The Enigmatic Fire Regime of Coast Redwood Forests and Why it Matters[1]

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Abstract

Of perhaps all forests in North America, the fire regime of coast redwoods (*Sequoia sempervirens* (D. Don) Endl.) is most enigmatic. Widely considered a temperate rainforest, a large number of fire history studies depict a forest dominated by frequent surface fire regimes. Coast redwood also has a long list of traits that allow it to persist and dominate under such a chronic fire regime: thick bark, flammable litter, ability to resprout, and rapid pruning. Determining how redwood fire regimes functioned is a major question for restoration and conservation efforts. The origins of frequent fires in redwood fire history studies is often assigned to Native American land uses, with little attention to lightning or the region's fire-prone adjacent ecosystems. Results from the few fires studied in the region suggest that we have much to learn from science and management perspectives about how fire behaves, its effects, and the elements of its enigmatic fire regime.

Keywords: fire-adapted traits, fire history, lightning, Native American fire use, *Sequoia sempervirens*.

Background: Redwoods – Rainforests or Fireforests?

Coast redwood (*Sequoia sempervirens* D. Don) Endl.) ecosystems are often characterized as temperate rainforests (Noss 2000), perhaps in spite of the abundant fire history evidence to suggest another story. Contemporary redwood forests offer many clues to their fire-prone past with large basal hollows ("goose pens") abundant fire scars on bark surfaces and within. These pieces of evidence contrast sharply with the protracted fire return intervals in contemporary redwood ecosystems (Lorimer et al. 2009, Oneal et al. 2006). This disconnect and the other traits of redwoods represent a classic enigma—how did frequent fires burn in these wet forests?

Redwood's Fire Regime

For a species with such a small native range, there have been a surprising number of fire history studies in redwood forests. Kane (these proceedings) reviewed the fire history studies in coast redwood ecosystems, noting their high frequency across the range. Stephens and Fry (2005) plotted seven fire history studies over the range of coast redwood, showing mean fire return intervals (mFRI) that ranged from 2 to 87 years, with most studies showing mFRIs ranging from 6 to 25 years (see also Lorimer et al. 2009). Although less studied than mFRIs, the season of historical fires in redwoods has been recorded in several studies and these have found that fires have been recorded in latewood and dormant periods (Brown and Baxter 2003, Brown and Swetnam 1994, Stephens and Fry 2005). Overall, the fire history studies conducted in redwood forests consistently show frequent fires that contrast sharply with the notion of a rainforest ecosystem.

What Was the Source of Redwood Fires?

A persistent question regarding fire in redwoods is the origin of such a frequent fire regime. We categorize two hypotheses regarding the source of fire in redwoods as endogenous or exogenous sources. Endogenous sources include those origins within redwood ecosystems: humans and lightning. Native American ignitions are widely assumed to be the primary source of the frequent fires found in the fire scar literature (Lorimer et al. 2009). Tribal populations were high in the region

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and the many uses of fire have been highlighted elsewhere. While lightning strikes are less frequent in redwoods than in the fire-prone Sierra Nevada or Klamath Mountains, lightning strikes average 3.0 per km^2 per year in redwoods. These lightning ignitions and more recent human ignitions coupled with the substantial capacity of redwoods to have "holdover" fires in the heavy amounts of downed wood or in crown duff (so-termed arboreal histosols that create "fire caves" in redwood crowns; Enloe et al. 2006) may have been sufficient to support such high frequency fire regimes.

Exogenous, or fires that originated outside of redwood forests, offer another possible source for the high frequency fire history of redwoods. As with endogenous fire, these were either ignited by lightning or humans. As with the redwood region, much of the adjacent inland areas were inhabited by a diversity of Native American tribes (Lorimer et al. 2009, Stuart and Stephens 2006). It is notable that redwood's adjacent ecosystems include many of the most fire-prone ecosystems in the Pacific west. Mixed evergreen forests and Jeffrey pine (*Pinus jeffreyi* Balf.) woodlands border many northern redwood forests (Stuart and Stephens 2006). Oak woodlands, dominated by open stands of Oregon white oak (*Quercus garryana* Douglas ex Hook.) or California black oak (*Quercus kelloggii* Newb.) abut many central and northern redwood forests. In more southerly sites, upland fire-prone oak woodlands and chaparral neighbor the more dissected redwood stands. Fires that originated in those adjoining ecosystems are capable of burning into redwoods under dominant east winds that characterize most of the region during the late summer-early fall peak fire season. This landscape approach has been little studied, but offers a somewhat novel explanation for the high fire frequencies of the past.

Recent wildfires in redwood ecosystems provide further evidence of these ecosystems' capacity to spread fire. The 2003 Canoe Fire in Humboldt Redwoods State Park (fig. 1) burned 5,554 ha (13,774 ac) in alluvial flats and upland mixed forests. In 2008, several redwoods wildfires were ignited by the June lightning event, most notable of these were the 1,518 ha (3,750 ac) Orr Fire in Montgomery Woods State Park and the 65,920 ha (162,818 ac) Basin Complex in Big Sur. The large > 50,000 ha (130,000 ac) Soberranes Fire was burning across much of the Basin Fire's footprint during the 2016 conference. These fires all defied the general contention that fires in redwoods were rare and small.

Figure 1—Photograph of large coast redwood within the 2003 Canoe Fire in Humboldt Redwoods State Park, California. Coast redwood has thick bark, prunes rapidly, and has flammable litter that fuels surface fires in these ecosystems. (L. Quinn-Davidson photo)

Redwood's Fire-adapted Traits

Species traits reflect selection pressures and can often inform species relationships to fire. Coast redwood possesses a number of traits widely held to be reflective of a past of frequent fire. Bark thickness is a primary trait that enables trees to survive heating of underlying cambium and xylem structure. Coast redwood's bark thickness provides an obvious advantage in surface fire regimes. Many fire-adapted species have highly flammable litter that can kill neighbors (Varner et al. 2015). Among the western conifers, coast redwood has the third most flammable litter, behind only ponderosa pine (*Pinus ponderosa* Lawson & C. Lawson) and Jeffrey pine, two notable fire-adapted trees (Fonda et al. 1987). Other adaptations that redwood has include rapid pruning, rapid height growth, great maximum height, the capacity to resprout basally and epicormically, and seed germination requirements for exposed mineral soil, and (Agee 1993, Lorimer et al. 2009). Each of these traits may have evolved independently of fire, but collectively they confer an advantage for redwood and are suggestive of its past fire regimes.

Why it Matters

Determining how fires spread and what the ecological consequences of frequent fires were and might be in the future are key questions for the conservation and restoration of redwood ecosystems. If redwoods were dominated by frequent fires in their past, understanding the consequences of those fires may provide us with a better model for how to restore redwood dominance. Frequent fires can consume large wood, particularly decayed wood that is so apparent in many old-growth redwood stands (Graham 2009). Fire also differentially selects understory plant species based on their tolerance to heating and their life history. How might the vegetation of redwood ecosystems differ

with fires at the frequency recorded in the fire history record? How might have vertebrates and invertebrates adapted to these fire regimes? These questions become more relevant in light of the number and extent of the recent wildfires in redwoods across the region. Understanding the past effects will increase our ability to predict future changes in redwood ecosystems and perhaps embrace fire as a necessary tool to sustain redwood ecosystems.

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