Coast Redwood Seedling Regeneration Following Fire in a Southern Coast Redwood Forest[1]

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It has been hypothesized that individuals adapted to conditions near the species' range edge, may increase the likelihood that the species will persevere under changing climatic conditions (Rehm et al. 2015). The southern coast redwood (*Sequoia sempervirens* (D. Don) Endl.) forests vary from more northern redwood forests in terms of stand size, genetics, forest associates, and have less annual precipitation (Noss 2000). Redwoods regenerate through both seed and basal sprouting, with sprouting being the dominate regeneration method (Douhovnikoff et al. 2004). A study of three recent fires in the Santa Cruz Mountains, California found that one site had significantly more redwood seedlings 1 year post-fire than the other two sites (Lazzeri-Aerts and Russell 2014). Our objectives were to: 1) quantify seedling germination and size, and 2) characterize environmental conditions on this site 8 years post-fire. Prolific seedling recruitment and growth may help the species persist under changing climate conditions. As conditions become drier and warmer in the southern part of the redwood range, the increased ability to regenerate through seed germination may be an advantage.

The Whitehurst Fire burned 103 ha (256 ac) within the Mt. Madonna County Park, Santa Clara County, California in June 2008 within a mixed coast redwood forest. Twenty-six plots were sampled in 2009 and 2016 for number of seedlings in three size classes (small: < 0.05 m (< 1.64 ft), medium: 0.5 to 1.0 m (1.64 to 3.28 ft), and large: > 1.0 m (> 3.28 ft)), height of tallest seedling, canopy cover, shrub cover, duff depth, soil moisture, slope, and aspect.

On average, more redwood seedlings were found than seedlings of three other common forest associates—madrone (*Arbutus menziesii* Pursh), tanoak (*Notholithocarpus densiflorus* (Hook. & Arn.) P.S. Manos, C.H. Cannon, & S.H. Oh), and mixed oak (*Quercus agrifolia* Née, *Q. chrysolepis* Liebm., *Q. wislizeni* A. DC.)—in both 2009 and 2016. There were fewer redwood and madrone seedlings per square meter in 2016 than 2009, but more tanoak and oak seedlings per square meter in 2016 (fig. 1). The difference in mean number of seedlings was significantly lower for redwood ($p = 0.03$) and significantly higher for tanoak ($p = 0.0004$).

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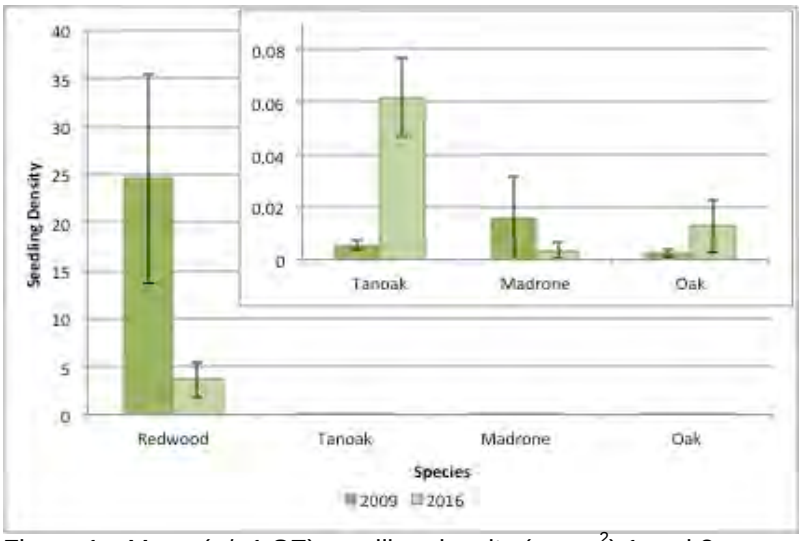

Figure 1—Mean (+/- 1 SE) seedling density (per m^2) 1 and 8 years after fire in a mixed coast redwood forest in the Santa Cruz Mountains, California. Inset figure highlights changes in seedling density for low density tree species. Units of inset figure are the same as main figure.

Between 2009 and 2016, most plots had fewer redwood seedlings and mortality ranged from 22 percent to 100 percent. However, six plots had more redwood seedlings in 2016 compared to 2009. The largest increase was from 75 to 3,623 total seedlings. The difference in mean number of seedlings on these six plots between 2009 and 2016 was significant ($p < 0.001$). These results indicate that new seedlings continued to germinate up to 8 years post-fire.

