Pinyon Jays and Pinyon Pines at North Oscura Peak, White Sands Missile Range, New Mexico

2008 Annual Report

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Introduction

After four-and-a-half years of studying the pinyon-juniper woodland and pinyon jays at North Oscura Peak (NOP) on White Sands Missile Range, the dominant impression is that of change. Vigor ranks of the pinyon trees change between years, cone crops vary from year to year, and trees die. Pinyon jays are present some times of the year and absent others; their wintering grounds are unknown. Nesting varies temporally and spatially, and nesting effort and success are inconstant.

And yet some changes are at least sometimes predictable. The pinyon jays have returned to the top of NOP in the spring for five years running. They bred in 2005, 2006, and 2007. In 2004 we arrived too late to observe breeding activity but the presence of second-year birds in 2005 suggests that they bred in 2004 as well. In 2008 a few pairs probably nested but reproductive effort and success were very limited. The flock has left NOP during the winter for four years, and we have no evidence that they remain in their breeding home range. Where they go and how they survive the winter is still unknown. Although we have not observed a large mast crop, at least some trees produced seeds in the fall in 2004-2007 (Johnson and Smith 2006, 2007, 2008). For three of the four fall seasons, enough pinyon cones were produced that the NOP flock stayed to harvest and cache seeds. In the spring of 2007, following the best pinyon seed crop of the four years, we predicted that the jays would return early to breed in the spring, relying on seeds cached in the fall of 2006. Our prediction was borne out. We observed the most successful nesting season of the study and documented 64% maximum nesting success for the colony (Johnson and Smith 2008).

However, the cone crop of 2006 was neither widespread nor particularly large. Only 156 of 297 trees sampled (52.5 %) produced seeds, and only trees at the top of the mountain produced large numbers of seeds. Trees in other areas produced a few or no cones per tree. Enough seeds were produced on the very top of NOP to allow the flock to cache seeds into October, and reproduction was likely enhanced during the spring. However, it was by no means a legendary mast crop that required an entire winter to cache or supported multiple breeding events in a year, as reported following significant mast crops (Ligon 1978, Marzluff and Balda 1992). The following year, 2007, was poor indeed. Birds left the area when fledglings could fly, without a seed crop to cache, and few pairs nested the following spring. In 2008, the cone crop was the worst of all five years, with very few trees producing even a single cone. The absence of cones does not bode well for reproductive success at NOP in 2009.

The purpose of this study is to investigate the health and productivity of the pinyon-juniper woodlands at NOP and their relationship to population health and reproductive success of the woodland's primary long-distance seed disperser, the pinyon jay. The five years of data we have collected on bird behavior and pinyon productivity have greatly increased our understanding of the pinyon jay-pinyon pine mutualism at NOP. The length of mast cycles means that an even longer-term study is necessary for a complete understanding of the complex dynamics in this system.

Methods

Tree Data

We collected vegetation data on 24, 25, and 30 July 2008 on six existing transects (Johnson and Smith 2007). Transects contained 11 (one transect), 12 (two transects) or 13 (three transects) points each. Using the point-centered quarter method, we collected data from the nearest tree over 1 m tall, in each quarter at each point on each transect, 288 trees in all. Points were approximately 50 m apart and situated at the same GPS coordinates used for each point in 2004, 2005, 2006, and 2007. Due to limitations in GPS accuracy, some points were not exactly at the same spot as in previous years, but we recognized many as being in the same place. Tree selection likewise varied among years. In 2006, 2007, and 2008, we flagged the tree in the northeastern quadrant at each point, to facilitate collecting data on the same trees in subsequent years.

For each tree, we recorded a vigor ranking from 1-5 (1-dead/defoliated, 2- majority of needles lost or brown, 3- half or more of needles present and green, 4- a few needles brown or lost, 5- vigorous). Standing approximately 5 m from the uphill side of the tree, we counted the number of cones within a binocular field, using the same binoculars for all counts. Counts were made for three fields in each tree, from areas of the tree containing the most cones. We averaged the three field counts for each tree to produce an index of cone production. We performed statistical analyses using Minitab 13 (Minitab, Inc. 1999) .

