Pinyon Jays and Pinyon-Juniper Woodlands at Kirtland Air Force Base

2011-2012 Final Report

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Executive Summary

In 2011, we followed one nesting colony of Pinyon Jays at Kirtland Air Force Base. This colony, the "South Colony," was also active in 2010. We found 13 nests in Pinyon-Juniper Woodland and Pinyon Woodland at the South Colony. No birds nested at the Winch Site in 2011.

In 2012, we found two new colony sites. Both overlapped with predicted colony sites from our DOD Legacy colony-scale habitat model. We found 17 nests at the new Office Colony. We determined that 10 of these were 2012 nests and the remaining seven were from previous years. At the new Receiver Colony, we found 25 Pinyon Jay nests, 12 of which were from 2012 and 13 from previous years.

In 2010, the year the first five grids were established, we collected tree measures (Johnson et al. 2011b). In 2011, we collected data on pinyon tree vigor and cone number on 228 trees on the five grids established in 2010. In 2012, we created three new tree grids covering the two new 2012 colonies. We collected tree measures on the three new 2012 grids and cone and vigor data from 364 trees on all eight grids.

The mean density of trees on all eight grids was 470 pinyon trees per hectare and varied across grids from 205-1061 trees/ha. Mean tree height on all grids was 3.39 m (SD=1.53), and mean root crown diameter was 14.3 cm (SD=8.24). Grids with the tallest trees were Winch and Winch 2, and South and Office1 grids had the largest diameters.

Cone production was low in 2011, with an overall cone index of 1.55 (SD=0.28), about five cones/tree. The South Grid had the highest mean cone index, with 3.21 (SD=4.19), about 10 cones/tree. Cone production was extremely low in 2012, with an overall mean cone index of 0.21 (SD=0.76), or less than one cone/tree. The transect with the highest per-tree cone average in 2012 had an index of 0.75, less than three cones/tree (SD=1.4).

In 2011, the best predictors of cone production were tree height (taller trees produced more cones) and tree vigor (trees with higher vigor ranks produced more cones), but due to the small cone crop, results should be viewed with caution. In 2012, too few cones were produced for a meaningful analysis. In both years, taller, thinner trees had the highest vigor ranks, but R^2 values were small, suggesting that the measured variables did not explain much variation in tree health.

Continued monitoring of Pinyon Jay colonies, pinyon tree health, and cone productivity are recommended. A pilot research program including thinning pinyon trees is suggested.

Introduction

Pinyon-juniper (*Pinus edulis*, *P. monophylla*, *P. cembroides*, *Juniperus* spp.) woodlands cover approximately 40 million hectares of the western US (Romme et al. 2009). They represent the dominant woody vegetation and contain the most biodiverse terrestrial habitats on at least six DOD installations (Johnson et al. 2011a). Pinyon-juniper habitats throughout their range, including on military installations, are currently threatened by drought, insects, disease, and fire, all of which can be exacerbated by climate change. Since 2001, dramatic, rapid, large-scale mortality of pinyon pine trees has occurred in the southwestern US due to drought-related insect and disease outbreaks (Allen-Reid et al. 2005, Breshears et al. 2005). In addition to natural impacts, some private, state, and federal land managers are implementing pinyon-juniper management programs that include thinning, mechanical clearing, herbicides, and fire (Bureau of Land Management 2009). Outside DOD lands, development and livestock management also contribute to degradation of pinyon-juniper woodlands. Unlike private lands, which are subject to development, management for livestock, and fuelwood exploitation, woodlands on military installations have been managed relatively sustainably.

Pinyon Jays are year-round residents in pinyon-juniper habitats across the southwestern US. They nest colonially and breed (often cooperatively) on traditional nesting grounds. They are omnivorous, taking pine seeds, acorns, juniper berries, arthropods, and small vertebrates, but they especially depend on the seeds of pinyon pines. With their ability to carry up to 50 pinyon seeds at a time, Pinyon Jays are the main long-distance seed disperser for pinyon trees. In turn, the trees provide mast crops of abundant, highly nutritional seeds. Cached seeds sustain Pinyon Jays over winter, support successful breeding, and strongly influence Pinyon Jay population viability (Marzluff and Balda 1992). Pinyon Jays form large winter flocks that historically have numbered up to several hundred birds and range widely in search of pinyon seeds and other foods. Due to its unique keystone mutualism with pinyon trees (Ligon 1971, 1974, 1978), the Pinyon Jay is arguably the most important avian indicator of pinyon woodland productivity.

Pinyon Jays are considered to be at risk because populations range-wide have been declining significantly for over 40 years (Sauer et al. 2011). As a result, the Pinyon Jay is listed: as a DOD Species at Risk, a New Mexico Partners in Flight Level 1 Species of Concern (New Mexico Partners in Flight 2007), on the North American Partners in Flight Watch List (Rich et al. 2004), and a Species of Greatest Conservation Need in Colorado and New Mexico (Colorado Division of Wildlife 2006, New Mexico Department of Game and Fish 2006). Despite documented declines, their habitat use in pinyon-juniper woodlands has hardly been studied.

Here we report results from a study of Pinyon Jays and their relationship with pinyon pines (*P. edulis*) at Kirtland Air Force Base (KAFB). This study was funded in 2010 and 2011 by KAFB. Funding for 2011 arrived so late that we extended field work through September 2012. Objectives for 2011 were accomplished using remaining 2010 funds and with assistance funded by our DOD Legacy grant. These objectives included surveying for Pinyon Jay flocks, finding new nesting colonies, monitoring use of old colony sites, and monitoring vigor and productivity of pinyon trees in the pinyon-juniper woodlands at KAFB.

Methods

Pinyon Jay Nesting

We trapped Pinyon Jays at a feeder at the Starfire Optical Range (SOR) on 19 February, 6 July, and 27 July 2011 and 17 March 2012. We used a 107 x 61 x 20 cm welded wire walk-in trap designed after a standard pigeon trap and baited with *P. edulis* seeds. Each captured bird was banded with a USGS numbered aluminum band and a unique combination of three plastic color bands. We recorded the following data on each captured bird: age class, 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 three birds captured on 19 February 2011 and six birds captured on 17 March 2012. We tied each transmitter to the base of the two central rectrices with sturdy thread then glued the body of the transmitter to the top of the same two rectrices. All birds were released unharmed after processing. We attempted to locate birds with transmitters at least twice weekly through the breeding season in both years. Pinyon Jays were captured and banded under USGS Federal Marking and Salvage Permit #22158 and New Mexico Department of Game and Fish Scientific Permit #1795.

In 2011, addition to following birds fitted with transmitters several times each week, we checked both of the 2010 colony sites (Winch and South, Figure 1) and other areas of jay activity for evidence of breeding activity. We found colonies by watching areas where jays were actively courting or carrying nesting material, or where males were feeding incubating females on nests. At each nesting colony we sat on a hill that afforded a clear view of the nesting colony, at distances of ~30-~200 m from the nearest nest, and recorded nest visits by adult jays. We found nests by using landmarks seen from a distance, took a GPS point ~5 m from each nest, and quickly left the area. Some nests were also flagged on an adjacent tree but never at the nest tree.

