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Simulating avian species and foraging group responses to fuel reduction treatments in coniferous forests

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A B S T R A C T

Over a century of fire suppression activities have altered the structure and composition of mixed conifer forests throughout the western United States. In the absence of fire, fuels have accumulated in these forests causing concerns over the potential for catastrophic wildfires. Fuel reduction treatments are being used on federal and state lands to reduce the threat of wildfire by mechanically removing biomass. Although these treatments result in a reduction in fire hazard, their impact on wildlife is less clear. We use a multi-species occupancy modeling approach to build habitat-suitability models for 46 upland forest birds found in the Lake Tahoe Basin in the Sierra Nevada based on forest structure and abiotic variables. Using a Bayesian hierarchical framework, we predict species-specific and community-level responses to changes in forest structure and make inferences about responses of important avian foraging guilds. Disparities within and among foraging group responses to canopy cover, tree size and shrub cover emphasized the complexities in managing forests to meet biodiversity goals. Based on our species-specific model results, we predicted changes in species richness and community similarity under forest prescriptions representing three management practices: no active management, a typical fuel reduction treatment that emphasizes spacing between trees, and a thinning prescription that creates structural heterogeneity. Simulated changes to structural components of the forest analogous to management practices to reduce fuel loads clearly affected foraging groups differentially despite variability in responses within guilds. Although species richness was predicted to decrease slightly under both simulated fuels reduction treatments, the prescription that incorporated structural heterogeneity retained marginally higher species richness. The composition of communities supported by different management alternatives was influenced by urbanization and management practice, emphasizing the importance of creating heterogeneity at the landscape scale.

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1. Introduction

The mixed-conifer forests of the Sierra Nevada have undergone substantial change in structure and composition due to over a century of fire suppression (Agee, 1993). Historically described as clusters of trees separated by large open-gap conditions, these fire-dependent systems have been replaced with dense, closed-canopy forests lacking the structural heterogeneity of their past (Barbour et al., 2002; Beaty and Taylor, 2007; North et al., 2007). The accumulation of fuels in these forests and their proximity to urban development has increased our awareness of the risks and costs associated with catastrophic wildfires (Dombeck et al., 2004), particularly in the face of climate change (Westerling et al., 2006). Surface fires that once would have burned at low to moderate severity now have the ability to spread rapidly and with high severity through the forest canopy. The consequence of this alteration to the fire regime has led to a more proactive approach to managing forests through fuel reduction treatments (e.g. Healthy Forest Restoration Act, 2003). Fuel reduction treatments are forest thinning efforts that aim to reduce fire hazard by decreasing surface fuels, removing mid- and understory vegetation (i.e. "ladder fuels") and opening the forest canopy (Agee and Skinner, 2005).

While fuel reduction treatments have been shown to reduce the risk of high-severity wildfires (Stephens and Moghaddas , 2005; Safford et al., 2009; Stephens et al., 2009), concerns about the incompatibility of fire hazard reduction and the needs of wildlife often lead to opposition in applying treatments in fire-suppressed

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forests (Stephens and Ruth, 2005; Collins et al., 2010; North et al., 2012). These concerns have made it challenging to assess the consequences of fuel reduction experimentally on wildlife as proposed treatments are often delayed, modified or not implemented. In attempts to balance potential trade-offs in these resource values, there has been increasing interest in designing silvicultural prescriptions that not only reduce fire hazard, but also increase forest resiliency and improve habitat conditions for wildlife (Carey, 2003; Verschuyl et al., 2008, 2011; North et al., 2009). Current silvicultural strategies that emphasize reducing ladder fuels and canopy closure result in homogenization of the forest stand (Dellasala et al., 2004; Westerling et al., 2006; North et al., 2009). For instance, forest thinning treatments failed to reconstruct historical forest composition, tree spacing, or past variation in tree size in a study conducted in a mixed-conifer forest of the Sierra (North et al., 2007). Consequently, fuel reduction prescriptions that include increasing forest structural heterogeneity are more likely to replicate historic forests and meet forest management goals targeted at conserving biological diversity (North et al., 2009). However, prescriptions that attempt to retain forest heterogeneity are only now starting to be implemented in Sierran mixed conifer forests. Whether these treatments improve wildlife habitat is untested and complicated by ill-defined biodiversity goals (North et al., 2012). For instance, an assessment of management actions that are intended to improve wildlife habitat could result in different conclusions depending on whether biodiversity targets are focused on a few ecologically important species, species richness, or species composition.

