Forest Ecology and Management 455 (2020) 117694

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Black-backed woodpecker occupancy in burned and beetle-killed forests: Disturbance agent matters

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ARTICLE INFO

Keywords:
Picoides arcticus
Wildfire
Bark beetle
California
Occupancy
Drought
Habitat

ABSTRACT

In the western United States, the black-backed woodpecker (*Picoides arcticus*) is a "snag specialist", found predominantly in burned montane forests. While fire is a key disturbance agent in this system, recently, unprecedented large tracts of drought-stressed forest in the Sierra Nevada and Southern Cascades of California have succumbed to bark beetle outbreaks. Although this tree mortality could potentially be a boon for snag-dependent species, it is unclear whether the resulting snag forests provide sufficiently high-quality habitat for black-backed woodpeckers and other wildlife that are regionally associated with burned forests. We tested for differences in black-backed woodpecker occupancy between fire- and beetle-killed forests, and whether key environmental relationships driving woodpecker occupancy differed between stands affected by the two disturbance agents. Between 2016 and 2018, we surveyed for black-backed woodpeckers during 4448 surveys at 75 burned and 113 beetle-killed forest stands throughout the black-backed woodpecker's range in California, detecting at least one black-backed woodpecker on 448 surveys (16.2%) in burned forests and 115 surveys (6.8%) in beetle-killed forests. Controlling for a suite of environmental variables that can affect habitat quality, the odds of black-backed woodpeckers occurring in burned forests were predicted to be 12.6 times higher than in beetle-killed forest. Occupancy declined with time-since-disturbance in fire-killed but not beetle-killed forests, but occupancy increased similarly with snag density resulting from either disturbance agent. Across our broad study region, black-backed woodpeckers were more likely to occur in burned forests at higher latitudes and elevations; these patterns were even stronger in beetle-killed forests, where we found woodpeckers only at the more northerly and higher elevation sites. Our results demonstrate that for this disturbed-habitat specialist, disturbance agent matters; black-backed woodpeckers do not use habitat created by bark beetle outbreaks as readily as habitat created by fire. Given the likely increased magnitude and extent of bark beetle outbreaks in the future, further work is needed to assess the role of beetle-killed forests in longer-term population dynamics of black-backed woodpeckers beyond the first decade after disturbance, and to investigate whether these results can be generalized to other fire-associated wildlife species in the region.

1. Introduction

Black-backed woodpeckers in western North America associate strongly, though not exclusively (Fogg et al., 2014), with recently burned conifer forests (Hutto, 1995; Kotliar et al., 2002; Smucker et al., 2005). The birds feed primarily on the larvae of woodboring beetles (e.g., Buprestidae and Cerambycidae; Murphy and Lehnhausen, 1998; Powell, 2000; Villard and Beninger, 1993), which colonize recently burned forests in large numbers. Woodpecker population density in the western U.S. typically peaks within about five years after fire and then rapidly declines (Tingley et al., 2018), reflecting both concurrent declines in prey (Ray et al., 2019) and the lifespan of individual birds that colonized the burned area, or of offspring that they produced in the early postfire years (Siegel et al., 2015). In California, the southernmost extension of the species' range (Tremblay et al., 2016), the black-backed woodpecker's relatively small population and the species' association with burned forests that are often subjected to intensive postfire management has led to concerns about its conservation status (Siegel et al., 2018). The US Forest Service has designated black-backed woodpeckers a Management Indicator Species for snags in recently

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https://doi.org/10.1016/j.foreco.2019.117694
Received 20 August 2019; Received in revised form 9 October 2019; Accepted 13 October 2019
Available online 09 November 2019
0378-1127/

burned forest across ten National Forests in California, and explicitly analyzes effects to its habitat when planning post-fire management activities (Tarbill et al., 2018; Tingley et al., 2016).

Elsewhere in western North America, black-backed woodpeckers are also known to colonize forests with elevated tree mortality due to disturbance agents other than fire (Bonnot et al., 2008; Goggans et al., 1989; Rota et al., 2014a,b), especially outbreaks of native bark beetles (Coleoptera: Scolytinae). Compared to other parts of western North America, bark beetle outbreaks in California's forests have historically been comparatively limited in scope (Fettig et al., 2019; Stephens et al., 2018), rarely yielding the extensive tracts of snags preferred by black-backed woodpeckers (Tingley et al., 2014). However, severe drought and increasing temperatures during the past decade have stressed trees throughout the region, making California forests more susceptible to bark beetle outbreaks (Bentz et al., 2010; Marini et al., 2017; Williams et al., 2013), which have increased dramatically in severity and extent (Preisler et al., 2017; Young et al., 2017). Between 2012 and 2015, tree mortality in California increased by an order of magnitude – from tens to hundreds of dead trees per km^2 – with especially heavy mortality during 2015, concentrated at low latitudes and elevations (Asner et al., 2016; Young et al., 2017). The resulting large and numerous patches of forest with highly elevated tree mortality have been described as 'unparalleled' in the modern history of the region (Preisler et al., 2017), and thus provide a somewhat novel environment for local populations of disturbance-adapted wildlife species like the black-backed woodpecker.

