. Of greater concern is the potential long-term impact of climate change on the ecosystem. Changing climate has probably already impacted the size and frequency of pinyon mast crops, which are essential not only to sustaining many wildlife species, but also to the continuation of the woodland.

From 2009-2012, we studied habitat use by two sensitive pinyon-juniper bird species, Pinyon Jay (*Gymnorhinus cyanocephalus*) and Gray Vireo (*Vireo vicinior*), on three Department of Defense (DoD) installations. The Pinyon Jay is a New Mexico BLM Sensitive Species, federal Bird of Conservation Concern (BCC), DoD Partners in Flight (PIF) priority species, NM PIF Level 1 Species of Concern, and New Mexico Species of Greatest Conservation Need (SGCN). Pinyon Jays are the main long-distance seed disperser for pinyon trees, which provide the jays with mast crops of highly nutritional seeds. Due to its unique keystone mutualism with pinyon trees (Ligon 1971, 1974, 1978), the Pinyon Jay is likely the most important animal indicator of pinyon woodland health and productivity.

The Gray Vireo is a New Mexico BLM Watch Species, BCC, DoD Species at Risk, DoD PIF priority species, NM PIF Level 1 Species of Concern, listed as threatened by the State of New Mexico, a US Forest Service Sensitive Species (Region 3), and an SGCN. Gray Vireos are insectivores; thus, Gray Vireo population viability is not closely tied to pinyon mast crops as is that of Pinyon Jays. Pinyon Jays are resident and highly social, while Gray Vireos are territorial, migrant breeders. The fact that two very different pinyon-juniper birds are both species of conservation concern suggests a general decline of these habitats that could affect other pinyon-juniper birds such as Black-throated Gray Warbler (*Dendroica nigrescens*) and Juniper Titmouse (*Baelophus ridgwayi*, also a BCC), both SGCN in New Mexico. Other pinyon-juniper species that rely on pinyon, juniper, and/or oak mast production include mule deer, black bear, and turkey.

To date, the DoD project has provided significant insight into the habitat needs of both bird species at multiple scales (Johnson et al. 2011, 2012). The project we report on here expands our study of pinyon-juniper birds and their habitats to Bureau of Land Management lands in New Mexico. We are investigating habitat use by Pinyon Jays and Gray Vireos, in light of predicted impacts of climate change on pinyon-juniper ecosystems in the Southwest, and considering land use and vegetation management practices at the Farmington BLM Field Office.

Gray Vireo fledgling, Pump Canyon, 6/12/2013.

Methods

Pinyon Jays

In April and May 2013, Natural Heritage New Mexico surveyed for nesting colonies of Pinyon Jays in the Farmington BLM Resource Area. We first visited four potential sites where Pinyon Jays had been previously observed: Palluche Canyon, Cave Spring, Rawhide Canyon (all on 11 April, Figure 1), and Crow Mesa (12 April, Figure 1). Pinyon Jays had been observed only in the fall at Cave Spring, and Palluche Canyon was more difficult to access than Rawhide Canyon and Crow Mesa. We therefore began surveys at Crow Mesa and Rawhide Canyon, both sites where Pinyon Jays had been observed during the breeding season. We detected nesting activity at both Crow Mesa and Rawhide Canyon and thereafter focused our efforts for the rest of the breeding season at those two sites.

During our reconnaissance visit to Crow Mesa on 12 April, Pinyon Jays were present, prompting us to look for nests. We made three additional visits to Crow Mesa (17 and 24 April, 2 May) to look for breeding activity and nests. We made two reconnaissance visits (11 and 25 April) to Rawhide Canyon to survey for Pinyon Jays. We returned twice (17 April, 3 May) to the colony site we had found in 2012 and five times (3, 7, 8, 14, and 15 May) to a new 2013 colony site to look for nests.

Field measurements

We collected vegetation data at modified BBird plots at all three sites: Crow Mesa on 4 and 17 June, Old Rawhide on 5 and 18 June, and New Rawhide on 6, 18, and 19 June; and 1, 2, and 3 July. We collected nest-scale data following a modified BBird protocol. Circular nest plots were centered at a nest, and non-overlapping random plots were centered at a non-nest tree 100 m in a randomly selected direction from each nest. All random plots were at least 50 m from any other nest or random plots, were within nesting habitat, and were not located on roads or well pads. In some cases, nests or their corresponding random plots were so closely spaced that we were unable to use a random bearing and still follow our rules for distance between plots. In those cases we placed plots in available directions or used slightly longer or shorter interplot distances.

At each plot we collected data within 5-m and 11.3-m (0.04 ha) radius plots. We collected the following data within 11.3-m nest plots: plot slope, plot aspect, number of trees, tree species composition, and tree size class.

At the 5-m plot we collected: elevation, indices of live and non-live ground cover, shrub species and counts, tree heights and root crown diameters, canopy cover, nest tree canopy width, nest height, nest aspect, distance of nest to tree edge, and number and size of supporting branches. For canopy cover, we used a vertical canopy densitometer to determine the presence or absence of canopy cover at 1, 2, 3, 4, and 5 m from the nest in each of the four cardinal directions. We summed the four readings (1 or 0) taken at each distance and computed total score (out of 20 possible) for each plot. Root crown diameter is a better measure of tree size than diameter at breast height for juniper trees, which can have multiple trunks. Ground cover was indexed in 10% intervals (e.g., 1-10%=1, 11-20%=2, etc.).

John Hansen, Farmington BLM Field Office, provided noise levels for all wells near the Old and New Rawhide colonies, using an "impulse sound level meter" model 2700, by Quest Technologies, Oconomowoc, WI. He recorded A scale decibel readings (dBA) on 24 July 2013, between 0855 and 1145. Winds were calm, skies mainly overcast, and humidity high. Beginning temperature was 22.2^0 C, ending temperature 28.9^0 C. Sound levels were recorded within 1.6 m of the compressor exclosures. Levels at the nearest nest were recorded directly below the nest.

Derived and GIS measurements

Using ESRI ArcGIS (ESRI 2011), we calculated a north-south aspect index from the cosine of the plot aspect, with values ranging from -1 (south) to 1 (north). We gathered distances from each nest and random tree to edge of habitat, road, building, and oil or gas well, using 2013 Bing Imagery (Harris Corp., Earthstar Geographics LLC, copyright Microsoft Corp.).

Statistical analysis

We modeled nest-site selection using case-control conditional logistic regression (conditional logistic regression for related samples, Menard 2009). Because Pinyon Jays are loosely colonial nesters and not territorial, we compared the set of nest plots to the same number of unpaired random plots within the colony site. Among-year and among-site variation were treated as nuisance effects and were controlled by using a "strata" statement denoting a unique year-site combination for each plot. We built models using the Survival package in the R statistical environment (R-3.0.2., R Core Team 2013).

We used a combination modeling approach: exploratory data analysis to identify important predictors (Stephens et al. 2007) and *a priori* multi-model inference (Burnham and Anderson 2002) to identify the best-performing nest-site selection models. We examined Pearson correlations among predictors, avoiding issues of multi-collinearity by ensuring no variable pair with $|r|>0.6$ was included together in a model. We grouped variables into three groups associated with Pinyon Jay natural history or management: topographic (slope, aspect, and elevation), vegetation (trees and ground cover), and infrastructure (distance to edge, road, building, and military infrastructure).

Within each group, we built a global model using all variables and their quadratic terms. Using significant variables from the exploratory models, (which turned out to all be variables associated with the nest tree), we built a final candidate set of seven models representing *a priori* hypotheses. We considered any model with an Akaike Information Criterion (AIC_c) value < 2 units above that of the lowest AIC_c model to be competitive. We assessed the discriminatory power of each model based on the area under the curve (AUC) statistic generated for each model. An AUC of 0.7 to 0.8 indicates that a model provides acceptable discriminatory power (0.5 is expected by chance), an AUC of 0.8 to 0.9 indicates good discriminatory power, and an AUC > 0.9 indicates excellent discriminatory power (Fielding and Bell 1997, Hosmer and Lemeshow 2000).

Gray Vireos

Animas Biological Studies targeted four sites to survey for Gray Vireos: Aztec, Pump Canyon, Pump Mesa and Crow Mesa (Figure 2). We visited Aztec on 4, 5, 17, and 19 June and 3 July 2013. Crow Mesa we surveyed on 28 and 29 May and 12 and 13 June. We surveyed Pump Canyon on 23 May and 11 and 12 June. Pump Mesa we visited on 2, 9, 10, and 11 July. In addition, we conducted a single-day survey for Gray Vireos in the Mesa Mountains on 12 June, in conjunction with another project on BLM lands.

Field measurements

During initial visits to each site, we used playbacks of Gray Vireo vocalizations to determine presence/absence of territorial birds. We recorded locations of vireo detections using a GPS unit. We documented the number of birds detected, sex, and behavior (e.g.; singing male, pair, etc.). During initial and follow-up visits to occupied territories, we observed vireos for nesting behavior and searched for nests. Where we located nests, we checked their contents, if possible, and recorded their locations using GPS.

We collected BBird data at nests and their corresponding random plots following a similar protocol as for Pinyon Jays, except that vireo nests were not so closely spaced to require modification of the 100 m rule for random plots. We collected data within 5-m and 11.3-m (0.04 ha) radius plots, as for Pinyon Jays; although several measurements differed for Gray Vireo plots. We collected the following within 11.3-m plots: plot slope, plot aspect, number of trees and height of each tree, tree species composition, and canopy cover. Tree height was measured using a clinometer. For canopy cover, we used a vertical canopy densitometer to determine the presence or absence of canopy cover at each plot center and at 1-m intervals to 11 m along the four cardinal directions. We summed the readings (1 or 0) taken at each distance, computed the total score (out of 45 possible), and converted to a percentage for each plot. In the 5-m plots we collected elevation, indices of live and non-live ground cover, shrub species and counts, nest tree foliage width, nest height, nest aspect, and distance from nest to tree edge. Ground cover was indexed in 10% intervals (e.g., 1-10%=1, 11-20%=2, etc.).

Derived and GIS measurements

Using ESRI ArcGIS (ESRI 2010), we gathered distances from each nest and random plot center to the nearest road and oil or gas well, using a combination of 2011 ortho-imagery and GIS shapefiles of oil-and-gas wells provided by the BLM. Outside of well pads, few buildings occurred in our study areas; thus, we did not measure distance from nest and random plot centers to buildings.

Statistical analysis

We modeled nest-site selection of Gray Vireos as for Pinyon Jays, using case-control conditional logistic regression (Menard 2009), pairing each nest with a randomly-selected plot approximately 100 m from the nest at a random bearing. Among-site variation was treated as a nuisance effect and was controlled by using a "strata" statement indicating a unique site-territory combination for each plot. We built models using the Survival package in the R statistical environment (R-3.0.2., R Core Team 2013).

We used a similar combination modeling approach for Gray Vireos as for Pinyon Jays, including exploratory data analysis to identify important predictors (Stephens et al. 2007) and *a priori* multi-model inference (Burnham and Anderson 2002) to identify the best-performing nest-site selection models. We first examined Pearson correlations among predictors, avoiding issues of multi-collinearity by ensuring no variable pair with $|r|>0.6$ was included together in a model. Within each of three groups of variables, topographic, vegetation, and infrastructure, we used a stepwise modeling approach using all variables in the group and their quadratic terms. Using significant variables from the exploratory models, we built a final candidate set of models representing *a priori* hypotheses. We considered any model with an AIC_c value <2 units above that of the lowest AIC_c model to be competitive. We assessed the discriminatory power of each model based on the AUC statistic generated for each model.