Many studies on the responses of wildlife to fuel reduction treatments thus far have focused on forest management in the wildlands, with less attention paid to treatments in more developed or urbanized areas (Noss et al., 2006; Kennedy and Fontaine, 2009). Urbanization may modify wildlife responses to forest treatments. As a stressor, urbanization may decrease habitat suitability for some species and the additive effects of fuel reduction treatments may further marginalize available habitat. Research has repeatedly demonstrated the impact that urbanization can have on ecological communities, with human activity, habitat loss and fragmentation, resulting in a reduction in species richness and changes in community composition (McKinney, 2002; Lepczyk et al., 2008; Schlesinger et al., 2008). Therefore, a species' response to urbanization may overshadow its response to fuel reduction treatments. Given that fuel reduction treatments are costly and may need to be repeated periodically to retain their fire-resistant properties (Collins et al., 2011; Stephens et al., 2012), the vast majority of fuel reductions will likely be targeted at the wildland–urban interface (Dombeck et al., 2004). When attempting to assess the impact of fuel treatments on biodiversity it is important to consider the level of urbanization and its combined impact on species responses.

Human impacts on avian diversity and abundance has led to a substantial loss in bird populations globally (Gaston et al., 2003; Jetz et al., 2007; Hoffmann et al., 2010). Birds are a primary conservation concern as they perform a diverse array of ecosystem services, including the control of invertebrate and vertebrate pest populations, pollination, seed dispersal, and nutrient cycling (Şekercioğlu et al., 2004; Şekercioğlu, 2006). Understanding how forest management practices may impact species occurrence, richness and community composition of forest-associated avian species is crucial to the effective management and conservation of these ecosystem services.

To predict the effects of fuel reduction treatments on avian biological diversity, we investigate how forest structure affects the probability of species occurrence in upland forested areas in the Sierra Nevada. Our objectives are to (1) determine if there is consistency in responses to structural components of the forest within and among foraging guilds, (2) use estimates of species occurrence probabilities based on forest structure to predict and compare avian biodiversity under three simulated forest management scenarios: a fire-suppressed forest lacking management intervention, a standard fuel reduction prescription that removes ladder fuels and increases tree spacing, and a prescription where structural heterogeneity in the remaining forest is retained or increased while biomass is removed; and (3) determine if avian responses to these management practices are influenced by placement of the hypothetical treatment in an urbanized area, where fuel reduction treatments are often focused, and in areas without urbanization (i.e. wildlands).

2. Methods

2.1. Survey data and community occurrence model

The data used in this study were collected in the upland forests of the Lake Tahoe Basin, in the states of California and Nevada, USA. The elevation gradient within the basin (1900–3400 m) supports Jeffrey pine (*Pinus jeffreyi*), mixed-conifer, white fir (*Abies concolor*), red fir (*A. magnifica*), and lodgepole pine (*Pinus contorta*) forest types. Other common tree species include incense-cedar (*Calocedrus decurrens*) and sugar pine (*Pinus lambertiana*). Mean annual precipitation is 150 cm, falling primarily as snow between December and March and varying with elevation and latitude. Several distinctive institutional and ecological factors influence fuel reduction treatments within the Basin. The preservation of Lake Tahoe, an ultra-oligotrophic lake that is the centerpiece of the basin, complicates forest management practices as treatments to reduce fuel loads can mobilize sediment and nutrients and impact the clarity of the lake (Miller et al., 2010). Forest structure surrounding the lake has been dramatically altered by past practices including logging, grazing and suppression of natural fires. Approximately 67% of Basin forests were clear-cut during the last third of the 19th century with less intensive harvesting continuing into the 20th century for residential and recreational purposes (Lindström, 2000). Fuel reduction treatment costs are dramatically higher here than elsewhere in the Western US for a variety of reasons. Additionally, because the wildland–urban interface is extensive and concerns over the risks of fire damage to person and property are high, nearly 75% of the lower montane zone is planned for treatment (Marlow, 2007).

The avian data were collected at 742 point count stations in forested areas of the Lake Tahoe Basin during May–July 2002 through 2005 during which all birds detected (seen or heard) in a 10-min period within 100 m of the sample location were counted. Point count stations were located on a mixture of state, federal and private lands and were selected to represent a range of urbanization classes and elevation zones across the basin. All point counts were separated by a minimum of 200 m. Sample points were visited between two and three times during the course of the breeding season with visits separated by approximately 1 week. Within a season, stations were visited by multiple observers to limit observer bias across study sites. Although stations were visited repeatedly within a season, each station in the study was visited during a single year only.

As birds are likely to use a larger area than the area in which they were detected, we used a 150-m radius to characterize habitat around each sampling point. This area (17.5 acres) corresponds to the average size of a commercial thinning treatment in the Tahoe Basin. All forest structure parameters were derived from a GIS vegetation layer (30 m $\times$ 30 m raster cell) based on IKONOS satellite imagery collected in 2002 (Dobrowski et al., 2006) and the average and standard deviation in variables were calculated within the