Capturing and Banding

In 2007 we purchased a solar-powered, battery-operated automatic feeder (Sweeney Enterprises, Boerne, TX). The feeder holds about five pounds of pinyon seeds and delivers a pre-set volume of pinyon seeds as programmed, obviating the need to fill feeders several times each week. We modified the seed tray on the feeder to create a larger platform the jays could perch on. We set up the feeder on 17 April 2008, along the road between the barracks and the top of NOP. We set the feeder to deliver about two cups of seeds twice a day, early morning and late afternoon. We stopped filling the feeder after we finished trapping in June.

On 10, 18, and 25 June we captured jays in a modified Australian crow trap and a welded wire walk-in trap set near the feeder and baited with pinyon seed. We removed birds from the trap, placed them in closed cardboard boxes, and took them to a truck parked near the trap for processing. We took the following data on each bird: age, sex, weight, tarsus, wing, and culmen. Each bird was banded with a US Fish and Wildlife Service numbered aluminum band and a unique combination of one to three color bands (Figure 1). Although it is not possible to unequivocally determine the sex of HY (hatch-year) pinyon jays (Pyle 1997), for our information we attempted to assign sex using a combination of weight, tarsus, and culmen, as we have done for adult and SY (second-year) pinyon jays. (Because they were not definite, sexes of HY birds were not reported to the Bird Banding Lab.) Birds were released in groups within sight of the trap after processing.


Figure 1. Second-year bird, banded and ready for release.

We visited the study site on 17 March; 7, 17, and 23 April; 5, 19, and 29 May; 9, 10, 11, 17, 18, and 25 June; and 24 and 25 July; noting flock size and location. We stopped visiting the study site for the winter after we were unable to find jays at NOP on the three days in late July when we collected tree data.

Pinyon Jay Nesting

We visited the study site on 13 days during the 2008 nesting season to survey for nesting and monitor fledglings. Due to funding limitations, we did not search for nests in 2008. In June, if we heard fledglings begging, we followed them and took GPS points, counted the number of fledglings in the group, and noted flight development.

Results and Discussion

NOP Pinyon Jay Population

We first detected the pinyon jay flock at NOP this year on 17 March, when we counted a flock of 86 birds below the buildings at the top of NOP. As in previous years, flock counts at NOP declined after this, presumably due to the breakup of the winter flock. We counted no more than 30 birds the rest of the 2008 breeding season, and most days we observed fewer than 10 at a time (Figure 2). We captured 17 new birds and recaptured three birds banded in previous years.

Several major peaks in flock size have occurred over the four-and-a-half years of the study. The two largest peaks were in September of 2005 and 2006, when birds were caching seeds. These counts are higher than the numbers of breeders plus their fledglings and probably included birds from nearby areas that moved in to harvest seeds. Comparable numbers of birds were not present in September of the poor cone years, 2007 and 2008, even though many fledglings were produced in 2007. Two lesser but notable peaks were counts of wintering flocks in February and March of 2007 and 2008. The large flock counted in 2007 was likely retrieving cached seeds from the fall 2006 crop, prior to the breeding event of spring 2007. Given the poor cone crop of 2007, that is probably not the case for the flock observed in early 2008. The most consistent peaks were relatively small increases that occurred in April every year when breeders returned to NOP. Counts during the height of the nesting season are inevitably underestimates of the numbers of birds present, as incubating and brooding females would typically not be counted.

For the first three years of the study, we observed few or no birds in the winter months. The flocks left the study site in September 2004 and 2007 and October 2005 and 2006, following a period of pinyon seed harvest in which flock size swelled to at least 100 birds. In 2008, the birds left the area between 25 June, after we finished trapping and removed the feeder, and 24 July, when we returned to collect transect data.

