Long-term declines in the Pinyon Jay and management implications for piñon–juniper woodlands

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Abstract: The Pinyon Jay (*Gymnorhinus cyanocephalus*) is closely associated with piñon–juniper woodlands in the Intermountain West and Southwest regions of the United States. It is of conservation concern, given it is one of the landbirds declining the fastest and most persistently in these regions, at an average rate of –3.6% from 1968 to 2015, according to the Breeding Bird Survey. Despite the population's falling by >50% over this period, the Pinyon Jay has not been widely studied, and little is known about the factors responsible for its diminishing numbers. Although the Pinyon Jay's rate of decline exceeds that of the Greater Sage-Grouse (*Centrocercus urophasianus)*—a species targeted for significant conservation efforts—no comprehensive effort designed to benefit this jay has been implemented. Current management in Great Basin piñon–juniper woodlands includes removal of trees to create or protect shrublands for the benefit of sage-grouse and other sagebrush-associated wildlife, and southwestern piñon–juniper woodlands are being thinned for fuels reduction or management of other wildlife. The effect of these treatments on the Pinyon Jay and other piñon–juniper birds, however, has been little studied. Thus further research is needed to clarify the causes of the jay's decline, develop habitat models for this and other piñon–juniper species, and devise approaches for management of piñon–juniper woodland that balance the interests of the Pinyon Jay and other species of concern, including the Greater Sage-Grouse.

Keywords: climate change, ecosystem management, fuel treatment, Greater Sage-Grouse, vegetation management, woodland health

The Pinyon Jay (*Gymnorhinus cyanocephalus*) is a highly social corvid widely known for its mutualistic relationship with piñon pines (Ligon 1978), most notably the single-leaf piñon (*Pinus monophylla*) and two-needle piñon or Colorado piñon (*P. edulis*). The Pinyon Jay has evolved to harvest piñon nuts efficiently, thus benefitting from a nutritious resource while also effectively dispersing and "planting" seeds as a by-product of caching them (Balda 2002). The bulk of the Pinyon Jay's distribution lies in the southern half of the Intermountain West region, extending into the Southwest, roughly corresponding with the extent of piñon–juniper woodland. The species is most abundant in eastern Nevada and west-central New Mexico (Sauer et al. 2017). Much is known about the Pinyon Jay's social organization (Marzluff and Balda 1992), caching behaviors and spatial memory (Balda et al. 1997), general biology (Balda 2002), mate choice (Johnson 1988a, b), and mutualism with piñons (Ligon 1978). This information, however, is derived almost exclusively from the southern portion of the Pinyon Jay's range, leaving its broader patterns of habitat and landscape use largely unexplored (Balda 2002). This lack of information exists in part because distances between Pinyon Jay flocks tend to be large, rendering the species less tractable for field study than songbirds that are more evenly and predictably distributed. Thus our understanding of the Pinyon Jay's habitat use is poor for such a widely distributed and easily seen species.

In addition to its unusual ecological niche and distinctive social structure, the Pinyon Jay is also notable in having experienced a steeper and more sustained population decline than any other songbird associated with piñon–juniper woodland (Sauer et al. 2017). Indeed, its sustained rate of decline during the period of analysis from 1968 to 2015 exceeds that of the Greater Sage-Grouse (*Centrocercus urophasianus*) (Connelly et al. 2004, Sauer et al. 2017), which is a species

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of major conservation concern and action in the same region (USFWS 2016). Furthermore, it exceeds that of every sagebrush-associated songbird (Sauer et al. 2017). Despite its persistent and pronounced decline, however, the Pinyon Jay has not received any regional conservation action or focused conservation planning. In part, this inaction may be explained by a dearth of information about the causes of the decline.

