Nest-scale Habitat Use by Pinyon Jay and Gray Vireo in the BLM Farmington Resource Area 2013−2014

Final Report

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Abstract

We studied nest-scale habitat requirements of Pinyon Jay and Gray Vireo in the BLM Farmington, NM Resource Area. Pinyon Jays nested at Rawhide Canyon and Crow Mesa from 2013−2014 and one additional site near Rawhide Canyon in 2012−2013. Pinyon Jays placed nests (*n*=56) in roughly equal proportions in pinyon and juniper trees. Using conditional logistic regression, we compared habitat on BBIRD plots at nests to random plots within nesting colonies. The best model comparing nest to random plots indicated that Pinyon Jay nest trees were significantly taller and larger in diameter than central trees on random plots, but the jays did not nest in the very tallest, emergent trees. The use of larger-than-random trees for nests is consistent with our results in a previous study on DoD installations, except that in that study, canopy cover at the nest plot and litter under the nest tree were included in the best nest-scale model. The density of trees on nest plots in the DoD study was over twice that at BLM.

We attached transmitters to 11 Pinyon Jays and collected data on their locations from 10 June−14 October. These provided 44 transmitter-weeks of data and 81 detection points, a mean of 7.4 detections per bird. These location data provided three estimates of home range area for the Rawhide flock from mid-April to mid-October: 3102.88 ha (MCP), 4033.66 ha (95% Kernel Density Estimator), and 4200 ha (all 100-ha detection blocks and interconnecting blocks). These areas are larger than most home ranges reported in the literature.

We recorded 229 detections of Gray Vireos at the five study sites in 2013 and 2014, including males, females, pairs, and fledglings. We found 120 territories in 2013 and 95 in 2014 at all sites. Juniper dominated the Aztec, Pump Canyon, and Pump Mesa Gray Vireo territories, with mean juniper to pinyon proportion of 0.95, 0.82 and 0.80, respectively. Territories on Crow Mesa were dominated by pinyon (mean nest plot juniper to pinyon proportion, 0.32). Combining years and sites, 53 (82%) Gray Vireo nests were in juniper trees, 10 (15%) in pinyons, and 2 (3%) in big sagebrush. The best nest site selection model indicated that Gray Vireos showed a preference for nest sites with more trees and taller trees, compared with the proportion of available habitat within their territories. Vireos also selected nest trees with slightly smaller canopy width than trees on random plots within their territories. The inclusion of a quadratic term for mean tree height suggests vireos may select sites with taller, but perhaps not the tallest, trees. Although our data suggest weak trends for tree height and canopy width, these results are consistent with the results of the DoD study.

To manage for Pinyon Jay nesting habitat, trees should be maintained in approximate species proportions and size distributions as reported here. Trees at nesting colony sites should not be removed. To allow for tree mortality expected as a result of climate change, potential nesting habitat surrounding existing colonies should be preserved. Pinyon Jays are tolerant of some well noise and limited vehicle traffic, but they apparently do not tolerate noise levels above ~40 dB, and foot traffic is quite disruptive to nesting Pinyon Jays. To support populations of nesting Gray Vireos, we recommend no net loss of juniper trees, especially in juniper-dominated woodlands. In addition, Gray Vireos should be also considered where tree removal is proposed in pinyon-dominated landscapes in the BLM Farmington Resource Area. For Pinyon Jay and Gray Vireo, results from this and a previous study on DoD lands indicate the importance of retaining taller

than average trees for nesting. This study indicates that trees surrounding the nest tree are also important for both bird species and should not be thinned.

Introduction

Pinyon-Juniper Habitat Declines

Pinyon-juniper (*Pinus edulis, P. monophylla, P. cembroides*, *Juniperus* spp.) woodlands cover approximately 40 million hectares of the western U.S. (Romme et al. 2009). Several recent studies have attributed morbidity and mortality of pinyon and juniper trees in the Southwest to climate change. Since 2001, dramatic, rapid, large-scale mortality of pinyon trees has occurred in the southwestern U.S. 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 due to drought (Zlotin and Parmenter 2008). Under climate change, the range of pinyon-juniper habitat is predicted to contract significantly across the Southwest (Cole et al. 2007, Thompson et al. 1998) and expand into northern New Mexico and Colorado (Cole et al. 2007).

The insecure status of several native pinyon-juniper wildlife species provides further evidence that these habitats are threatened. The Gray Vireo (*Vireo vicinior*) and Oscura Mountains Colorado chipmunk (*Neotamias quadrivittatus oscuraensis*) are listed as threatened by the State of New Mexico. Several federal Birds of Conservation Concern (BCC, US Fish and Wildlife Service 2008), Pinyon Jay (*Gymnorhinus cyanocephalus*), Juniper Titmouse (*Baeolophus ridgwayi*), and Black-chinned Sparrow (*Spizella atrogularis*), breed in pinyon-juniper habitats. An additional BCC, Rufous Hummingbird (*Selasphorus rufus*), uses pinyon-juniper habitats on migration. The above species (except Black-chinned Sparrow) are classified as Species of Greatest Conservation Need (SGCN) by the New Mexico Department of Game and Fish (NMDGF) (NMDGF 2006).

Several of the above wildlife species depend directly on pinyon and juniper trees for food and nest sites. Both pinyon and juniper are mast species, producing large seed crops at irregular intervals (Zlotin and Parmenter 2008). Oscura Mountains chipmunks eat and cache pinyon seeds (Johnson unpublished). Pinyon Jays have a close mutualism with pinyon trees, serving as short- and long-distance seed dispersers for pinyon pines, and pinyon mast crops enhance Pinyon Jay reproductive success and survival (Ligon 1978, Marzluff and Balda 1992). Pinyon Jays also eat juniper berries (Balda 2002). The Juniper Titmouse is a major predator of pinyon seeds (Balda 1987). Gray Vireos and Pinyon Jays nest in both pinyon and juniper trees (Johnson et al. 2013). The Juniper Titmouse nests in cavities in stumps of pinyon trees (Panik 1976, cited in Cicero 2000) and crevices in twisted trunks of large junipers (Grinnell and Miller 1944, cited in Cicero 2000). Decreasing mast crops, declining tree health, tree mortality, and other effects of climate change will directly impact these sensitive species of pinyon-juniper habitats.

Recent Research on Habitat Use by Pinyon-Juniper Birds

In 2014, we completed a four-year study, Habitat Use at Multiple Scales by Pinyon-Juniper Birds on Department of Defense Lands (Johnson et al. 2011, 2012, 2014). For that project, we studied habitat use by two SGCN, Gray Vireo and Pinyon Jay, at the landscape, territory/colony, and nest scale at three New Mexico DoD installations: White Sands Missile Range (WSMR), Kirtland Air Force Base (KAFB), and Camel Tracks Training Area (CTTA). We have also studied other aspects of Pinyon Jay (WMSR and KAFB) and Gray Vireo (KAFB and CTTA) biology for several years. This study of habitat use by two at-risk species that differ in seasonal movements, social structure, and foraging habits, viewed at multiple scales and several sites across the state, provides a broad perspective on the management of pinyon-juniper woodlands for birds.

In 2012, we extended our study of Gray Vireo and Pinyon Jay habitat use to the BLM Farmington Resource Area. The goals of that ongoing study are to:

1. collect multi-scale habitat use data for Gray Vireo and Pinyon Jay on BLM lands,
2. compare results to those of the four-year DoD study,
3. provide management recommendations for pinyon-juniper woodland habitats in the Farmington Resource Area.

2014 Accomplishments

In 2013, we made significant progress locating breeding territories for Gray Vireo and nesting colonies for Pinyon Jay; however, we wanted to increase our sample size of nests for statistical modeling at the nest scale. BLM funded the second year of the study at a reduced level in 2014. NMDGF provided additional funds in 2014 to support the collection of additional nest-scale data. The goals for 2014, all of which were accomplished, were to:

1. revisit Gray Vireo and Pinyon Jay nesting areas identified in 2013, survey additional areas, and locate additional nests of both species,
2. collect Gray Vireo and Pinyon Jay nest-scale habitat data,
3. for each bird species, compare habitat features at nest and random plots,
4. collect observation points for Gray Vireos, for later habitat modeling at the landscape scale,
5. capture and radio-tag Pinyon Jays from the Rawhide Canyon flock, collect observation points, and delineate the flock home range for later habitat modeling at the landscape scale, and
6. based on the modeling results, provide nest-scale habitat management recommendations for these two SGCN and pinyon-juniper habitat in general.

Our nest-scale analyses may be used to develop guidelines for habitat management projects in pinyon-juniper woodlands, to maintain tree densities and age classes suitable for nesting Gray Vireos and Pinyon Jays.

Methods

Study Areas

The study areas are in the BLM Farmington Resource Area in San Juan and Rio Arriba Counties. We surveyed for nesting Pinyon Jays at colony sites occupied in 2013 at Crow Mesa and Rawhide Canyon. We also looked for new colonies at Tank Mountain and Palluche Canyon (Figure 1). We surveyed for nesting Gray Vireos at four study sites: Crow Mesa, Pump Canyon, Pump Mesa, and BLM lands north and west of Aztec, NM (Figure 1).

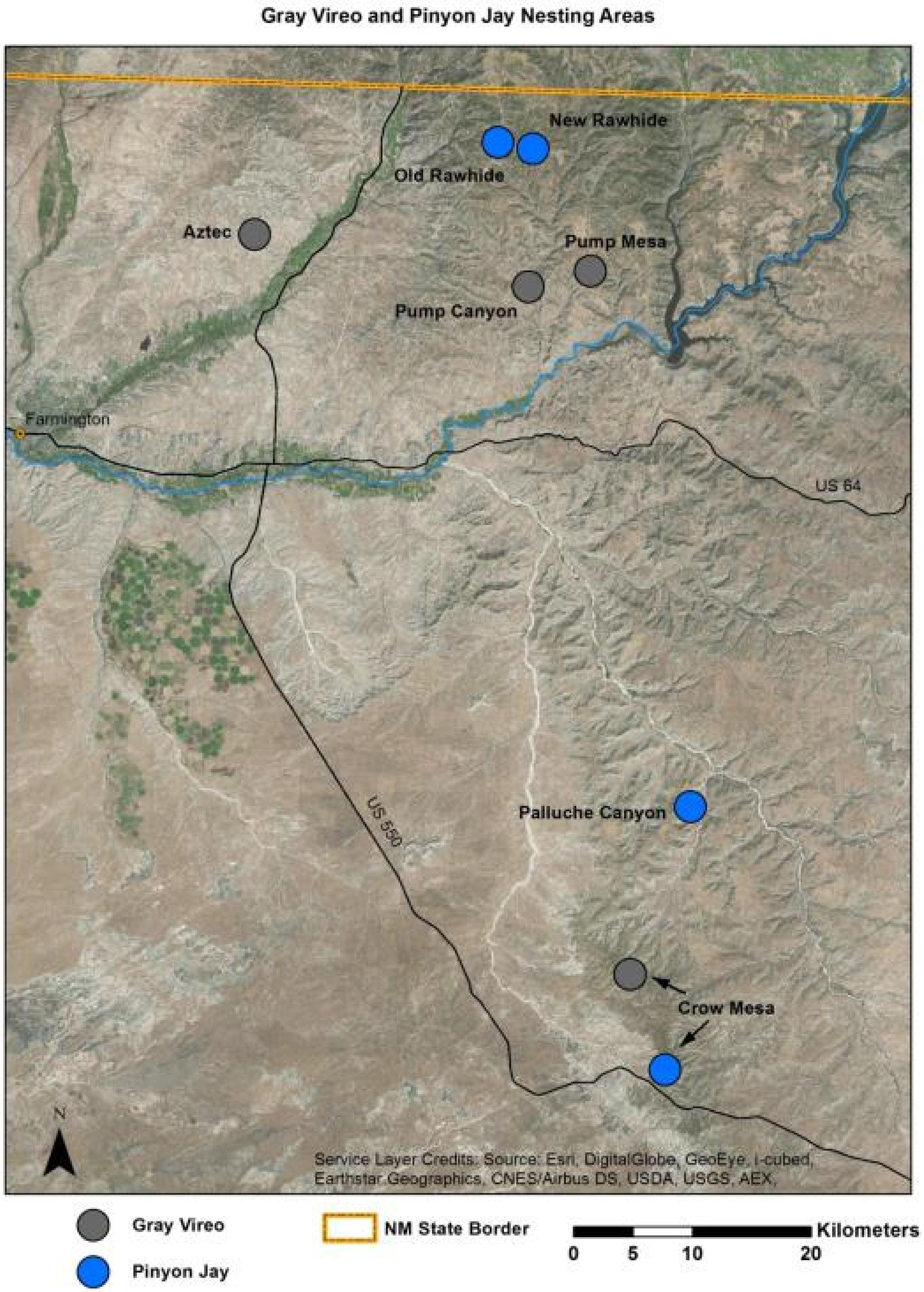

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Figure 1. Pinyon Jay and Gray Vireo survey areas at Farmington BLM, 2013−2014. Circles indicate location of the approximate center of each study area and are not intended to depict the study area boundaries.