Pinyon Jay Reproduction

Breeding Activity

In 2008, we did not systematically search for nests. However, it was clear that few if any jays nested. None of the 20 birds captured in 2008 was a hatch-year (HY) bird, in contrast to 2007, when 61.5 % of captured birds were HY birds and 2006, when 31.6% were HY. Of 2008 captured birds, 61.1% were second-year birds molting into their first adult plumage, which is consistent with the successful reproduction that occurred in 2007 and the proportion of HY birds captured in that year.

We observed a few dull birds that appeared to be poorly-flying fledglings and heard some begging, which suggested that a few pairs nested successfully at the study site. However, the lack of HY birds trapped and the absence of a juvenile flock later in the summer is evidence that a nesting event like that of 2007 did not occur in 2008. This is not surprising, given that the cone crop in the fall of 2007 was very poor. The poor 2008 crop does not bode well for 2009 reproduction at NOP.

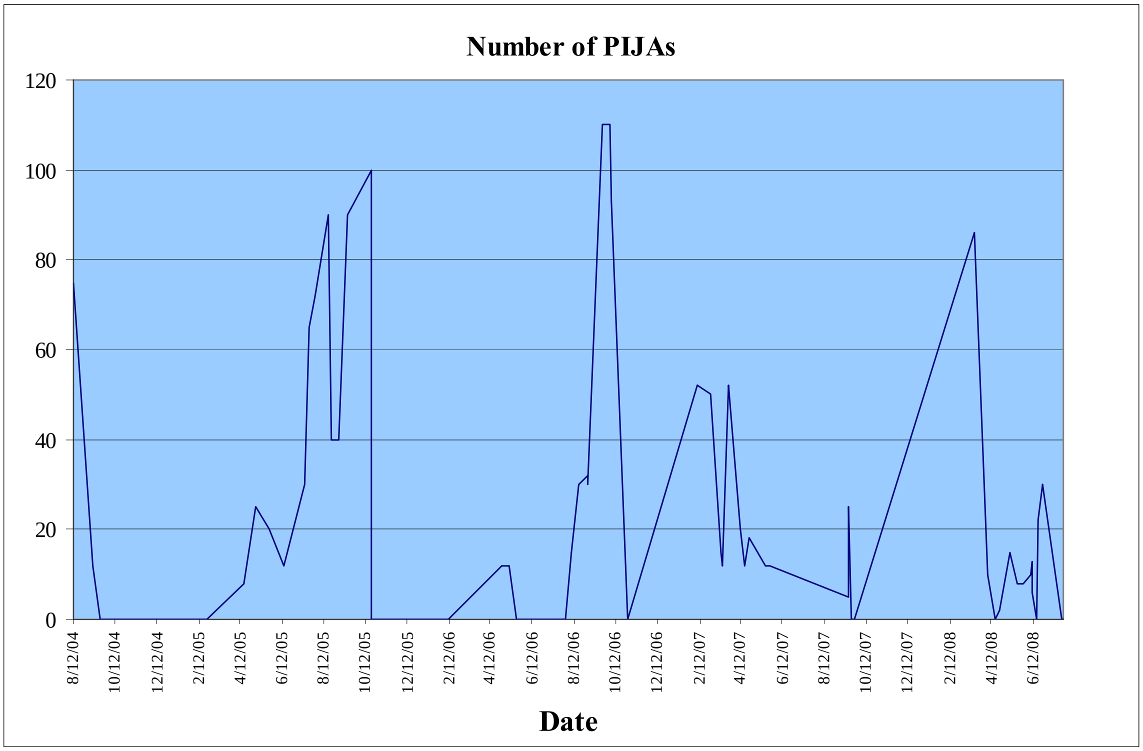

Figure 2. Size of pinyon jay flock at NOP, 2004-2008.

