

Stand Dynamics of Coast Redwood/Tanoak Forests Following Tanoak Decline¹

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Abstract

Current threats to North American forests increasingly include exotic tree pathogens that cause extensive mortality. In California, tanoak (*Lithocarpus densiflorus*) mortality has increased rapidly since 1995, due to *Phytophthora ramorum*, believed to be an introduced pathogen. Tanoak frequently grows as a major component of redwood forests along the northern California coast. This research examined the response of residual trees (primarily neighboring tanoak and redwood) to the decline of tanoak clumps. Redwood/tanoak forests currently infected with the pathogen and utilized in this study were located within the Marin Municipal Watershed District, Marin County, while uninfected sites with comparable forest age and species composition were located within Jackson State Demonstration Forest, Mendocino County. Stand reconstruction methodology was utilized to detect baseline growth patterns and changes related to the tanoak decline. Similar patterns of stand development appeared on both study sites, with codominant tanoak and suppressed redwoods occupying a middle canopy stratum below codominant redwoods. The lower strata, suppressed redwood may benefit the most from tanoak decline as they gain access to increased growing space.

Key words: exotic pathogen, forest pathogen, *Lithocarpus densiflorus*, *Sequoia sempervirens*, stand development

Introduction

Worldwide introductions of organisms beyond their natural range have increased tremendously in the past 100 years with increased globalization. Introduced organisms frequently do not establish and maintain populations. The environment is favorable for a handful of organisms however, due in part to changing landscapes and lack of co-evolution. Forest ecosystems in North America are no exception to these trends and continue to face new and emerging exotic pests.

Contributing to extensive mortality and decline of tree species throughout the United States are exotic insects and pathogens. A few of the most widely cited pathogens include chestnut blight (*Cryphonectria parasitica*), white pine blister rust (*Cronartium ribicola*), Dutch elm disease (*Ophiostoma ulmi* and *O. novo-ulmi*) and pine pitch canker (*Fusarium circinatum*) (Liebhold 1995). Chestnut blight, in particular, was primarily responsible for relegating American chestnut (*Castanea dentata*) to a mostly sapling size tree in the understory of eastern hardwood forests. In the 1990s, *Phytophthora ramorum* (a water mold) emerged as a new threat to

¹ This paper was presented at the Redwood Science Symposium: What does the future hold? March 15-17, 2004, Rohnert Park, California.

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forest trees in coastal California ecosystems (Rizzo and Garbelotto 2003). While many species of trees, shrubs, and herbs are infected with *P. ramorum*, tanoak (*Lithocarpus densiflorus*) has been hardest hit, suffering widespread mortality within infected ecosystems (Rizzo and Garbelotto 2003). Tanoak has long been considered a “weed species” by some foresters along the California coast, primarily because it tends to inhibit redwood (*Sequoia sempervirens*) growth following timber harvesting. However, it is a mast producing species that provides complexity to forest stands beneath the conifer strata. Tanoak serves to enhance wildlife habitat, prevent erosion and increase biodiversity within the forest stand.

Stand reconstruction provides a retrospective analysis of stand development patterns through time (Agrawal 1995, Oliver and Stephens 1977). Limitations to the use of stand reconstruction methods include small sample sizes (due to intensive sampling procedures) and lack of information regarding past mortality. Restoration of forest stands following invasion of exotic species is warranted in many ecosystems, and is becoming a growing concern in coastal California following *P. ramorum* invasion (Swiecki 2002). However, patterns of development in redwood/tanoak stands have not been described. Understanding these patterns is crucial background knowledge for directing future stand conditions and restoration activities. Without knowledge of historic stand development patterns and an understanding of how those patterns may be changing, land managers face a daunting task of meeting management objectives, such as restoration, without the necessary tools and quantitative basis for the development of such tools. Through use of reconstruction, the pest arrival time into the ecosystem can be estimated and the resulting changes through time can be compared to similar stands that are yet to be invaded by the pest. Our objectives were to describe development patterns in redwood/tanoak stands and show quantitatively how those patterns are changing in response to tanoak decline.