Pinyon Jay field work was performed by Natural Heritage New Mexico, UNM Biology Department, and Gray Vireo field work was performed by Animas Biological Studies, Durango, CO.

Field Methods

Pinyon Jays

On 30 April 2014, we surveyed for Pinyon Jay nests at Tank Mountain, near a wildlife guzzler frequented by Pinyon Jays. Some jays banded and radio-collared at the Rawhide Canyon feeder have been detected at the guzzler. On 1 May 2014, we surveyed for Pinyon Jays and searched for nests at Palluche Canyon, where Pinyon Jays have been observed during the breeding season (Figure 1).

From April to June 2014, we revisited two Pinyon Jay colonies active in 2013, at Crow Mesa and Rawhide Canyon. We found Pinyon Jay nests and marked their locations in the field using GPS. After nesting activities were complete, we collected nest-scale data following a modified BBIRD protocol (Martin et al. 1997). 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 inter-plot distances.

At each plot we collected data within 5- 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.).

On 24 April, we installed feeders at Rawhide Canyon and the Tank Mountain wildlife guzzler. Feeders were solar powered, electronic feeders manufactured by Sweeney Enterprises, Inc.; Boerne, TX. Each feeder was set to deliver about two cups of either *P. edulis* seed (obtained from Goods from the Woods) or a combination of *P. edulis* and black oil sunflower seed, at approximately 07:00 each day. Because the Rawhide Canyon feeder was close to a nesting colony and more accessible than the Tank Mt. feeder, we decided to trap at Rawhide and removed the Tank Mt. feeder in late May. We filled feeders two or three times per week until transmitters arrived. On 10 and 11 June and 8, 15, and 30 July, we trapped Pinyon Jays at the Rawhide Canyon feeder.

We captured jays in a walk-in pigeon trap (Figure 2) or a modified Australian crow trap (Figure 3) baited with *P. edulis* seed. We set and baited each trap before the feeder delivered seed in the morning. We watched feeders from a distance and approached traps when we had captured several jays. Pinyon Jays are quite social and are comfortable in traps with other birds, as long as pinyon seed is present.


Figure 2. Walk-in pigeon trap used to capture Pinyon Jays.


Figure 3. Modified Australian crow trap used to capture Pinyon Jays.

Each captured bird was banded with a US Geological Survey (USGS) numbered aluminum band and a unique combination of three plastic color bands. We recorded the following data on each captured bird: age, probable sex, weight, culmen length, bill height, tarsus, and wing chord. We attached 2.0 g, tail-mounted, whip antenna radio transmitters (Holohil Systems, Ltd.) to a subset of the captured birds. We tied each transmitter to the base of the two central rectrices with sturdy thread, and then glued the body of the transmitter to the top of the same two rectrices (Figure 4). All birds were released unharmed after processing. Pinyon Jays were captured and banded under USGS Federal Marking and Salvage Permit #22158 and NMDGF Scientific Permit #1795.


Figure 4. Pinyon Jay with transmitter.

After transmitters had been attached to the birds, we used a TRX 1000S receiver from Wildlife Materials to listen for transmitter birds two to three times each week from mid-June until mid-October. Each time we received a signal, we recorded the time of day, our GPS coordinates, and the compass bearing of the strongest signal. We then attempted to take a second GPS point and directional bearing from a different location, to triangulate on the bird's specific location. Using ArcGIS, we mapped GPS coordinates for all jay sightings, transmitter detections, and vectors indicating the direction we heard the strongest radio signal. Where the vectors crossed on the map, we added a point to signify the approximate location of the bird. Each point was associated in the GIS with date, time, and transmitter frequency.

We combined all GPS coordinates of Pinyon Jay locations into a GIS layer. This included points derived from visual and audio detection of Pinyon Jays and radio telemetry bearings.

Gray Vireos

In 2014, we visited Aztec on 22 and 23 May and 13 and 26 June. We surveyed Crow Mesa on 27 and 29 May and 10 and 18 June. We surveyed Pump Canyon on 15 May and 4, 11, 12, and 17 June. Pump Mesa we visited on 14 and 26 May, 12 June, and 1 July (Figure 1). The 2013 survey dates are provided in Johnson et al. (2013).

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 GPS units. We documented the number of birds detected, their sex, and observed status (e.g., singing male, pair). 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 modified 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- and 11.3-m radius (0.04 ha) 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. On the 5-m plots we collected the following: elevation, indices of live and non-live ground cover, shrub species and counts, nest tree canopy width, nest height, nest aspect, and distance from nest to tree edge.

Derived and GIS Measurements

We calculated the cosine of plot aspect resulting in a north-south index ranging from -1 (south) to 1 (north). Using ESRI ArcGIS (ESRI 2013), we gathered distances from each nest and random plot center to the nearest road and oil or gas well, using a combination of 2013 digital air photos (Pinyon Jays and Gray Vireos, ESRI 2013) and GIS shapefiles of wells obtained from the New Mexico GO-TECH website (Gray Vireos, http://gotech.nmt.edu/gotech/Main.aspx). For Pinyon Jays, we also gathered distance to edge of habitat.

Analysis

We modeled nest-site selection in both species 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 Development Team 2014).

We first checked each variable for normality by viewing histograms of the data. We log- or arcsin-transformed variables not normally distributed and checked the transformed data for normality by viewing histograms of the data. If the transformed histogram indicated normal distribution, we retained the transformed variable for analysis.

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 $|r|>0.7$ was included together in a model. We grouped variables into three groups associated with natural history or management: topographic (slope, aspect, and elevation), vegetation (trees and ground cover), and infrastructure (distance to edge, road, and infrastructure). Within each of three groups of variables, we used a stepwise modeling approach to identify significant variables and built a global model using all variables and their quadratic terms.

Using significant variables from the exploratory models, we built a final candidate set of five models for Pinyon Jays, representing *a priori* hypotheses. We considered any model with a sample-size adjusted 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).

We modeled nest-site selection of Gray Vireos, as for Pinyon Jays, except that we paired each nest with a randomly-selected plot approximately 100 m from the nest at a random bearing. We used a similar combination modeling approach for Gray Vireos as for Pinyon Jays, including exploratory data analysis to identify important predictors and *a priori* multi-model inference to identify the best-performing nest-site selection models. Using significant variables from the exploratory models, we built a final candidate set of 16 models representing *a priori* hypotheses.

We mapped Pinyon Jay locations in ArcGIS and created a minimum convex polygon (MCP) around all detection points. The area inside the MCP provided a minimum estimate of the location of the Rawhide flock's summer home range. We buffered the MCP by 100 m for map depiction of the home range. Because jays undoubtedly moved through a larger area than the MCP, we also calculated an approximate home range including all 100-ha blocks in which we detected jays. Finally, we used the Kernel Density Estimator (KDE) tool in ArcGIS to construct a 95% home range and compute its area.

Results

Pinyon Jays

Nests

At Tank Mountain, we found only one old apparent Pinyon Jay nest. Potential nesting habitat is abundant around Tank Mountain, but the area of habitat is too large to allow naïve nest surveys (lacking information on where the jays might be nesting). At Palluche Canyon, we heard a few Pinyon Jays calling but found no nests in the area where we heard the jays. We assume Pinyon Jays nest in the general area but saw no behavior indicating where a colony might be located.

We found 17 new Pinyon Jay nests in 2014, 12 at the New Rawhide Canyon site and five at Crow Mesa. Nesting areas were within the general 2013 study areas at both sites, but nest locations had shifted somewhat at both sites. At Rawhide Canyon, three 2014 nests were located within the boundaries of the 2013 colony site but nine were north of all 2013 nests, eight of these on the east side of the canyon (Figure 5). Thus, there was little overlap in the 2013 and 2014 colony areas.

Although search effort on Crow Mesa was similar in both years, we found fewer nests in 2014. In 2014, we found three new nests within the boundaries of the 2013 colony, but Pinyon Jay activity led us to two nests approximately 200 and 400 m south of the 2013 colony area (Figure 6).

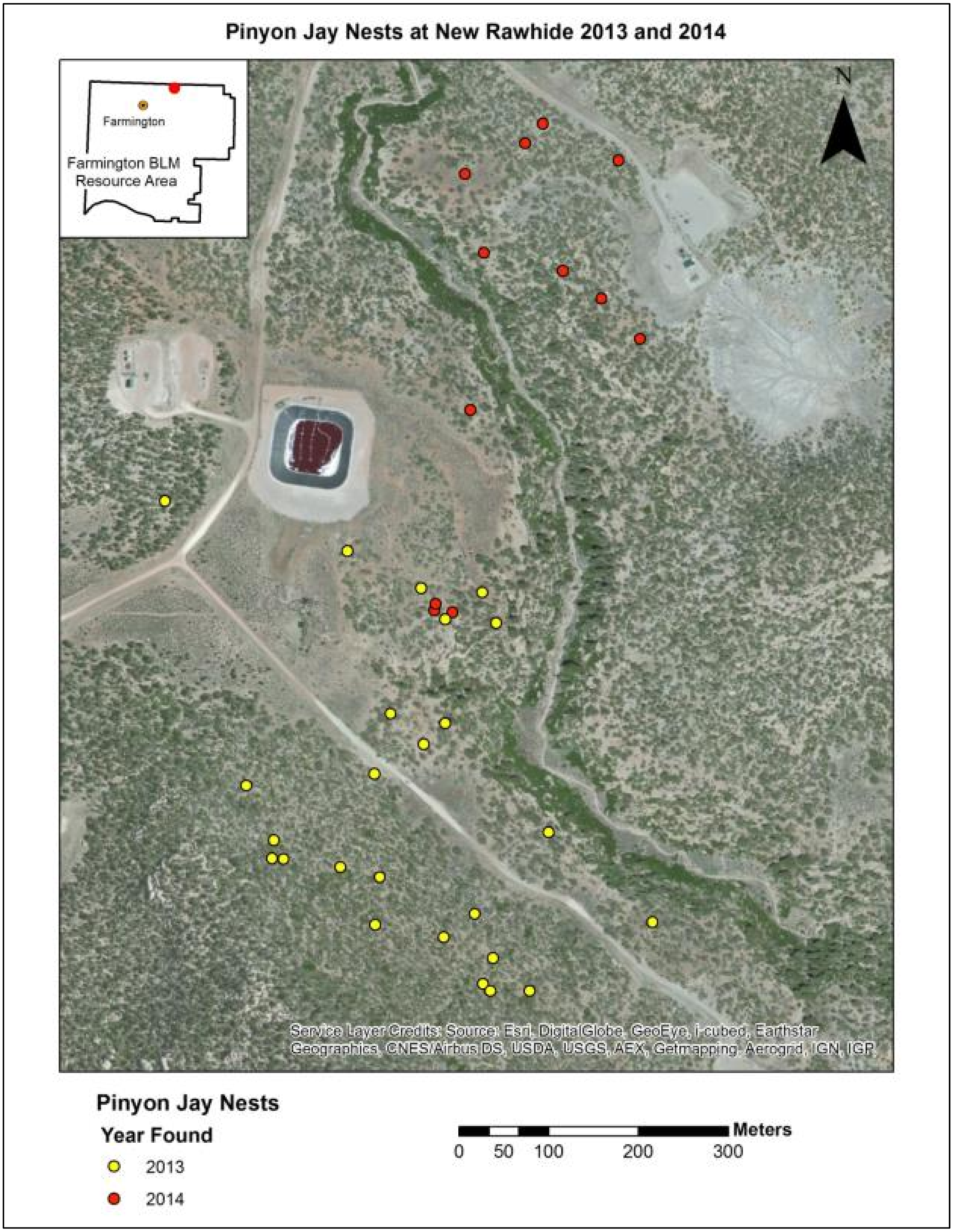

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Figure 5. Pinyon Jay nests found at Rawhide Canyon in 2013 and 2014.