We returned to collect precise GPS coordinates of each nest after nesting activity at the colony had ceased. After nesting was complete, we searched the entire colony area and recorded locations of any additional Pinyon Jay nests. Based on the condition of the outer nest structure and nest lining, we classified each nest as a nest of the year or one from a previous year. We used the nest location data, including old nests, to delineate colony boundaries and map them in GIS. Current-year nests were used for nest-scale habitat analysis for our DOD Legacy habitat use project.

Tree Measures

On 17, 18, 30, and 31 August 2011, we collected data on pinyon pines on five grids. In 2012, we added three new grids, to sample trees within the new Receiver and Office Colonies (Figure 1). We sampled trees on the eight grids on 29, 30, and 31 August and 4, 13, and 14 September 2012. All grids were within the summer home range of a Pinyon Jay flock (Johnson et al. 2011b). Grids were plotted beforehand using GIS and situated to sample trees within each colony, except the Winch Colony, which contained only juniper (*Juniperus monosperma*) trees. Winch Grid points were placed in nearby habitat containing pinyon trees. Grid points were arranged 50 m apart, except one grid where terrain was too steep to sample all points planned for the grid (South Grid, Figure 1). Grids were placed in Pinyon-Juniper Woodland, Pinyon Woodland, or a combination of both habitats. The number of points in a grid varied from 6 to 16 (Table 1).

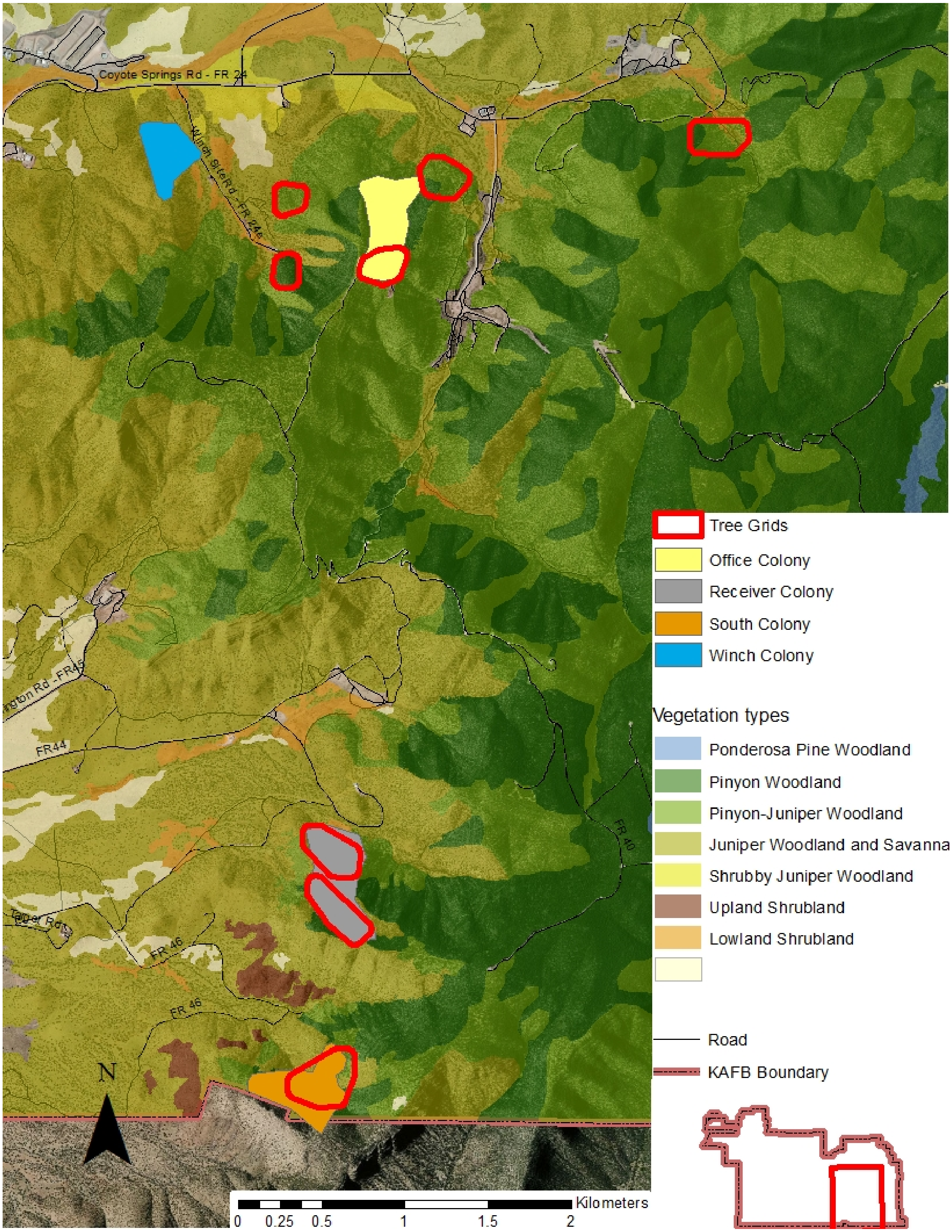

Figure 1. Study area on KAFB showing tree grid sites, Pinyon Jay colonies, and vegetation types.

Grid Name	Location	Habitat Type	Number of Points
Office 1	Sol se Mete Canyon	P (2), P-J (13)	15
Burn	Burn Site	P (3), P-J (10), J (3)	16
South	South Colony	P (5), P-J (7), J (2)	14
Winch	Winch Site	P (6)	6
Winch 2	Winch Site	P-J (6)	6
*Office Top	Sol se Mete Canyon	P-J (10)	10
*Receiver North	Receiver Site	P (3), P-J (7), J (4)	14
*Receiver South	Receiver Site	P (12)	12

Table 1. Pinyon tree grid sampling points at KAFB, 2010-2012. P=Pinyon Woodland, P-J=Pinyon-Juniper, J=Juniper, number of points in parentheses. *New grids added in 2012.

To compute tree density, we collected data using the point quarter method. At each point in the grid, we delineated four quadrants based on lines extending from the point in the four cardinal directions. We measured the distance from the center point to the nearest pinyon tree in each quadrant. We defined a tree as any pinyon at least 1 m tall and rooted to the ground. We collected distance data in the year each grid was established, collecting distance data on only the new grids in 2012. We computed tree density on each transect by squaring the average distance between trees, then taking the reciprocal. The resulting number was multiplied by 10,000 to convert the result from trees/m^2 to trees/ha.

For each of the four trees at a point, we estimated height and measured root crown diameter in the year the grid was established. Every year, we ranked vigor of each tree on a scale from 1-5 and counted cones. We spray painted the four trees at each point for identification the following year.