Current management of piñon–juniper woodlands is driven by a long-established interest in providing for grazing of livestock, mitigating fire risk, and more recently, creating sagebrush habitat for sage-grouse conservation (Miller et al. 2008, Baruch-Mordo et al. 2013). Where piñon–juniper woodland mixes with sagebrush, the predominant management is the removal of trees from selected areas, most typically along the woodland's lower margin where it abuts or intergrades with sagebrush shrubland. In piñon–juniper woodlands lacking sagebrush, thinning for fuels reduction (Huffman et al. 2009), ecohydrologic condition (Jacobs 2015), or management for other wildlife such as the mule deer (*Odocoileus hemionus*; Kramer et al. 2015) is becoming common (Bombaci and Pejchar 2016). Existing protocols and paradigms for managing piñon–juniper woodland give little or no consideration to possible effects on the Pinyon Jay or wildlife associated with that habitat in general (see Bombaci and Pejchar 2016 for review of effects on wildlife).

Here we highlight the pronounced, extended decline experienced by the Pinyon Jay across most of its range, discuss potential causes for the decline, consider current practices for management of piñon–juniper woodland and their rationale, and highlight the urgency of further investigating the causes of the Pinyon Jay's decline. We suggest that management agencies reevaluate vegetation management that may inadvertently affect sensitive obligate species of piñon–juniper woodland and sagebrush–woodland ecosystems such as the Pinyon Jay.

Pinyon Jay Status and Trends

The Pinyon Jay was considered to be "common" in Nevada in the early 1900s (Linsdale 1936). Bailey (1928:500) wrote that in New Mexico, "Vast flocks watered all day long, September 30–October 2, at a small watering tank a few miles north of the Ruins of Gran Quivera. They were without doubt the most numerous of any birds inhabiting the timbered parts of the Mesa Jumanes region," and "at Lathrop Spring literally thousands must have come to drink … from 2 p.m. to 9 a.m." Although it is difficult to draw rigorous comparisons on the basis of such qualitative descriptions, our review of data from the North American Breeding Bird Survey (BBS; Sauer et al. 2017), the Christmas Bird Count (netapp.audubon.org/cbcobservation/), and the eBird program (www.eBird.org) suggests that very large flocks (arbitrarily defined as >200 individuals) are becoming infrequent.

BBS data for the Pinyon Jay in the Western BBS Region show a large, statistically significant long-term decline (–3.6% per year from 1968 to 2015) and a large (–2.7% per year) but nonsignificant decline from 2005 to 2015 (Table 1, Figure 1). This decline applies across most of the Pinyon Jay's range, most notably in the areas where the species' abundance is greatest, such as Nevada's Great Basin and west-central New Mexico (Figures 2A, B). No BBS region shows a significant positive trend (Sauer et al. 2017).

According to BBS data, the only landbirds whose trend in the Western BBS Region from 1968 to 2015 was more negative than the Pinyon Jay are (in order of descending magnitude) the Black-billed Cuckoo (*Coccyzus erythropthalmus*), Black Swift (*Cypseloides niger*), Brown Thrasher (*Toxostoma rufum*), Rusty Blackbird (*Euphagus carolinus*), Eastern Phoebe (*Sayornis phoebe*), Yellow-bellied Sapsucker (*Sphyrapicus varius*), Bendire's Thrasher (*Toxostoma bendirei*), Allen's Hummingbird (*Selasphorus sasin*), Purple Martin (*Progne subis*), Pine Siskin (*Spinus pinus*), and Evening Grosbeak (*Coccothraustes vespertinus*). Of these, the cuckoo, Brown Thrasher, blackbird,

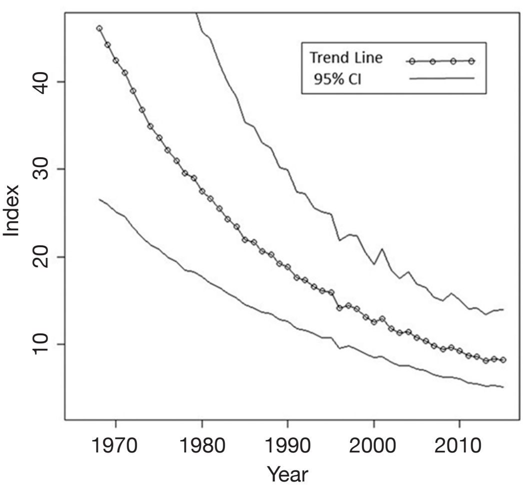

Figure 1. Declining trend and 95% credible intervals (CIs) of the Pinyon Jay within the Western BBS Region, 1968–2015 (from Sauer et al. 2017). The *y*-axis is an index of observed abundance on BBS routes.