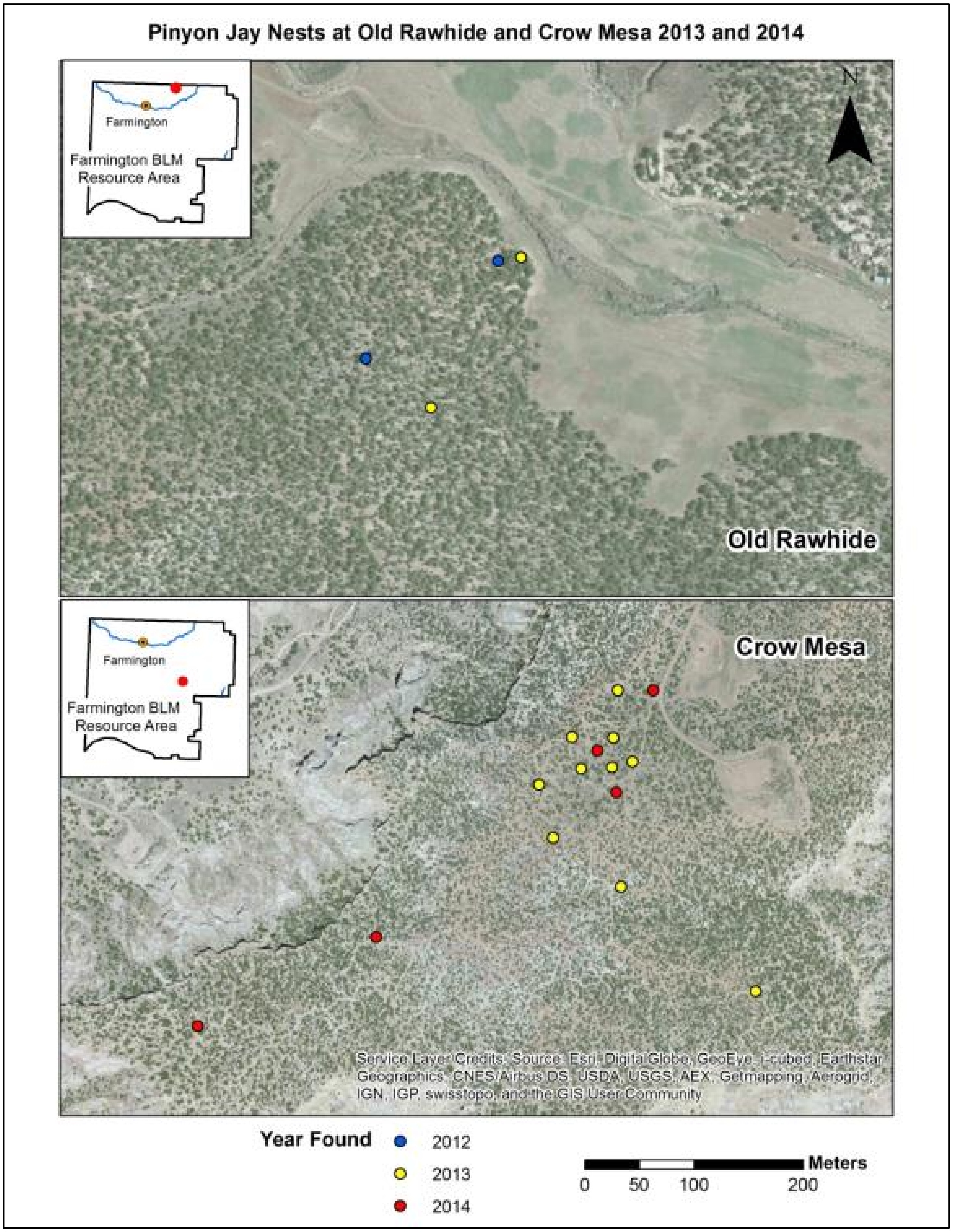

Figure 6. Pinyon Jay nests found at Old Rawhide, 2012−2013, and Crow Mesa, 2013−2014.

Including nests from multiple years, at Old Rawhide we found two nests in 2012 and two nests in 2013, for a total of four (Figure 6). At New Rawhide, we found 25 nests in 2013 (some from previous years, Johnson et al. 2013) and 12 in 2014, for a total of 37. At Crow Mesa, we found 10 nests in 2013 and 5 in 2014, for a total of 15. The total of nests for three years, three sites, is 56. We collected plot data at each nest and at an equal number of random plots.

Vegetation on Plots

Table 1. Summary statistics for Pinyon Jay nest and center random plot trees. Trees from 2012 and 2013 nest and random plots are included with 2014 trees in the analysis.

Measure	N	Mean	SE	Min	Max
Nest Trees					
Juniper					
TreeRCD	32	40.56	2.09	19.50	68.50
Height	32	6.54	0.32	3.0	10.0
Canopy Width	32	4.26	0.21	1.70	6.55
Pinyon					
TreeRCD	24	25.67	2.18	12.0	60.50
Height	24	5.38	1.99	2.50	10.0
Canopy Width	24	4.45	0.27	2.45	7.10
Random Trees					
Juniper					
TreeRCD	30	26.73	3.52	2.60	70.50
Height	30	4.81	0.39	1.30	11.0
Canopy Width	30	3.13	0.29	0.90	7.70
Pinyon					
TreeRCD	26	16.99	1.73	1.20	39.10
Height	26	3.79	0.41	1.20	9.0
Canopy Width	26	3.37	0.29	1.60	7.95

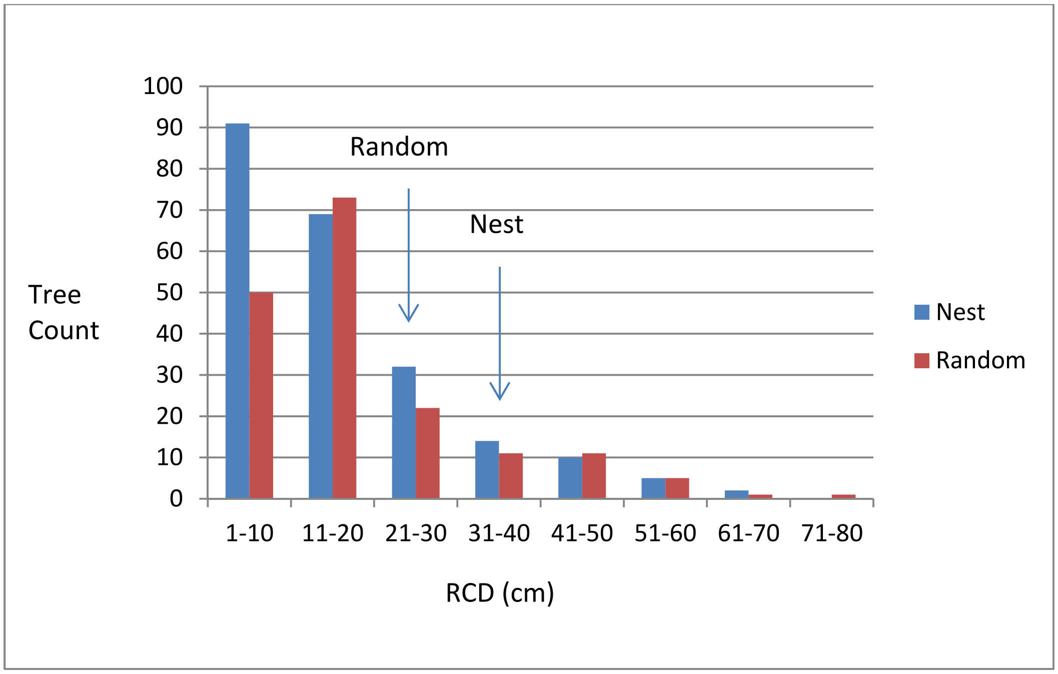

Figure 7. Tree RCDs on Pinyon Jay nest and random plots. Arrows indicate size class of mean nest and central random plot trees.

Densities of trees on nest plots and random plots were similar. Mean nest plot tree density (not counting the nest or central random tree) was 435.75 trees/ha (range 75−900, SE 20.90). Mean random plot tree density was 423.25 trees/ha (range 0−1675, SE 35.20). Mean density of all tree species on all plots was 429.5 trees/ha (range 0−1675, SE 20.40).

We measured RCD (root crown diameter) and estimated height of 56 nest trees, 32 junipers and 24 pinyons. Mean diameter of nest trees was 34.18 cm (range 12.0−68.50, SE 1.80), and mean nest tree height was 6.04 m (range 2.50−10.0, SE 0.26). Central (non-nest) trees on random plots were on average smaller than nest trees. Mean diameter of 56 random (non-nest) trees (30 junipers, 26 pinyons) was 22.10 cm (range 1.20−70.50, SE 2.10), and mean random (non-nest) tree height was 4.35 m (range 1.20−11.0, SE 0.29). Broken down by species, juniper trees were taller and larger in diameter than pinyons and the nest vs. random patterns persist within tree species (Table 1).

We compared the size distributions of all tree diameters on 11.3-m nest and random plots (Figure 7). Nest plots contained relatively more trees in the smallest diameter class, 1−10 cm RCD (Figure 7), but other classes were similarly distributed on nest and random plots. Hence, Pinyon Jays selected nest trees in areas with more small trees than on random plots but placed their nests in trees that were larger than the central trees on random plots.

Pinyon Jay nest plots included more trees than random plots in all height classes except 3.1−4.0 m (Figure 8). As with tree diameter, Pinyon Jays selected nest trees in areas with more short trees than random plots but placed their nests in taller than random trees. This result is not surprising, given that tree RCD and tree height are correlated ($r=0.53$, $p<0.001$).

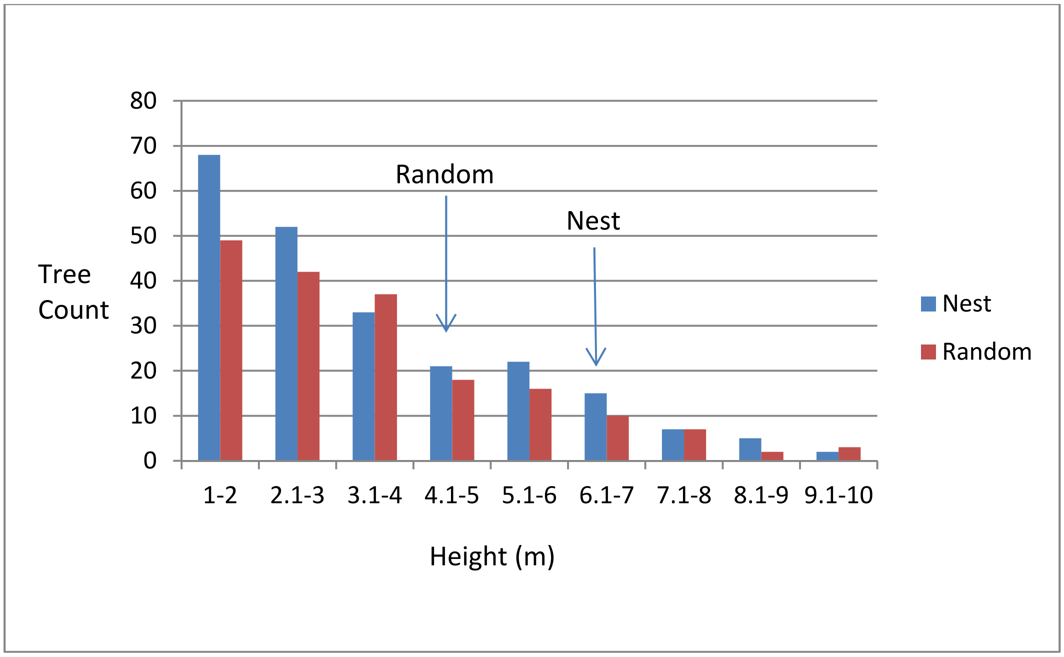

Figure 8. Tree heights on Pinyon Jay nest and random plots. Arrows indicate size class of mean nest and central random plot trees.

Nest-scale Habitat Analyses

We analyzed distance to infrastructure and topographic variables separately from BBIRD plot variables. No single infrastructure distance and no combination of distance variables provided significant conditional logistic models, suggesting that distances to roads, edges, and wells did not differ between Pinyon Jay nest and random plots. Similarly, no topographic variables (elevation, slope, plot aspect) differed between nest and random plots.

The final model set for the BBIRD plots included: the best tree count variables, best ground cover variables, all nest tree measures, the best cover and nest tree measures together, and the best nest tree measures only (Table 2).

Table 2. Variables and attribute type in final model set for Pinyon Jay nest vs. random plot analysis.

Number	Attribute	Variables
1	best ground cover	litter + dead + dead^2
2	best tree counts	arcsin largeS + arcsin largeS^2 + medium S + medium S^2 + small S + alltree S + alltree S^{2+} all tree L + all tree L^{2+} pied S + pied S^2
3	nest tree	tree RCD + tree RCD^{2+} height + height^2 + width + width^2 + canopy + canopy^2
4	best cover and nest tree	litter + dead + dead^{2+} tree RCD + tree RCD^2 + height + height^2
5	best nest tree	tree RCD + tree RCD^{2+} height + height^2

The best model was model 5, with two variables describing the nest tree, RCD^2 (root crown diameter and its quadratic term) and height^2 (height and its quadratic term, Table 3). The AUC of the best model is 0.849, indicating good discrimination between nest and random plots. The next-best model, 4, had a ΔAIC_c (difference in AIC_c between models) of 0.981, which qualifies it as an acceptable model. However, for the two additional cover variables included in model 4, litter cover and standing dead cover (quadratic), $p>0.15$, which indicates that they are uninformative parameters (Arnold 2010). The remaining two variables (tree RCD and height plus their quadratic terms) in the second model are identical to those in the best model. Although AUC of the second-best model is higher than the best model, this tends to occur with the addition of variables, even if they are uninformative and does not justify model averaging. Therefore, we accept model 5, tree RCD^2 and height^2, as the best and only acceptable model. All other models except model 4 had ΔAIC_c values >2. This model had a weight of 61.45% of the model set.

