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Avian communities are decreasing with piñon pine mortality in the southwest☆

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ABSTRACT

An increase in tree mortality is expected to occur worldwide due to climate-induced drought and increasing temperatures. The 2000–2002 drought in the southwestern United States was one of the most severe in the last 50 years. It led to a severe outbreak of bark beetles that resulted in high mortality of piñon pine (*Pinus edulis*) trees on the Pajarito Plateau in Northern New Mexico beginning in 2002. Many areas in piñon-juniper habitat had entire stands of piñon die leaving only juniper (*Juniperus* spp.). Point count surveys were used to determine avian responses to tree mortality from 2003 to 2013. We also tested whether birds responded differently in sites that were mechanically thinned in 2002 and 2003 on Los Alamos National Laboratory property compared to sites not thinned. Junipers and dead piñon pines due to bark beetles and drought were removed on thinned sites. Richness, diversity, and abundance steadily declined after 2003. There was a 73% decrease in abundance and a 45% decrease in richness from 2003 to 2013. There was no difference in community composition between thinned and unthinned sites. Bird abundance and species richness declined faster in thinned sites than unthinned sites, but diversity decreased similarly in both treatments. Several species disappeared over time and some declined substantially. Our results suggest a delay in bird responses to tree mortality on the Pajarito Plateau. Piñon mortality may be a significant threat to bird communities in the southwestern U.S., and tree thinning to control fire may be an added risk.

1. Introduction

Tree mortality is predicted to increase worldwide from a combination of drought and increasing temperatures driven by climate change (Allen et al., 2010; McDowell et al., 2016). The drought of 2000–2002 in the southwestern United States was one of the most severe in the last 50 years. Precipitation for this region was 25% below average during 2000 and 2001 and 65% below average through the summer months in 2002. In addition, large-scale bark beetle (Coleoptera, Curculionidae) outbreaks during the same time period impacted most of the southwest region. The combined effects of prolonged drought, bark beetles, and fire resulted in tens of millions of dead trees over thousands of square miles in Arizona, New Mexico, Colorado, and Utah (Van Mantgem et al., 2009; Allen et al., 2010). Highest mortality levels were seen in ponderosa pine (*Pinus ponderosa*), Douglas fir (*Pseudotsuga menziesii*), and piñon pine (*P. edulis*) trees.

Regional droughts and increasing temperatures due to climate change are among the most significant factors responsible for tree mortality in the southwest. These processes leave substantial and easily recognizable impacts on ecosystem processes (Allen and Breshears, 1998). Drought and increasing temperatures are linked to bark beetle outbreaks and subsequent tree mortality (McHugh et al., 2003; Rouault et al., 2006; Raffa et al., 2008; Gaylord et al., 2013; Weed et al., 2013). Bark beetles in western North America are known to cause high mortality over large areas following drought events (Raffa et al., 2008). The piñon bark beetle (*Ips confusus*) feeds primarily on phloem tissue of the inner bark of piñon pine trees. This has the same effect as girdling the tree (i.e. peeling off the bark), which acts as a tourniquet cutting off the flow of nutrients. During prolonged drought stress, trees become more susceptible to bark beetle infestation because they cannot successfully defend themselves (Raffa et al., 2008; Marini et al., 2012; Weed et al., 2013).

Piñon-juniper is the third largest vegetation type in the continental U.S. (West, 1984). Predictions are that there will be almost complete loss of conifers in the southwest by the year 2100 (McDowell and Allen, 2015; McDowell et al., 2016). Many areas in piñon-juniper habitat in

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the southwest have already had entire stands of piñon die leaving only oneseed juniper trees (*Juniperus monosperma*). It is estimated that tree mortality will continue due to the combination of increasing temperatures, prolonged droughts, and bark beetle outbreaks (Raffa et al., 2008; Adams et al., 2009; Plaut et al., 2013; Williams et al., 2013; McDowell et al., 2016). Little is known about how wildlife is affected and will be affected following large-scale mortality in the southwest. A recent study showed Pinyon Jays (*Gymnorhinus cyanocephalus*) have a lower probability of nesting in areas with low piñon pine vigor than in areas where vigor is high (Johnson et al., 2017). Although just one species, these data highlight the need to understand the consequences of tree mortality for wildlife management and conservation.

During drought and large beetle outbreaks, changes in vegetation are likely to have cascading effects on avian communities by reducing available habitat and food availability (Martin, 1987; Kelly, 1993; Martin et al., 2006). The abundance and richness of birds in temperate forests are known to change in response to bark beetle outbreaks (Yeager and Riordan, 1953; Bull, 1983; Stone, 1995; Matsuoka et al., 2001; Martin et al., 2006). For example, after an initial mountain pine beetle (*Dendroctonus ponderosae*) attack in Canada, cavity-nesting birds increased in abundance due to an increase in available nesting opportunities (Martin et al., 2006). However, as damage from beetles progressed, some species began to decline such as nuthatches and chickadees. It is still unclear how bird communities change following large-scale tree mortality and if there are substantial lags in species responses. Bird communities are of particular concern regarding piñon pine mortality in the southwest because these communities are understudied and bird communities can be an early indicator of environmental change and its effects on ecological communities (Roberge and Angelstam, 2006). Additionally, the percent die-off of trees in the southwest is predominately piñon pine, which is an important component of bird habitats throughout the region (Sedgwick, 1987).

