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Canopy arthropod responses to thinning and burning treatments in old-growth mixed-conifer forest in the Sierra Nevada, California

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ABSTRACT

We compared canopy arthropod responses to common fuels reduction treatments at Teakettle Experimental Forest in the south-central Sierra Nevada of California. We sampled arthropod communities among four dominant overstory conifer species and three dominant understory angiosperm species before and after overstory or understory thinning or no thinning treatments followed by burning or no burning treatments. Arthropods were sampled in overstory trees by climbing and bagging foliage-bearing branches and counting all arthropods by taxon in each sample. Understory plants were sampled similarly from the ground. Arthropod assemblages showed significant differences among tree species and seasons, but not among treatment combinations. Taxa showing significant differences in abundance among plant species likely reflected differences in foliage quality or other host-associated conditions among plant species. Some arthropods showed significant value as indicator species. Overall, our results indicated that the restoration treatments recommended for Sierra Nevada mixed-conifer forests have little effect on associated canopy arthropods. However, given the significant differences in arthropod assemblages among plant species, restoration treatments should ensure that the full range of plant species characterizing these forests is maintained in order to protect their associated arthropods.

1. Introduction

Forest canopy arthropods can respond dramatically to disturbances or environmental changes in ways that, in turn, alter canopy structure and function, either contributing to or undermining management goals (e.g., Mattson and Addy, 1975; Romme et al., 1986; Schowalter, 2011, 2013). For example, low intensity of feeding on foliage by insects can stimulate nutrient turnover and increase tree growth (Alfaro and Shepherd, 1991; Schowalter et al., 1991), whereas high intensity of feeding on foliage can reduce tree growth, and lead to tree mortality and opening of the canopy (Schowalter et al., 1986).

Management practices can affect arthropod populations in the same manner as natural disturbances, depending on species adaptations (Schowalter, 2011). Establishment of relatively even-aged forests dominated by commercially-valuable species has led to widespread outbreaks of defoliators and bark beetles, among others, especially when dense forests are stressed by moisture limitation (Aukema et al., 2010; Lombardero et al., 2006; Mattson and Haack, 1987; Raffa et al., 2008). Tree mortality resulting from insect outbreaks can increase the likelihood of catastrophic fire in such forests (McCullough et al., 1998), depending on the timing of ignition relative to fuel decomposition (Jenkins et al., 2008). However, silvicultural treatments designed to restore historic forest structure as a means of reducing risk of insect pest outbreaks or fire (North et al., 2007), have the potential to trigger other arthropod or pathogen responses (e.g., Witcosky et al., 1986).

This study was designed to investigate canopy arthropod responses to prescribed thinning and burning treatments (North et al., 2007; Schowalter et al., 2005). We compared arthropod communities among four dominant overstory conifer species and three dominant understory angiosperm species in mixed-conifer forest before and after the thinning and burning treatments. We expected to find significant differences in arthropod abundances and assemblage structure among treatments, specifically, reduced abundances of herbivores in treatments that reduced host plant densities.

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2. Methods

2.1. Study site

The Teakettle Experimental Forest (36°58′N, 119°02′W) is situated in the Sierra National Forest north of the North Fork of the Kings River, approximately 80 km east of Fresno, California (Fig. 1). The 1300 ha of Teakettle's old-growth forest spans the upper montane red fir and lower montane mixed-conifer ecotone of the southern Sierra Nevada on the west side of the crest at an approximate elevation of 2100 m. Jeffrey pine (*Pinus jeffreyi* Balf.) is dominant on more shallow upland soils, but the majority of the study area is a mix of conifer species: red fir (*Abies magnifica* A. Murray), white fir (*Abies concolor* (Gordon & Glend.) Hildebr. var. *lowiana* (Gordon) Lemmon), incense cedar (*Calocedrus decurrens* (Torr.) Florin), sugar pine (*Pinus lambertiana* Douglas) and Jeffrey pine. In a study of 526 stumps remaining from thinning prescriptions in the Teakettle Ecosystem Experiment (North et al., 2002), these respective species ranged in age up to 332, 397, 403, 354 and 407 years (North et al., 2005) with individual trees reaching heights >65 m.

Historically, this forest was co-dominated by large (>1 m diameter), widely spaced conifers with a sparse understory maintained by relatively frequent, low-intensity ground fires. Fire exclusion during the past century has promoted recruitment of more fire-intolerant species, resulting in large areas of closed canopy forest dominated by young white fir and incense cedar (<100 yrs old, <50 cm diameter). The forest now has a mean basal area of 68 m^2 ha^{-1} with 60% canopy cover characterized by discontinuous groups of trees separated by large gaps (North et al., 2004). Black oak (*Quercus kelloggi* Newb.) is found in the understory, and the canopy gaps are frequently characterized by manzanita (*Arctostaphylos patula* Greene and *A. nevadensis* Gray), bush chinquapin (*Castanopsis sempervirens* (Kellogg) Dudley ex Merriam) and whitethorn (*Ceanothus cordulatus* Kellogg).