In 2009, all measured seedlings were in the small size class except one oak in the medium size class. The tallest redwood seedling was 0.28 m (0.92 ft). By 2016, 2.45 percent of redwood seedlings were in the large size class, 13.06 percent were in the medium size class, and 84.49 percent were in the small size class (fig. 2). The tallest redwood seedling measured was 3.0 m (9.8 ft), and the tallest seedling of any other species was a madrone at 1.6 m (5.2 ft).

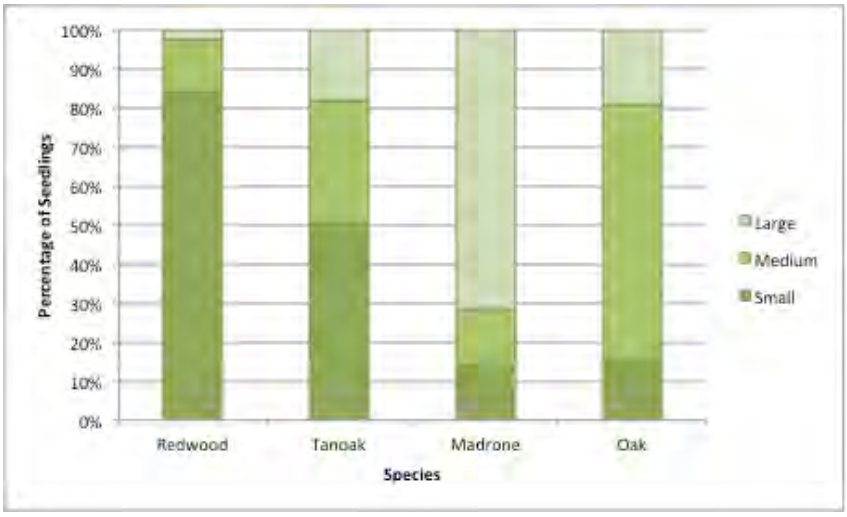

Figure 2—Percentage of seedlings in three size classes (small: < 0.05 m, medium: 0.5 to 1.0 m, and large: > 1.0 m) 8 years after fire in a mixed coat redwood forest in the Santa Cruz Mountains, California.

Percent canopy cover was measured with a spherical densitometer and we found a significant increase in the percent canopy cover ($p = 0.0002$) from 2009 to 2016. The mean canopy cover was

68.7 percent and 80.0 percent in 2009 and 2016, respectively. However, we found no correlation between canopy cover and number of seedlings. Mean duff depth was 3.4 cm (1.3 in) and 4.2 cm (1.6 in) in 2009 and 2016, respectively. The difference between duff depths was not statistically significant, and we found no correlation between duff depth and number of seedlings for either year. While shrub cover was not measured in 2009, we observed few shrubs in and around the plots. In 2016, we found a 16 percent mean shrub cover, but there was no correlation between percent shrub cover and number of seedlings. Additionally, slope and aspect were not significantly correlated with the number of redwood seedlings in either 2009 or 2016, and soil moisture was not significantly correlated with the number of redwood seedlings in 2016.

Although the overall number and density of redwood seedlings declined between 2009 and 2016, redwood seedlings are continuing to germinate as evidenced by the six plots with more seedlings in 2016 than 2009. Additionally, many of the seedlings increased in size over the same time span. This result was unexpected as seedlings typically have low vigor (Olson et al. 1990). While we measured no redwood seedlings in the medium or large size classes in 2009, a combined 15.51 percent of the seedlings we measured in 2016 were large or medium. This shows that some of the redwood seedlings are thriving. Olson et al. (1990) suggest that seedlings need high soil moisture levels and full sunlight to grow best after germination. However, we found no statistically significant relationship between seedling density or seedling height and soil moisture or canopy cover (as a proxy for light availability). Combined with the lack of relationship to duff depth, shrub cover, slope, and aspect, this leaves the cause of continuing seedling recruitment and increasing vigor on this site unexplained. As abundant seedling germination and growth may be advantageous with continuing climatic changes, we suggest ongoing investigations of southern coast redwood regeneration. These studies should focus on genetics, soil, and past land use and management.

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