Vigor rankings were as follows: 5 – vigorous, no dead needles, foliage dense; 4 – a few brown needles, foliage moderately dense; 3 – about half of needles missing or brown; 2 – dying, needles sparse or mainly brown; 1 – dead. Scores of 0.5 above/below whole numbers were allowed.

Standing 5 m from each tree, we counted the number of cones in three binocular fields, choosing the three fields having the largest number of cones. We used the same 8 x 42 binoculars to count cones on each tree. We averaged the totals from the three binocular fields to create a cone density index for each tree. Because the cone index is a mean of the number of cones in the three most cone-rich binocular fields, for a minimum estimate of cones per tree, the index can be multiplied by three. In a large cone crop, the actual number of cones can be much larger, but in a moderate or low cone year, the index is a close approximation to one-third the number of cones on the tree. Data were entered into an Access database, output into an Excel file, and analyzed with Minitab 16.

Results

Trapping and Colony Detection

We captured eight Pinyon Jays at SOR on 19 February 2011 and placed transmitters on three. Transmitters were not helpful in revealing colonies in 2011. We found only one colony, the

South Colony, in 2011. In 2011, jays did not nest at the Winch Colony, which had been active in 2010 (Figure 1).

On 17 March 2012 we captured 10 Pinyon Jays, nine new and one recapture. We placed transmitters on six of these. In 2012, we repeatedly detected transmitters east of the SOR trapping site, between SOR and the Receiver Site. After we observed jays carrying nesting material and heard females begging, we expanded our search to the east and found the Receiver Colony. We found some 2012 nests by searching areas where we observed nesting activity. Others we found in a thorough search of the area after nesting was complete.

We did not detect any 2012 transmitters in the area of the Winch Site or Office Site. We found the Office Colony by observing Pinyon Jay breeding behavior in the area (first noticed by Steve Cox, contractor with Sandia National Labs). Jays did not nest at the Winch or South Colony Areas in 2012 (Table 2).

		Years Active		
Colony Name	**Location**	**2010**	**2011**	**2012**
Winch	Coyote Springs Rd	(13)		
Office	Coyote Springs Rd			(10, 7)
South	South Boundary	(9)	(13)	
Receiver	SOR			(12, 13)

Table 2. Pinyon Jay colonies at KAFB, 2010-2012. Number of nests in parentheses (active nests, old nests).

Pinyon Jay Nesting Habitats

The Winch Colony (Figures 1, 2) was active in 2010 but not in 2011 or 2012 (Johnson et al. 2011b). The South Colony (2011) was situated on both sides of a canyon running north-northwest to south-southeast adjacent to the south installation boundary (Figures 1, 3). In 2011, South Colony nests were in Pinyon-Juniper Woodland (N=6), Pinyon Pine Woodland (N=6), and Juniper Woodland and Savanna (N=1) at elevations from ~2070 to ~2234 m. Nests were constructed in pinyon (N=10) and juniper (N=3) trees.

The Office Colony (2012) extended from 1972 m to 2131 m in elevation and included a gently sloping, northeast-facing mesa top section and a lower-elevation section on the northeast-facing

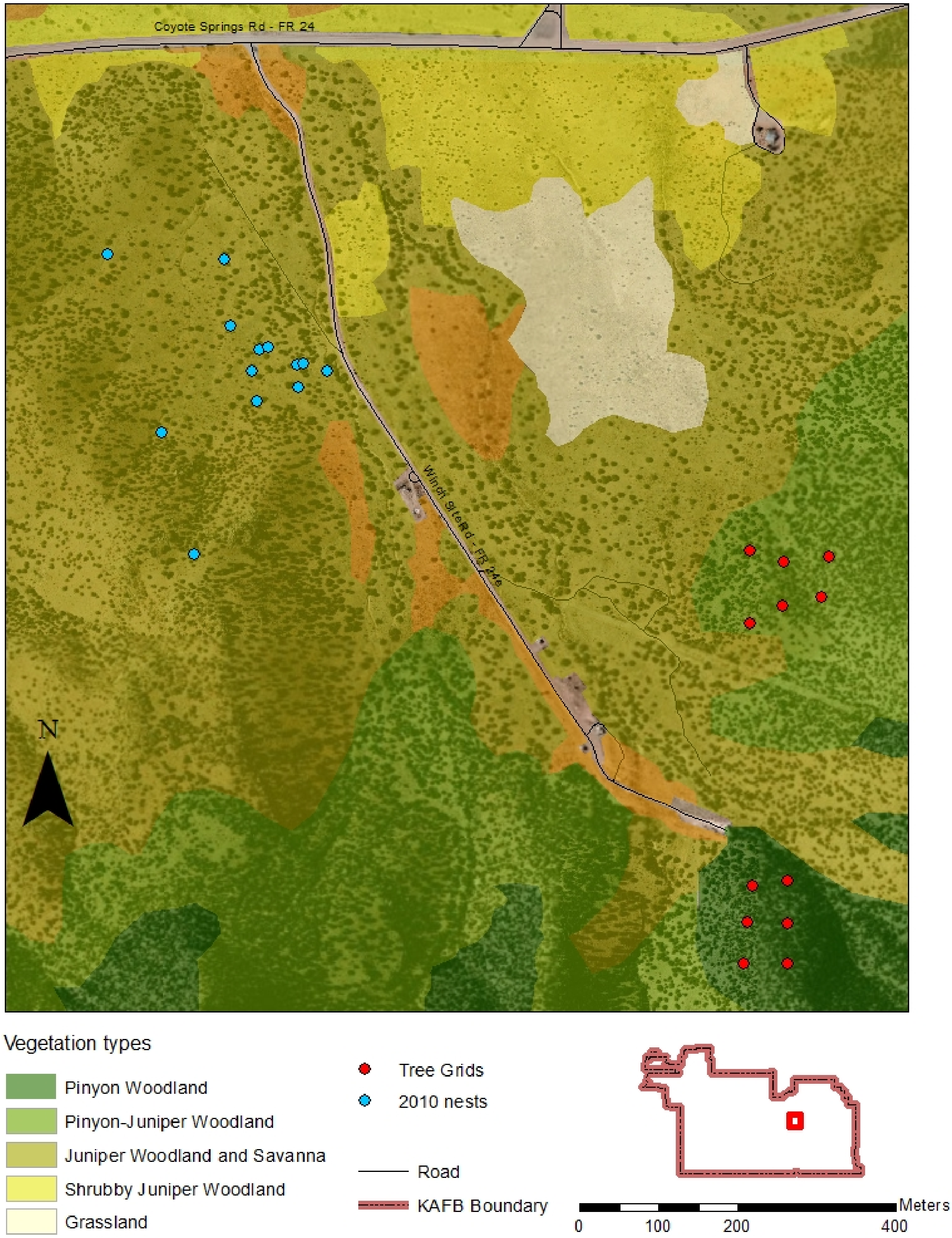

Figure 2. Winch Colony site showing tree grid points and 2010 nests. Grid points are outside colony site because Winch Colony had no pinyon trees.