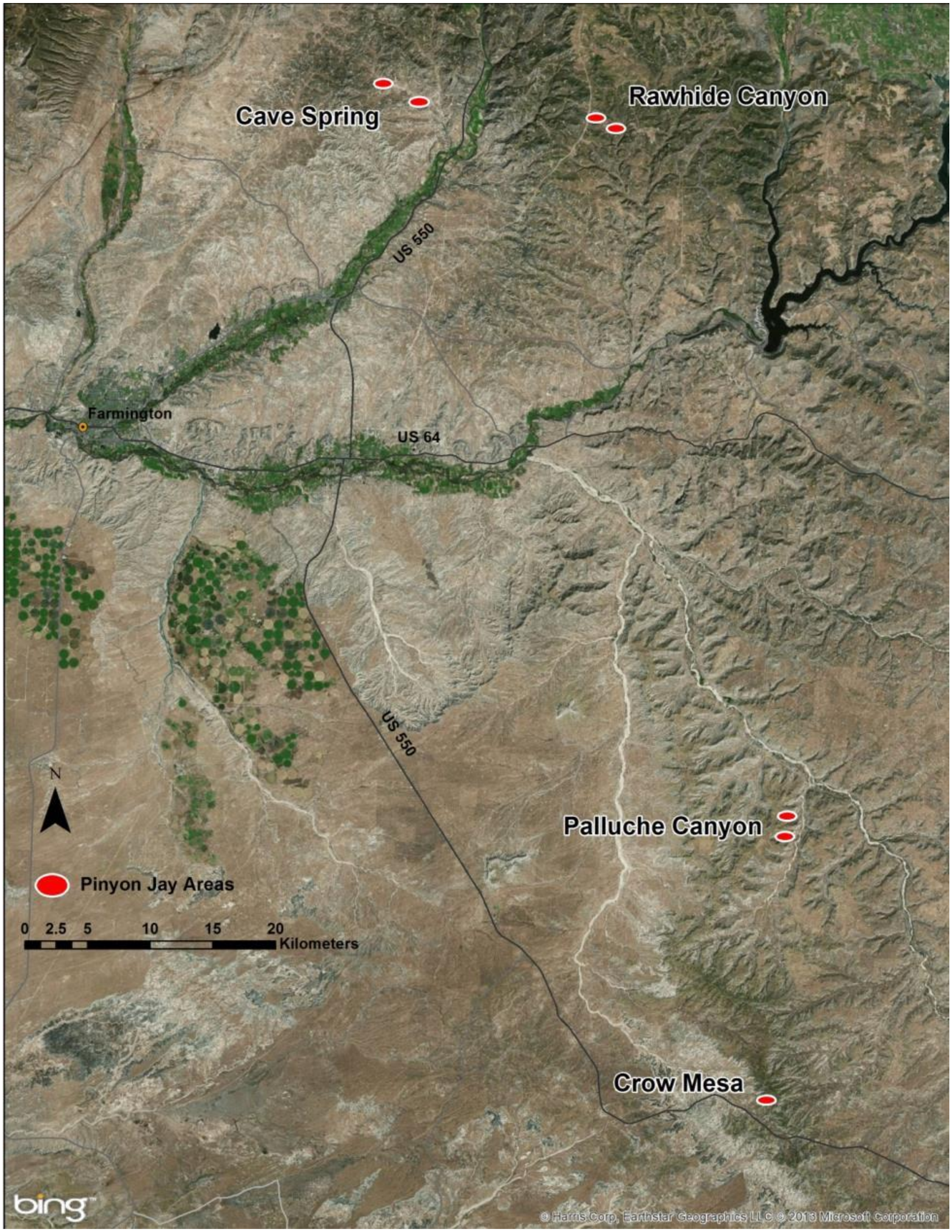


Figure 1. Sites surveyed for potential Pinyon Jay nesting colonies, 2013.

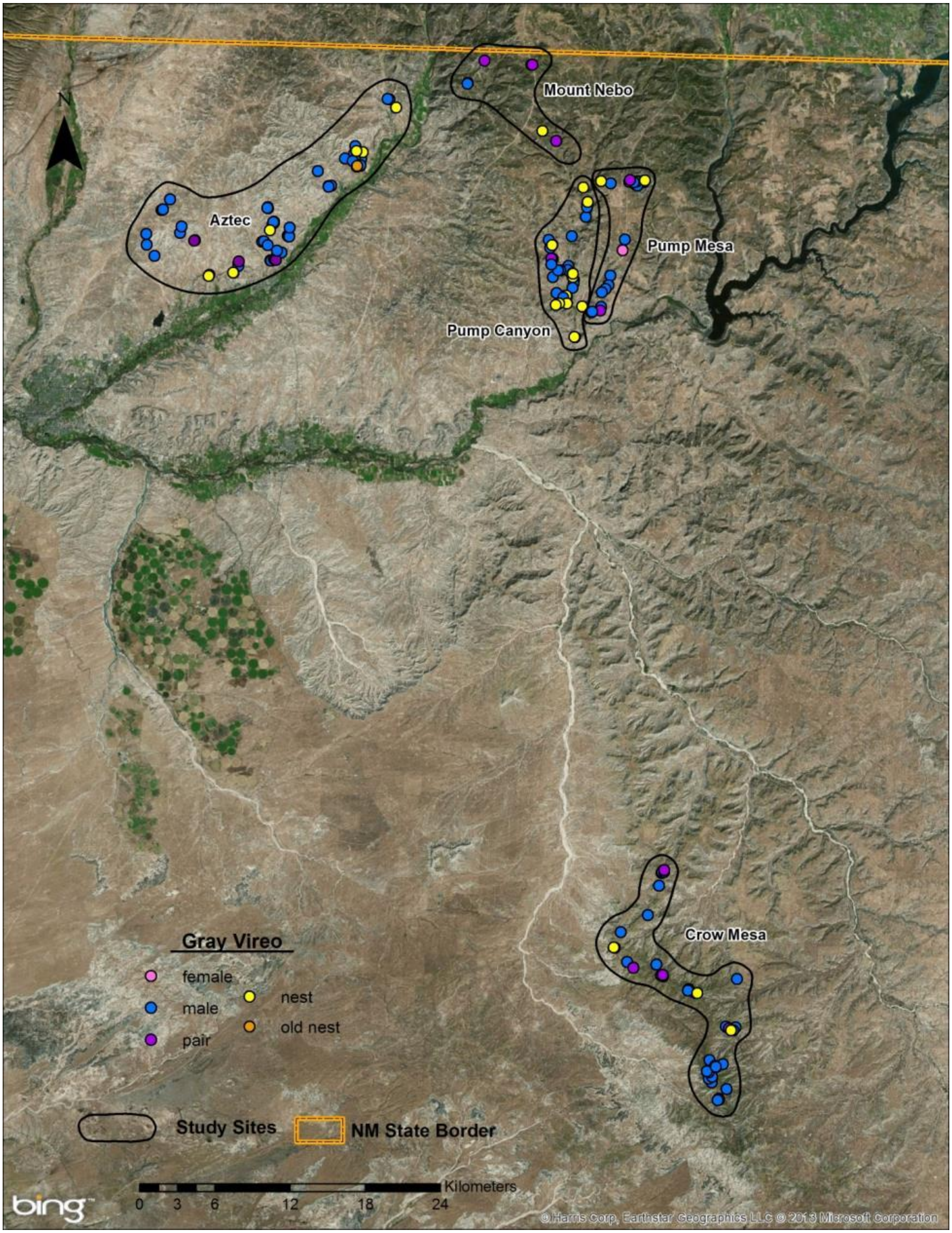


Figure 2. Gray Vireo survey and nesting areas, 2013.

Results

Pinyon Jays

Nests and birds

In preliminary surveys at Rawhide Canyon in 2012, we found five complete Pinyon Jay nests and one nest under construction (Figure 3). In 2013, the 2012 nest start had been completed, probably after our visit in 2012. In 2013, we found one additional nest at the 2012 site, for a total of seven nests. We re-evaluated all nests at the site ("Old Rawhide") in 2013 and kept four recent, definite Pinyon Jay nests, for which we collected BBird plot data.

We found 15 potential Pinyon Jay nests at Crow Mesa in 2013 (Figure 4). Four were recent Pinyon Jay nests, six were old Pinyon Jay nests, and five could not be definitely identified as Pinyon Jay nests, either because of age or structure. One of the recent nests was active, with several large nestlings. We retained 10 nests for paired BBird plots.

At the 2013 Rawhide Canyon site ("New Rawhide"), we found 26 potential Pinyon Jay nests (Figure 5). Eight of these looked old, and one was possibly made by a different species, leaving 17 nests likely constructed in 2013 and eight old nests. Two nests appeared to be active when we found them (3 and 8 May), based on adult alarm calling or activity nearby. On 13 May, we observed a female incubating or brooding on a third active nest, and a bird apparently flushed from a fourth active nest. We retained the 25 definite Pinyon Jay nests for BBird plots. We collected plot data on 39 nests and 39 random plots at all sites combined. Minimum Convex Polygons including all nests for which we collected data indicate that the Old Rawhide colony covered 5.0 ha, Crow Mesa 15.8 ha, and New Rawhide 40.7 ha, in 2013.

We observed 60-80 birds in the 2013 Rawhide Canyon flock in May. Several broods of fledglings were flying with that flock in May, indicating that several nests had fledged young before we found the colony site. We heard fledglings calling when we were collecting plot data in June. By our last trip to New Rawhide on 18-19 June, most of the flock had left the area; we heard only a few Pinyon Jay calls, presumably from a late-nesting pair and their fledglings.

Vegetation at colonies

All three Pinyon Jay colony sites are in woodland dominated by a mixture of Colorado pinyon (*Pinus edulis*) and Utah juniper (*Juniperus osteosperma*), with a few one-seed junipers (*J. monosperma*). At Crow Mesa, a shrub layer of big sagebrush (*Artemisia tridentata*) occurs below an open canopy of pinyon and juniper. At Rawhide Canyon, the pinyon-juniper woodland occurs mainly on hills, with some trees extending into flatter, low-lying areas, interspersed with open, flat areas dominated by big sagebrush. At or near all three colony sites, we observed pinyon cones on the ground and on trees, evidence that a cone crop occurred in the area during the fall of 2012. John Hansen, Farmington BLM, confirmed cone production in the area in 2012.

All Pinyon Jay nests were placed in pinyon or juniper trees. Of the 39 Pinyon Jay nests for which we collected data, 19 were in Utah juniper trees and four in one-seed juniper trees (23 in junipers). Sixteen nests were in Colorado pinyon trees. The proportions of random-plot nest trees were similar, with 22 nests in junipers and 17 in pinyons. The similar species composition of nest and random trees suggests that the jays choose nest tree species approximately in proportion to tree species availability (Table 1).

Table 1. Species of nest and random, "non-nest" trees at three BLM Pinyon Jay study sites, 2013.

Study Site	Tree Type	Utah Juniper	One-Seed Juniper	Colorado Pinyon
Crow Mesa	Nest	0	3	7
	Random	0	2	8
New Rawhide	Nest	18	0	7
	Random	16	2	7
Old Rawhide	Nest	1	1	2
	Random	2	0	2
Total		37	8	33

Table 2. Summary statistics for tree sizes on 5 m radius Pinyon Jay nest plots and random plots.

Plot Type/Tree Measure	Mean	SE	Range
Nest Tree RCD (cm)	15.4	0.88	1.5-62.4
Random tree RCD (cm)	17.8	1.15	2.6-71.3
Nest Tree Height (m)	3.5	0.16	1-10
Random tree Height (m)	3.8	0.18	1-10

Number of trees did not differ significantly between nest and random plots by the conditional logistic regressions. Tree size distribution did differ somewhat between nest and random plots, with distribution of trees on nest plots more skewed toward smaller tree classes and random plots more nearly normally distributed. A difference between size distributions is more noticeable for tree height (Figure 6). Although Figure 6 might suggest that tree RCD and height would be greater on random than on nest plots, that was not the case: nest and random 5 m plots did not differ significantly in plot tree RCD ($T=-1.7$, $P=0.091$, $df=273$) or height ($T=-1.11$, $P=0.269$, $df=293$; Table 2).

Infrastructure and noise

We only have noise data for wells near the Rawhide colonies. Nest-to-well distances at Old Rawhide ranged from 449.7 m to 618.9 m. The New Rawhide colony was situated with a well to the north, south, east, and west (Figure 7). The mean nest-to-well distance at New Rawhide was 343.87 m (range= 138.5-473.9 m, SE=16.59).

A-scale decibel readings (dBA) are adjusted to reflect human hearing and thus may not be the best indication of how well pumps sound to Pinyon Jays. Unfortunately, there is no straightforward conversion method between the dBA scale and decibels. Mean sound level recorded at wells was 81.65 dBA (range=78.3-85.2, SE=1.09). The mean sound level at the nest nearest each Rawhide well (Figure 7) was 40.03 dBA (range=39.1-43.5, SE=0.69). Sound levels at nests were inversely correlated with nest-well distance ($r=-0.676$, $N=6$), which may only indicate that sound intensity decreases with distance. However, the sound level at five of the six nests nearest wells was ~39, which suggests that Pinyon Jays tolerate well noise up to about 40 decibels. One outlier nest only 139 m from a loud well had a sound level of 43.5.