Table 3.Candidate model set of conditional logistic regression models discriminating Pinyon Jay nest plots from unused plots, 2012−14. 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	wi	AUC
5	3	-44.685	99.936	0.000	0.614	0.849
4	5	-41.759	100.917	0.981	0.376	0.867
3	5	-44.161	108.087	8.151	0.010	0.852
1	3	-60.980	130.334	30.399	0.000	0.698
2	7	-58.885	140.921	40.986	0.000	0.748

Parameter estimates (Table 4) indicated that Pinyon Jays nested in trees that were taller and larger in diameter than central trees on random plots. The quadratic terms suggest that, although the jays nested in larger than average trees, they did not prefer the very largest available trees. The confidence interval for the quadratic term for height, however, included zero, indicating weak directional influence. The inclusion of quadratic terms fits well with our observations in the field. Pinyon Jays placed their nests in large trees but almost never nested in the most emergent tree in an area.

Table 4. Parameter estimates from best candidate conditional logistic regression model discriminating Pinyon Jay nest plots from random plots, 2012-14. Tree RCD and height are quadratic terms.

Variable	Coefficient	SE	95% CI Lower	95% CI Upper
Tree RCD	0.2337	0.082	0.0722	0.3952
Tree RCD^2	-0.0028	0.001	-0.0476	-0.0008
Height	1.922	0.843	0.2705	3.5735
Height^2	-0.122	0.065	-0.2494	0.0054

Rawhide Flock Home Range

We attached six transmitters to jays on 10 June (two transmitters), 11 June (one), 8 July (one), and 15 July (two). Two attached on 10 June, one on 11 June, and one on 15 July (total of four) fell off the birds and were recovered. Finding the casings cracked, we returned them and another old one with the same defect to the manufacturer, who immediately replaced them. We attached the five replacement transmitters to new birds on 30 July. Although we never had more than six transmitters in the field at one time, 11 individual birds wore a transmitter for some period of time (Table 5).

We recovered five transmitters which fell off or were detached by the birds. One transmitter was found on a dead bird, and five were still attached when we lost track of the birds wearing them. Of these five, we followed three for six, 11, and 13 weeks, after which we assumed that their batteries failed. The remaining two transmitters were detected for only one and three weeks, suggesting that the birds were depredated or dispersed from the area, or the transmitters failed, possibly for reasons other than batteries.

Table 5. Transmitters attached to Pinyon Jays in 2014.

Freq	Date Attached	Dates Detected	Last Detected or Lost	Recovered	Data Weeks	Detec-tions
382	6/10/2014	6/11, 6/16, 6/17		6/20/2014	1	3
783	6/10/2014	6/11, 6/17		6/20/2014	1	2
862	6/11/2014	6/11, 6/16, 6/17, 6/20,		6/23/2014	2	4
981	7/8/2014	7/10, 7/11, 7/15, 7/17, 7/21, 7/22, 7/28, 7/31, 8/1, 8/8, 8/13, 8/19, 7/30	8/19/2014		6	13
942	7/15/2014	7/15, 7/16, 7/17, 7/21, 7/22,		7/24/2014	1	5
902	7/15/2014	7/15, 7/17,	7/18/2014		1	2
252	7/30/2014	7/31, 8/1, 8/8, 8/13, 8/19, 8/23, 8/25		8/28/2014	4	7
862.2	7/30/2014	7/31, 8/1, 8/6, 8/8,		8/11/2014	1	4
382.2	7/30/2014	7/31, 8/1, 8/6, 8/8, 8/13, 8/19,	8/19/2014		3	6
783.2	7/30/2014	7/31, 8/1, 8/8, 8/13, 8/19, 8/23, 8/25, 8/27, 8/28, 8/29, 9/4, 9/10, 9/18, 9/26, 10/2, 10/3, 10/9, 10/14,	10/14/2014		11	18
942.2	7/30/2014	7/31, 8/1, 8/8, 8/13, 8/19, 8/23, 8/25, 8/27, 8/28, 8/29, 9/4, 9/11, 9/18, 9/26, 10/2, 10/9, 10/14,	10/14/2014		13	17
TOTAL					44	81

Between 11 June and 14 October, we acquired 81 location points for Pinyon Jays from radio telemetry data on 11 birds, a mean of 7.4 detections per bird, including four defective transmitters which fell off birds within the 10 days (Table 5). Individual birds were detected from 2−18 times. Because Pinyon Jays are highly social, we assumed that detections of individual radio-tagged birds indicated flock locations. We also collected 26 separate visual and/or auditory detections of the flock, for a total of 107 detections.

We searched for transmitters for three weeks after we last detected a signal, with no success. We did not see or hear any Pinyon Jays during that period. The two transmitters last detected on 14 October had been detected regularly for 11 and 13 weeks. Transmitter batteries were expected to last 14 weeks, which suggests that the flock might have moved far beyond their summer home range in late October. However, it is also possible that the batteries failed earlier than expected.

The area of the MCP from all detections is 3102.88 ha. This can be considered the minimum estimate of the Rawhide flock's summer home range because it is unlikely that our detections covered the entire home range. Assuming that the Pinyon Jay flock used a larger area than indicated by our detections, another approach to estimating home range size is to include the area of each 100-ha block in which the jays were detected, and each block between or connecting these (Figure 9). This method provides an estimated home range size of 4200 ha, which, although a more approximate estimate, may better represent the flock's actual home range size. Finally, the 95% KDE for the Rawhide flock was intermediate between the MCP and 100-ha block methods, 4033.66 ha (Figure 9).

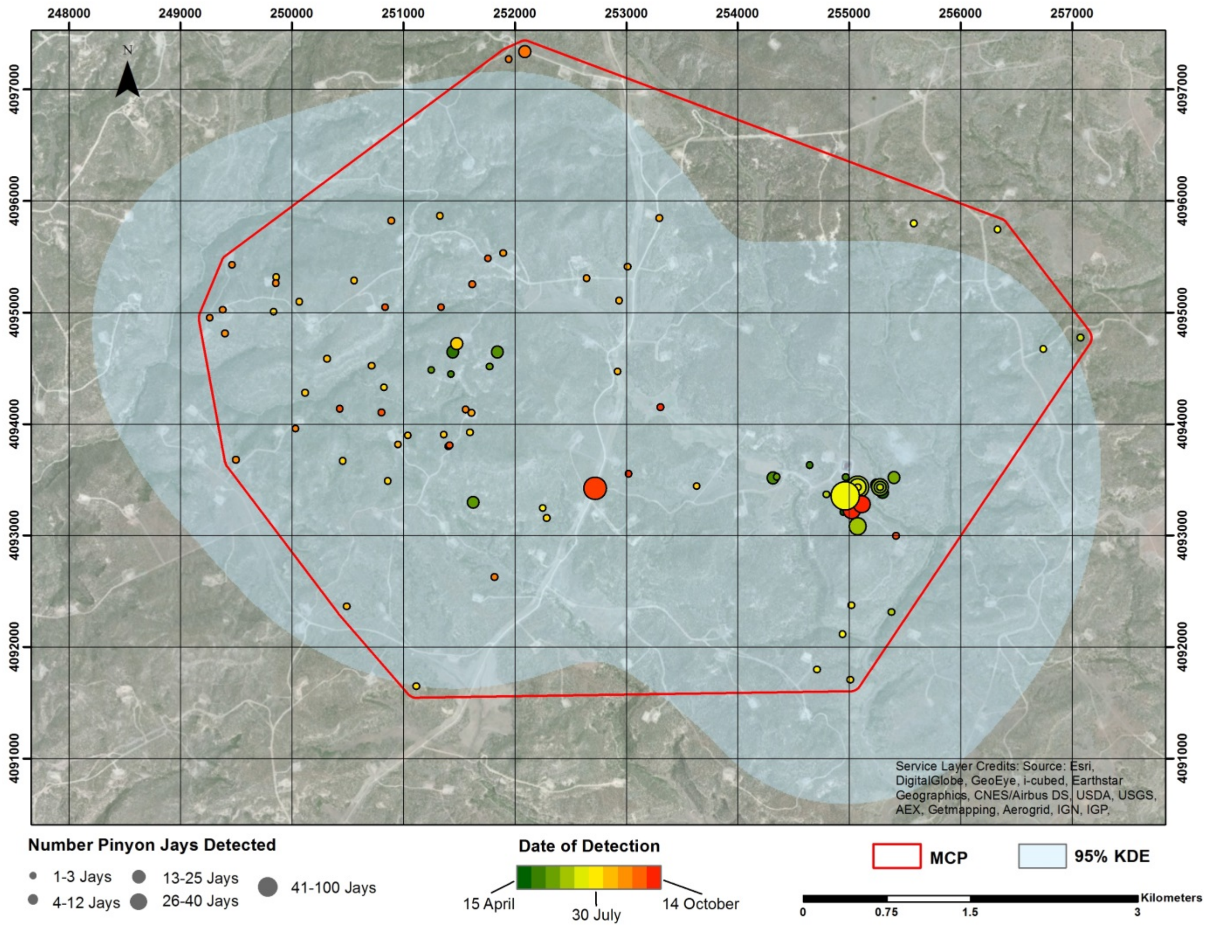

Figure 9. Locations of Pinyon Jays between 15 April and 14 October 2014. Size of dot indicates number of jays detected. Color of dot indicates season. Home range boundary is MCP with 100 m buffer added for depiction. Blue shaded area is 95% KDE. Map shows 100-ha blocks.

An accurate land cover map for the area is not available. However, pinyon-juniper woodland is the primary woodland type within the flock's home range. Near the edges of Rawhide Canyon, ponderosa pine (*Pinus ponderosa*) and Douglas fir (*Pseudotsuga menziesii*) occur in small numbers. Lower elevations contain juniper woodland and savanna, and big sagebrush (*Artemesia tridentata*) occurs in monotypic stands and with pinyon and juniper. Rocky canyons are well-represented within the home range polygon, and roads and well pads are abundant.

Comparison with DoD Legacy Results

Mean density of all tree species on 11.3-m nest plots in this study was 435.75 trees/ha (range 75−900, SE 20.90). In the DoD study (Johnson et al. 2014), mean density of trees on nest plots was 960 trees/ha (range 25−2725, SE 82.40).

In the DoD Legacy study (Johnson et al. 2014), neither topographic nor infrastructure variables discriminated between nest and random plots, similar to the results of this study (see Discussion, below, regarding infrastructure results). In that study covering three years and seven colony sites, the best model distinguishing nest and random plots indicated higher values for canopy cover at the nest, nest tree RCD, and litter on the 5-m plot. Canopy cover and litter are indicators of cover at and near the nest. Litter accumulation is correlated with canopy cover and indicates a history of dense foliage at the nest tree.

Tree densities on nest plots were more than twice as high in the DoD study than at BLM, likely because the pinyon woodlands in which Pinyon Jays nested in that study tend to be much denser than the Colorado pinyon-Utah juniper woodlands in the BLM study. Both studies emphasized features of the nest tree above all other measured variables, and both studies indicated that Pinyon Jays place nests in larger-than-random trees. Although RCD rather than height entered the best model for the Legacy analyses, the two measures are correlated, and nest tree height was also larger than random tree height in that study. Canopy cover and litter were not included in the best BLM model, suggesting greater preference for tree size than nest concealment at BLM.

Home range areas in the DoD Legacy study for WSMR were 3415.7 ha (MCP) and 3486.8 ha (95% KDE). The Pinyon Jays left the WSMR study area in September or October each year; hence, the combined breeding and non-breeding months for WSMR are generally comparable to the months we followed jays at BLM. The MCPs for the two study areas are remarkably similar, 3415.7 (WSMR) vs. 3102.9 (BLM). The 95% KDE areas were 3486.8 (WSMR) and 4033.66 (BLM).

At KAFB, home ranges were divided into breeding (March−July) and nonbreeding (August−February). At that study site, nonbreeding home ranges were 11.5% and 33.4% larger than breeding season home ranges for MCPs and KDEs, respectively. At BLM, we do not have winter ranges but we suspect that the jays there likewise expanded their home range after October. In summary, both DoD and BLM studies suggest that Pinyon Jay summer and fall home ranges in pinyon-juniper habitat cover at least 3500 ha, and considerably larger areas are likely needed in winter.

Gray Vireos

Gray Vireo Observations

In 2013 and 2014, we recorded 229 Gray Vireo detections at the five study sites, including males, females, pairs, fledglings, and family groups (Figures 10−13). We recorded more territories (and more than 60% of the detections) in 2013, primarily because we visited most territories more than once that year, first to conduct playback surveys to determine occupancy, and subsequently to search for nests. Thus, some detections were replicates from the same territories. In 2014, we re-visited territories identified in 2013 and focused only on nest searching. We visited most territories only once in 2014 and recorded only one detection for most territories. Because the first 2014 visit to some territories occurred in June, when most males sing less and tend more to their nests, we may have missed some territorial birds, which may explain why we found fewer territories that year.