Trees

Vigor

An ANOVA comparing the vigor per tree on all transects across five years showed significant differences among years (F=56.63, P<0.001). Multiple comparisons showed that 2004 had significantly higher vigor than all other years. Vigor was also significantly higher in 2005 than in 2006 and 2007, which did not differ from each other. Vigor was also higher in 2006 than in 2008, which did not differ in vigor from 2007.

We performed another ANOVA to compare vigor among years on each transect (Table 1). On all except transect 9, trees had significantly higher vigor scores in 2004 than in at least one other year. On transects 5 and 7, 2005 vigor was also significantly higher than in 2008 (and 2007 on transect 7). Vigor on transect 7 in 2006 was also higher than in 2007, and on transect 8 was higher in 2004 than in 2008. This analysis is generally consistent with the overall ANOVA but indicates that vigor scores on transect 9 did not vary among years in concert with the other transects.

Comparisons of transects within years showed that transects 0 and 2 were ranked significantly higher than other transects in all five years. Transects 5 and 7 were ranked intermediate over the four years, and transects 8 and 9 were ranked lowest or intermediate, making them the least vigorous transects over the five years (over four years in the case of transect 9, which was not created until 2005; Table 2).

Cone Production

An ANOVA comparing the number of cones per tree on all transects across four years showed significant differences among years (F=25.83, P<0.001). Multiple comparisons showed cone number to be significantly higher in 2006 than in 2004, 2005, 2007, and 2008. Cone number in 2004 and 2005 did not differ, but in 2005 trees produced significantly more cones than in 2007 and 2008. Cone number was significantly higher in 2004 and 2007 than in 2008, the year in which the fewest cones were produced of the five years.

Transect	F	P	Comparisons Among Years
0	5.38	0.001	04>05=06=07=08
2	12.85	<0.001	04>05=06=07=08
5	4.82	0.002	04=05; 04>06=07=08; 05>08
7	14.77	<0.001	04>05=06>07=08
8	3.47	0.013	04=05=06=07; 04>08
9	1.08	0.369	04=05=06=07=08

Table 1. ANOVAs comparing vigor among years, on each transect.

	Transect					
No. Years Ranked	0	2	5	7	8	9
Best	5	5				
Moderate			5	5	1	1
Worst					4	3

Table 2. Relative vigor rankings of the transects over four years. Transect 9 was not created until 2005.

Transect	F	P	Among Years
0	3.23	0.019	06>04=05=07=08
2	2.19	0.082	04=05=06=07=08
5	2.69	0.039	06>04=05=07=08
7	5.53	0.001	06>04=05=07=08
8	7.52	<0.001	06=05; 06>04=07=08; 05>04=08
9	15.02	<0.001	06>05=07=08

Table 3. ANOVAs of cone number by transect among years.

Breaking the cone data down by transect reveals that trees on all transects except transect 2 produced more cones in 2006 than in at least one other year (Table 3). Transect 2 showed no significant differences in cone number among years. When cone number was compared among transects in each of the five years, only three years showed significant differences among transects (Table 4). The two years that showed no differences among transects were 2006, the year in which cone production was highest, and 2008, the year in which almost no trees produced cones on any transect.

Transects 0 and 2 ranked highest on cone production over the five years, transects 5 and 8 ranked intermediate, and transects 7 and 9 ranked lowest, making them the poorest producers over the three years (Table 5). The cone results were consistent with vigor results, except that the ranks of transects 7 and 8 are reversed (Table 4). Thus, for the most part, trees on transects with higher vigor ranks produced more cones over the four-year period.

Year	F	P	Among Transects
2004	3.97	0.004	0>7,8
2005	4.78	<0.001	2>0,5,7,8, 9; 8>9
2006	1.03	0.4	0=2=5=7=8=9
2007	2.4	0.037	8>5,7
2008	1.17	0.334	0=2=5=7=8=9

Table 4. ANOVAs comparing cone number by transect for each of four years.