In addition to the effects of drought-induced environmental change, wildlife populations are influenced by drought directly (Singer et al., 1989) and indirectly (Fair and Whitaker, 2008; Shaman et al., 2003). For example, in the course of a six-year study of cell-mediated immune function of 3 common cavity-nesting bird species in northern New Mexico, there was a dramatic decrease in immune responsiveness of developing nestlings associated with unusually dry conditions (Fair and Whitaker, 2008). Therefore, it is critical we investigate the effects of environmental disturbance on avian habitats and populations to better estimate, and possibly mitigate, long-term consequences.

In May 2000, the Jemez Mountains and some of the Pajarito Plateau in Northern New Mexico experienced a massive fire called the Cerro Grande fire. In order to decrease the risk of catastrophic fire in the future, Los Alamos National Laboratory (LANL), located on the Pajarito Plateau, began a tree-thinning project in January 2002 in which trees were removed on laboratory property. Trees were not thinned on Bandelier National Monument property, also located on the plateau. Tree thinning was completed on approximately 2800 ha of LANL property at the start of this study and included both ponderosa pine and piñon-juniper habitats. In piñon-juniper habitats, predominantly live juniper trees were removed mechanically, and dead piñon pines were removed from sites to decrease fuel loads. Trees that died after the thinning activities in 2002 were not removed from the landscape. Previous studies suggest tree thinning does not severely impact wildlife communities (Bombaci and Pejchar, 2016; Holmes et al., 2017; Knick et al., 2017). In a recent review, Bombaci and Pejchar (2016) found little evidence to suggest thinning piñon-juniper woodlands positively or negatively affects bird communities. Thinning piñon-juniper woodlands was shown to benefit ground and shrub nesting species because of increased shrub cover (Holmes et al., 2017). However, these positive effects may be small and the influence on overall bird communities may be negligible (Knick et al., 2017). These negligible effects may be the result of having a mix of shrubs and interspersed trees instead of complete removal of trees from the landscape (Bombaci and Pejchar, 2016).

In addition to thinning activities, there has been extensive tree mortality since 2002. The mortality caused by drought and bark beetles left a mosaic of live and dead trees in our study areas in 2003. High mortality and different thinning treatments offered an opportunity to determine the effects of both piñon pine mortality and thinning activities on breeding birds. Quality of breeding habitat for migratory birds can be estimated by determining avian use of these areas during the breeding season. In cases of extreme and rapid environmental change, avian use can give insight into how species are affected by comparing communities over time. Here, our objectives were to determine avian community responses to tree thinning and tree mortality over time using point counts. We hypothesized that thinned and unthinned areas would have similar breeding bird use during the summer months. We also hypothesized that piñon pine mortality would result in declines in avian communities due to the loss of key habitat components and drastic changes to habitat structure throughout the Pajarito Plateau.

2. Methods

2.1. Study sites

This study was completed in piñon-juniper woodlands on the Pajarito Plateau in north-central New Mexico. Pine tree mortality began in this region during the summer of 2002 due to drought and resulting bark beetle infestation. We chose 5 general “locations”. We used areas on the Pajarito Plateau and not areas farther away to control for climate and other environmental variables. The 5 locations selected were named Frijoles, Gate 9, Ancho, Cañada, and Tsankawi (Fig. 1). These locations contained 2 paired “sites”, except Tsankawi, for a total of 9 separate sites. At each location, one site was thinned and one was unthinned. These sites were across the road from one another, except the Cañada sites (Fig. 1). However, the Cañada sites were located in the same watershed. Tsankawi was an unthinned site, but was not paired with a thinned site. All sites varied in tree mortality at the beginning of the study in 2003.

2.2. Vegetation measurements

At each site, we estimated tree mortality in 100 m diameter circles in summer 2003. The areas where the vegetation surveys were completed were the same as where the point counts were conducted (see below). Therefore, there were three vegetation surveys at each site. Inside each circle, the condition and species of each tree were recorded, including the number of live and dead piñon and juniper trees. These data were used to calculate percent dead piñon pine trees. If small saplings were present at a site, they were counted as live trees. However, this was very rare; these areas were mature forests with little regeneration. We also recorded juniper mistletoe (*Phoradendron juniperinum*) abundance in juniper trees. Approximately 12 months after the start of the study, all 9 sites underwent massive piñon mortality in a short time. Each site had mortality levels between 90 and 95% in summer 2004, so both treatments were very similar throughout the entire study period. Vegetation surveys were not completed again until summer 2013. Piñon mortality was estimated at all sites using the same methods and the same 100 m diameter plots.

2.3. Point count surveys

In our study locations, point counts for paired sites (thinned vs. unthinned) and Tsankawi (unthinned) were conducted from 2003 until 2013, excluding 2004. Point counts were completed during the breeding season of the first and second weeks of June every year. In total, we aimed to have 90 sampling points (10 years × 9 sites). Due to problems reaching some of the sites during some years, we ended up with 81 (49 unthinned, 32 thinned over 10 years). Bird surveys were