Exploratory models yielded no significant infrastructure predictors; i.e., there was no detectable difference between Pinyon Jay nest and random plot distances to roads, wells, buildings, or edge of habitat.

Nest-scale vegetation

Exploratory models yielded no significant topographic predictors. Of the vegetation measures, no ground cover estimate or tree count variable was significant. Only measures relating to the nest tree or area immediately surrounding it were significant or nearly so: canopy cover within 5 m of the nest, nest tree RCD, nest tree height, and nest tree canopy width. The final set of candidate models was drawn from these measures in and around the nest tree (Table 3). Canopy cover, tree RCD, and tree height were log distributed, so we included log functions of these variables in the models. Because tree width and tree RCD were highly correlated (r=0.7), we avoided including both variables in the same model.

We compared the discriminatory power of the seven models of nest tree/near nest tree measures (Table 4). The best model discriminating nest from random plots was the two-variable model, log of tree RCD + tree height, with an AIC_c of 80.16 and an AUC of 0.795, on the line between good and acceptable discriminatory power. The second-best model included the same two variables plus log of canopy cover around the nest. This second-best model had an AIC_c of 81.81 an AUC of 0.794, and a ΔAIC_c= 1.66. The ΔAIC_c would make the second-best model competitive, except that it contained the same two variables as the best model, and the third variable, canopy cover, was a non-informative ($p>0.05$) parameter. The third-best model, with a ΔAIC_c of 2.31, was non-competitive. Hence, the only competitive model was the one including tree diameter and tree height. Parameter estimates (Table 5) indicated that Pinyon Jays nested in trees that were taller and had larger diameters than random trees within the colony.

Additional landscape-scale factors influencing colony location

The BLM Farmington Resource Area apparently contains large areas of pinyon-juniper woodland similar to those at Crow Mesa and Rawhide Canyon; i.e., having medium-sized pinyon trees with mean RCD of ~15 cm and height of ~3-4 m (Figure 6). Given the limited number of nesting colonies in the Farmington Resource Area, some other factors, such as food for nestlings or water, must influence the suitability of colony sites.

The Farmington Field Office monitored wildlife waters with wildlife cameras at 18 sites spread over 36,422 ha (90,000 acres) during June and July 2013. Only six of the 18 cameras recorded Pinyon Jay use, and all six of those were within 5.6 km (3.5 miles) of the New Rawhide colony site (Figure 8). Two of the water sources within 2.7 km (1.7 miles) of the colony site were likely used by the Rawhide flock. Hence, nearby water may be a second requirement for a nesting colony.

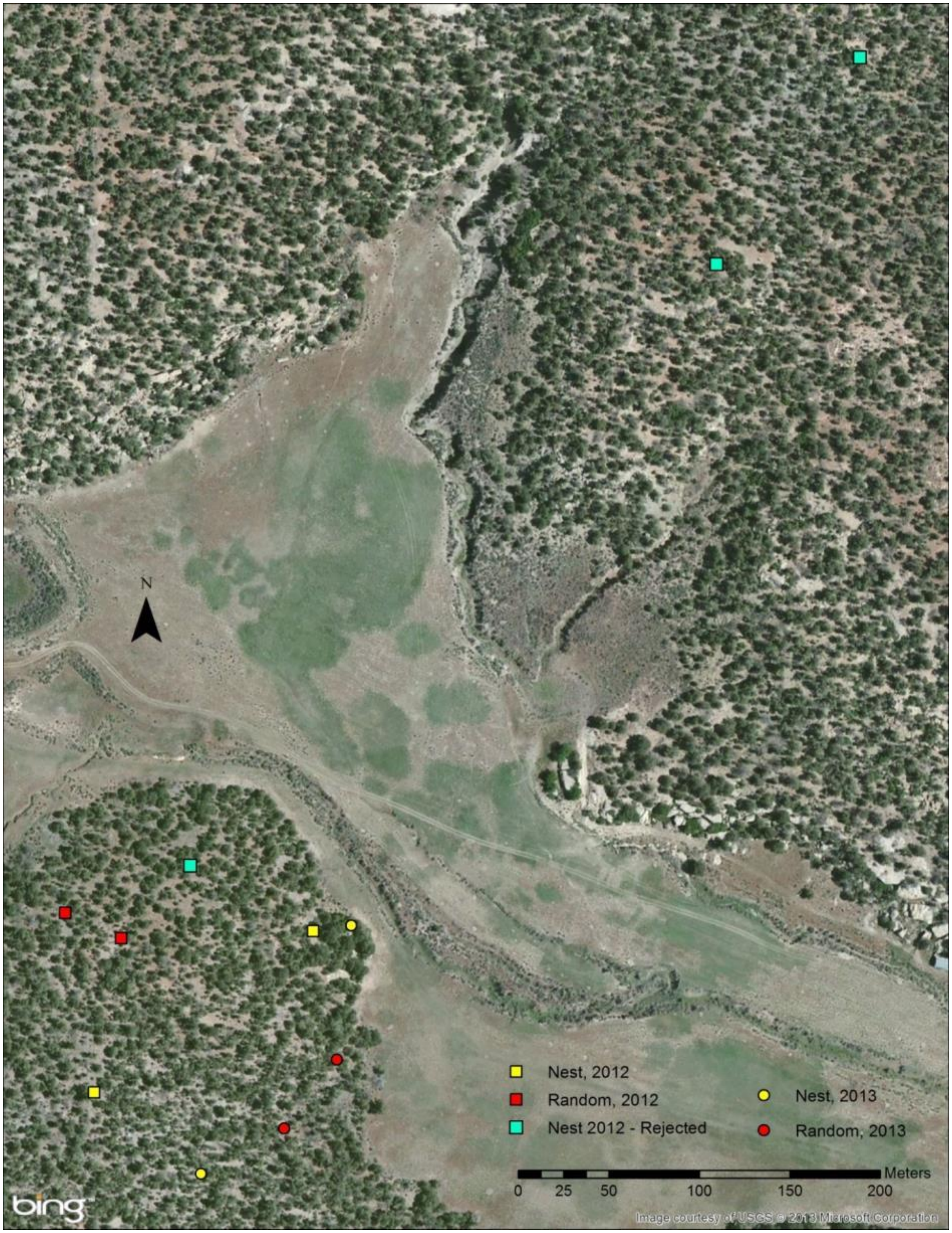


Figure 3. Pinyon Jay nests found at 2012 ("Old") Rawhide Canyon site in 2012 and 2013. Locations of paired random plots are indicated in red. Rejected nests were likely Pinyon Jay nests but were deemed too old for plot data collection.

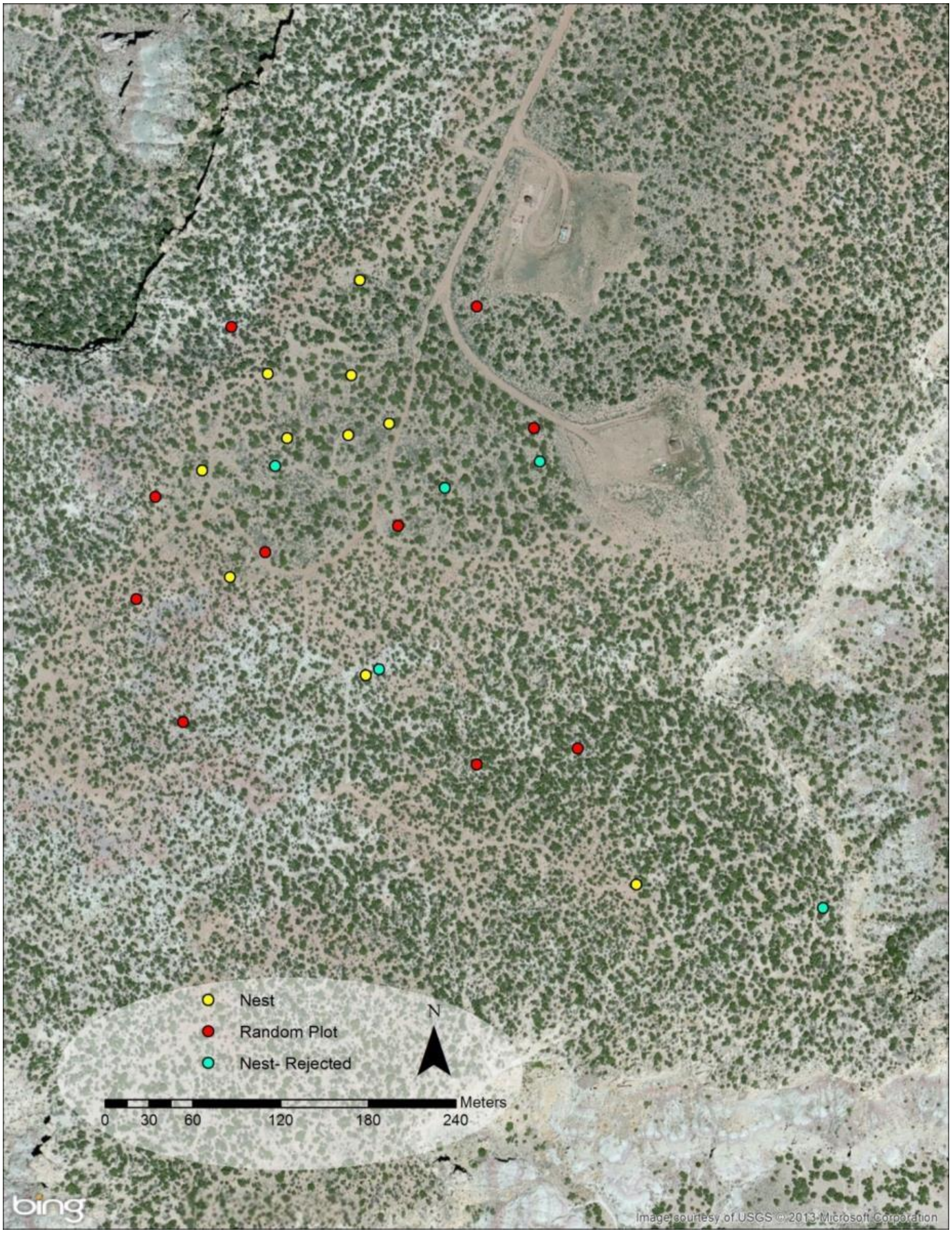


Figure 4. Pinyon Jay nests found at Crow Mesa in 2013. Locations of paired random plots are indicated in red. Rejected nests were likely Pinyon Jay nests but were deemed too old for plot data collection.