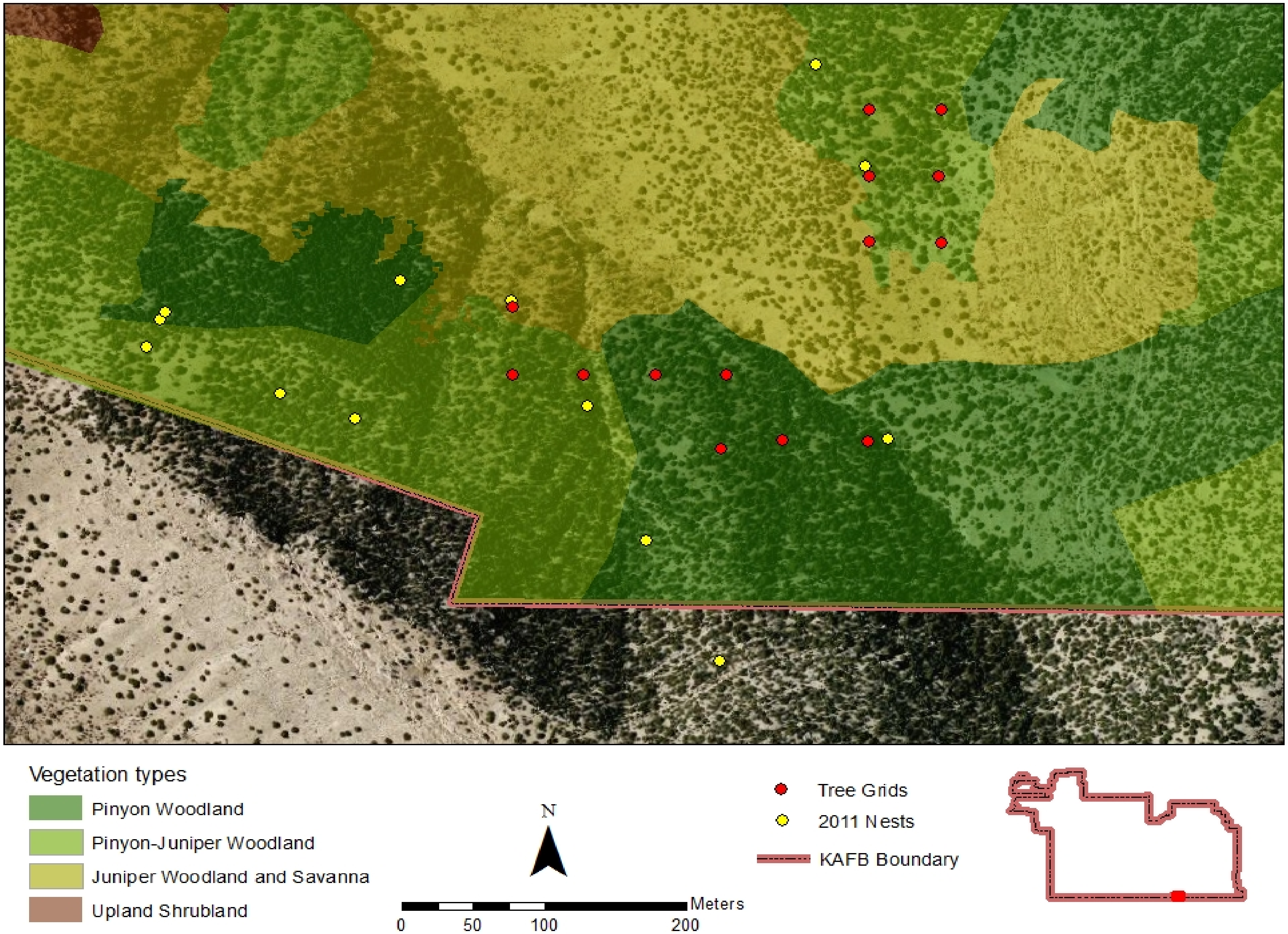

Figure 3. South Colony site showing tree grid points and 2011 nests.