	Transect					
No. Years Ranked	0	2	5	7	8	9
Best	1	1			1	
Moderate	2	2	2	1	1	1
Worst			1	2	1	1

Table 5. Relative rankings among transects on cone number over four years (2008 showed no significant differences among transects).

We measured root crown diameter and computed tree density in 2004 on each transect except transect 9, which was done in 2005. Transects 0 and 2, the highest cone producers over the four years, had significantly lower tree density than transects 7, 8, and 9, indicating that more densely packed trees consistently produce fewer cones. We previously found tree density to be the single most important variable determining cone production, with tree maturity providing additional influence (Johnson and Smith 2006). The five-year results further support the finding that tree density strongly influences cone production, presumably through competition among trees.

Correlations among Vigor, Cone Production, and Years

We added transect 9 after 2004, so we performed correlations of vigor among years per point over just four years, leaving out 2004 but including all transects. Vigor measurements among years at each transect point were highly correlated ($P<0.001$ for all possible comparisons). This result suggests that health within transects tended to remain consistent among years.

Average cone number per point, however, was not significantly correlated between 2005-2006, 2006-2008, or 2007-2008 but was correlated between 2005-2007, 2005-2008, and

2006-2007 (Table 6). Two of three significant correlations among years were between non-consecutive years, and two of three non-significant correlations were between consecutive years. These results suggest that trees in an area tend not to produce moderate or large numbers of cones in consecutive years. This is consistent with knowledge of pinyon mast behavior and is not surprising, given the energy and environmental requirements necessary for a cone crop. The two exceptions probably occurred because of the cone crop in 2006. The absence of a correlation between 2006 and 2008 is a consequence of essentially no cones being produced in 2008 and substantial numbers being produced in 2006. The most plausible explanation for a significant correlation between 2006 and 2007 cone production is that big cone producers in 2006 managed to produce a few cones in 2007, while trees that produced a few cones in 2006 produced none in 2007.

	2005	2006	2007
2006	-0.076		
2007	0.275*	0.352**	
2008	0.277*	0.02	-0.053

Table 6. Correlations among four years on average cone number per point. *P≤0.05, **P≤0.01

Cone number and vigor were significantly correlated in 2004, 2005, and 2008, but not in 2006 or 2007 (Table 7). This result may have occurred because in 2004 and 2005, only more vigorous trees produced many cones, thus creating the correlation. In contrast, 2006 was a better cone year in which many trees, not only the most vigorous, were able to produce cones. In 2008, only a very few of the healthiest trees produced cones, which created the correlation, but this does not explain the absence of a correlation in 2007, also a poor cone year.

		Vigor			
Cone	2004	2005	2006	2007	2008
2004	0.345**				
2005		0.247*			
2006			0.199		
2007				0.227	
2008					0.295*

Table 7. Correlations between cone number and vigor by year. *P≤0.05

Conclusions

Summary Results

The year 2008 marks the fifth year we have collected data on pinyon jay seasonal movements and nesting, along with pinyon condition and cone production. The NOP flock of pinyon jays is relatively small, ranging from just over 100 in the only fall with notable cone production, to around 20 pairs of breeders, to a few stragglers that stayed late at the end of the 2007 nesting season. Given that fall/winter flocks probably comprise members of more than one flock, the breeding flock is the best indicator of the status of the NOP population over time. Except for 2008, an unusually poor nesting season, the breeding flock has numbered around 18 pairs. Based on numbers of hatch-year birds observed and captured, 2005 and 2006 were marginally successful breeding years, 2007 was successful, and 2008 was extremely poor. As established in previous studies (Marzluff and Balda 1992, Ligon 1978), pinyon jays at NOP have produced significant numbers of fledglings only when a cone crop was produced the previous fall. Given that NOP has not seen a "bumper" crop in at least 12 years, prospects appear dim for this small flock of jays, and there is no reason to expect a turnaround. The *P. edulis* cone forecast for 2008 is good across southwestern Colorado and northern New Mexico but poor for southern New Mexico. Pinon [sic] Nuts.org (2008) reports that "Prospects for southern and mid-central New Mexico's crop are poor. Trees are loaded with cones but field examinations are showing only one or two nuts per cone."