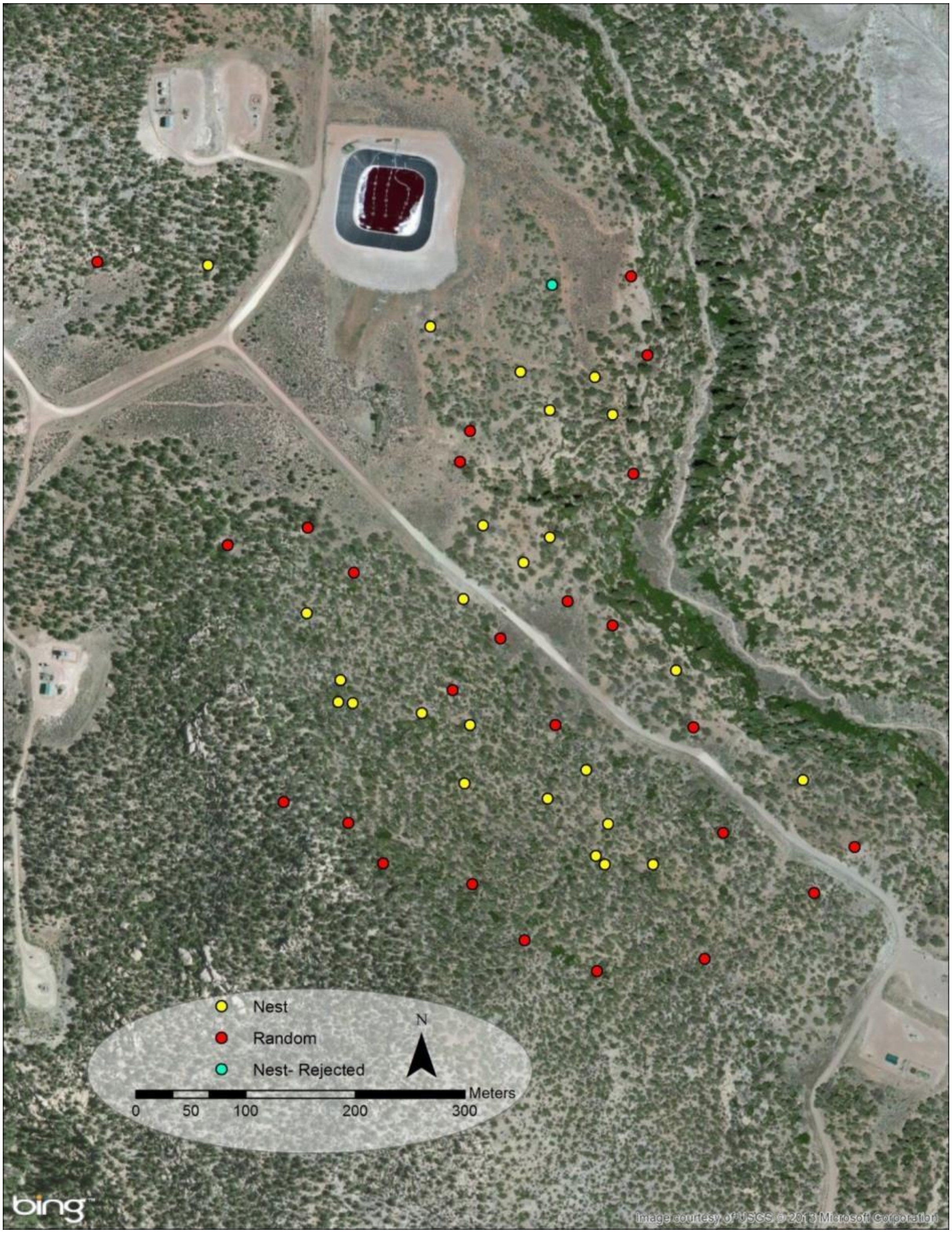
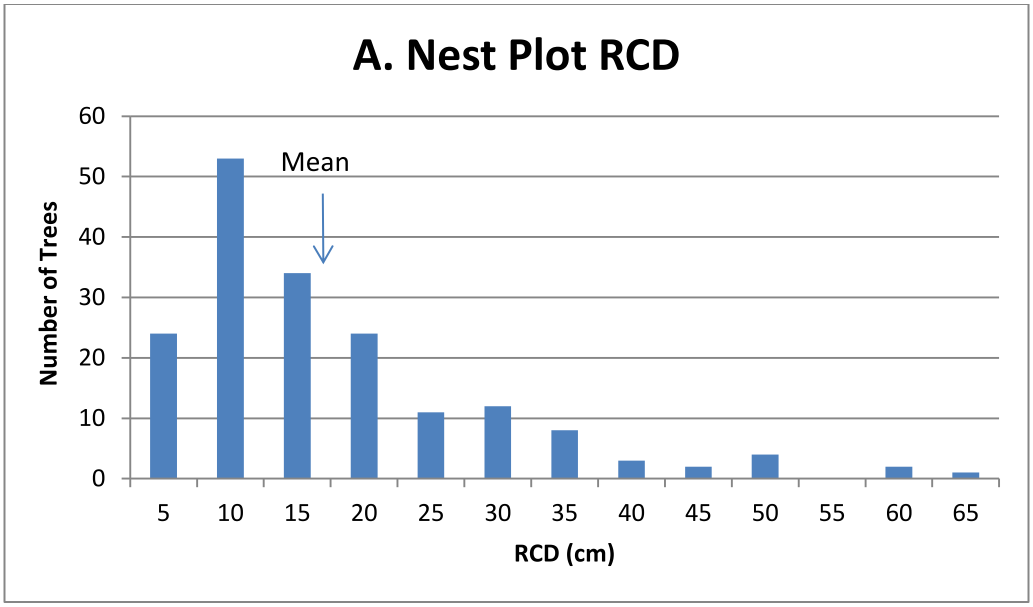
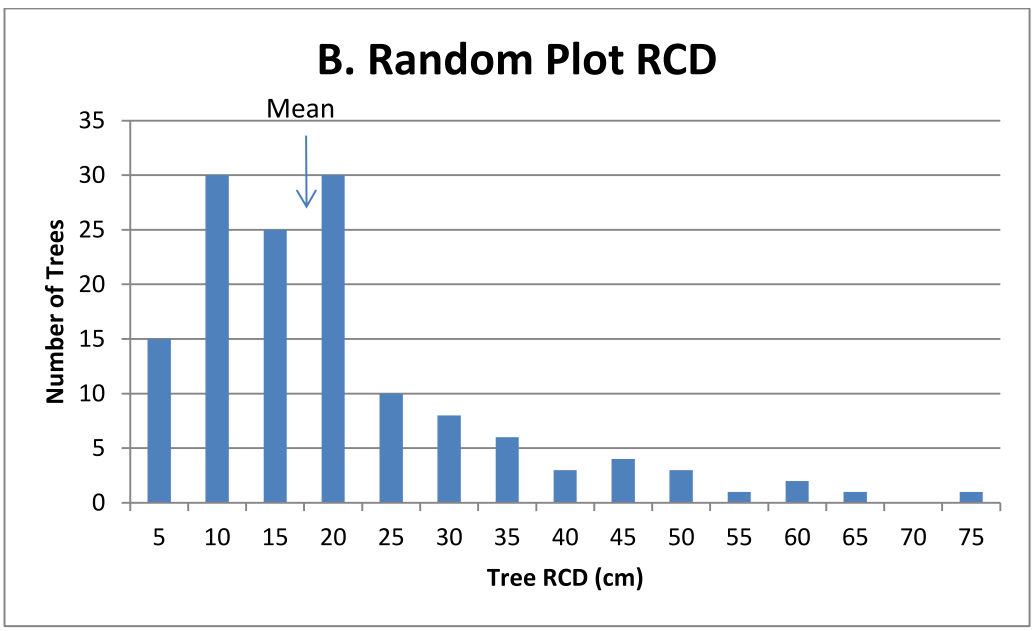
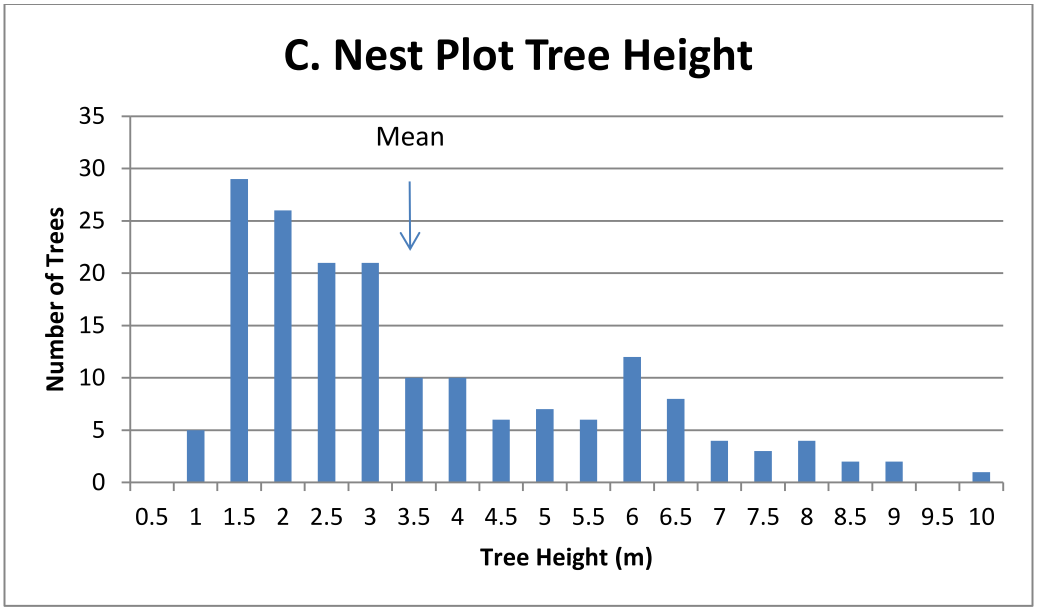


Figure 5. Pinyon Jay nests found at 2013 Rawhide Canyon site. Locations of paired random plots are indicated in red. Rejected nest was not a definite Pinyon Jay nest.


A. Nest Plot RCD
Mean
Number of Trees
60
50
40
30
20
10
0
5
10
15
20
25
30
35
40
45
50
55
60
65
RCD (cm)


B. Random Plot RCD
Mean
Number of Trees
35
30
25
20
15
10
5
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
Tree RCD (cm)



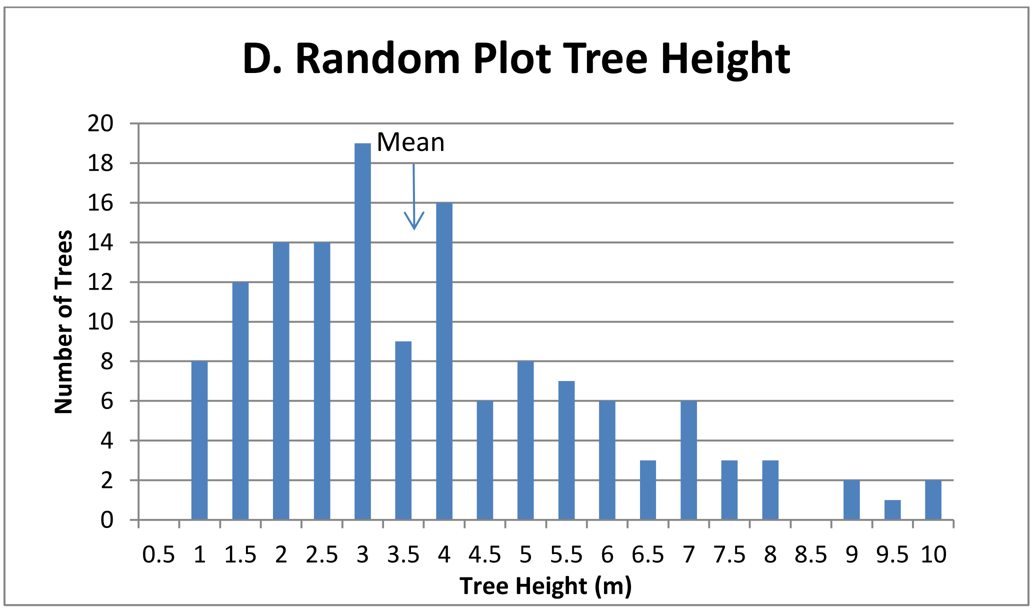


Figure 6. Distribution of tree sizes on 5 m Pinyon Jay plots, 2013.