Nests

We identified 23 nests within 120 Gray Vireo territories in 2013 and 42 nests within 95 territories in 2014 (Figures 12, 14−16, Table 6). Combining years and sites, 53 (82%) of nests were in juniper trees, 10 (15%) in pinyons, and 2 (3%) in big sagebrush (*Artemesia tridentata*).

However, nests in pinyon were identified almost exclusively (nine of 10 nests) at Crow Mesa, while both nests in big sagebrush were found at Pump Canyon. During both 2013 and 2014, we observed family groups in territories where we did not find nests. We also found several old nests which we suspected were used in the prior breeding season. We retained 22 vireo nests for BBIRD plots in 2013 and 40 vireo nests for BBIRD plots in 2014. Omitted nests included those abandoned prior to egg laying or not found when we returned to the nest site for habitat sampling. The latter may have been torn out by predators or blown down during storms.

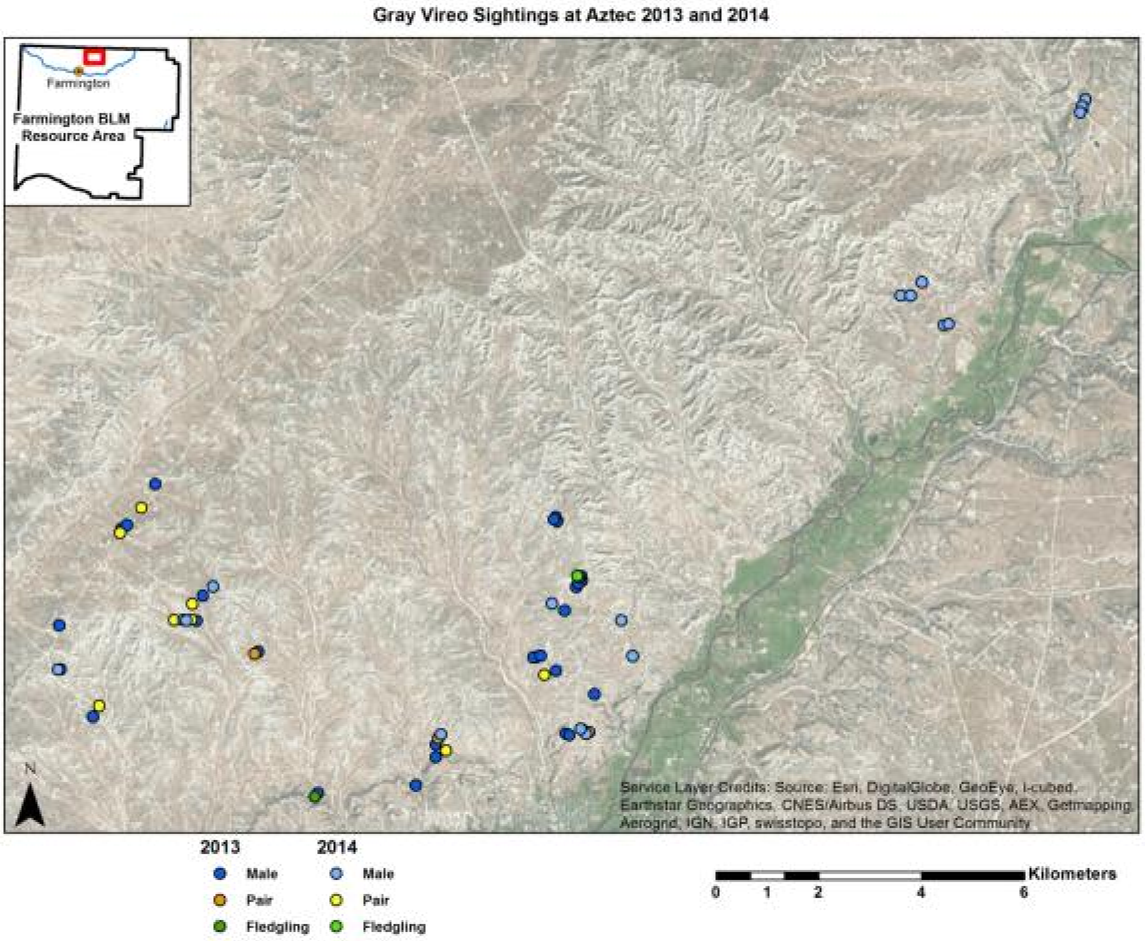

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Figure 10. Gray Vireos observed at Aztec, 2013 and 2014.

Table 6. Number of Gray Vireo territories and nests identified in the Farmington Resource Area study sites, 2013–2014.

Site/Year	No. of Territories	No. of Nests	No. nests in juniper	No. nests in pinyon	No. nests in sagebrush
2013					
Aztec	38	6	6	0	0
Crow Mesa	30	3	0	3	0
Mount Nebo	8	1	1	0	0
Pump Canyon	28	11	10	1	0
Pump Mesa	16	2	2	0	0
2013 total	**120**	**23**	**19**	**4**	**0**
2014					
Aztec	27	9	9	0	0
Crow Mesa	17	9	3	6	0
Pump Canyon	27	12	10	0	2
Pump Mesa	24	12	12	0	0
2014 total	**95**	**42**	**34**	**6**	**2**
2013–2014 total	**207**	**65**	**53**	**10**	**2**

Vegetation on Plots

Gray Vireo territories were all located in pinyon-juniper woodlands; however, the proportion of pinyon to juniper varied among sites. Juniper dominated the Aztec, Pump Canyon, and Pump Mesa territories, with mean juniper to pinyon proportions of 0.95, 0.82 and 0.80, respectively. Territories on Crow Mesa were dominated by pinyon (11.3-m nest plot juniper to pinyon mean proportion 0.32). Understory vegetation was scarce in some territories and moderate in others. 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 0 (sagebrush nests) to 700 (mean 316.13, SE 22.05); most plots ranged between 100 and 400 trees per hectare (Figure 17). The proportion of juniper to pinyon trees on nest plots ranged from 0.04−1.00; however, juniper was the dominant tree species on most plots (mean juniper to pinyon proportion 0.75, SE 0.04).

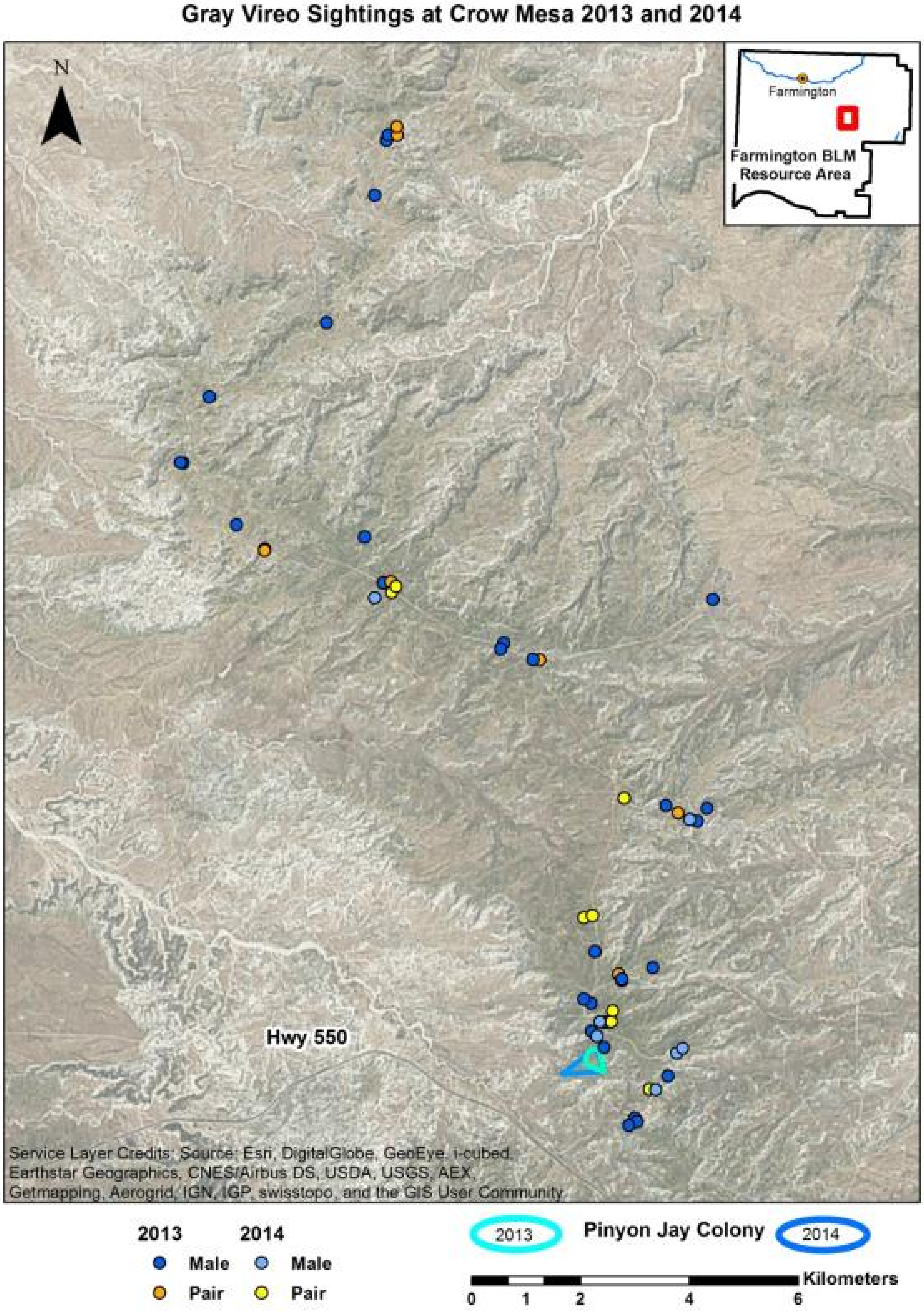

Figure 11. Gray Vireos observed at Crow Mesa, 2013 and 2014.

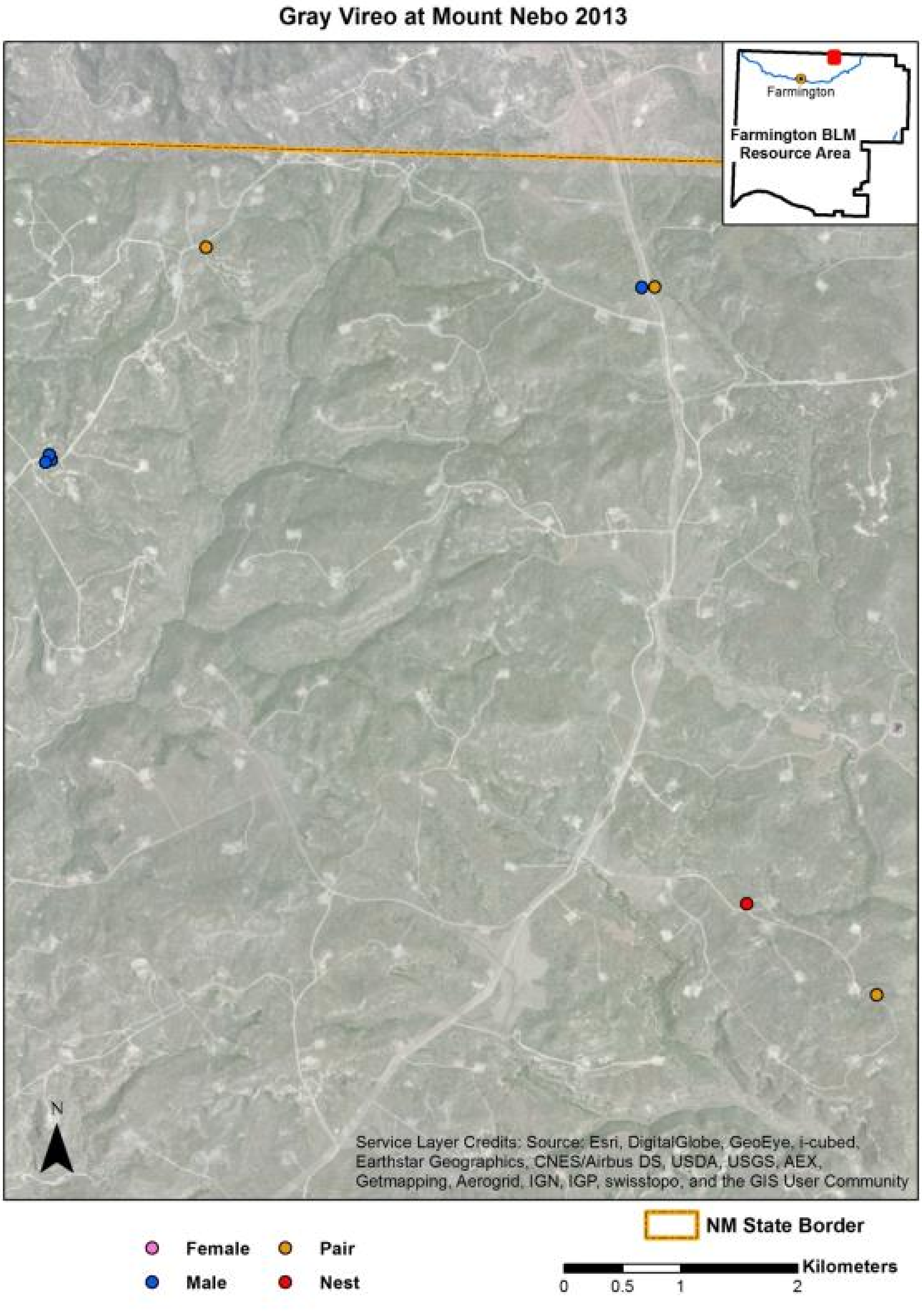

Figure 12. Gray Vireos and nests observed at Mount Nebo, 2013.