Table 1. Comparison of average annual change estimated for songbirds commonly encountered in piñon–juniper woodlands, and for selected birds of sagebrush shrublands, in the West on the basis of the Breeding Bird Survey over two periods.[a]

Species	1968–2015 % annual change	1968–2015 Lower and upper 95% C.I.	2005–2015 % annual change	2005–2015 Lower and upper 95% C.I.	Regional credibility rank[b]
Pinyon Jay[c] *Gymnorhinus cyanocephalus*	**–3.59**	–4.93, –2.24	–2.70	–4.94, 0.39	High
Greater Sage-Grouse[d] *Centrocercus urophasianus*	–1.55	–4.99, 1.00	–0.89	–6.95, 4.86	High
Virginia's Warbler[c] *Oreothylypis virginiae*	**–1.36**	–2.39, –0.38	–1.35	–3.20, 0.36	High
Mountain Chickadee[c] *Poecile gambeli*	**–1.34**	–1.85, –0.87	–0.88	–1.91, 0.22	High
Sage Thrasher[d] *Oreoscoptes montanus*	**–1.21**	–1.95, –0.48	–1.26	–2.97, 0.54	High
Scott's Oriole[c] *Icterus parisorum*	**–0.92**	–1.77, –0.13	–0.84	–2.65, 0.99	High
Bushtit[c] *Psaltriparus minimus*	–0.62	–1.72, 0.37	–0.27	–3.20, 2.70	High
Brewer's Sparrow[d] *Spizella breweri*	–0.61	–1.35, 0.13	**–4.28**	–7.41, –1.60	High
Bewick's Wren[c] *Thryomanes bewickii*	–0.43	–1.05, 0.13	–0.51	–1.93, 0.92	High
Western Scrub-Jay[c, e] *Aphelocoma californica*	–0.14	–0.59, 0.29	0.39	–0.72, 1.55	High
Sage Sparrow[d, f] *Artemisiospiza belli*	–0.10	–1.27, 1.13	0.08	–2.30, 2.52	High
Juniper Titmouse[c] *Baeolophus ridgwayi*	0.29	–1.13, 1.57	1.79	–0.70, 5.08	Medium
Townsend's Solitaire[c] *Myadestes townsendi*	0.31	–1.06, 0.96	0.85	–0.62, 2.28	Medium
Western Bluebird[c] *Sialia mexicana*	0.70	–0.27, 1.43	1.25	–0.16, 2.90	High
Gray Vireo[c] *Vireo vicinior*	2.10	–0.28, 4.24	5.07	1.88, 8.47	Medium
Gray Flycatcher[c] *Empidonax wrightii*	2.43	1.45, 3.51	3.43	1.93, 6.62	High
Blue-gray Gnatcatcher[c] *Polioptila caerulea*	2.69	1.87, 3.46	2.44	0.60, 4.40	Medium

[a]Data from Sauer et al. 2017 for the Western BBS Region. Species are listed from most negative to most positive values for the longer-term trend. Values in boldface type are statistically significant (see Sauer et al. 2017).

[b]"High" rankings indicate data with at least 14 samples in the long term, with at least moderate abundance on BBS routes. "Medium" rankings indicate data with a deficiency such as low abundance, small sample size, or low precision. See www.mbr-pwrc.usgs.gov/bbs/credhm09.html for a full description of criteria for credibility ranking.

[c]Species commonly encountered in piñon-juniper woodland.

[d]Species primarily associated with sagebrush shrubland.

[e]Trend calculated before the splitting of the Western Scrub-Jay (*Aphelocoma californica*) into the California Scrub-Jay (*A. californica*) and Woodhouse's Scrub-Jay (*A. woodhouseii*).