Methods

Research plots were located on Marin Municipal Watershed District land (MMWD), Marin County, California, and Jackson Demonstration State Forest (JDSF), Mendocino County, California. These sites are characterized by a Mediterranean climate, experiencing between 900 to 1100 mm average rainfall each year, the majority of which occurs between November and March. MMWD has been experiencing mortality of tanoak due to *P. ramorum* since the mid-1990s. Presence of *P. ramorum* within the study stands has recently been confirmed by DNA analysis (Spencer and O'Hara 2006). To date, *P. ramorum* has not been found within JDSF, and it was used as a control site for this research. A protocol was developed for use by all parties involved in this research to avoid spread of the pathogen between sites. All samples removed from each site were autoclaved upon arrival at the lab.

At each site, stands with similar management histories and species composition were selected. Target species composition for this research within the conifer component was at least 75 percent coast redwood, with Douglas-fir (*Pseudotsuga menziesii*) and occasional grand fir (*Abies grandis*) comprising the remainder of the conifers. Tanoak comprises the vast majority of the hardwood component within this forest type, with minor components of madrone (*Arbutus menziesii*) and bay (*Umbellularia californica*) (Zinke 1988). Four stands were sampled in the MMWD, and three stands were sampled in JDSF. Three circular plots ranging in size from 1/100th ha to 1/10 ha were located in each stand, and all trees at least 1.37 m (breast

height) tall were included in the plot inventory. Location of plots in MMWD was based on location of dead tanoak stems, with plots centered around groups of tanoak mortality. Plots in JDSF were of similar density and species composition as MMWD plots, centered around live tanoak. Between six and 10 sample trees were selected from each plot for more intensive sampling. Data collected from sample trees included total height, age and growth.

To complete age and growth analysis on the sample trees, two separate methods were undertaken at each site. At MMWD, non-destructive sampling was used, and each sample tree was cored at the base, breast height, and three meters up the bole. Cores were removed to the lab, where they were glued and sanded for growth and age analysis. At JDSF, destructive sampling took place during 2002, and involved felling the sample trees on six of the nine plots. After each tree was felled, bole and live crown length were recorded, in addition to five-year height growth. Cross sections were removed from the base, breast height, and at intervals along the tree bole. Interval distance varied by species and size, as there were restrictions on log length for utilization following sampling. Where the tree could not be utilized for timber, cross sections were removed every 3 meters. The cross sections were then taken to the lab, where they were planed and sanded. After preparation, each core and cross section was aged. All samples were sanded up to 600 grit and manually aged using a dissecting microscope.

Results

Results shown here compare one stand in MMWD with one stand in JDSF. Species composition of each stand met the original objectives, with at least 75 percent redwood in the conifer stratum and a majority of tanoak in the hardwood stratum. Species composition was similar between sites, particularly among trees greater than 10 cm DBH. Redwood plot density per hectare was 933 at MMWD and 567 at JDSF; for trees larger than 10 cm DBH, plot density per hectare was 333 at MMWD and 400 at JDSF. Plot density per hectare of tanoak at MMWD was 1700, compared to 833 at JDSF. Among tanoak trees larger than 10cm DBH, plot density per hectare was 400 at MMWD and 533 at JDSF. There were no large dead tanoak trees on plots at JDSF, compared with a plot density of 300 per hectare at MMWD.

The JDSF stand exhibited a higher site index (43 m, base 100) than MMWD (37 m, base 100) (Lindquist and Palley 1963). *Figure 1* shows the pattern of height development over time for three individual trees from one plot in the JDSF stand. A comparative plot from MMWD is shown in *figure 2*. The site at JDSF was logged approximately 80 years ago, which corresponds with initiation of the trees shown. Likewise, the MMWD stand was logged approximately 90 years ago, which also corresponds to the age of the main canopy trees.