The NOP flock has left the nesting grounds each year to roam or to winter elsewhere. The main frustration of this study has been our inability to discover where the birds go in the non-breeding season, and fall/winter movements will be a focus of future work. Regardless of where they go, the winter season poses potential threats to the flock, particularly if they roam widely or spend the winter without adequate food. Potential winter losses of hatch-year birds probably combine with poor reproductive success in year after year of poor cone crops, to limit the size of the NOP flock.

Our tree data support several conclusions. First, stand structure varies across our study area at NOP. Transects 0 and 2 are significantly less dense than transects 7, 8, and 9, and transect 5 is less dense than transects 7 and 8. Second, in the areas represented by our six transects, the least crowded trees and largest trees consistently produce the most cones. Third, tree vigor score is also related to cone production. Size being equal, trees in more open stands are more vigorous, and more vigorous trees produce more cones. In most years, these larger, healthier trees are the only ones producing cones. Mast events are reported to have occurred historically every five to eight years (Ligon 1978, Christensen and Whitham 1991, Floyd 2003). Thus, even allowing for variability around these averages, much of the woodland at NOP has apparently been less productive over the past several years than is or has historically been typical for pinyon-juniper woodlands.

Disturbances of Persistent Woodlands

The woodlands atop NOP fit the definition of "persistent woodlands" proposed by Romme et al. (2007). These are woodlands with relatively dense stands of large trees. Pinyon and/or juniper were historically and are currently the dominant species. In contrast to pinyon-juniper savannahs, persistent woodlands "do NOT [emphasis added] represent 20th century conversion of formerly non-woodland vegetation types to woodland" (Romme et al. 2007). Low-intensity surface fires had a very limited role in determining stand structure and dynamics of persistent woodlands. In sparse woodlands, fires typically burned individual trees but did not spread, while surface spread was more likely to occur in higher-density woodlands, where most or all trees were killed. These fires did not “kill from below.” Some persistent woodlands are stable for hundreds or thousands of years, and stand dynamics are driven more by climate, insect outbreaks, and disease than by fire. During the 20th century, gradual increase in canopy cover in most persistent woodlands has not been due primarily to fire exclusion but likely to livestock grazing or favorable climatic conditions (Romme et al. 2007).

Climate change is one hypothesis that should be considered for the recently low productivity of pines and jays at NOP. The effect of climate on flowering, seed set, and germination in pinyon is largely unexplored, as is the long-term effect of mast production on stand structure (Betancourt et al. 1993). However, it is clear that weather could potentially influence pinyon cone production over three growing seasons. Winter buds containing cone primordia form between August and October, go dormant over winter, and resume growth the next May. Cones become visible and pollination occurs in late May-early June. Cones remain small until the following (third) growing season, when cones enlarge, turn green, and later ripen in September. Cones open and seeds disperse in early fall, ~2.5 years and three growing seasons after they are initiated (Betancourt et al. 1993).

Forcella (1981) compared 10-year cone production from five Colorado pinyon (*P. edulis*) sites in New Mexico with weather data from nearby US Weather Bureau stations. Mast production occurred when temperatures in late August and early September were about one standard deviation below the mean at the time of cone primordium initiation, a significant negative exponential relationship. Temperatures in this range are expected to occur 1.65 years out of 10, a frequency that corresponds roughly to the occurrence of pinyon bumper crops (Forcella 1979).