[e]Trend calculated before the splitting of the Sage Sparrow (*Artemisiospiza belli*) into the Sagebrush Sparrow *(A. nevadensis)* and Bell's Sparrow (*A. belli*), and designated as "Sage/Bells Sparrow (lumped)" in BBS results.

phoebe, sapsucker, and martin have distributions that extend only marginally into the Western BBS Region. The swift and Bendire's Thrasher have relatively small or spotty distributions within the region. Allen's Hummingbird has taken to urban habitat, in which it is rapidly increasing (Clark 2017) and not adequately sampled by the BBS. Only the siskin and grosbeak are as broadly distributed in the region's natural habitats as the Pinyon Jay. Both of these species' long-term annual trends (–3.7%) are comparable to the Pinyon Jay's (–3.6%), but their more recent trends

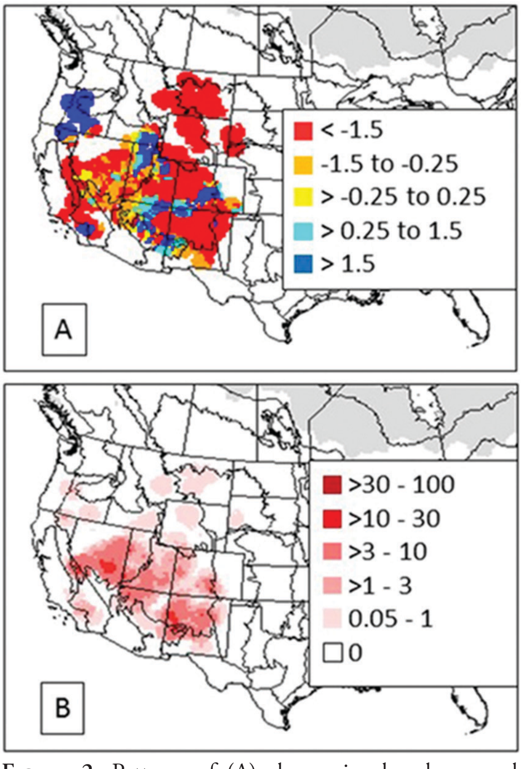

Figure 2. Patterns of (A) change in abundance and (B) relative abundance of the Pinyon Jay in the western United States (maps from Sauer et al. 2017).

for 2005–2015 are slightly positive, in contrast to the Pinyon Jay's recent trend of –2.7% per year (Sauer et al. 2017). We conclude that over the last half-century, the Pinyon Jay may have experienced a larger and more persistent decline than any other broadly distributed landbird in the interior West.

Using BBS data, Rich et al. (2004) estimated a population of 4.1 million Pinyon Jays rangewide. Other data from Nevada, however, suggest that the BBS estimate from that state may be too high (GBBO 2010). Given the continuing rate of decline, the BBS-derived population size suggests that the total Pinyon Jay population may reach a threshold of viability in the coming decades, particularly given the species' narrow food selection (Ligon 1978) and complex social structure (Marzluff and Balda 1992). Reflecting the decline, the Pinyon Jay is designated a "watchlist" species under Partners in Flight's North American Landbird Conservation Plan (Rich et al. 2004), a "bird of conservation concern" by the U.S. Fish and Wildlife Service (USFWS 2008), and a "sensitive species" in Nevada, Idaho, Arizona, and New Mexico by the Bureau of Land Management (www.blm.gov; search "sensitive species").

Changes Across the Piñon–Juniper Landscape

Piñon–juniper woodlands cover 40 million hectares across the American West (Romme et al. 2009), a footprint many times larger than that inferred in the mid-19th century (Miller et al. 2008, Romme et al. 2009). Comparisons of photographs and other documentation suggest that piñon–juniper woodlands not only expanded over the last 150 years but also underwent a transition in age structure. Over much of the woodland's range, the proportion of mature or senescent stands with a largely closed canopy increased substantially at the expense of younger, more open stands (Miller and Wigand 1994, Miller et al. 2008, Romme et al. 2009). The cause of these changes in the extent and structure of piñon–juniper woodlands is thought to have involved a synergistic interplay between changing fire regimes, land-use practices, and climate (Miller and Wigand 1994, Miller and Tausch 2001, Romme et al. 2009).