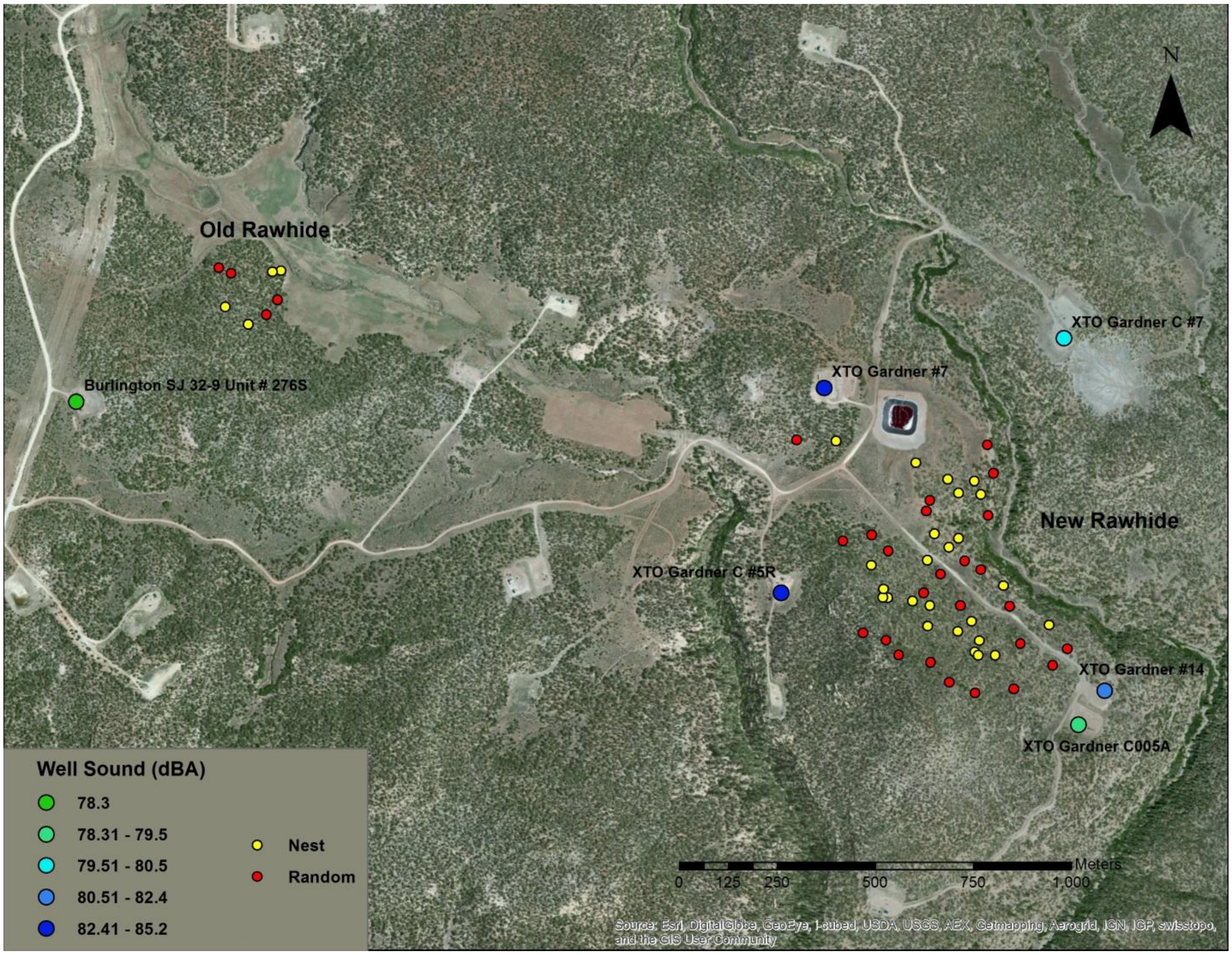


Figure 7. Old Rawhide and New Rawhide Pinyon Jay colonies, 2013, showing nests, nearest wells to each colony, and noise levels.

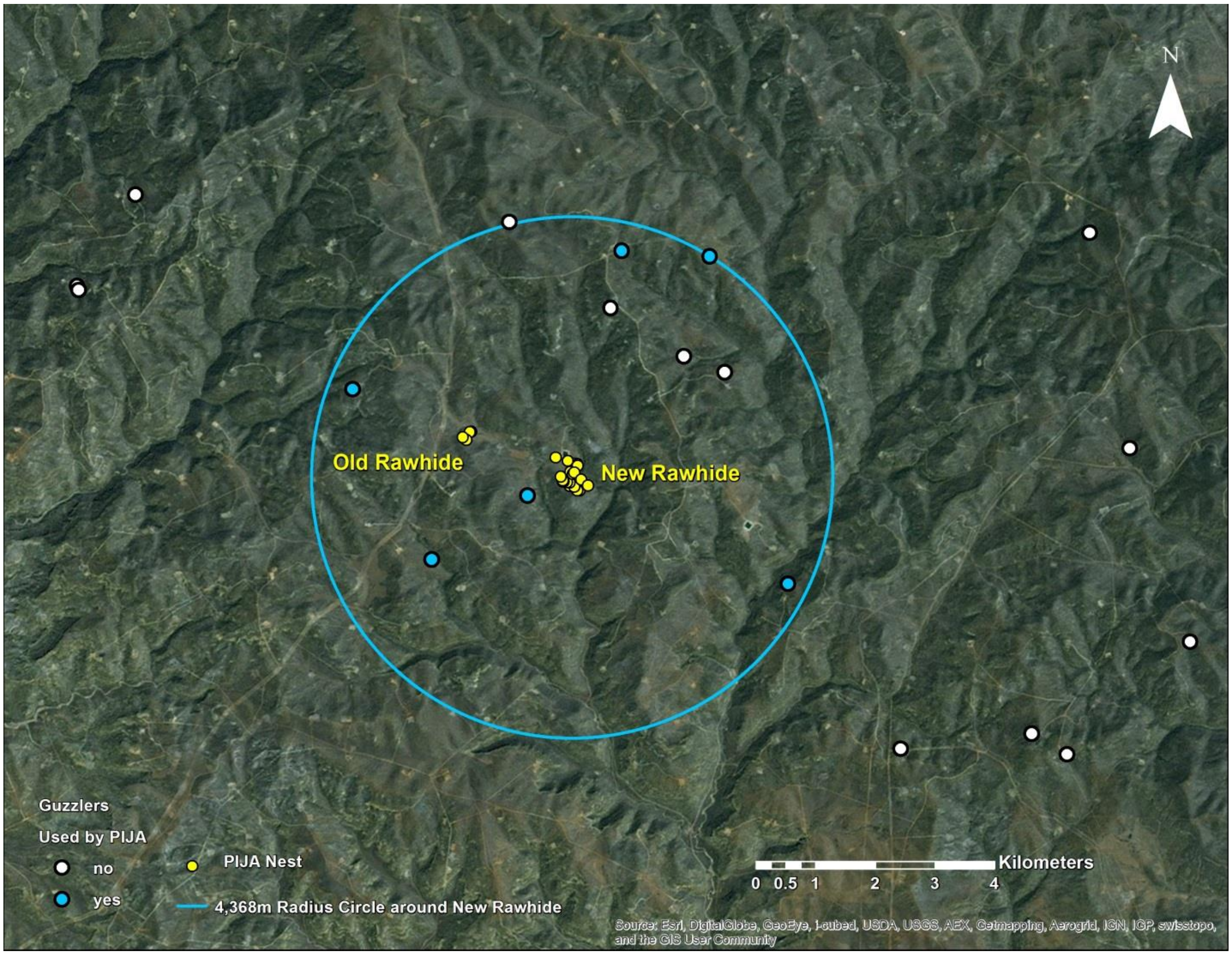


Figure 8. Wildlife camera locations, Farmington BLM, 2013. Blue circle (4368 m radius) encloses all cameras that recorded Pinyon Jays. Blue dots indicate detection of Pinyon Jays at cameras. Old and New Rawhide nests are shown in yellow.

Table 3. Final set of candidate models for Pinyon Jay nest-scale habitat.

Model Number	Variables
1	height + logwidth
2	height + log canopy
3	log treeRCD + log canopy
4	log treeRCD + log canopy + height
5	log treeRCD + height
6	log canopy + logwidth
7	log canopy + logwidth + height

Table 4. Candidate model set of conditional logistic regression models discriminating Pinyon Jay nest plots from unused plots, 2013. k= number parameters in model, including a stratification term, -LL= negative log-likelihood of the model, AIC_c = small sample adjusted Akaike's information criterion value of the model, ΔAIC_c = difference in AIC_c between models with lowest and higher values, w_i = weight of each model in candidate set, and AUC is area under the receiver operator curve, a measure of model classification accuracy.

#	Model	k	-LL	AIC_c	ΔAIC_c	w_i	AUC
5	log treeRCD + height	3	-36.917	80.158	0.000	0.495	0.795
4	log treeRCD + log canopy + height	4	-36.633	81.814	1.656	0.216	0.794
3	log treeRCD + log canopy	3	-38.073	82.471	2.313	0.156	0.767
1	height + logwidth	3	-38.819	83.961	3.803	0.074	0.761
7	log canopy + logwidth + height	4	-38.687	85.922	5.764	0.028	0.765
2	height + log canopy	3	-40.342	87.009	6.851	0.016	0.750
6	log canopy + logwidth	3	-40.343	87.011	6.853	0.016	0.741

Table 5. Parameter estimates from best candidate conditional logistic regression model discriminating Pinyon Jay nest plots from random plots, 2013. Tree RCD was log-transformed prior to modeling.

			95% CI	
Variable	Estimate	SE	Lower	Upper
logtreeRCD	1.35	0.518	0.335	2.365
Height	0.375	0.167	0.048	0.702

Gray Vireos

Nests and birds

We identified 119 Gray Vireo territories and 23 nests in 2013 (Figures 9, 10, 11, and 12; Table 6). Nineteen nests were found in juniper trees and four in pinyons, including all three nests found on Crow Mesa (Figure 11). In addition, we observed three family groups in territories for which we did not find nests, as well as several old nests we suspected were used the prior breeding season. We retained 22 vireo nests for BBird plots.

Table 6. Number of Gray Vireo territories and nests identified in the BLM Resource Area study sites, 2013.

Study Site	No. Territories	No. Nests	No. Nests in Junipers	No. Nests in Pinyons
Aztec	38	6	6	0
Crow Mesa	30	3	0	3
Mesa Mountains	7	1	1	0
Pump Canyon	28	11	10	1
Pump Mesa	16	2	2	0
Total	119	23	19	4

Topography
Topography of Gray Vireo territories varied among study areas. Nest plot elevation ranged from 1733−2227 m (mean = 1879) among sites; however, elevation was lower (~1700−1900 m) in the Aztec and Pump Canyon study sites compared with Pump Mesa and the Mesa Mountains (~1900-2100 m) and Crow Mesa (~2100−2250 m).

Vireos generally occupied toe slopes of the Pump Canyon sites, toe slopes or rolling terrain in Aztec and the Mesa Mountains, and flat to rolling terrain on Crow Mesa and Pump Mesas. Slope at nest plots ranged from 2−17° (mean = 9.1°). Exploratory conditional logistic regression models indicated none of the topographic variables was important in nest site selection.

Infrastructure
Combining study sites, distance from Gray Vireo nests to the nearest road ranged from 10−288 m (mean = 98.4 m), and distance to the nearest gas well ranged from 78−541 m (mean = 300.4 m). Exploratory conditional logistic regression models yielded no significant infrastructure predictors to nest site selection.

Vegetation on territories
Gray Vireo territories were all located in Colorado pinyon-Utah juniper woodlands. The proportion of juniper to pinyon trees on nest plots ranged from 0.2−1.0, but juniper was the dominant tree species on most plots (mean juniper to pinyon proportion = 0.8). The proportion of pinyon to juniper varied among sites. Juniper dominated the Aztec, Pump Canyon and Pump Mesa territories; mean juniper:pinyon ratio in nest plots was 0.99, 0.79 and 0.83, respectively. Territories on Crow Mesa were dominated by pinyon (mean nest plot juniper:pinyon ratio = 0.33).

Understory vegetation was scarce in some territories and moderate in others, particularly on Crow Mesa. Dominant shrub species at all sites included big sagebrush, antelope bitterbrush (*Purshia tridentata*) and rubber rabbitbrush (*Ericameria nauseosa*). Territories often included scattered grasses, forbs, yuccas (*Yucca* spp.) and prickly pear (*Opuntia* spp.). The number of trees per hectare on nest plots ranged from 50−525 (mean = 296); most plots ranged between 100 and 300 trees/ha (Figure 13).

Nest-scale vegetation
Mean nest height and nest tree height were 2.2 m (range = 1.4−3.7 m) and 3.3 m (range = 1.7−5.5 m), respectively. Nest tree foliage diameter ranged from 1.4−6.8 m (mean = 3.0 m). Shrub density ranged from 50−1025 shrubs/ha (mean = 250). Live ground cover was very low on nest plots (mean live index = 1.4). Exploratory conditional logistic regression modeling of vegetative variables indicated tree density and tree foliage diameter were important predictors in nest site selection. We excluded nest/random tree height and mean plot tree height from the final model set because both were highly positively correlated (r>0.7) with tree foliage diameter, and the latter variable was more competitive in predicting nest sites.