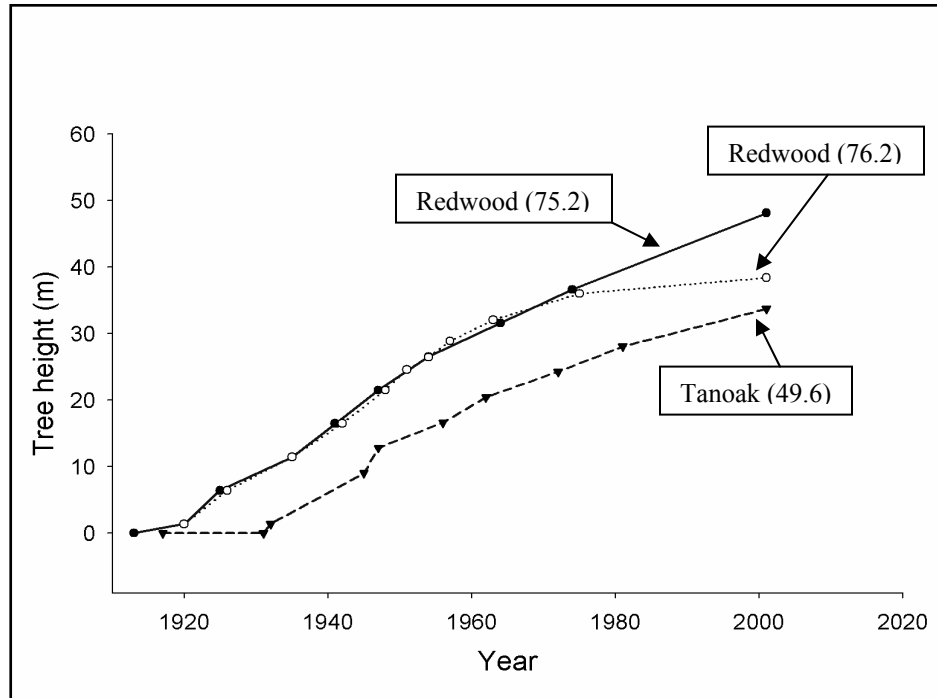


Figure 1—Stand development pattern for three trees at Jackson Demonstration State Forest, Mendocino County, CA. Number in parentheses is diameter at breast height (cm).

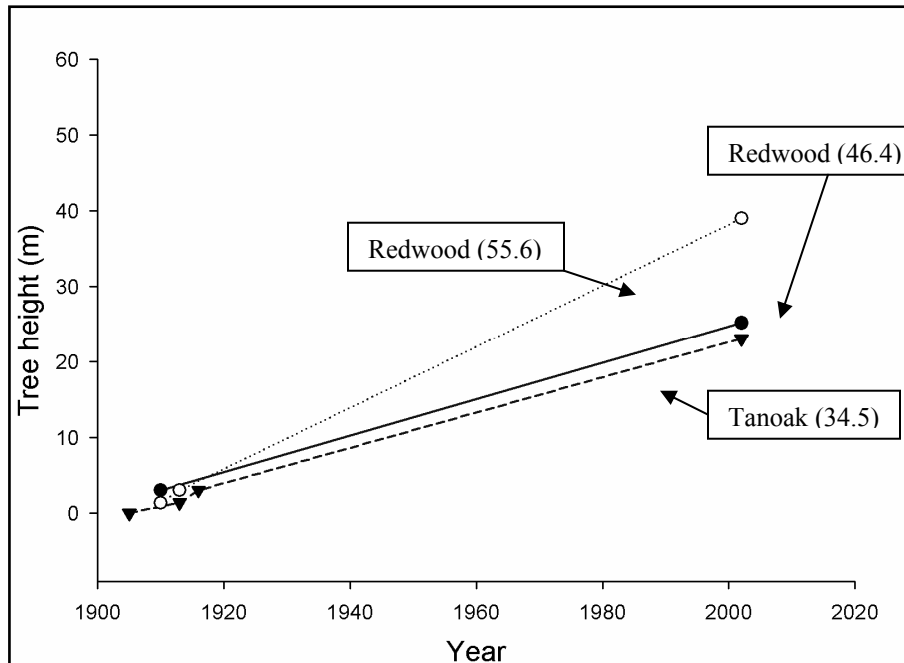


Figure 2—Development pattern of three trees at Marin Municipal Water District, Marin County, CA. Number in parentheses is diameter at breast height (cm).