Although most current management of piñon–juniper woodlands has specific intended outcomes, it is also motivated and justified to some extent by a general desire to return the landscape to a more "original" condition. Identifying an appropriate archetype for this natural condition, however, has proven difficult with regard to piñon–juniper woodlands. In particular, there is uncertainty as to whether "early settlement conditions" are representative of "natural condition" (Miller and Wigand 1994, Belsky 1996, Miller et al. 2008, Romme et al. 2009). For example, in the Great Basin, some evidence suggests that expansion and infilling of piñon–juniper in the 20th century resulted, in part, from the reestablishment of woodlands previously cleared for timber used in mines and to support livestock grazing and agriculture (Lanner 1981). This uncertainty has led to an extended debate between those who consider all piñon–juniper expansion problematic and those who are more inclined to interpret it as a characteristic ecosystem dynamic (e.g., Belsky 1996, Baruch-Mordo 2013). Additional research into this topic is badly needed (Romme et al. 2009).

More recent dynamics that have been documented in the Southwest include climate-related mortality of piñons (Breshears et al. 2005, Allen-Reid et al. 2008), significant reductions in canopy cover (Clifford et al. 2011), and declines in production of piñon cones (Redmond et al. 2012). Models predict massive, widespread mortality of piñons and junipers across the southwestern United States by 2100 (McDowell et al. 2016), highlighting the regional challenges to managing piñon–juniper landscapes across the jay's entire range.

Hypotheses for Declines

Given that Pinyon Jay populations have declined during a period when the species' preferred habitat of piñon–juniper woodland has expanded through much of its range, it appears that changes in woodland extent are not driving the decline in jay numbers. More likely causes include changes in habitat structure and quality, landscape-scale structural changes, and pine productivity, some of which are likely mediated by changes in climate.

Structurally, piñon–juniper woodlands of the Great Basin region have a greater proportion of mature or senescent stands, greater canopy cover, and less of an understory of shrubs than was the case a century or more ago (Miller et al. 2008, Romme et al. 2009). If in this region Pinyon Jays have a strong affinity for more open stands with a shrub understory for foraging and caching, and/or for a diverse mix of woodland age classes, it is possible that this shift in woodland structure has contributed to their decline. Similarly, climate-mediated declines in trees' health and increases in their mortality, which have been documented in New Mexico (Johnson et al. 2017), could reduce the availability of suitable nest sites and depress nest success.

At the landscape scale, today's Great Basin is characterized by larger woodland patches and less of a woodland–shrubland mosaic than was found 100–150 years ago (Romme et al. 2009). Although Pinyon Jays are most closely associated with woodlands, they use shrublands for seed caching and foraging (Balda 2002, GBBO 2010) and appear to be concentrated in areas where open shrubland is nearby (GBBO unpubl. data). Therefore, it is possible that changing landscape structure has played a role in the Pinyon Jay's decline in the Great Basin. In contrast, infill and expansion of woodlands are not widespread in western Colorado or New Mexico (Romme et al. 2009). Data on the Pinyon Jay's habitat use and population dynamics in landscapes with different tree densities are needed in both regions for the role of habitat structure in the jay's decline to be fully understood.

Changes in climate (Zlotin and Parmenter 2008) or in a woodland's structure or age profile could have direct or indirect effects on piñons' productivity (Redmond et al. 2012). Considerable evidence suggests that the productivity of piñon mast affects the Pinyon Jay's nest success and population viability (Ligon 1978, Marzluff and Balda 1992, Balda 2002); decreases in the size and frequency of piñon crops could therefore contribute to the species' decline. Furthermore, although climate change likely affects Pinyon Jays indirectly, primarily through its effects on vegetation, it may also have some direct effects, such as decreased availability of drinking water and increased thermal stress. Recent climate-vulnerability models for the Pinyon Jay project a substantial range reduction this century. The National Audubon Society (2015) projected a range reduction of 24% in summer and 37% in winter by 2080, and Hatten et al. (2016) projected a 31% decrease in the jay's overall range by 2099.