Black-backed woodpeckers have sometimes been observed to forage on bark beetle larvae (Goggans et al., 1989; Lester, 1980), but these larvae are much smaller-bodied (typically < 6 mm long) than the woodpeckers' preferred diet of woodboring beetle larvae (up to 50 mm long; Powell, 2000). Even if bark beetles are not a preferred food item for black-backed woodpeckers, the beetles likely create habitat by killing or weakening trees and thus facilitating colonization by woodboring beetles. Unlike bark beetles, most woodborers are unable to attack otherwise healthy trees, and instead concentrate in dead or dying trees (Hanks, 1999). Some woodborer genera are able to find appropriate fire-damaged trees by sensing smoke or heat emanating from actively burning forest fires (Álvarez et al., 2015; Schmitz et al., 1997; Schütz et al., 1999). While recent evidence indicates that populations of smoke- or fire-sensing woodborers may be higher in burned forests than in forests affected by bark beetle outbreaks, other less specialized woodborers can also colonize beetle-killed forests in large numbers (Ray et al., 2019). It is unclear whether California's unburned forest stands that have been disturbed by bark beetle outbreak may provide sufficient food for black-backed woodpeckers, and if they do, whether populations in California have the behavioral plasticity to identify and colonize such areas in large numbers.

Differences in ecological effects of specific forest disturbance agents on opportunistic species are relatively poorly studied. In boreal and temperate forests, vastly more information is available about the ecological effects of fire than the effects of bark beetles (Thom and Seidl, 2016). Nevertheless, the existing data generally support contrasting effects of the two agents on ecosystem services, but a lack of clear differences in effects on overall biodiversity (Thom and Seidl, 2016). Systematic comparisons of the effects of fire versus bark beetles on particular forest taxa (rather than overall biodiversity) are generally rare, but in the Black Hills region of South Dakota, Rota et al. (2014b) found that post-disturbance growth rates of black-backed woodpecker populations were positive only in habitat created by summer wildfire. In their study region, black-backed woodpeckers in forest disturbed by mountain pine beetle (*Dentroctonus ponderosae*) outbreaks had negative population growth rates and larger home ranges than in early post-fire forests (Rota et al., 2014a,b).

We sought to compare black-backed woodpecker occupancy in California forests disturbed by different agents – fire versus bark beetle outbreak. Previous work has already demonstrated key patterns of black-backed woodpecker occupancy in burned forests of California (e.g., Saracco et al., 2011; Tingley et al., 2016, 2018). In this study, we sought to examine whether the birds were as likely to occur in beetle-killed forests and whether the key covariates that affect occupancy in burned forests – including time since fire, snag density, elevation, and latitude – also exhibit similar relationships to occupancy in beetle-killed forests. Snag density is a particularly key variable, as it represents a common metric for assessing the severity of disturbance across both disturbance types. Addressing these questions is necessary to predict population responses to disturbance, model suitable habitat across the ecoregion, and assess the effects of post-disturbance management such as logging on available habitat. Thus, our results will be directly relevant to management and conservation efforts for this species in the Sierra Nevada and Southern Cascade ecoregions, where large-scale bark beetle outbreaks are a relatively new phenomenon, leading to questions about the potential value of vast quantities of newly disturbed habitat to species like the black-backed woodpecker.

2. Methods

2.1. Study area and survey locations

We conducted surveys for black-backed woodpeckers as part of a long-term project to monitor the species' occupancy and population trends in montane forests of California. This ongoing study (Saracco et al., 2011; Tingley et al., 2018) began in 2009 and has primarily focused on surveying black-backed woodpeckers in National Forest System lands that burned between 1 and 10 years prior to the sampling year. Our study area comprised ten contiguous National Forest units within the Sierra Nevada and Southern Cascades ecoregions of California (Fig. 1), where we randomly selected 50 fires to visit each year that met our sampling criteria. Each year, we conducted single-visit surveys for black-backed woodpeckers at 5–24 survey sites (median = 20) in each of the 50 fire areas selected for survey that year. Within a fire, survey sites were spaced at least 250 m from one another.

Starting in 2016 and continuing through 2018, we additionally surveyed for black-backed woodpeckers in forests subject to non-fire tree mortality (Fig. 1). We used Forest Service Region 5 Aerial Detection Survey (ADS) data (https://www.fs.usda.gov/detail/r5/forest-grasslandhealth/?cid=fseprd506712) to identify forest stands with elevated tree mortality, presumably due to a combination of the recent drought (Young et al., 2017) and bark beetle outbreaks (hereafter 'beetle-killed' stands). Although we did not sample or identify bark beetles in these stands, other research (Ray et al. 2019) has indicated that abundant species include the fire engraver beetle (*Scolytus ventralis*), western pine beetle (*Dendroctonus brevicomus*), and Jeffrey pine beetle (*Dedocronus jeffreyi*). Portions of ADS polygons that overlapped with recent fire areas (less than ten years old) were removed from consideration, as were polygons with total area < 250 ha. We drew a random sample of the remaining polygons and then assessed road length and vegetation coverage in each selected polygon to ensure that it contained enough road length within coniferous forest to accommodate a survey transect comprising at least ten sampling points. Smaller polygons that could not fit two complete survey transects in conifer forest were paired with a second polygon by selecting the closest neighboring polygon that met all of the above criteria. Selected polygons were visited in a random priority order (while allowing slight modifications due to access), and survey points were laid out with the same methods and restrictions as for burned areas, above. The number of points per beetle-killed stand varied from 5 to 20, with a median of 10.

Assigning the exact year when a disturbance occurred was straightforward where the disturbance agent was fire, although we note that fire-damaged trees that survived the initial fire may continue to die during the early post-fire years (Hood and Cluck, 2007). However, assigning a year to bark beetle outbreaks was more complicated. Droughts