The final set of eight candidate models included the variables tree density and tree foliage diameter and their quadratic terms (Table 7). Three models were competitive ($\Delta AIC_c<2$). The best model ($AIC_c=48.512$) discriminating nest from random plots was the two-variable model including both tree density and tree foliage diameter. The AUC of the best model was 0.742, indicating acceptable discriminatory power. The second-best model included only tree density, with a ΔAIC_c=0.606 and an AUC of 0.687. The third-best model included only tree foliage

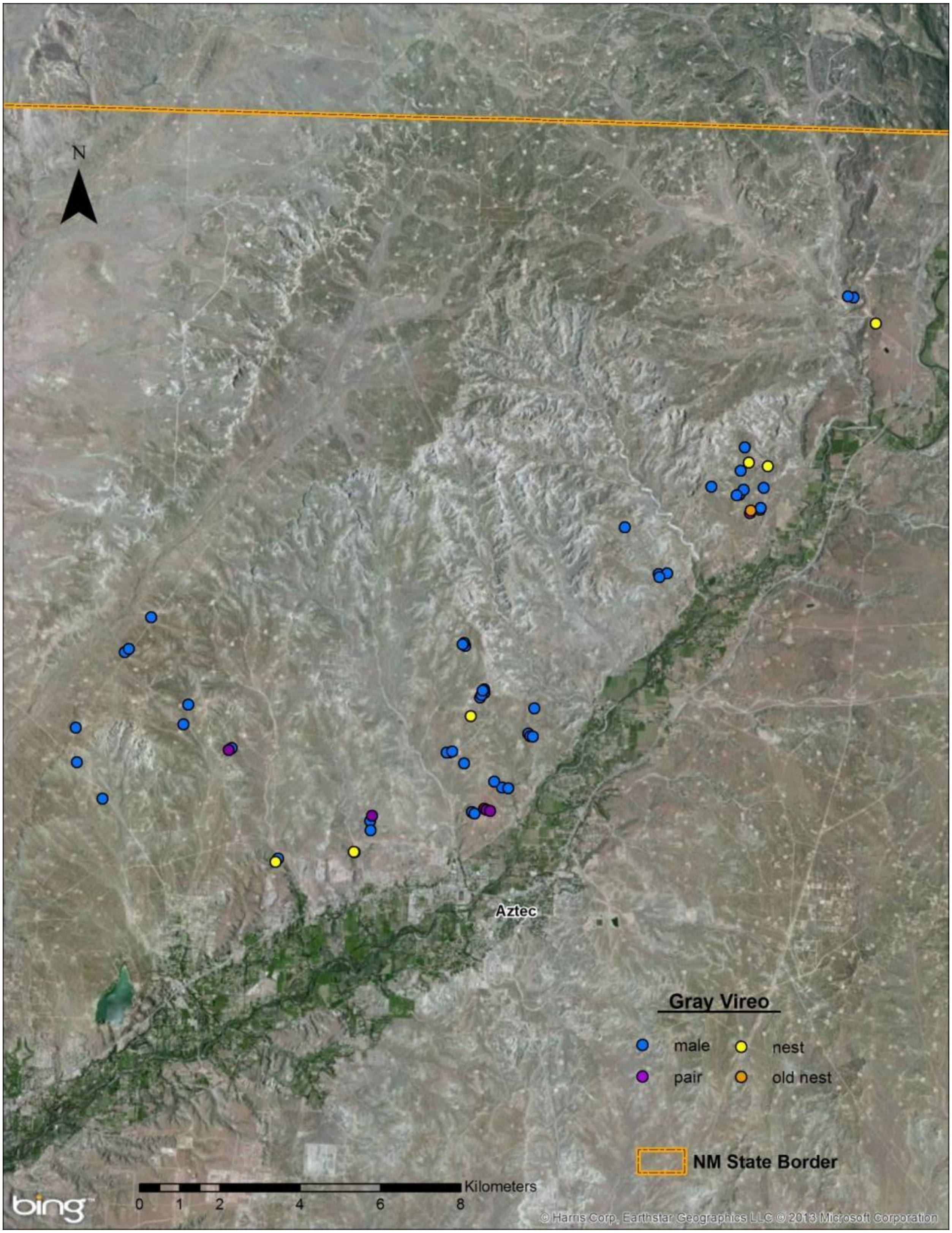


Figure 9. Gray Vireo observations at Aztec study site, 2013.

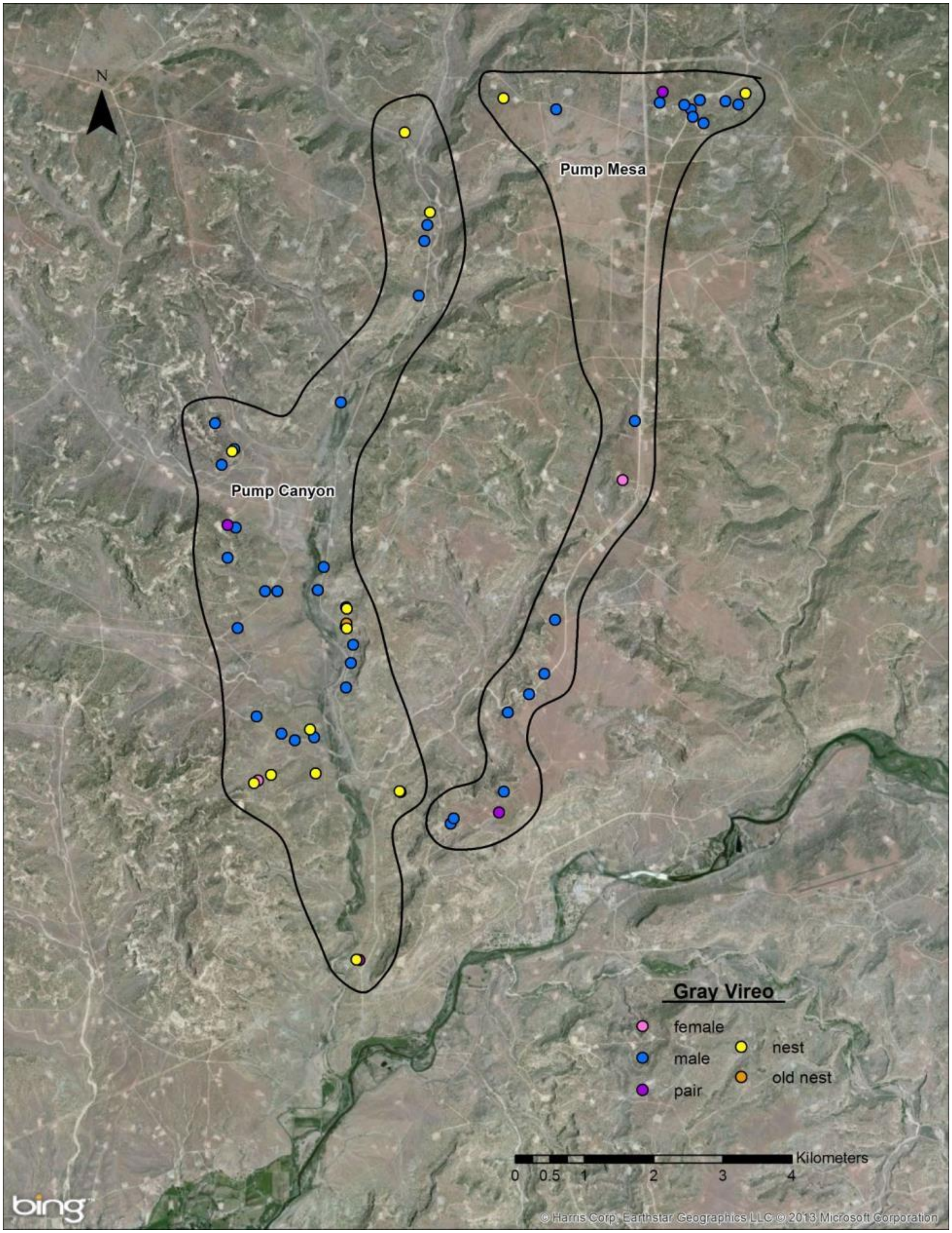


Figure 10. Gray Vireo observations at Pump Canyon and Pump Mesa study sites, 2013.

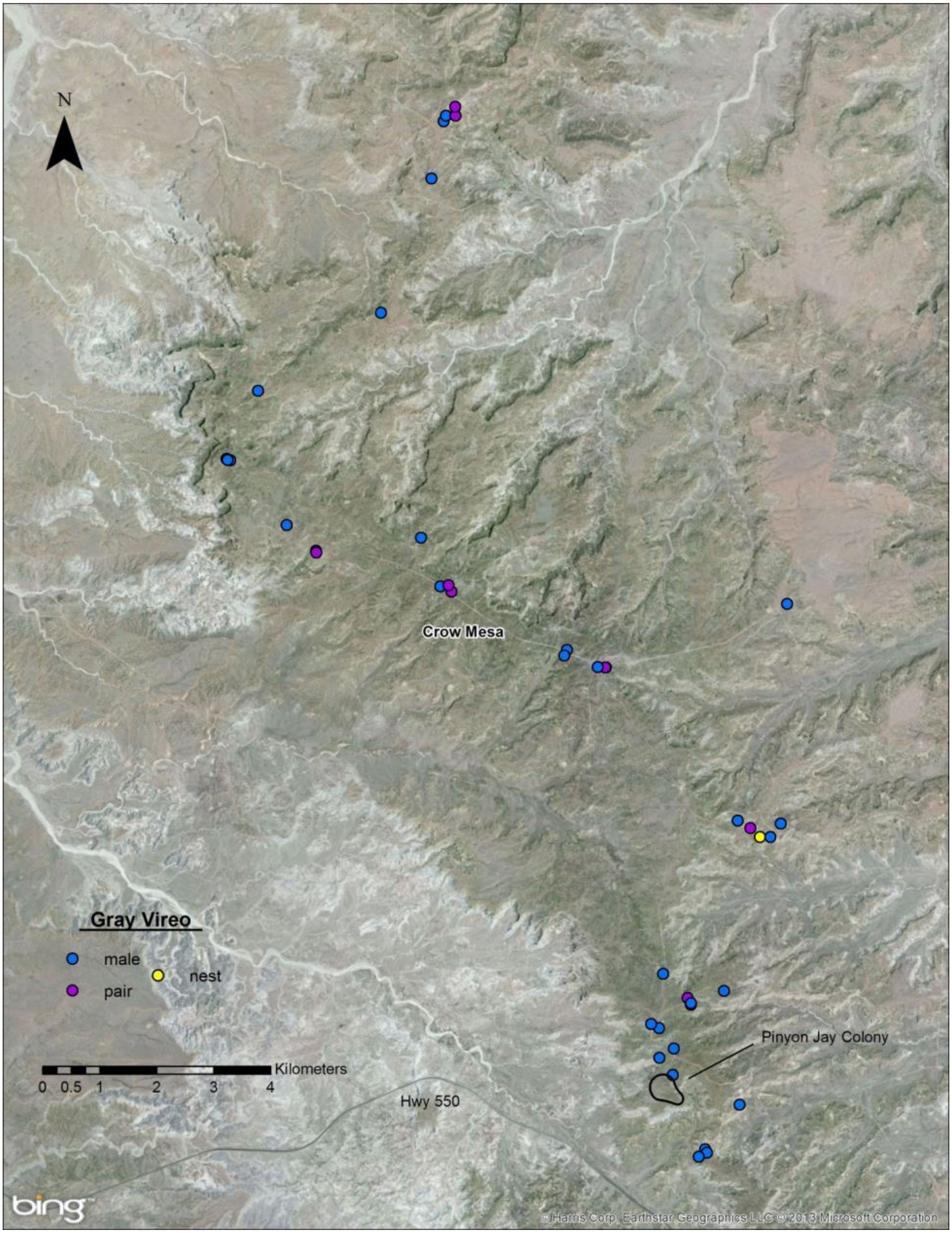


Figure 11. Gray Vireo observations at Crow Mesa study site, 2013.