Management Considerations

Until the hypotheses discussed above are explored more fully, it is premature to propose detailed revisions to woodland-management guidelines to better conserve Pinyon Jays. However, we recommend that the jay be surveyed routinely so removal of habitat actively used by Pinyon Jay flocks can be avoided, a precaution not currently taken. On the basis of our field experience, Pinyon Jays appear to occupy a relatively small proportion of the woodland extent in most areas, leaving extensive acreage still available for reduction of piñon even if areas the jay occupies are excluded. As the causes of the Pinyon Jay's decline become better understood, different approaches to management may be needed to mitigate that decline where management of the Greater Sage-Grouse is a significant concern than in the southern part of the Pinyon Jay's range where the sage-grouse is absent.

In the Great Basin, criteria for selecting the areas and techniques for woodland removal should be broadened to include consideration of the Pinyon Jay and, more generally, of how to optimize overall ecosystem benefits. We suspect that existing guidelines for vegetation treatment could be modified to reduce the loss of, or perhaps create, high-quality Pinyon Jay habitat while still restoring open shrubland to benefit the sage-grouse and other sagebrush species. We concur with Crawford et al. (2004), who suggested that sage-grouse management be reviewed and refined to prevent unintended effects on the ecosystem. But we suggest further that the review be extended beyond sagebrush landscapes, and that the entire sagebrush–woodland complex be considered as an interconnected landscape. Because effects of woodland treatment on multiple species are closely tied to the treatment's type and extent (Bombaci and Pejchar 2016), such a review offers an excellent opportunity to create broad ecosystem benefits within the current imperative to manage a single species.

In the southern part of the Pinyon Jay's range, complete removal of a stand has been confirmed to disfavor multiple species, but thinning that leaves some trees appears to be less harmful (Bombaci and Pejchar 2016). In this region, trees' health and size appear to be important considerations deserving of further investigation. For example, modeling of habitat use at the scale of the nest suggests that in New Mexico Pinyon Jays place their nests in larger-than-average trees (Johnson et al. 2014, 2015). Several other birds restricted to piñon–juniper in this region are associated with high coverage of junipers and the presence of piñon trees (Pavlacky and Anderson 2001). Hence preferential thinning of large trees could affect the quality of nest habitat for the Pinyon Jay and other birds. Also in this region, large piñons and other pine trees produce more seeds than do smaller trees (Johnson and Smith 2006, Calama and Montero 2007), and widespread loss of cone-producing trees may be detrimental to Pinyon Jays and other seed-eating species. Conversely, under some circumstances, tree mortality may be positively related to tree density (Greenwood and Weisberg 2008), suggesting that carefully targeted thinning may contribute to the woodland's health, productivity, or resilience in the face of climate change. More research is necessary to test that hypothesis, and to identify region-specific criteria that optimize specific outcomes, including improving the quality of Pinyon Jay habitat.

Conclusions

The management of piñon–juniper woodlands is currently driven by the imperative to protect and create sagebrush shrubland to benefit the Greater Sage-Grouse, a mandate to reduce wildfire risk (especially at the wildland–urban interface), management that favors the livestock industry, and efforts to restore landscapes to a previous condition. Treatments to accomplish these goals currently account for a significant proportion of the effort and resources devoted to managing upland vegetation in the Intermountain West. Considerations of how best to manage the piñon–juniper ecosystem for the Pinyon Jay and other woodland-associated wildlife are currently secondary. Although the conservation attention given to the Greater Sage-Grouse is clearly warranted (Connelly et al. 2004, USFWS 2016), we emphasize that management of piñon–juniper woodland may also affect the more rapidly declining Pinyon Jay, as well as other piñon–juniper birds, in ways that are currently not well understood. Critical research priorities include assessing the causes of the Pinyon Jay's decline; understanding the changes in the distribution, structure, and productivity of piñon–juniper woodlands, leading to a better ability to distinguish "natural" ecosystem dynamics from problematic "departure" conditions caused by ecosystem perturbations; documenting the Pinyon Jay's habitat needs, including availability of food and water; and experimenting with various practices for managing piñon–juniper woodland, followed by monitoring of the habitat's wildlife. As this knowledge accrues, it is imperative that it be incorporated into existing criteria for managing piñon–juniper woodland to help prevent further declines in Pinyon Jay populations.

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