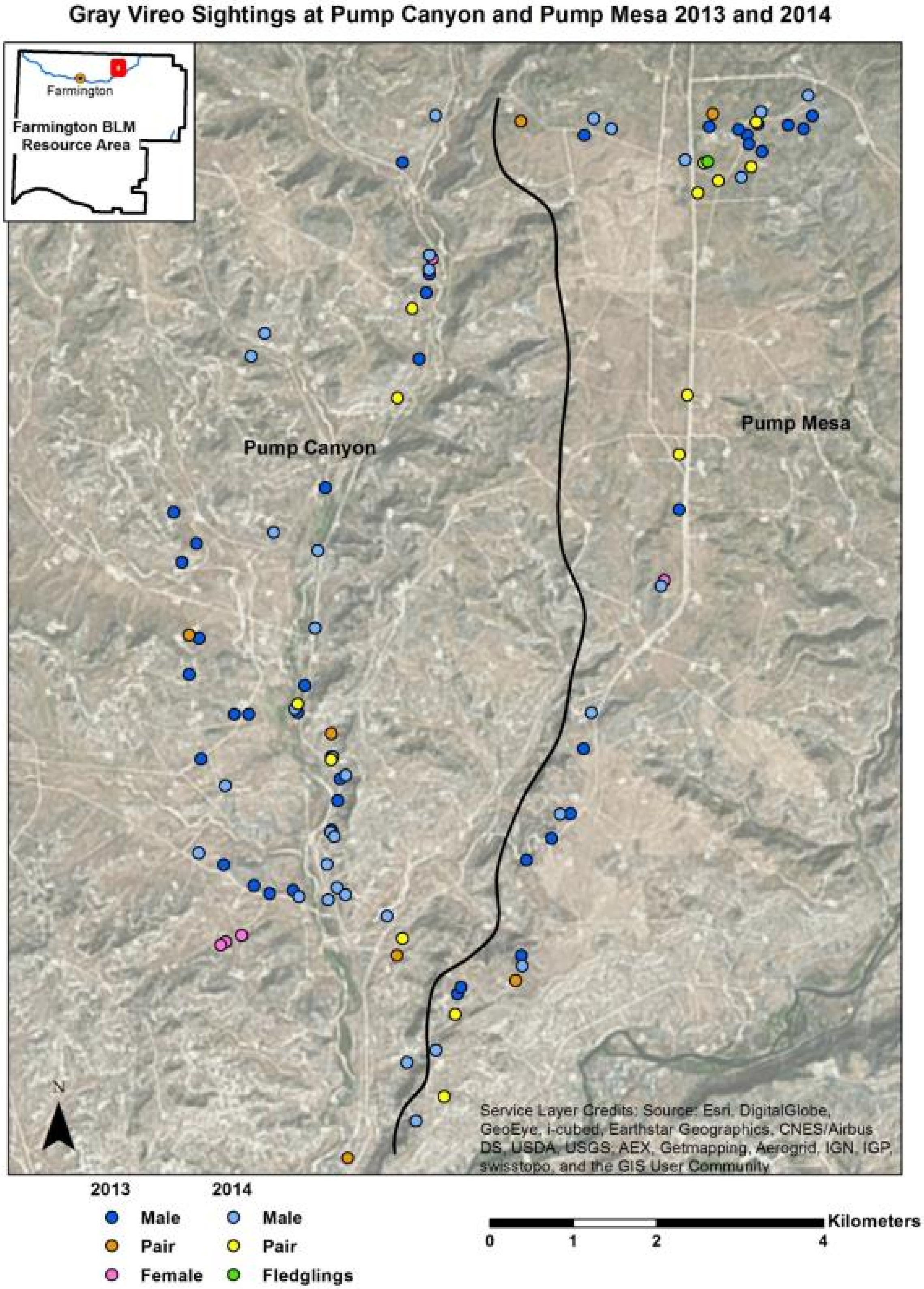

Figure 13. Gray Vireos observed at Pump Canyon and Pump Mesa, 2013 and 2014.

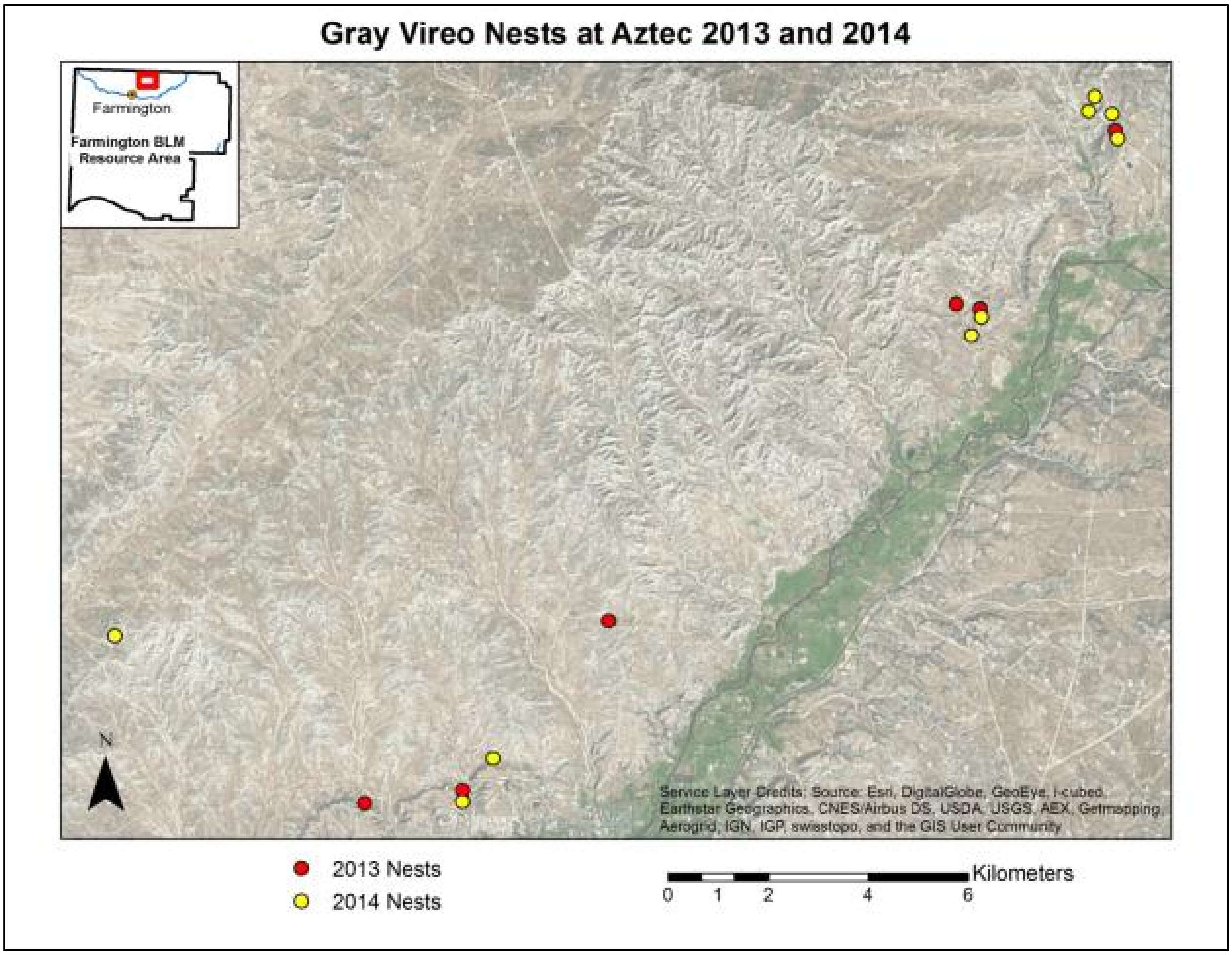

Figure 14. Gray Vireo nests at Aztec, 2013 and 2014.

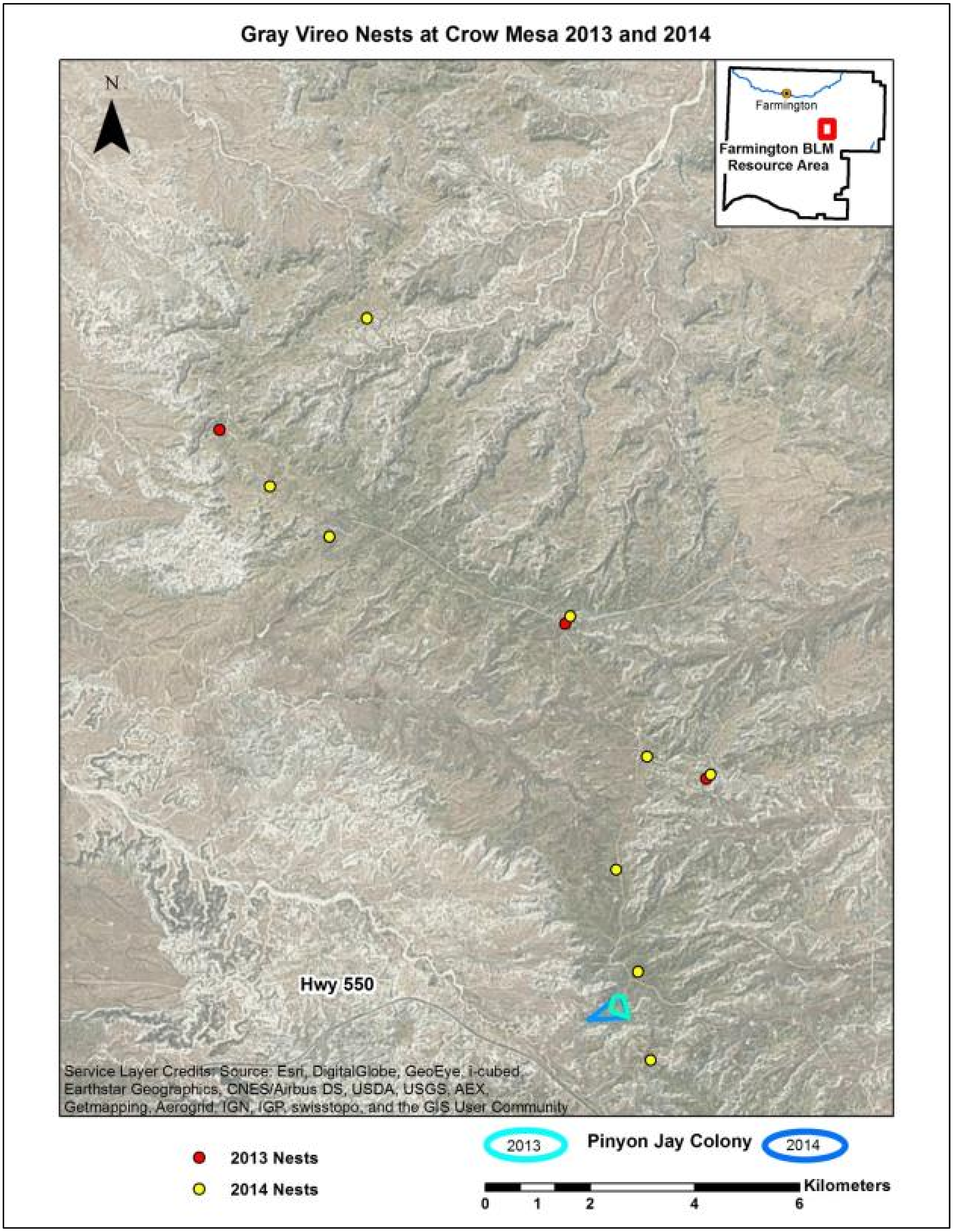

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Figure 15. Gray Vireo nests at Crow Mesa, 2013 and 2014. Pinyon Jay colony boundaries are shown in blue for reference.

