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Multi-disciplinary approach to identifying Native American impacts on Late Holocene forest dynamics in the southern Sierra Nevada range, California, USA

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ABSTRACT

Fire is a natural disturbance component and driver of forest composition in the western United States. Cooler/wetter climates are typically associated with less frequent fires and succession of montane forests to more shade-tolerant, fire-sensitive taxa. Native Americans have lived in California since the terminal Pleistocene and used fire to alter the landscape and maximize natural resources. Determining the extent and impact of anthropogenic burning on California's landscape is difficult; however, because the archaeological record is mostly silent on the subject. The region's ethnographies also mention the practice from a prehistoric context only in passing. Here, we show that comparing the prevalence of fire-sensitive to fire-adapted taxa in the pollen record can help distinguish periods when vegetation does not respond as expected to climate change. We argue that the prevalence of shade-intolerant/fire-adapted taxa during climatically cool, wet periods such as the Little Ice Age provide evidence for anthropogenic burning. At Holey Meadow, in Sequoia National Forest, we find strong evidence for a Native American influenced landscape from 750 to 100 cal yr BP. We also see a strong anthropogenic effect on modern vegetation following European settlement in A.D. 1854, a period marked by a precipitous decline in traditional tribal use of the area and the inception of modern fire exclusion policies. These results indicate that anthropogenic impacts on forest composition can be distinguished from climatic drivers through the use of paleoenvironmental proxies. They further indicate that anthropogenic burning helped structure Late Holocene southern Sierra Nevada biomes.

1. Introduction

Fire is a natural disturbance component in many forests, especially in the western U.S. As climate changes, the frequency at which natural fires occur on the landscape also changes (Dale et al., 2001, 2000; Flannigan et al., 2000; Keeley et al., 2011; Swetnam, 1993), and succession theory predicts associated changes in forest composition. Cooler/wetter climates are associated with less frequent fires and more available soil moisture, with succession leading to closed forest canopies with more shade-tolerant/fire-sensitive taxa (*i.e.* increasing *Abies* spp. and *Calocedrus decurrens*) (Dale et al., 2001; Lenihan et al., 2003). Warmer/drier climates have less available soil moisture and greater fire occurrences, leading to the opening of forest canopies and more shade-intolerant/fire-adapted taxa (*i.e.* increasing *Pinus*,*Quercus*, Poaceae, and Rosaceae) (Engber et al., 2011; Fites-Kaufman et al., 2007; Henne et al., 2012; Innes et al., 2006; Peterson and Hammer, 2001). The climate-driven model of forest succession (Fig. 1a) assumes climate is the main driving force of forest structure and composition, and predicts that any variation in fire and vegetation as reconstructed from charcoal and pollen to be positively correlated to changes in independently derived climate reconstructions (*i.e.* drier climate = more charcoal and more shade-intolerant taxa). This model also predicts a positive correlation between vegetation and fire with regards to fire-sensitive/fire-adapted taxa (*i.e.* more fire-adapted taxa during periods of increased charcoal accumulation).

In the southern Sierra Nevada, *Abies concolor* (white fir) is a classic example of a very shade-tolerant/fire-sensitive species in mid-elevation, mixed-conifer forests. Saplings show high mortality when exposed to low-intensity fires (Kilgore, 1973). Further, fire suppression policies in the last 150 years have allowed documented expanded succession of *Abies* spp. (Franklin and Fralish,

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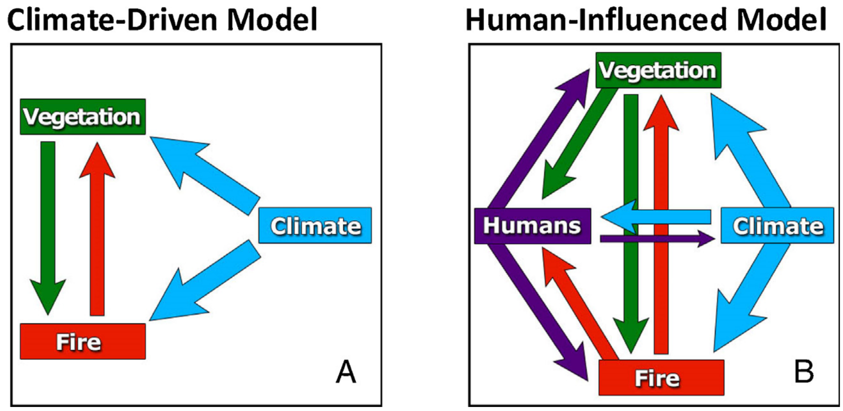

Fig. 1. Climate-driven model of forest succession (A) versus a human-influenced (B) model.