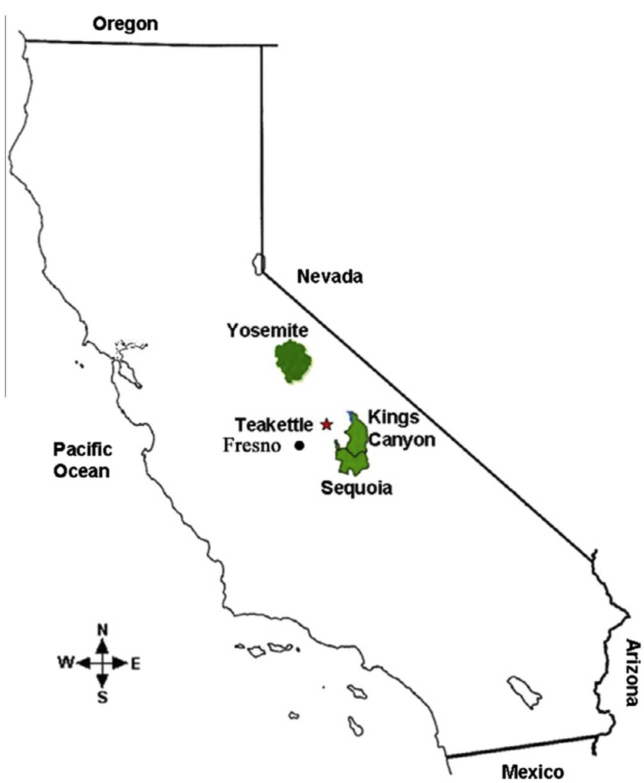

Fig. 1. Map of California showing approximate location of the Teakettle Experimental Forest in relationship to the Central Valley city of Fresno, and Yosemite, Kings Canyon and Sequoia National Parks in the Sierra Nevada.

Warm, dry summers contrast with much cooler, moist winters in this Mediterranean climate. Annual precipitation averages 125 cm and falls mainly as winter snow, which generally persists through May. Mean summer and winter temperatures in 2004 at 5 m above surface in un-thinned forest were 15.6 and 0.0 °C, respectively (Rambo and North, 2009). Soils are generally granitic Inceptisols and Entisols (North et al, 2002).

2.2. Teakettle Ecosystem Experiment

This research was conducted within the context of the Teakettle Ecosystem Experiment, which established eighteen 200 × 200 m plots to study the ecological effects of thinning and burning on Sierra mixed-conifer forest. Analysis of the Teakettle forest structure determined that plot size needed to be approximately 4 ha to include the range of composition and stand variability that characterizes the discontinuous canopy cover of southern Sierra mixed-conifer forest (North et al., 2002). Treatments included two different forest thinning strategies. Six plots were thinned primarily from the understory following California Spotted Owl Report (CASPO) guidelines (Verner et al., 1992), which retained 40% of live BA while removing trees 25–76 cm diameter at breast height (dbh). This treatment left an average of 44 trees ha^{-1} with a mean dbh of 91 cm (see Rambo and North, 2009 for stand visualizations and metrics). Originally designed to minimize impact on Spotted Owl habitat, CASPO guidelines became a widely used thinning practice in the Sierra Nevada during the 1990s, and continues as a ladder fuels reduction treatment (SNFPA, 2004). Another six plots were thinned primarily from the overstory, which harvested all trees $\geqslant$ 25 cm (dbh) except for 22 large trees ha^{-1} left regularly dispersed 20–25 m apart (Rambo and North, 2009). This prescription was widely practiced in Sierra Nevada forests prior to CASPO and approximates fuels reduction thinning currently used in defensible space zones where tree crowns are spaced widely to reduce potential for crown fire spread. Six plots were left unthinned. Half of the plots in each thinning treatment were subsequently treated with broadcast slash and surface fuel prescribed burning. Thinning treatments were performed in the fall of 2000 and spring of 2001, and the prescribed burning in the fall of 2001.

2.3. Sampling

In the pre-treatment year of 2000, sampling was conducted in late spring (June) and again in summer (August) to represent seasonal variation in arthropod assemblages. In the post-treatment year of 2002, sampling was done once in late spring. The overstory in each of five plots was sampled by climbing one tree each of incense cedar, white fir, Jeffrey pine and sugar pine. Three crown strata were distinguished for collecting three samples in each tree: one from within 5 m above the lowest live branches, one from mid-crown, and one from within 5 m of the tree top.

Each sample was collected by slipping a 40 l plastic bag quickly and stealthily over a randomly selected live branch (ca. 0.5 m length, 30–50 g dry wt.), clipping the branch, and sealing the bag for lowering to the ground. This sampling technique emphasizes the sedentary fauna present on foliage and twig surfaces at any given sampling time (e.g., aphids, caterpillars, spiders, mites) while potentially underrepresenting more mobile species that could be alarmed and escape capture (Schowalter, 1995; Schowalter and Ganio, 1999). Other sampling techniques have different biases. For example, interception trapping emphasizes flying adult insects that may or may not be associated with a particular plant or even a particular treatment unit, and canopy fogging emphasizes unattached arthropods that can reach ground collectors when many