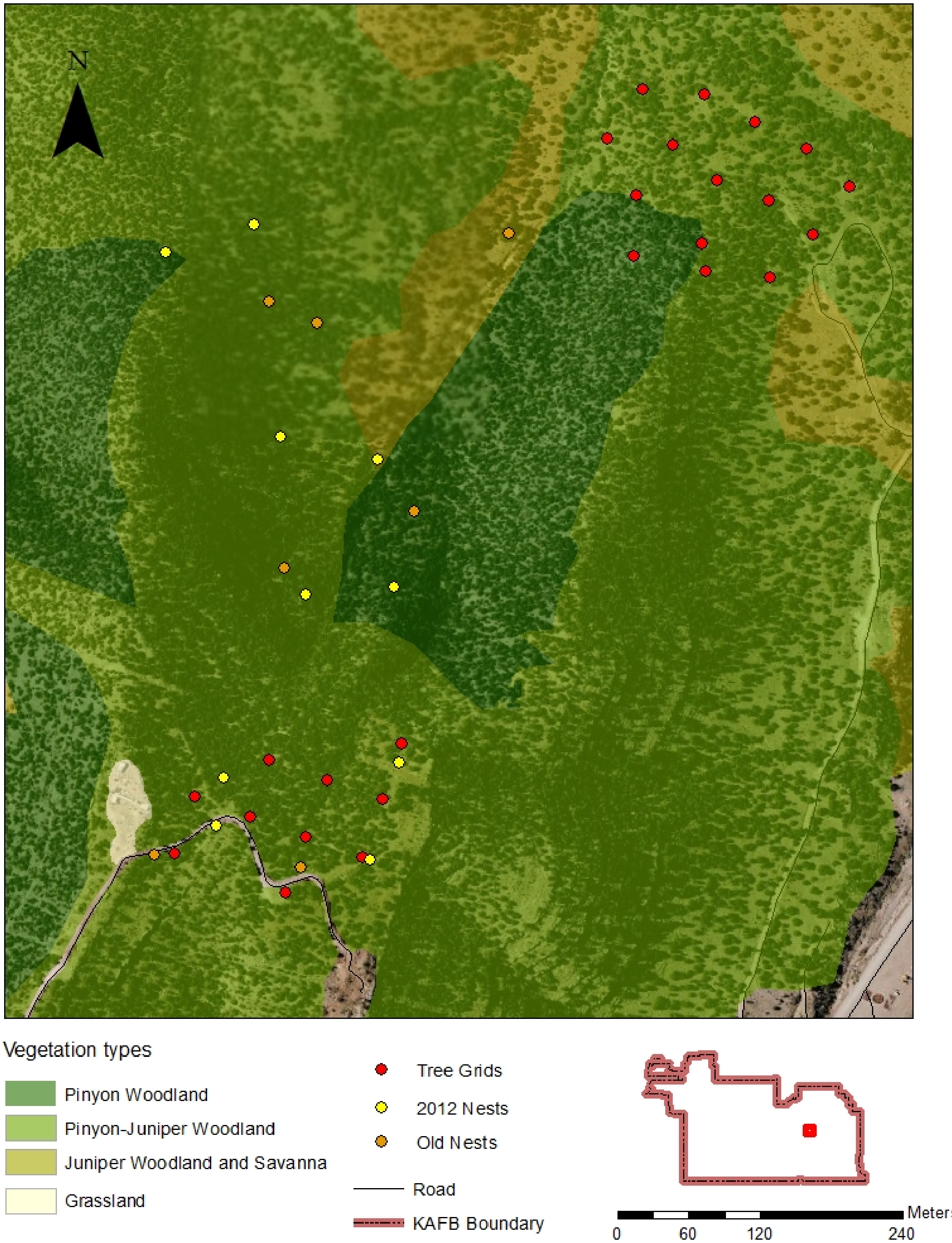

Figure 4. Office Colony site showing tree grid points, 2012 nests, and older nests. Northern Office Colony grid was established outside the nest area before the 2012 colony was discovered.

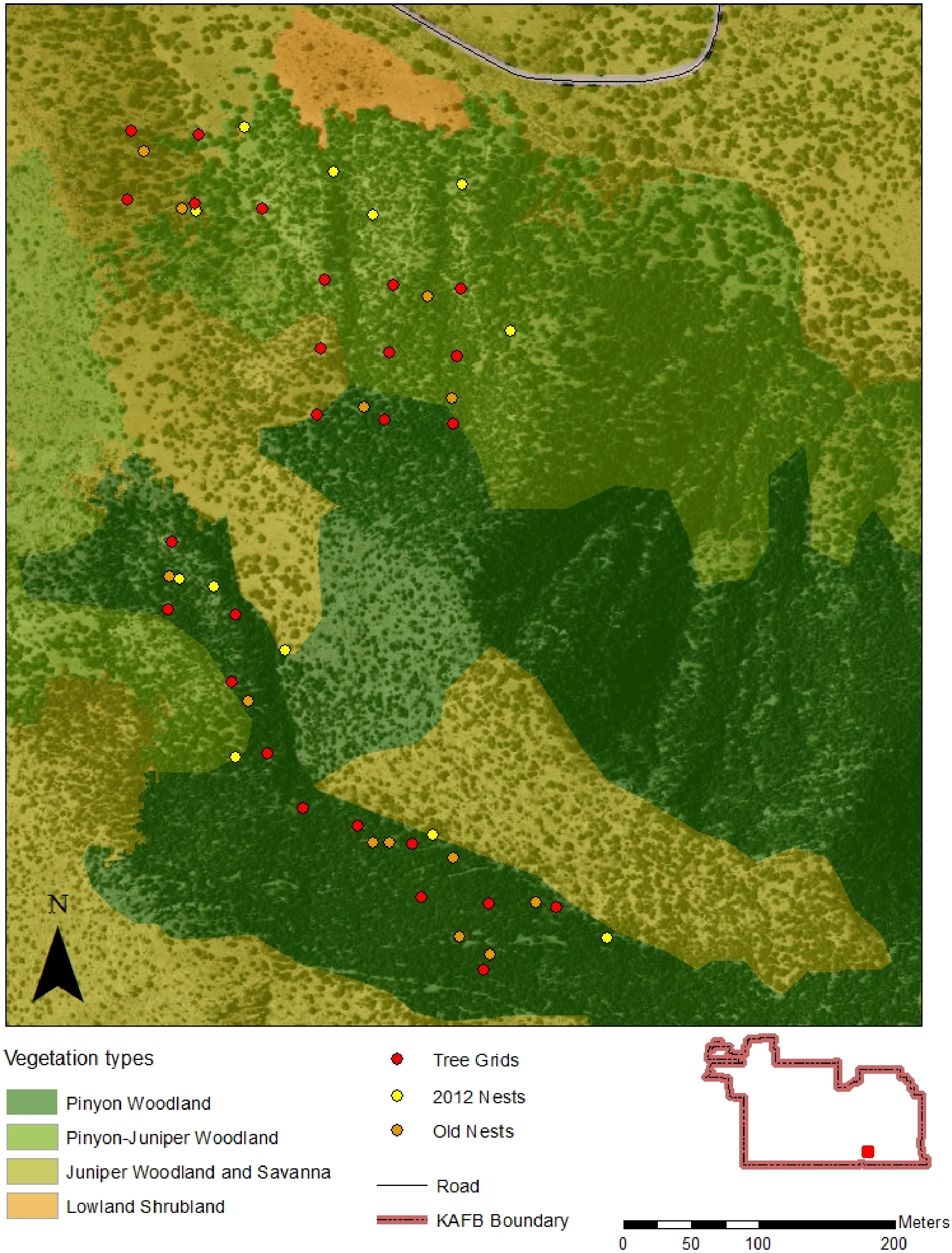

Figure 5. Receiver Colony site showing tree grid points, 2012 nests, and older nests.

slope of Sol Se Mete Canyon (Figures 1, 4). Nests were placed on slopes ranging from 4° to 36°, with most of the nests on steeper slopes occurring in the lower-elevation section. Office Colony nests were in Pinyon-Juniper Woodland (N=7), Pinyon Woodland (N=2), and Juniper Woodland and Savanna (N=1). Nests were constructed in pinyon (N=9) and juniper (N=1) trees.

The Receiver Colony (2012) extended from 1977 m to 2165 m in elevation and also included two main sections. Nests in the northern section were situated on a north-facing slope, while nests in the southern section were placed on the steep, north-facing side of a canyon (Figures 1, 5). Receiver nests were in Pinyon Woodland (N=3), Pinyon-Juniper Woodland (N=6) and Juniper Woodland and Savanna (N=3) and were placed in pinyon (N=10) and juniper (N=2) trees.

Tree Measures

We collected data from 228 trees from five grids in 2011 and 364 trees from eight grids in 2012. On all eight grids, the mean density of trees was 470 pinyon trees per hectare. Density differed among grids, ranging from a low of 205 trees/ha at the Receiver South Grid to 1060 trees/ha at the Winch Grid (Table 3).

Mean height of trees on all grids was 3.39 m (SD=1.53), ranging from a low mean height of 2.46 m (SD=0.94, Table 3) at Receiver North to 4.03 m (SD=1.34) at Winch. Mean root crown diameter of all trees was 14.3 cm (SD=8.24), with grid means ranging from 11.72 cm (SD=7.31, Receiver North) to 16.78 cm (SD=8.4, South).

Mean pinyon tree vigor on a scale of 1-5 (with 5 being highest) was 3.32 (SD=0.96) on the five 2011 grids and 3.44 (SD=0.83) on the eight 2012 grids. Variation among grids in vigor was low in both years, with means ranging from 3.08-3.55 in 2011 and 3.16-3.67 in 2012.