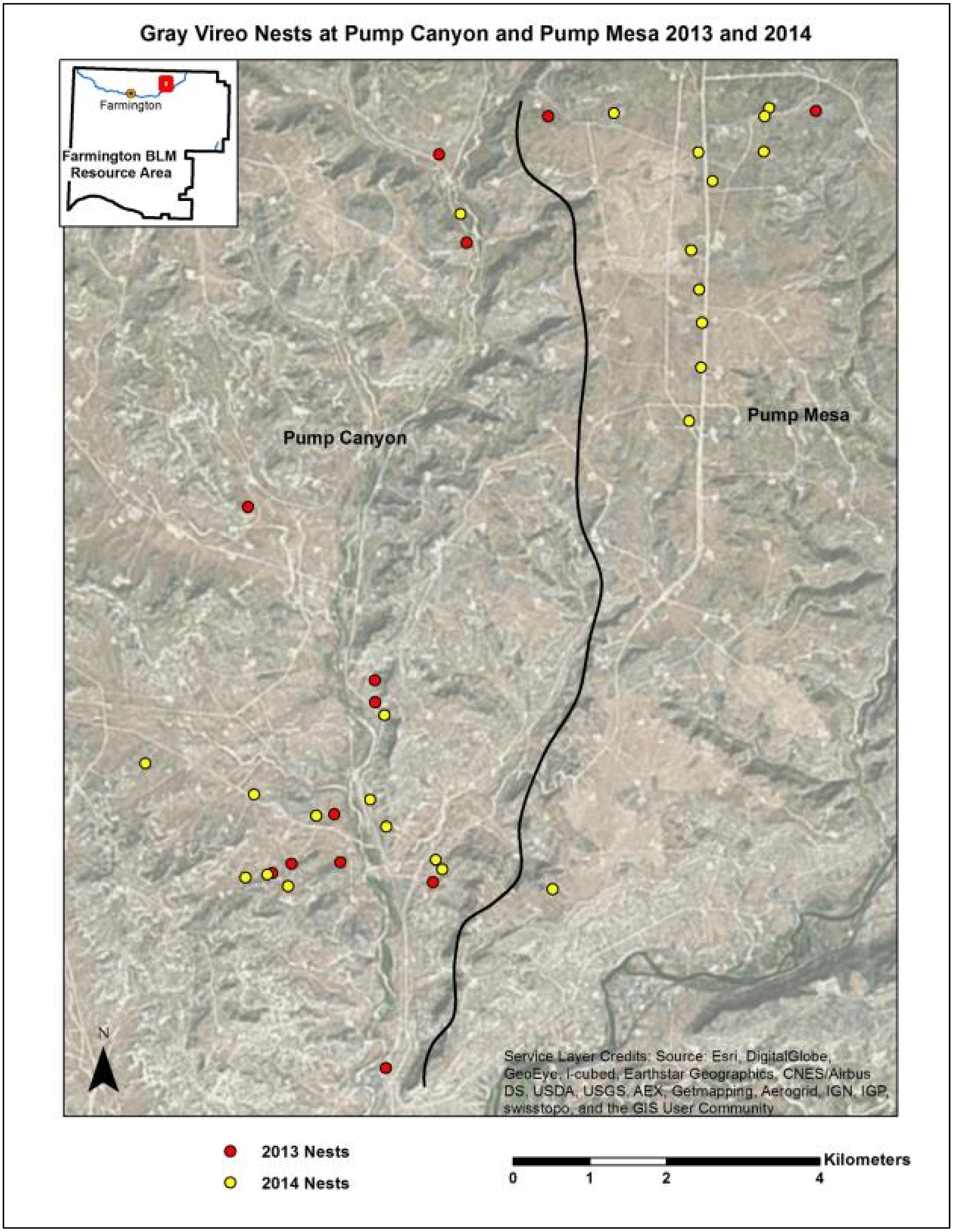

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Figure 16. Gray Vireo nests at Pump Canyon and Pump Mesa, 2013 and 2014.

Table 7. Nest tree height and mean canopy width for Gray Vireo nests in the BLM Farmington Resource Area, 2013−2014.

		Nest Trees/Shrubs			
Measure	**N**	**Mean**	**SE**	**Min**	**Max**
		Juniper			
Height	50	3.5	0.2	1.7	7.9
Mean Canopy Width	50	3.0	0.2	1.2	6.8
		Pinyon			
Height	10	2.3	0.2	1.6	3.6
Mean Width	10	2.5	0.3	1.3	3.7
		Sagebrush			
Height	2	1.8	0.2	1.5	2.1
Mean Canopy Width	2	1.7	0.2	1.4	2.0
		Random Trees/Shrubs			
		Juniper			
Height	50	3.7	0.2	1.7	8.5
Mean Canopy Width	50	3.9	0.3	0.9	8.7
		Pinyon			
Height	10	3.1	0.3	1.8	4.6
Mean Canopy Width	10	3.2	0.5	1.6	5.6
		Sagebrush			
Height	2	2.0	0.3	1.5	2.4
Mean Canopy Width	2	2.8	0.6	1.9	3.7

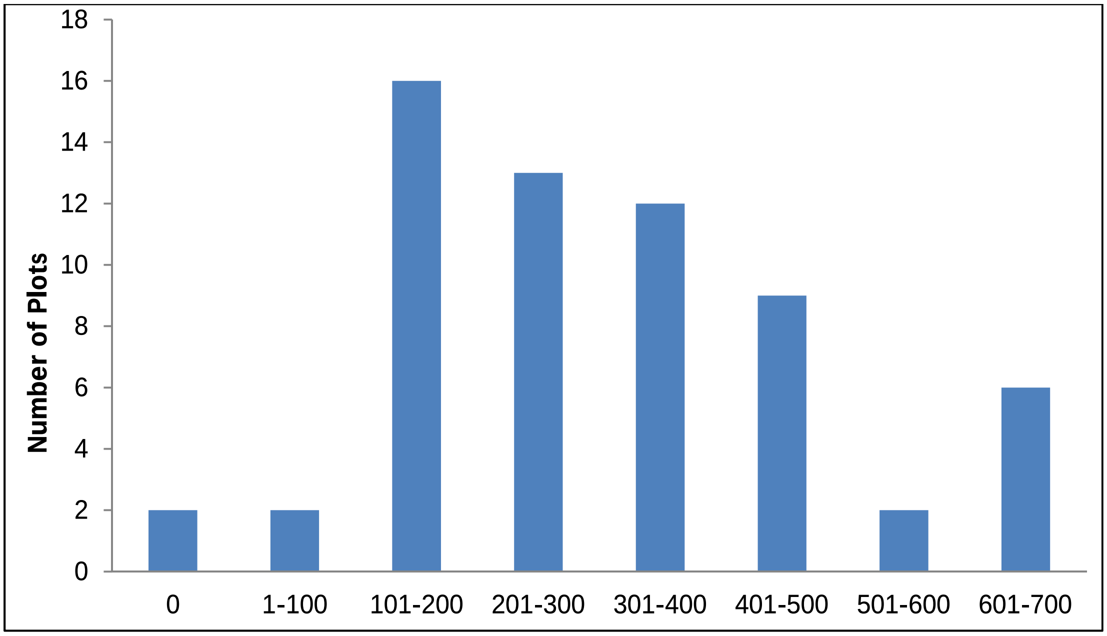

Figure 17. Distribution of tree density on Gray Vireo nest plots in the BLM Farmington Resource Area, 2013−2014.

Mean nest height and nest tree height were 2.15 m (range 0.8−3.8, SE 0.10) and 3.23 m (range 1.50−7.90, SE 0.16), respectively. Nest tree canopy width ranged from 1.15−6.80 m (mean 2.78, SE 0.14). Tree height was significantly higher for juniper compared with pinyon nest trees (means shown in Table 7; tree height t=2.83, df=58, *p*=0.006). Mean height and canopy width of the two sagebrush nest plants were lower than both junipers and pinyons (Table 7); however, the small sample of sagebrush nests precluded meaningful statistical analyses. Nest height was also significantly higher (t=2.39, df=58, *p*=0.02) for nests in juniper (mean 2.29 m, SE 0.11) compared with nests in pinyon (mean 1.68 m, SE 0.16). Shrub density ranged from 0−1,025 shrubs/ha (mean 260.89, SE 30.81). Live ground cover was very low on nest plots (mean live index 1.31, SE 0.08).

Nest-scale Habitat Analyses

Topography of Gray Vireo territories varied among study areas. Nest plot elevation ranged from 1773−2344 m (mean 1928.77, SE 21.06); however, mean elevation was considerably lower at the Aztec and Pump Canyon sites compared with Crow and Pump Mesa (Table 8). Nest plot slope ranged from 1−23° (mean 7.16°, SE 0.63). Vireos generally occupied toe slopes or rolling terrain at Pump Canyon and Aztec, reflected in higher on-average slopes compared with the flatter terrain of Crow and Pump Mesas (Table 8). Raw aspect data indicated that vireos nested on north-, east-, south-, and west-facing slopes. Exploratory conditional logistic regression models indicated that cosine of plot aspect was a potentially important predictor in nest site selection.

Table 8. Topographic and infrastructure variables of Gray Vireo nest locations in the BLM Resource Area study sites, 2013–2014.

Site	Mean Elevation (m)	Mean Slope (°)	Mean Distance to Road (m)	Mean Distance to Well Pad (m)
Aztec	1840	8.2	100.9	242.9
Crow Mesa	2180	6.3	87.2	467.3
Pump Canyon	1818	8.9	82.3	292.7
Pump Mesa	2004	3.8	108.6	244.9
Mean across sites	1929	7.2	93.3	304.4

Combining study sites, distance from Gray Vireo nests to the nearest road ranged from 10−319 m (mean 93.27, SE 9.92), and the nearest gas well from 65−1499 m (mean 304.42, SE 25.47). Distances to nearest well pad varied little among study sites, except at Crow Mesa, where well density is lower than at the other three sites (Table 8). Exploratory conditional logistic regression models yielded no significant infrastructure predictors of nest site selection.

Exploratory conditional logistic regression modeling of vegetation variables indicated that tree density, tree canopy width, juniper to pinyon proportion, and mean tree height were potentially important predictors of nest site selection. The final set of 16 candidate models included the variables cosine of aspect and its quadratic term, tree density, tree canopy width, juniper to pinyon proportion and its quadratic term, and mean tree height and its quadratic term (Table 9). Three models were competitive ($\Delta AIC_c<2$). The best model ($AIC_c=128.161$) discriminating nest from random plots included tree density, tree canopy width, and mean tree height with its quadratic term. The AUC of the best model was 0.756, indicating acceptable discriminatory power. Both remaining competitive models also included tree density. The second-ranked model also included mean tree height, with its quadratic term, while the third ranked model included tree canopy width, both variables which were included in the best model. Parameter estimates indicated that Gray Vireos nested in areas with more and taller trees than random within the habitat (Table 10). The inclusion of the quadratic term for mean tree height suggests vireos may select sites with taller, but not the tallest, trees. In addition, our data suggest that vireos selected nest trees with slightly smaller canopy width than randomly selected sites within their territories. Confidence intervals around parameter estimates for tree height, its quadratic, and tree diameter included zero, indicating weak trends.

Table 9. Candidate model set of conditional logistic regression models discriminating Gray Vireo nest plots from random plots. 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	$dAIC_c$	*wi*	AUC
NoTrees+CanopyWidth+MeanTreeHt+ MeanTreeHt^2	5	-58.826	128.161	0.000	0.449	0.756
NoTrees+MeanTreeHt+MeanTreeHt^2	4	-60.813	129.962	1.801	0.182	0.734
NoTrees+ CanopyWidth	3	-61.920	130.040	1.879	0.175	0.739
NoTrees+MeanTreeHt+MeanTreeHt^2+ CosAspect+CosAspect^2	6	-59.131	130.980	2.819	0.110	0.757
NoTrees	2	-64.131	132.362	4.201	0.055	0.726
NoTrees+CosAspect+CosAspect^2	4	-62.686	133.709	5.548	0.028	0.747
CanopyWidth	2	-69.429	142.957	14.796	0.000	0.628
MeanTreeHt+MeanTreeHt^2+CosAspect+ CosAspect^2	5	-66.773	144.054	15.893	0.000	0.660
CanopyWidth +J:P	3	-68.965	144.130	15.969	0.000	0.645
MeanTreeHt+MeanTreeHt^2	3	-69.269	144.737	16.576	0.000	0.567
J:P+MeanTreeHt+MeanTreeHt^2+CosAspect+ CosAspect^2	6	-66.210	145.138	16.977	0.000	0.670
J:P+MeanTreeHt +MeanTreeHt^2	4	-68.732	145.800	17.639	0.000	0.604
MeanTreeHt	2	-71.696	147.491	19.330	0.000	0.532
CosAspect+CosAspect^2	3	-71.006	148.212	20.051	0.000	0.628
CosAspect	2	-73.154	150.406	22.245	0.000	0.556
J:P	2	-73.267	150.633	22.472	0.000	0.529

Table 10. Parameter estimates from the best candidate conditional logistic regression model discriminating Gray Vireo nest from random plots in the BLM Farmington Resource Area, 2013−2014.