Zlotin and Parmenter (2007) found that pinyon, juniper, and oak showed decreased berry/seed production during an eight-year drought period. The effect was most pronounced for pinyon, which showed sharp decreases in both cone production and in the number of filled seeds within cones. They found no relationship between cone production and current-year or previous-year monsoon precipitation or previous-year non-monsoon precipitation. However, entire growth-year precipitation was associated with pinyon cone production (r=0.57). They also suggest that dry, warm, windy conditions in the last week of May and first week of June facilitate pollination of generative buds and contribute to mast production two years later. Given adequate seed production and dispersal, reproductive success may ultimately depend on conditions for seedling establishment during the fourth growing season after cone initiation (Betancourt et al. 1993).

Climate change models suggest that average temperatures worldwide will increase by as much as 3.5° C, precipitation will become highly variable, temperature extremes will increase, and severe weather will become more frequent (Romme et al. 2003, Meehl et al. 2005). The earth’s temperature was only about 4° C *cooler* during the last ice age, when today’s deserts were covered in pinyon-juniper woodlands. Even the much smaller climate changes that occurred in the drought of the 1950s have been shown to dramatically increase pinyon mortality and decrease mast production. The chronology of cone development leaves the pinyon tree vulnerable to climate change at multiple stages. These few studies suggest that high fall temperatures; cool, wet springs; and overall dry years could all negatively impact pinyon cone production at various times during development. Recruitment from a single year's reproductive effort could potentially be strongly affected by weather in multiple seasons of a potential seedling's first four years.

If average global temperatures rise by a few degrees in the next decades, pinyon-juniper woodlands will likely be replaced by more drought-tolerant species that grow in lower-elevation shrublands in New Mexico, Arizona, and Utah. Many ancient pinyon-juniper woodlands will likely disappear (Romme et al. 2003). Wildfire frequency and severity will also increase, further impacting fire-intolerant pinyon-juniper woodlands. Unlike the transition away from glacial climate, which occurred over thousands of years, current climate change is occurring over decades or even less. Species that are habitat generalists with short generation times and the ability to survive in disturbed habitats are best adapted to rapid climate change. But many organisms of the pinyon-juniper woodland, especially its corvid seed dispersers, have long generation times and highly specialized habitat needs. These species will likely be greatly challenged by climate change. This is especially true for the pinyon jay, whose long-term population viability is utterly dependent on regular pinyon mast crops.

Management Implications

Although pinyon jays are known to inhabit pinyon-juniper savannahs, juniper savannahs, and even ponderosa pine forest types, persistent woodlands are their most suitable habitat because of the large, mast-producing pinyon trees with which they have co-evolved and on which their population viability depends. The size and timing of cone crops have clear potential to impact the seemingly fragile pinyon jay population at NOP. As the jay population decreases, the jays will become unable to provide seed dispersal. We recommend that management of persistent pinyon-juniper woodlands such as those in the Oscuras consider the importance of maintaining and nurturing old-growth pinyon trees. The value of these trees lies in their necessity to the wildlife that perform essential ecosystem services for the woodland, as well as in production of succeeding generations of pinyon trees. Not only pinyon jays, but other species of concern such as the Oscura Mountains Colorado chipmunk (*Neotamias quadrivittatus oscuraensis*) are likely impacted by reduced pinyon seed productivity. Populations of several birds that occur at NOP such as mountain chickadee (*Poecile gambeli*), juniper titmouse (*Baeolophus inornatus*), and western scrub jay (*Aphelocoma californica*) have been identified as declining (Sauer et al. 2004). Management for old growth pinyon trees is critical for maintaining natural, healthy woodlands supportive of integral wildlife in this ecosystem. If changes in precipitation and temperature regimes due to global warming continue to impact tree health, thinning to benefit the oldest, largest trees, which produce the most seeds, might be useful. However, before any such programs are initiated, the self-thinning that naturally occurs in pinyon stands under stress should be better understood. Long-term data are necessary to understand the impact of climate change on the health, productivity, and resilience of this and other pinyon-juniper woodlands.

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