Cone production was very low in both years. In 2011, mean cone index per tree was 1.55 (SD=0.28), or approximately 5 cones per tree. In 2012, trees produced even fewer cones, with a cone index of 0.21 (SD=0.76), or ~0-1 cone per tree. Variation in cone number among grids was slight, except for the South Grid in 2011, which had an average cone index of 3.21 (~10 cones per tree); all other grids in 2011 averaged about three cones per tree. In 2012, most trees produced no cones, and mean cone indices ranged from 0.01-0.75, or zero to two cones per tree.

Comparisons with North Oscura Peak, White Sands Missile Range

We have been assessing vigor and cone production at North Oscura Peak, White Sands Missile Range (WSMR), since 2004. Below we compare tree measures for KAFB with those for WSMR. We measured tree size and density at WSMR initially in 2004 and re-measured them in 2011; the more recent measures are presented here. KAFB tree measures are from 2010 or 2012, depending on which year grids were established.

KAFB Means							
Grid Name	**Trees/ha**	**Height (m)**	**Root Crown (cm)**	**Vigor 2011**	**Cone Index 2011**	**Vigor 2012**	**Cone Index 2012**
Burn	360	3.53 (1.73)	14.03 (8.48)	3.4 (1.02)	0.98 (2.01)	3.31 (0.96)	0.06 (0.27)
Office 1	325	3.54 (1.67)	16.57 (10.43)	3.08 (1.04)	0.96 (1.6)	3.16 (1.14)	0.02 (0.13)
South	392	3.99 (1.68)	16.78 (8.4)	3.55 (0.75)	3.21 (4.19)	3.67 (0.7)	0.75 (1.4)
Winch	1061	4.03 (1.34)	13.13 (5.34)	3.26 (0.57)	1.07 (1.29)	3.43 (0.7)	0.01 (0.07)
Winch 2	418	3.45 (1.67)	13.91 (7.98)	3.24 (1.1)	1.17 (2.45)	3.42 (1.16)	0.01 (0.07)
Office Top	438	3.09 (1.05)	14.33 (8.02)			3.47 (0.86)	0.09 (0.28)
Receiver N	481	2.46 (0.94)	11.72 (7.31)			3.55 (0.28)	0.39 (1.08)
Receiver S	205	3.28 (1.19)	12.33 (5.08)			3.55 (0.28)	0.06 (0.37)
All	**470**	**3.39 (1.53)**	**14.3 (8.24)**	**3.32 (0.96)**	**1.55 (0.28)**	**3.44 (0.83)**	**0.21 (0.76)**
WSMR Means							
Transect Name	**Trees/ha**	**Height (m)**	**Root Crown (cm)**	**Vigor 2011**	**Cone Index 2011**	**Vigor 2012**	**Cone Index 2012**
0	380	3.26 (1.45)	15.54 (10.29)	3.51 (0.74)	0.56 (1.20)	3.59 (0.65)	0
2	340	3.4 (1.5)	18.58 (11.3)	3.52 (0.55)	0.4 (1.03)	3.66 (0.36)	0
5	470	3.71 (1.88)	16.04 (9.88)	3.12 (1.01)	0.44 (1.42)	2.98 (0.96)	0
7	1500	3.84 (2.17)	12.9 (8.34)	2.9 (0.71)	0.84 (1.82)	3.13 (0.62)	0
8	1120	4.71 (2.5)	17.71 (12.83)	2.9 (0.6)	0.65 (1.54)	2.9 (0.59)	0
9	900	4.03 (1.74)	18.55 (9.54)	2.62 (0.67)	0.02 (1.11)	2.89 (0.91)	0
10	1530	4.48 (1.83)	21.03 (11.79)	3.36 (0.42)	0.78 (1.28)	3.43 (0.37)	0
All	**690**	**3.91 (1.96)**	**17.03 (10.81)**	**3.13 (0.76)**	**0.53 (133)**	**3.22 (0.74)**	**0**

Table 3. KAFB pinyon tree measures (SD) collected 2011 or 2012, compared to those at WSMR.

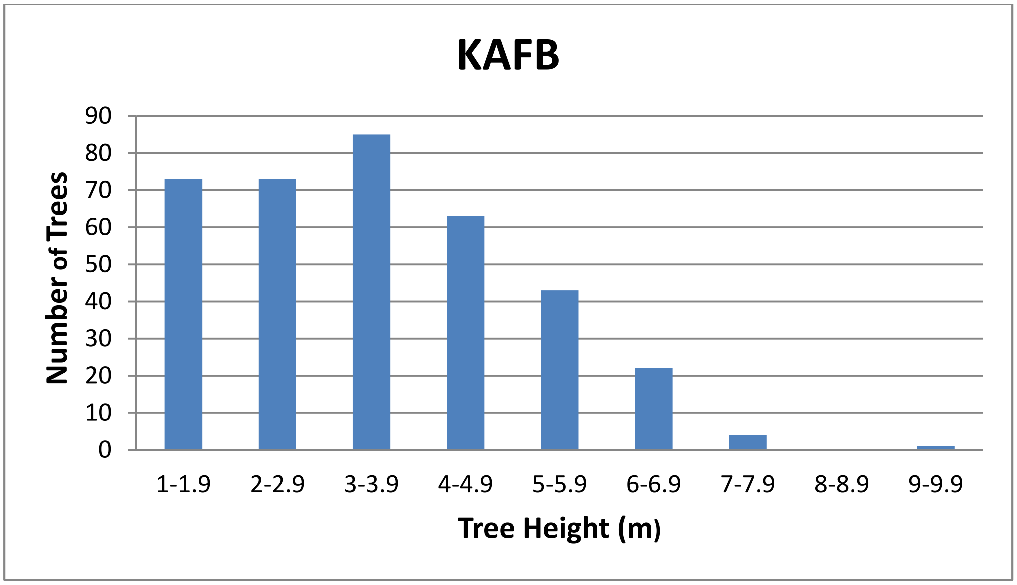

Figure 6. Size distribution of pinyon trees on all KAFB grids, measured in 2011 or 2012.