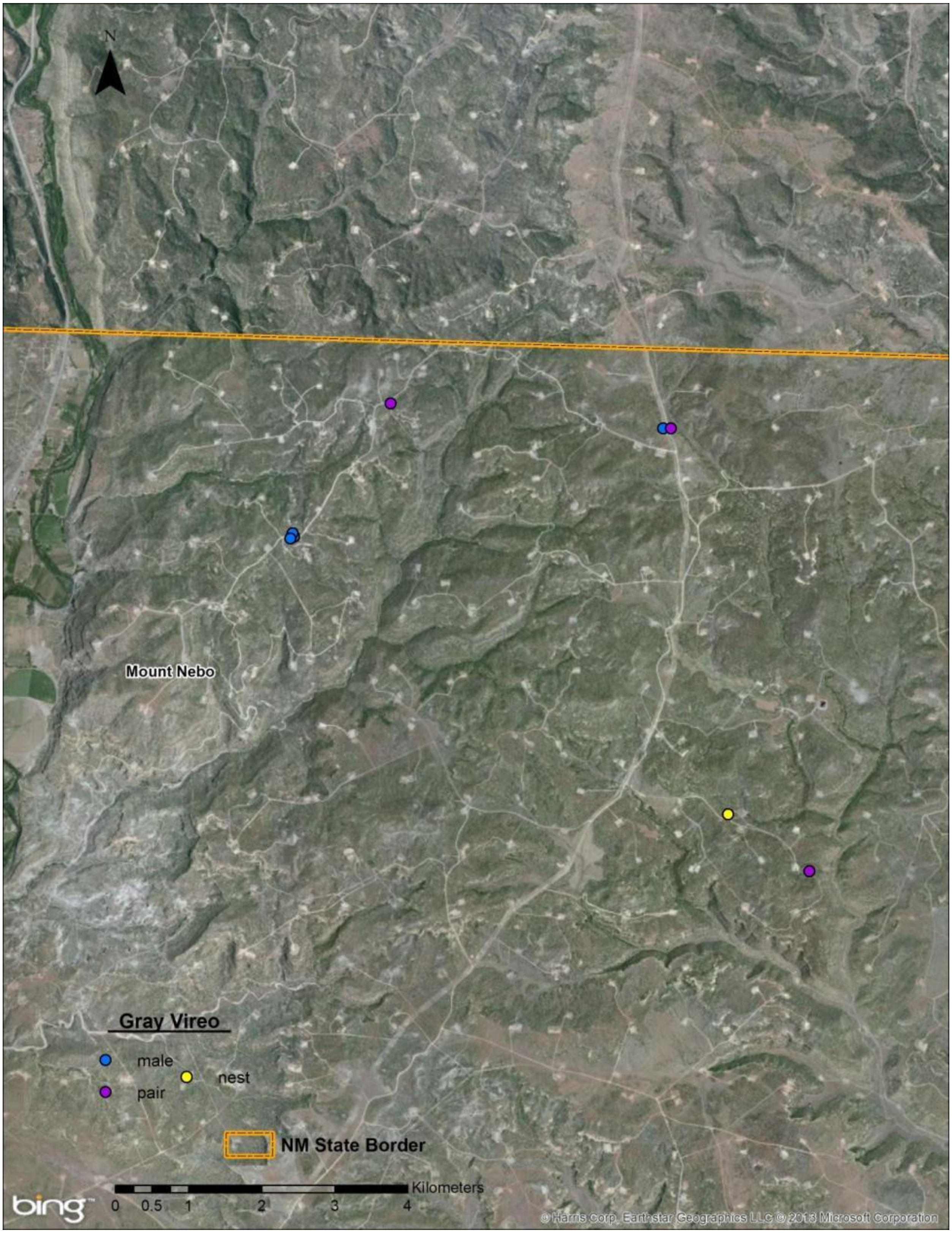


Figure 12. Gray Vireo observations at Mount Nebo study site, 2013.

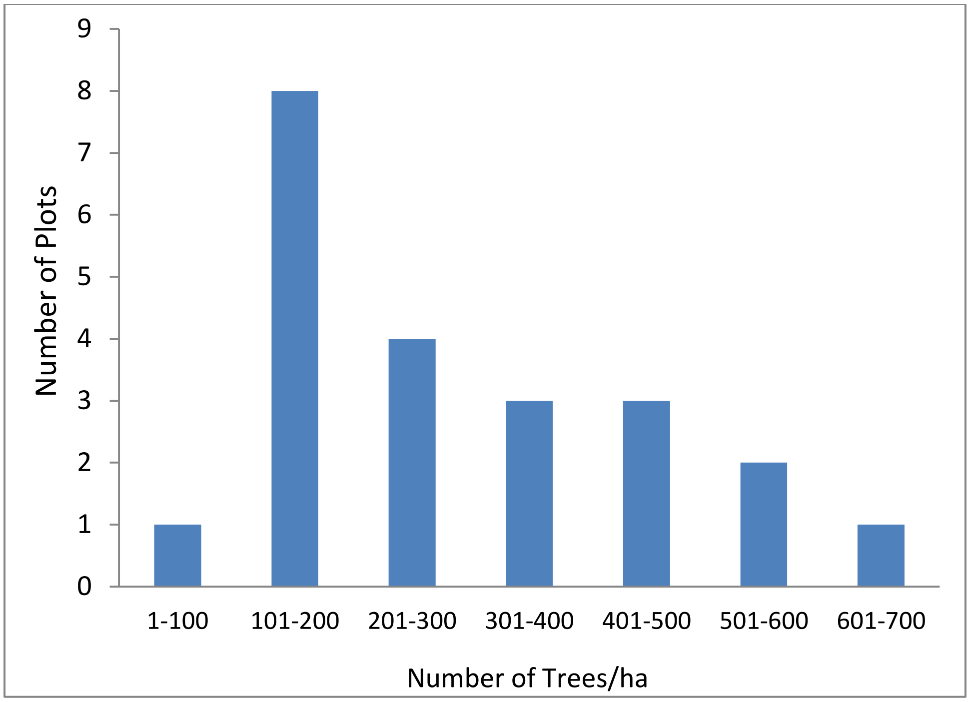


Figure 13. Distribution of tree density on Gray Vireo nest plots in the BLM Farmington Resource Area, 2013.

Table 7. Candidate model set of conditional logistic regression models discriminating Gray Vireo nest plots from random plots. TFD=total foliage diameter, k= number parameters in model, including a stratification term, -LL= negative log-likelihood of the model, AIC_c = small sample adjusted Akaike's information criterion value of the model, ΔAIC_c = difference in AIC_c between models with lowest and higher values, w_i = weight of each model in candidate set, and AUC is area under the receiver operator curve, a measure of model classification accuracy.

Model	k	-LL	AIC_c	ΔAIC_c	Awi	AUC
Trees+TFD	3	-20.956	48.512	0.000	0.269	0.742
Trees	2	-22.412	49.118	0.606	0.199	0.687
TFD	2	-22.449	49.191	0.680	0.192	0.712
Trees+(Trees^2)+TFD	4	-20.764	50.553	2.042	0.097	0.744
Trees+TFD+(TFD^2)	4	-20.950	50.926	2.414	0.081	0.738
Trees+(Trees^2)	3	-22.247	51.094	2.582	0.074	0.683
TFD+(TFD^2)	3	-22.438	51.475	2.963	0.061	0.716
Trees+(Trees^2)+TFD+(TFD^2)	5	-20.764	53.107	4.595	0.027	0.744

Table 8.Parameter estimates from the best candidate conditional logistic regression model discriminating Gray Vireo nest from random plots in the BLM Farmington Resource Area, 2013.

			95% CI	
Variable	Estimate	SE	Lower	Upper
Tree Density	0.120	0.091	-0.057	0.298
Tree Foliage Diameter	-0.440	0.329	-1.081	0.201

diameter, with a ΔAIC_c=0.680 and an AUC of 0.712. Although the second- and third-best models are competitive, both single variables are included in the best model. They therefore are uninformative, and model averaging is not necessary. This leaves only one competitive model, including tree density and tree foliage diameter. Parameter estimates indicated that Gray Vireos nested in areas with slightly more trees than available habitat, but selected nest trees with slightly smaller foliage diameter than randomly selected trees. Confidence intervals around both parameter estimates included zero, indicating these were weak relationships (Table 8).

Discussion

In one season of surveys for breeding Pinyon Jays and Gray Vireos, we have found nesting vireos at five sites and nesting jays at three sites. The New Rawhide site is used by a large flock of Pinyon Jays, comprising up to 80 birds. We were most successful at finding vireo nests in the Aztec area and at Pump Canyon/Pump Mesa sites, but active nests were found at all five sites.

Both species are found primarily in pinyon-juniper woodland habitat, and both species nest in both pinyon and juniper trees. Pinyon Jays apparently choose nest tree species in proportion to their availability, given enough trees of preferred sizes. At most sites, Gray Vireos establish territories in habitat with a larger proportion of juniper trees and nest more often in junipers than pinyons. However, we identified numerous territorial vireos in the pinyon-dominated (>50% pinyon) Crow Mesa, and documented four vireo nests in pinyon trees.

Pinyon Jays

Infrastructure and noise

The large Pinyon Jay colony at the New Rawhide site is surrounded by active gas wells, with a relatively loud well to the north, south, east, and west of the colony. A few small, shed-like buildings are associated with well pads, and gravel roads bisect or are situated adjacent to all three colony sites. Conditional logistic regression analysis of infrastructure data at nest versus random plots revealed no differences in distance to infrastructure. However, nest and random plots were 100 m apart, while roads and well pads were up to several hundred meters from both nest and random plots, such that nest and random plots could have been equidistant from disturbance (Figure 7). That is, the scale of the nest and random plots might have been too small to allow us to detect avoidance of infrastructure, if it occurs.

The presence of a Pinyon Jay colony in the midst of four gas wells suggests that the jays are tolerant of some pump noise. However, it is interesting that five of the six closest nests to wells had noise levels of ~39 dBA. Except for the one outlier (outside the rest of the colony, Figure 7) with a sound level of 43.5 dBA, this suggests that the jays may tolerate nest sites with well noise up to about 40 dBA but typically not higher. We know from studies of Pinyon Jay colonies at two military installations that the jays can tolerate occasional loud noises such as rifle firing and sonic booms (Johnson et al. 2012). The constant noise produced by gas wells, however, could be more detrimental than intermittent, louder sounds. Pinyon Jays are highly social, interactive, and vocal. Constant well noise would likely impact intra-flock communication such as alarm, begging, contact, and courtship calls. We need sound level data from more colonies having nests within 400 m of operational wells to further investigate Pinyon Jay noise tolerance limits.

Pinyon Jay nest-scale analysis

Pinyon Jays nested in trees that were larger than random trees, as indicated by height and RCD. This result accords with our results from a study of three Pinyon Jay colonies at two DoD installations, in the Oscura Mountains at White Sands Missile Range (WSMR) and in the Manzanita Mountains at Kirtland Air Force Base (KAFB). In that study, the jays chose nest trees with larger RCD, higher canopy cover within 5 m of the nest, and higher litter cover under the nest tree, compared to random plots. In the BLM study, canopy cover was nearly significant; with a larger sample size of nests, this variable might be shown to be important. Ground cover at BLM colony sites was noticeably sparse relative to that at WSMR and KAFB, which may explain the absence of ground cover measures in the best BLM models.

The results of the four-year DoD study and the first year of this study both emphasize the importance of mature pinyon and juniper trees to nesting Pinyon Jays. Utah junipers do not occur at the DoD sites, and Pinyon Jays nested mainly in Colorado pinyons in that study. Utah junipers are much taller and have more treelike, as opposed to shrublike, conformation than one-seed junipers. Availability of the larger Utah junipers may explain why the jays nest more frequently in junipers on BLM land than on DoD lands, where junipers (*J. monosperma*) are shorter and more shrublike. Mature pinyon and juniper trees are important to the jays not only as nesting trees, but also as mast trees. Tree RCD is a predictor of pinyon cone production (Johnson and Smith 2006, 2007); large trees are therefore important to Pinyon Jay population viability.

In addition to nest trees and mast trees, Pinyon Jays need water. Data from wildlife cameras suggest that the jays use the water sources closest to the New Rawhide Colony (Sandstone Canyon and Rawhide Canyon guzzlers). Although they probably prefer the close sources while they are nesting, they may use more distant sources when ranging farther from the colony for food. Alternatively, the birds using more distant water sources such as the Trail Canyon Trick Tank may belong to a different flock.

To manage Pinyon Jay habitat, it is necessary to delineate the boundaries of a flock home range and identify resources they use (besides nesting sites), such as water sources and areas with large pinyon trees for mast production. Pinyon Jays can have very large home ranges (5027 ha, Johnson et al. 2011; 6400 ha, Balda 2002), which they use differently in summer and winter. The best way to approach the above questions about landscape-scale habitat and resource requirements is therefore through a radio telemetry study.

Climate impacts to habitat

At WSMR, an index of tree vigor has declined over the last 10 years. By our ranking scale, trees with higher vigor ranks had greener, thicker foliage, which protects and hides nests. Declining mean annual vigor scores indicate needle loss, thinner foliage, more brown needles, and more dead trees (Johnson et al. 2012, Johnson et al. in review). Cone production has also been poor, with one moderate and no large cone crop since 2004. Our data indicate that pinyon trees at our WSMR study site are showing the effects of climate change (loss of canopy cover, tree mortality, and decreased cone production) like those documented in studies of pinyon-juniper habitat elsewhere in the Southwest (Breshears et al. 2005, Allen-Reid et al. 2005, Clifford et al. 2011, Redmond et al. 2012).