2002; Kilgore, 1973). Conversely, *Quercus kelloggii* (California black oak) is fire-tolerant and drought-resistant. While *Q. kelloggii* can tolerate some shade, it prefers open canopy and direct sunlight for best development (Franklin and Fralish, 2002). In cooler, wetter climates, or with less fire, *Abies* can outcompete *Quercus* given its rapid growth habit; therefore, in a climate-driven regime (Fig. 1a), we expect an inverse relationship between shade-tolerant/fire-sensitive *Abies* and shade-intolerant/fire-adapted *Quercus* spp. The role of fire in maintaining oak woodlands is widely recognized, where fire exclusion results in forest structure change to more fire-sensitive, shade-tolerant taxa (Bond and Keeley, 2005; Crawford et al., 2015; Engber et al., 2011; Higgins et al., 2000; Peterson and

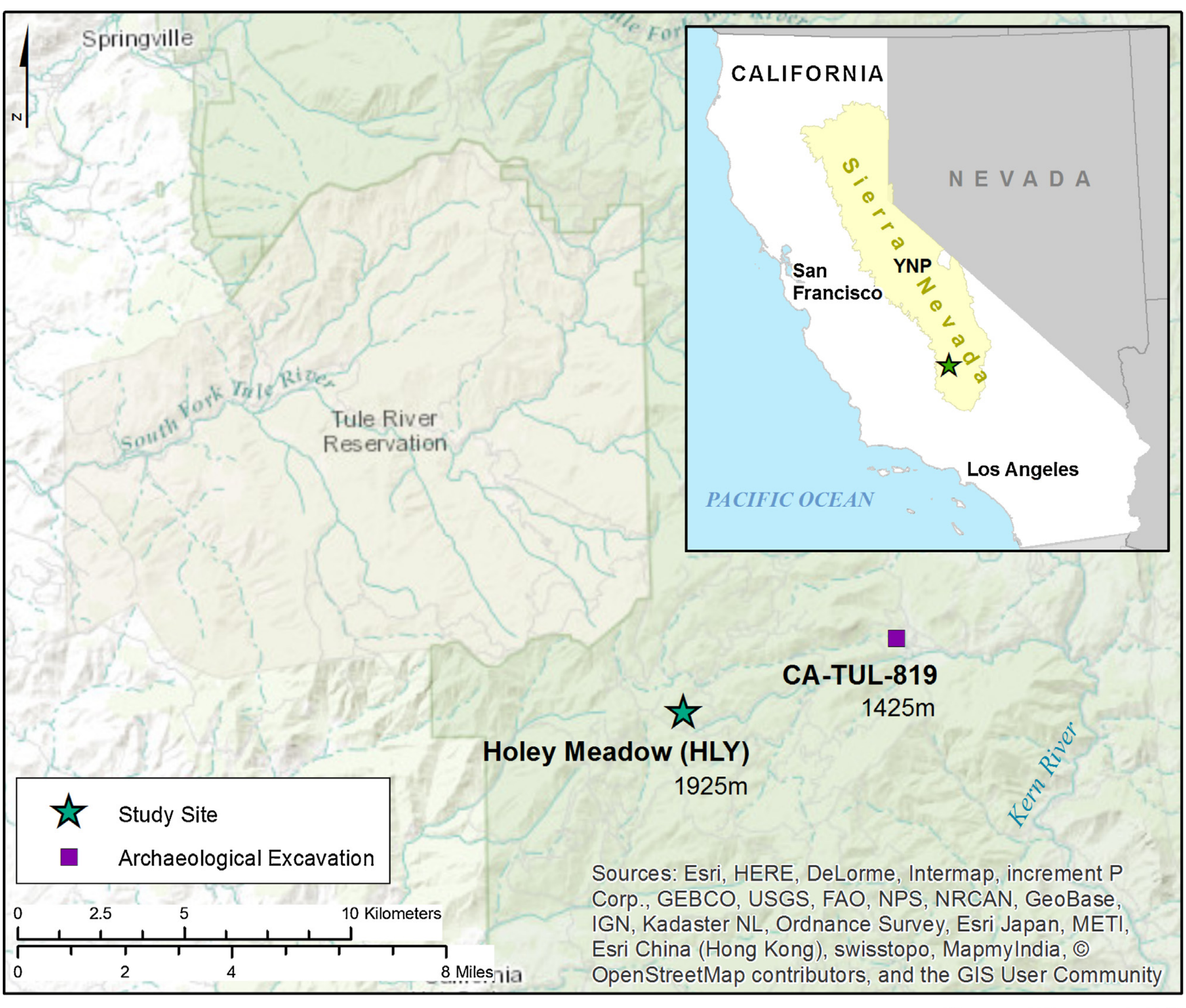

Fig. 2. Study area showing paleoenvironmental reconstruction site (HLY) and nearby archaeological site CA-TUL-819. YNP: Yosemite National Park.

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