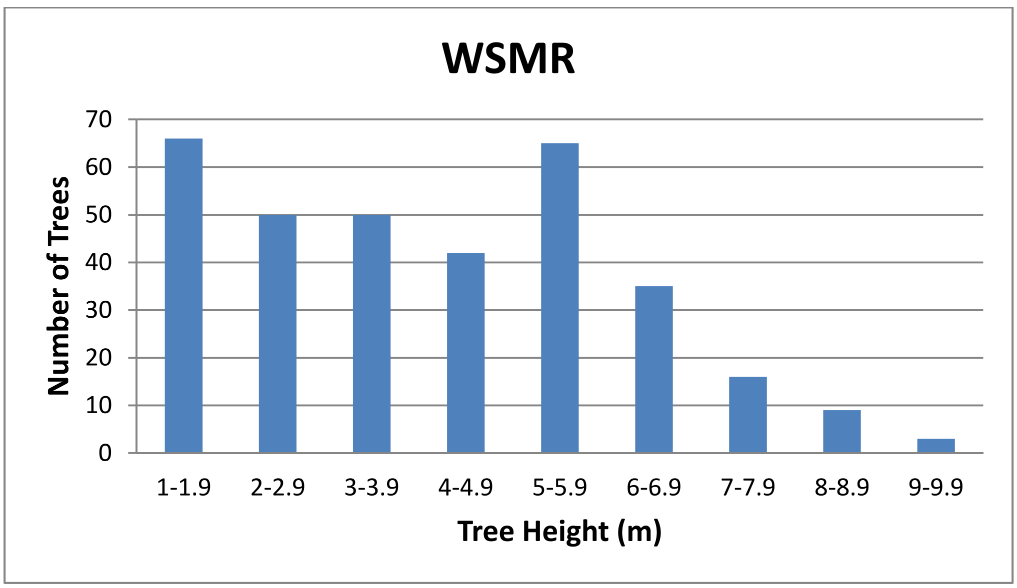

Figure 7. Size distribution of pinyon trees on all WSMR transects, measured in 2010 or 2011.

The size distribution of trees differs at KAFB and WSMR (Figures 6, 7). The size distribution at KAFB approximates a half normal distribution, with slightly more trees in the 3-3.9 m size class (Figure 6). The distribution of trees at WSMR, in contrast, is slightly U-shaped in the five smallest size classes, with the smallest (1-1.9 m) and the 5-5.9 m classes most abundant (Figure 7). The result is that trees at WSMR are generally taller than those at KAFB (Table 3; $T=3.92$, $P<0.001$, $DF=632$). This is also the case for root crown diameter (Table 3; $T=3.74$, $P<0.001$, $DF=624$).

Trees were on average closer together at WSMR than at KAFB (mean distance=3.82, 4.61 m, respectively; T=3.44; P=0.001; DF=693). Variation in distance between trees was similar at the two sites (distance SD=3.05 at both study sites), but mean tree density varied widely among grids/transects at both sites; for example, from 340-1530 trees/ha at WSMR and from 205-1061 trees/ha at KAFB.

Average tree vigor was higher at KAFB in both 2011 and 2012 (2011: mean KAFB=3.32, mean WSMR=3.13, T=2.6, P=0.01, DF=417; 2012: mean KAFB=3.44, mean WSMR=3.22, T=3.68, P<0.001, DF=697). Cone index was also higher at KAFB in 2011 (mean KAFB=1.55, mean WSMR=0.53, T=5.16, P<0.001, DF=298). Cone number did not differ between WSMR and KAFB in 2012, when neither study site had an appreciable cone crop.

In summary, WSMR pinyon trees are taller, larger in diameter, likely older, closer together, and less vigorous than trees at KAFB. In 2011, when a small cone crop was produced at both sites, WSMR trees produced fewer cones than those at KAFB.

Correlates of Tree Health at KAFB

We used stepwise multiple regression to investigate variables related to tree health, as measured by cone production and vigor ranks. In 2011, the best equation predicting cone production included tree height and vigor (R^2=25.2%, F=37.88, P<0.001). In 2012, too few cones were produced to perform a meaningful analysis. Cone production was also quite low in 2011; the 2011 result should therefore be viewed with caution.

In 2011, the best equation predicting tree vigor included root crown diameter and height, larger trees with smaller diameters having the highest vigor (R^2=7.1%, F=8.65, P<0.001). In 2012, the same two variables were included in the best regression model (R^2=6.6%, F=12.8, P<0.001). However, R^2 values are relatively low, indicating that these measures explain only a small portion of the variance in the vigor measure.

In summary, taller, thinner trees were healthier, as measured by vigor ranks. Taller, more vigorous trees produced more cones in a year when cone production occurred but was low.

Discussion

Pinyon Jay Nesting Colonies and Flocks

In 2011, we found only one nesting colony of Pinyon Jays at KAFB, the South Colony, also active in 2010 (Johnson et al. 2011b). The Winch Colony, active in 2010, was not active in 2011 (Johnson et al. 2011b). In 2012, neither the South Colony nor the Winch Colony was active, but we found two new colonies. The Receiver Colony was near the South Colony site, and the Office Colony was near the Winch Colony site (Figure 1). We estimated the number of Pinyon Jay pairs at each colony at between 10 and 15 pairs (Table 2). These estimates are slightly higher than the number of active nests found, because we could have missed a nest or two each year.

We did not detect any 2012 transmitters in the area of the Winch Site or Office Site, which suggests that birds banded at SOR nested near SOR at the Receiver Colony site, but not farther north. Color bands are very difficult to see in the field because Pinyon Jays are typically skittish and fast-moving; however, we did observe one bird color-banded at SOR nesting at the South Colony in 2010. The new Receiver Colony (2012) was quite close to the South Colony (2010-2011) site, and the Office Colony (2012) is just over a low ridge to the east of the Winch Colony Site (2010). This suggests that the Receiver and South birds were members of the same nesting flock, and the Office and Winch birds were likely members of the same, separate nesting flock. In 2012, transmitter birds were captured at SOR and detected near the Receiver Colony but never near the Office Colony. This provides additional evidence that the two nesting colonies comprise two breeding season flocks.

Suzanne Field, a security guard at the SOR gate, feeds birds through the winter and spring, and records color band combinations of Pinyon Jays sighted at her feeders. She observed young fledglings at her feeder on 22 April 2010, before we found fledglings at either the Winch or South Colony. In 2010, we speculated that the parents of these fledglings nested in Pinyon-Juniper Woodland east of the Receiver Site. We found the Receiver Colony in 2012. Several nests at the Receiver Colony site were constructed in previous years, so this colony was apparently active prior to 2012.

We have observed a winter flock with up to 100 birds. Based on these numbers, it is plausible that the winter flock comprises birds from both Winch/Office Colony and South/Receiver Colonies, plus their fledglings. An alternative hypothesis is that the South/Receiver Colony breeders comprise one wintering flock, and the Winch/Office Colony birds belong to a different wintering flock seen at Steve Cox's MAPS station near the Range Guzzler, the Four Hills area, and the Madera Canyon area. However, we have never recorded more than one large winter flock at KAFB on the same day, and the size of the winter flock is consistent with a combination of both breeding flocks. More winter radio tracking data are necessary to resolve this question.

After three years studying Pinyon Jays at KAFB, we know of two separate nesting colonies/flocks and at least one large winter flock. Unlike the nesting flock we have studied at WSMR since 2004, the KAFB flock stays within its home range in the winter and does not stray far from the winter range that encompasses both nesting colony areas (Johnson et al. 2011a).