Compared to our two DoD Pinyon Jay study sites in New Mexico, pinyon trees at our Farmington BLM study sites appear healthy; this impression is supported by the fact that a cone crop occurred at New Rawhide in the fall of 2012. The 2012 crop was large enough that Pinyon Jays were still retrieving caches at the New Rawhide colony site in May 2013. However, given predicted effects of climate change on pinyon-juniper ecosystems across the Southwest, climate impacts can be expected at Farmington BLM. It is important to document climate-related habitat changes and impacts on pinyon-juniper wildlife, including monitoring tree condition and mast production in both pinyon and juniper trees at the Farmington BLM study sites.

Gray Vireos

Infrastructure

Gray Vireos may be equally tolerant of gas well noise, as most nests and territories were found at similar or closer distances from well pads. However, we do not have noise levels on the wells near vireo nests; instead we used distances taken from imagery. Some of the well pads near vireo nests could therefore be inactive and silent.

Gray Vireo nest-scale analysis

Gray Vireos showed a weak preference for nest sites with more trees, compared with the proportion of available habitat within their territories. These results are consistent with the results of a study of Gray Vireo nest-site selection at two DoD installations in New Mexico—the Manzanita Mountains at KAFB and Camel Tracks Training Area (Johnson et al. 2012). Higher tree density may hide nests from some predators and Brown-headed Cowbirds (*Molothrus ater*). In addition, Gray Vireos often forage from leaves, branches, and tree trunks (Barlow et al. 1970); hence, more trees would increase foraging opportunities in close proximity to nests. In the DoD study, Gray Vireos also selected nesting areas with taller trees compared with the proportion of available habitat. While tree height was not an important predictor of nest sites in this BLM study, vireos did exhibit a weak preference for trees with smaller foliage diameter than available trees within their territories. Because measures of tree height were positively correlated with tree foliage diameter, our data suggest that vireos did not select nesting areas with taller trees than those in available habitat. Our results are based on a small (<30) sample of nest and paired, random plots; therefore, the information should be viewed with caution. Additional study is needed to increase sample size for a statistically rigorous analysis.

Habitat Management Recommendations for Pinyon-Juniper Birds

Pinyon Jays

For Pinyon Jays, we recommend no net loss of mature Colorado pinyon or juniper, especially Utah juniper, trees in pinyon-juniper nesting habitat at Farmington BLM. Size distributions on areas maintained for Pinyon Jay nesting colonies should be similar to those measured on colonies in this study.

Because Pinyon Jays are colonial nesters, they require large patches containing mature stands of pinyon-juniper woodland. The Old Rawhide colony covered 5.0 ha, Crow Mesa 15.8 ha, and New Rawhide 40.7 ha, in 2013. New Rawhide nests were closely packed between a ridgetop to the west, a canyon to the east, and gas wells in the four directions. The colony has little space for expansion, such that 41 ha for this colony does not allow for any colony growth. We recommend that patches of mature pinyon-juniper habitat ≥15 ha in area be retained for potential colony sites, particularly if a Pinyon Jay flock is observed regularly within 5 miles of the site. These patches should not be fragmented by roads or well pads, and wells should not be located closer than 150 m from the edge of a patch of nesting habitat. Future, colony-scale modeling will identify potential colony sites in pinyon-juniper habitat that are similar to existing colonies in slope, aspect, elevation, vegetation patch size, solar radiation, and other colony-scale variables.

Pinyon Jays also need large landscapes of productive pinyon trees for harvesting and caching pinyon seeds, and these areas should contain large trees for maximum cone productivity and nearby water. Our work at WSMR and KAFB indicates that the year-round home range of a Pinyon Jay flock can be from 3500-5000 ha. Hence, Pinyon Jay habitat management should occur at the nest, colony, and landscape scales. The goal of this project is to provide management guidelines at all three scales.

Gray Vireos

Our data suggest that both junipers and pinyons are important to nesting Gray Vireos in the BLM Farmington Resource Area. While previous studies suggested that vireos primarily occupy and nest in juniper-dominated habitats (Barlow et al. 1999, DeLong and Williams 2006, Johnson et al. 2012), our study demonstrates they also occur in pinyon-dominated landscapes and utilize pinyon trees for nesting. Gray Vireos have also reportedly nested in pinyons on WSMR (Jason Hobert, pers. comm.); however, this was not observed in the Johnson et al. (2012) study.

We recommend no net loss of juniper trees, especially in juniper-dominated woodlands, to support populations of nesting Gray Vireos. In addition, Gray Vireos should be considered where tree removal is proposed in pinyon-dominated landscapes in the BLM Farmington Resource Area. Where tree removal activities may occur, we recommend maintaining similar tree densities as reported in this study. Additional study is needed to determine if specific tree age and/or size classes are important to nesting vireos in the BLM Farmington Resource Area, as was shown on DoD lands.

Future Work

Pinyon Jays

Our goals for future Pinyon Jay work at Farmington BLM are to:

1. use radio telemetry to help establish the seasonal and year-round home ranges of one or more Farmington BLM Pinyon Jay flocks,
2. employ vegetation classification to model Pinyon Jay habitat at the landscape scale, including use of telemetry data to map other resources crucial to Pinyon Jay nesting,
3. increase nesting colony sample size for modeling colony-scale habitat,
4. acquire more paired BBird nest data to refine nest-scale models, and
5. begin to monitor pinyon health and productivity, as an indicator of climate impacts.

Gray Vireos

Our goals for future Gray Vireo work at Farmington BLM are to:

1. conduct additional surveys and nest searching at Crow Mesa, Mesa Mountains, and Pump Mesa, to increase the sample of nests and provide a more even the distribution across sites,

2. provide an estimate of Brown-headed Cowbird parasitism of Gray Vireo nests in the BLM Farmington Resource Area and compare it with DoD sites, and
3. employ vegetation maps to model Gray Vireo habitat at the landscape scale.

Acknowledgments

We thank Marikay Ramsey of the Bureau of Land Management New Mexico State Office for providing funding for this project. John Hansen of the BLM Farmington Field Office provided funding for preliminary field work on Pinyon Jays, logistical support for Pinyon Jay field work, review of reports, and an intern for Pinyon Jay field work. John Kendall of Farmington BLM provided logistical support for Gray Vireo field work. Cristin Salaz and Peter Skartvedt performed vireo field work.

Literature Cited

Allen-Reid, D., J. Anhold, D. Cluck, T. Eager, R. Mask, J. McMillan, S. Munson, T. Rogers, D. Ryerson, E. Smith, B. Steed, and R. Thier. 2005. Piñon pine mortality event in the Southwest: an update for 2005. US Forest Service. Accessed at: http://fhm.fs.fed.us/posters/posters05/pinon_pine.pdf

Balda, R. P. 2002. Pinyon Jay (*Gymnorhinus cyanocephalus*). *In* The Birds of North America, No. 605 (A. Poole and F Gill, eds.). The Birds of North America, Inc. Philadelphia, PA.

Barlow, J. C., R. D. James, and N. Williams. 1970. Habitat co-occupancy among some vireos of the subgenus *Vireo* (Aves: Vireonidae). Canadian Journal of Zoology. 48:395-398.

Barlow, J.C., S.N. Leckie, and C.T. Baril. 1999. Gray Vireo (*Vireo vicinior*). *In* The Birds of North America, No. 447 (A. Poole and F. Gill, eds.). The Birds of North America, Inc., Philadelphia, PA.

Breshears, D.D., N.S. Cobb, P.M. Rich, K.P. Price, C.D. Allen, R.G. Balice, W.H. Romme, J.H. Kastens, M.L. Floyd, J. Belnap, J.J. Anderson, O.B. Myers, and C.W. Meyer. 2005. Regional vegetation die-off in response to global-change-type drought. Proceedings National Academy Sciences 102:15144-15148.

Burnham, K. P. and D. R. Anderson. 2002. Model Selection and Multimodel Inference: a Practical Information-Theoretic Approach. Springer, New York, NY, USA.

Clifford, M.J., N.S. Cobb, and M. Buenemann. 2011. Long-term tree cover dynamics in a pinyon-juniper woodland: climate-change-type drought resets successional clock. Ecosystems 14:949-962.

Cole, K.L., K. Ironside, S. Arundel, P. Duffy, and J. Shaw. 2007. Modeling future plant distributions on the Colorado Plateau: an example using *Pinus edulis*. Pp. 319-330 *in*: the Colorado Plateau III; Integrating research and resources management for effective conservation. C. van Riper III and M. Sogge, eds. University of Arizona Press, Tucson, AZ.

Delong, J.P. and S.O. Williams. 2006. Status report and biological review of the gray vireo in New Mexico. Unpubl. report to New Mexico Department of Game and Fish, Santa Fe, NM. 50 pp.

ESRI (Environmental Systems Resource Institute). 2011. ArcMap 10.1, Redlands, California.

Fielding, A.H., and J.F. Bell. 1997. A review of methods for the assessment of prediction errors in conservation presence/absence models. Environmental Conservation 24:38-49.

Hosmer, D.W., and S. Lemeshow. 2000. Applied Logistic Regression. John Wiley & Sons.

Johnson, K. and J. Smith. 2006. Interdependence of pinyon pines and pinyon jays White Sands Missile Range, NM, 2004-2005 final report. Natural Heritage New Mexico, Biology Department, University of New Mexico, Albuquerque, NM.

Johnson, K. and J. Smith. 2007. Relationship of pinyon jays and pinyon pines at North Oscura Peak, White Sands Missile Range, 2006 final report. Natural Heritage New Mexico Publication No. 07-GTR-311. Biology Department, University of New Mexico, Albuquerque, NM.

Johnson, K., G. Sadoti, and J. Smith. In prep. Pinyon Jay behavioral response to declining pinyon condition. Manuscript in review.

Johnson, K, L. Wickersham, T. Neville, J. Wickersham, J. Smith, M. Baumann, and C. Finley. 2011. Habitat use at multiple scales by pinyon-juniper birds on Department of Defense lands: Landscape scale. Natural Heritage New Mexico Publication 10-GTR-360. Natural Heritage New Mexico, UNM Biology Department, Albuquerque, NM.

Johnson, K, L. Wickersham, T. Neville, J. Wickersham, J. Smith, M. Baumann, and C. Finley. 2012. Habitat use at multiple scales by pinyon-juniper birds on Department of Defense lands II: Nest and territory/colony scale. Natural Heritage New Mexico Publication 12-GTR-366. Natural Heritage New Mexico, UNM Biology Department, Albuquerque, NM.

Ligon, J.D. 1971. Late summer-autumnal breeding of the Piñon Jay in New Mexico. Condor 73:147-153.

Ligon, J.D. 1974. Green cones of the piñon pine stimulate late summer breeding in the Piñon Jay. Nature 250:80-82.

Ligon, J.D. 1978. Reproductive interdependence of piñon jays and piñon pines. Ecological Monographs 48:111-126.

Menard, S.W. 2009. Logistic Regression: From Introductory to Advanced Concepts and Applications. SAGE Publications, Thousand Oaks, CA.

R Core Development Team. 2013. R: A Language and environment for statistical computing. R Foundation for Statistical Computing, Vienna Austria. http://www.R-project.org.

Redmond, M.D., F. Forcella, and N.N. Barger. 2012. Declines in pinyon pine cone production associated with regional warming. Ecosphere 3:1-14.

Stephens, P.A., S.W. Buskirk, G.D. Hayward, C.M. Del Rio, and Hm. 2007. A call for statistical pluralism answered. Journal of Applied Ecology 44:461-463.

Thompson, R.S., S.E. Hostetler, P.J. Bartlein, and K.H. Anderson. 1998. A strategy for assessing potential future changes in climate, hydrology, and vegetation in the western United States. USGS Circular 1153. Accessed 6 August 2010 at: http://pubs.usgs.gov/circ/1998/c1153/.

Williams, A.P, C.D Allen, A.K. Macalady, D. Griffin, C.A. Woodhouse, D.M. Meko, T.W. Swetnam, S.A Rauscher, R. Seager, H.D. Grissino-Mayer, J.S Dean, E.R. Cook, C. Gangodagamage, M. Cai, and N. G. McDowell. 2012. Temperature as a potent driver of regional forest drought stress and tree mortality. Nature Climate Change 3:292-297. Accessed online at : www.nature.com/natureclimatechange.

Zlotin, R.I. and R.R Parmenter. 2008. Patterns of mast production in pinyon and juniper woodlands along a precipitation gradient in central New Mexico (Sevilleta National Wildlife Refuge). Journal of. Arid Environments72:1562-1572.