			95% CI	
Variable	**Estimate**	**SE**	**Lower**	**Upper**
NoTrees	0.138	0.041	0.059	0.217
MeanTreeHt	0.549	0.414	-0.259	1.356
MeanTreeHt^2	-0.418	0.364	-1.129	0.292
CanopyWidth	-0.308	0.160	-0.619	0.003

Comparison with DoD Legacy Results

Structural characteristics of Gray Vireo nesting areas in this BLM study varied from our earlier work (2009−2012) on three DoD installations (Johnson et al. 2014); however, nest site selection models were relatively consistent across studies. Tree density on Gray Vireo nest plots in this study (316 trees/ha, SE 22) was almost three times that of the DoD study (113 trees/ha, SE 9). Additionally, although two nest plots on BLM lands contained no trees, because they were located in sagebrush flats, the wide range for tree density (0-700 trees/ha) greatly exceeded that of the DoD study (25-425 trees/ha). Despite these differences, tree density was an important variable predicting nest site selection on both DoD and BLM lands, and Gray Vireos selected nest sites with greater tree densities compared with random sites in both studies. Mean tree height was also important in predicting nest sites on both DoD and BLM lands. Mean height of trees on vireo nest plots ranged from 3.3−4.0 m across the three DoD sites, greater than that reported on BLM lands (overall mean, 3.2 m; means ranged from 2.5−3.4 m across four sites); yet, in both studies, vireos selected nesting areas with greater mean tree height compared with random plots. Nest tree canopy width was important on BLM lands only, with vireos selecting slightly smaller diameter trees than randomly selected trees.

The DoD study indicated that Gray Vireos selected nest sites with more south-facing aspects compared with random locations (Johnson et al. 2014). In this BLM study, exploratory analyses also indicated that aspect was a potentially important predictor variable for nest site selection; however, it proved relatively unimportant when compared with tree density, size, and height. Infrastructure variables, distance to roads (BLM, DoD), buildings (DoD), and well pads (BLM), were not important predictor variables in either the DoD or the BLM study.

Discussion

Pinyon Jays

Pinyon Jays nested in taller trees having larger root crown diameters than trees on random plots within the colony area. Previous work on DoD installations also indicated the importance of larger-than-random trees for nesting (Johnson et al. 2012, 2014). However, the analyses including data from Farmington in 2014 provided additional insight into nest-scale habitat use. After finding Pinyon Jay nests in the Oscura and Manzanita Mountains for six years (Johnson et al. 2014) and Crow Mesa and Rawhide Canyon for three years (Johnson et al. 2013), we have the impression that Pinyon Jays nest in large trees with thick canopies but avoid nesting in the tallest, most emergent trees in the area. This impression is borne out in the conditional logistic regression based on nests found in three field seasons at Farmington BLM.

The two variables in the best model discriminating nest from random plots were both quadratic terms, meaning that nest trees were larger than random trees but were not the huge, emergent trees present in small numbers within the colony sites. We suggest that Pinyon Jays avoid nesting in the tallest trees because those trees are likely to be used as perches by avian predators such as Common Ravens (*Corvus corax*), hawks, or owls. The very large, old pinyons and junipers tend to show a more open growth pattern, with less dense foliage and more gaps between branches than trees in the size classes used for nesting. Hence, the emergent trees may also provide inadequate foliage cover for nests.

The distribution of tree sizes on nest plots indicates that Pinyon Jays placed their nests in patches of relatively small trees and chose the tall, but not the tallest, trees in the patch for nesting. Non-nest trees on nest plots provide cover for birds coming to their nests. The jays typically stop in several nearby trees before approaching the nest and often drop below the canopy of a neighboring tree, then approach the nest from below. The presence of smaller trees on the nest plot and their approach behaviors suggest that smaller trees near nest trees provide important nest cover.

Analysis of distance to oil and gas infrastructure revealed no differences between nest and random plots. It is possible that the scale of the nest and random plots prevented us from detecting any tendency of the jays to avoid oil and gas structures. All gas wells were outside colony boundaries, several hundred meters from most nests. The distances between random and nest plots to wells therefore did not differ appreciably.

The dates of data for flock home ranges differ between the two DoD installations (Johnson et al. 2011) and this study, making precise comparisons between all three study areas impossible. However, the combined breeding (March−July) and nonbreeding (August−October) season divisions for WSMR are similar to those for the entire BLM study (April−October), because Pinyon Jays typically returned to both WSMR and BLM colonies in April. At KAFB, data for the two seasons were different from those at either WSMR or BLM (breeding: March−July and nonbreeding: August−February). KAFB data are therefore only useful to demonstrate the increase in home range that occurs as Pinyon Jays move into lower-elevation juniper habitats in the winter and travel outside their breeding ranges. This phenomenon appears consistent between WSMR, KAFB, and BLM, although we have no occurrence data for BLM after mid-October. Nonetheless, the home ranges of the BLM and WSMR flocks are quite similar, surprisingly so given the differences in latitude and habitat types between the two sites.

Gray Vireos

Our top nest site selection models indicated that Gray Vireos showed a preference for nest sites with slightly more and taller trees compared to available trees on average within their territories. Although our data suggest weak selection for larger tree height and diameter, these results are consistent with the results of our 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, 2014). Higher tree density may hide nests from some predators and Brown-headed Cowbirds (*Molothrus ater*), a brood parasite. 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. While vireos also prefer nesting in areas with taller trees, the inclusion of the quadratic term for mean tree height suggests a possible avoidance of the tallest available trees in their territories. This effect was also consistent with the DoD study (Johnson et al. 2014). Taller trees provide better vantage points than shorter trees for broadcasting songs for mate selection and territory defense; however, the tallest trees may also be the most visible to avian predators, such as crows, ravens, and jays, which are common in our study areas. Thus, vireos' preferences for trees of intermediate height may result from balancing predator avoidance with enhanced advertisement.

In 2013, tree canopy width was an important predictor in our best Gray Vireo nest site selection models, with the parameter estimate indicating vireos selected trees with greater canopy width compared with random trees. The addition of 40 nest and random plots in 2014 reversed this trend. Although vireos may be attracted to stands with slightly taller trees, they appear to select smaller diameter trees for nesting.

Gray Vireos may be tolerant of noise associated with vehicles and gas wells, as distance to nearest road and well pad were not important predictors in nest site selection. Francis et al. (2011) demonstrated that occupancy of some pinyon-juniper bird species, specifically Western Scrub-Jay (*Aphelocoma californica*) and Gray Flycatcher (*Empidonax wrightii*), was lower in areas subject to noise from natural gas well compressors. In contrast, nest success of Gray Flycatchers increased in areas with compressor noise, as a result of reduced nest predation by Western Scrub-Jays. Quantifying noise levels was not a focus of this study, and we were not able to quantify noise from well pads near Gray Vireo nests. Our only measure is distance from well pads, which we measured using ortho-imagery. Some of the well pads near vireo nests may have been inactive and silent during our study. While Gray Vireos do not appear to avoid nesting near well pads (or roads), further study is needed on the effects of well pad noise on their nesting success.

Management Recommendations

Pinyon Jays

Results for Pinyon Jays indicate the importance of retaining trees in the size classes used as nest trees, and surrounding trees also provide cover for nesting birds. We recommend that no trees be removed from existing Pinyon Jay nesting colony sites. To manage potential habitat for Pinyon Jays and other bird species that nest in their habitat, tree size distributions similar to those in this study should be retained. It is especially important to maintain relatively large trees with dense canopies, along with other medium-height trees nearby. It might seem that removing large trees that provide predator perches could benefit the jays. However, selective removal of emergent trees would leave avian predators with only the preferred nest trees for perches, and Pinyon Jays would be less able to quickly determine likely predator perches and avoid nesting under them. Old, large trees produce the most cones and may also be more important than smaller trees in maintaining underground mycorrhizal fungi networks, which provide nutrients to surrounding trees (Dighton and Mason 2011).

Because Pinyon Jays are colonial nesters, they require large patches containing mature stands of pinyon-juniper woodland. Marzluff and Balda (1992) observed frequent colony movement in a flock that nested on the periphery of Flagstaff, AZ within a few kilometers of feeders. In contrast, they observed a more natural flock nesting within the same 100-ha area for 14 years. We have observed colony movements of a few hundred meters that apparently occurred in response to declining pinyon condition (Johnson et al. 2014, ms. in prep.). To provide options for colony movement in case of tree morbidity or mortality, we recommend that suitable nesting habitat surrounding established Pinyon Jay nesting colonies be retained. 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. The exact area of nesting habitat to be maintained around an existing colony should be based on the extent of tree decline and the availability of alternative colony sites. Over the two years we have monitored the Rawhide Canyon colony, it covered 37 ha. Suitable colony sites for nesting groups of this size (about 20 pairs) should be at least 50 ha, to include a 50 m buffer of suitable habitat. Larger nesting groups will require relatively larger colony sites.

Pinyon Jays need water. In surveys for new colonies in New Mexico (Petersen et al. 2014), we found small groups of Pinyon Jays nesting in sparse, apparently marginal habitat. One feature common to these sites was a nearby water source. Pinyon Jay flocks on Farmington BLM lands use wildlife guzzlers, and, during the breeding season, banded and radio tagged birds flew ~3600 m from the Rawhide colony site to use the Tank Mountain guzzler. Pinyon Jays are therefore most likely to nest in suitable habitat near water sources, and if they move a colony site, they are more likely to move to better habitat near existing colonies and water sources.

Consistent results from this and our DoD study indicate that a medium-sized Pinyon Jay flock needs very large areas (~3500-4000 ha) of productive pinyon trees for harvesting and caching pinyon seeds, and these areas should contain large trees for maximum cone productivity. Home ranges should also contain nearby water, suitable woodland stand structure for nesting, and ample post-breeding foraging habitat. The estimated home range size of the Rawhide flock is larger than most home range sizes cited in other studies: 1600 ha (Balda 2002), 2300 ha (Marzluff and Balda 1992), 2890 ha (Ligon 1971), and 6400 ha (Balda 2002). Those studies were not telemetry studies and may be less accurate than ours, and the Balda studies occurred in a different habitat, ponderosa pine. In the fall and winter, when Pinyon Jays typically range widely in search of pinyon crops and other foods (Balda 2002), they need even larger areas of suitable habitat. Hence, only land managers with jurisdiction over very large areas of Pinyon Jay habitat are able to manage for the year-round needs of even one Pinyon Jay flock. We emphasize that wintering habitats productive of pinyon seeds, juniper berries, and other foods are probably at least as important to Pinyon Jay long-term population viability as high-quality nesting colony sites.

In our 2013 report, we noted that the presence of a Pinyon Jay colony in the midst of four gas wells suggests that the jays are tolerant of some pump noise (Johnson et al. 2013). However, in that year, five of the six closest nests to wells had noise levels of ~39 dBA. Except for one outlying nest (outside the rest of the colony) 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 the DoD study 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 could be more detrimental than intermittent, louder sounds, which may explain why jays consistently failed to nest where dBA was higher than 40. 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. We have noted that humans on foot are quite disruptive to nesting Pinyon Jays; we recommend that hunting, hiking, and other foot traffic in and near nesting colonies be restricted to the nonbreeding season.

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 suggest 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, we did not observe this in the DoD study there (Johnson et al. 2012, 2014).

In addition to juniper and pinyon, we found two Gray Vireo nests in sagebrush in 2014. While this has been documented previously (see Barlow et al 1999), Gray Vireo nests in sagebrush are rare in this part of their range. The two nests were in narrow sagebrush bottomland adjacent to pinyon-juniper woodlands. In each case, the sagebrush patches were sub-components of the larger woodland habitat. One of the sagebrush plants was mature (2.4 m tall) and contained tree-like branching structure; the other was less than 2.0 m and less tree-like. In the southern portion of their breeding range, Gray Vireos are known to utilize shrubs for nesting; however, sagebrush in the absence of woodland trees should not be generally considered breeding habitat for Gray Vireos in northern New Mexico.

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 and heights as reported in this study, as these variables have consistently been important predictors of nest site selection for Gray Vireos on BLM and DoD lands.

Both Species

Recommendations for managing nesting habitat are rather similar for these two species which differ in diet, social behavior, migratory patterns, and nest timing and spacing. Recommendations are also surprisingly similar between studies, especially considering the differences in habitats between the DoD installations and the Farmington BLM area. Both species prefer larger than random trees, irrespective of nest tree species, for nesting, and density of trees surrounding the nest tree appears to be important for both species, significantly so for Gray Vireos.

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