Trees

<u>Cones</u>

Intervals between pinyon mast crops historically have been cited as about three to seven years (Ligon 1978, Forcella 1981, Lanner 1981). A moderately large cone crop was produced across much of New Mexico in 2008, including at KAFB. We observed cones on many trees before this study began, in the fall of 2008 near the Burn Site and Madera Canyon guzzler, but we did not begin collecting data on cone production at KAFB until 2010. KAFB had a negligible cone crop in 2010 (Johnson et al. 2011b), a small cone crop in 2011, and a negligible crop in 2012, which means that KAFB has had only one cone crop out of the last four years. Although our data for KAFB are limited, it appears that WSMR cone production over the past ten years has been lower than that at KAFB. Between 2004 and 2012, the WSMR site produced only one moderate crop, in 2006, and a small crop in 2011. Our data and anecdotal evidence suggest that a large cone crop has not been produced at the Oscura Mountains study site since at least 1999 (Horacio Perez pers. comm.). In 2011, KAFB trees produced more cones than WSMR trees.

Vigor and Productivity
Cone production is related to several factors. In this study, taller, more vigorous trees produced more cones. Similarly at WSMR, larger, more vigorous trees produced more cones, and cone production was inversely related to tree density (Johnson and Smith 2006). In 2011 and 2012 (as in 2010, Johnson et al. 2011b), vigor ranks on our pinyon grids at KAFB were higher than those on transects at WSMR. Trees are on average closer together at WSMR than at KAFB. Hence, higher cone production and vigor ranks at KAFB could reflect lower tree density and less competition for moisture or other resources than at WSMR.

If trees are healthier and the woodland is less dense at KAFB, cone production is expected to be higher. However, in years of cone production, larger trees tend to produce more cones (Johnson and Smith 2006), which should result in higher cone production at WSMR. We have no data on the 2008 cone crop at KAFB, but our impression is that the 2008 cone crop at KAFB was larger than the 2006 crop at WSMR. Masting behavior in pinyon pines is not well understood, but it is clear that cone production is influenced by a variety of factors. Not only tree age, density, and vigor, but also climate variability over a period of more than two years (Forcella 1981, Zlotin and Parmenter 2008) can influence cone production. More years of data, and most importantly more cone crops, will be required before these relationships can be well understood at KAFB.

Tree-Jay Interactions

Global climate change is expected to bring increased temperatures and frequent drought, which can be expected to impact cone production. In the Southwest, impacts of fire and insect damage to pinyon trees apparently are already increasing (Allen-Reid et al. 2005, Breshears et al. 2005). In addition, the range of pinyon-juniper habitat 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).

Pinyon Jay population viability is tied to pinyon mast crops. The size and frequency of mast crops can strongly affect Pinyon Jay reproduction and population viability (Ligon 1978, Marzluff and Balda 1992). If pinyon masting historically occurred every three to seven years but is now becoming less frequent, as may be occurring at WSMR, Pinyon Jay populations will suffer. Climate impacts on mast frequency may be the cause of the over-40-year decline in Pinyon Jay numbers indicated by BBS surveys (Sauer et al. 2011).

If pinyon health, productivity, and range in New Mexico decline as predicted, Pinyon Jay populations will decline as well. Without its most important long-distance seed disperser, *P. edulis* will be less likely to re-establish after fire or insect infestation, or to colonize new areas. This forecast does not bode well for a bird species that has already declined significantly for over 40 years, nor for the tree with which it is so intimately co-evolved. Pinyon Jay populations and pinyon trees at the southern edge of the species' range will be especially hard hit by increased temperatures and more frequent drought. We believe we are seeing the beginning of the woodland decline at WSMR, where pinyon trees have lower viability and cone production than at KAFB. The pinyon tree size distribution at WSMR suggests that trees there are older than at KAFB; more senescent trees may result in lower overall productivity there.

This situation makes the KAFB Pinyon Jay habitat especially important, for two reasons. First, KAFB is currently an area of relative habitat health and Pinyon Jay success. In addition, livestock grazing, firewood cutting, development, and other human activities that impact pinyon-juniper habitats do not typically occur at KAFB. Second, if southern populations of the tree and the bird disappear, KAFB may eventually become the southern edge of the range for the Pinyon Jay, and its last line of defense against habitat loss and degradation.

Management of Pinyon-Juniper Habitats for Pinyon Jays

Can pinyon-juniper habitats at KAFB be managed to benefit Pinyon Jays? The biology of Pinyon Jays strongly suggests that, other things being equal, larger, more frequent seed crops would benefit Pinyon Jay populations at KAFB. What, if any, management actions would increase seed crops? No obvious tools exist to alter climate change, and several possible management actions are clearly impractical:

1. Providing *supplemental water* to pinyon trees in times of drought would require excessive labor, and the necessary water is probably not available.
2. Pinyon Jays readily use bird feeders. In a very poor year, *supplementation* would help Pinyon Jays survive the winter and breed in the spring. However, this would be a short-term fix and would not address the impact of long-term climate change on Pinyon Jay populations.
3. One suggestion for the conservation of pinyon woodlands and their wildlife is to *manage trees for seed production*. Management actions could include thinning to reduce disease transmission and competition for water, pruning, and irrigation. The economic return from seed harvests could balance the cost of management actions. However, this alternative is more appropriate for private lands and multiple-use public lands such as Bureau of Land Management lands, than it is for a military installation.
4. It is possible that *thinning* alone would benefit pinyon trees. Our research at WSMR suggests that tree density is inversely related to cone production in years with a cone crop (Johnson and Smith 2006 and unpublished); however, no research has demonstrated the effectiveness of thinning per se in increasing seed production. Reduction of fuel loads might be considered an additional benefit of thinning. However, frequencies of spreading, low-intensity surface fires in pinyon and juniper woodlands have historically been very low, and some pinyon-juniper woodlands have been stable for hundreds of years without fire (Romme et al. 2009). This suggests that frequent fire is not a natural process in these woodlands, and thinning to reduce fire frequency in pinyon-juniper woodlands would therefore be inappropriate (Romme et al. 2009).

Recommended Research

Although certain types of management actions would not be appropriate for a military installation, KAFB remains an excellent site to study the impacts of climate change and other factors on the pinyon-juniper ecosystem and its wildlife, which KAFB is charged to conserve under the Sikes Act and Sikes Act Improvement Act of 1997 (16 U.S.C. 670) and other environmental rules and regulations. Data collected at KAFB over the past three years have greatly increased scientific knowledge of the needs of Pinyon Jays, Gray Vireos (*Vireo vicinior*; Johnson et al 2011a,b; 2012), and the pinyon-juniper woodlands upon which they and other wildlife depend. We recommend continued study of the Pinyon Jay population at KAFB, with focus on locating all colonies on base, monitoring their reproductive success, and continuing to monitor pinyon tree productivity and health. Second, we recommend that KAFB conduct a pilot thinning project in areas of highest pinyon tree density, where pinyon health and productivity would be monitored at thinned versus control sites. This work should be conducted in conjunction with the continuation of our three-year study of pinyon trees, which is due to end in 2013.

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