Discussion

Similar patterns of species composition and stand development were found on both the JDSF and MMWD study sites. Even though these two sites are separated geographically and have slightly different site indices, it appears that they are comparable and the use of JDSF as a control in this research is valid. As *figure 1* shows, data from JDSF are more comprehensive; each point on the graph represents a data point from along the tree bole. Conversely, in *figure 2*, the only data points available are quite low on the tree bole and at the treetop. Data from mid-bole is lacking and obscures patterns of stand development occurring in this range. Quantitative analysis of stand dynamics will allow managers to understand ongoing changes in development and serve as predictive tools for restoration. Additionally pre-infection data from JDSF is invaluable if *P. ramorum* arrives at JDSF in the future.

Stratification within these redwood/tanoak stands began shortly after stand initiation. Both tanoak and redwood trees likely originated from sprouts following harvesting in the 1910s. While it appears in *figure 1* that tanoak cannot compete with redwood in height growth, this data is contrary to general tanoak growth patterns in which it competes heavily with conifers following stand initiation (Tappeiner and others 1990). *Figures 1* and *2* show similar patterns of height growth through time for competing redwoods until differentiation causes one redwood to fall behind. Other redwoods likely fell behind through time and eventually died leaving no current evidence of their existence. These patterns of development serve to create additional vertical complexity within the stand. These forests are often composed of three to four canopy strata. Remnant (residual) redwood forms an emergent stratum above the second-growth stand. The next two strata are shown in *figures 1* and *2*; the uppermost being formed by redwood, with tanoak forming a third, lower strata. The middle stratum frequently contains suppressed redwood trees that probably began falling behind shortly after stand initiation. A fourth strata may be found in the understory, composed of small tanoak and redwood sprouts and seedlings.

Figure 3 shows a hypothetical pathway for stand development following the loss of a large tanoak. The current height differentiation patterns will likely impact future development, with the tallest redwood least likely to benefit and the trees that are differentiating below the most dominant redwoods most likely to benefit from tanoak mortality. Furthermore, suppressed or intermediate trees may increase their height growth as resources become available. However, these trees will continue to compete with larger, overtopping redwoods and the outcome of this competition remains to be seen. This work represents the first stage of an ongoing project that will not only quantify stand development and residual tree response but also provide managers with guidelines for management and restoration in these forest systems.

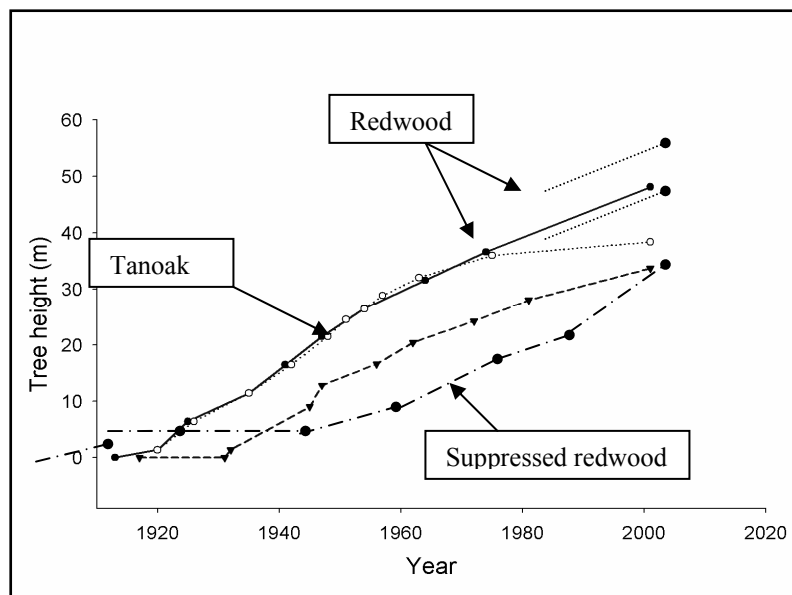


Figure 3—Hypothetical development of three redwood trees following loss of a tanoak.

References

- Agrawal, A. 1995. **Use of dendrochronological methods to estimate an ecological impact date of the chestnut blight.** Virginia Journal of Science 46(1): 41-47.
- Liebholt, A.M.; MacDonald, W.L.; Bergdahl, D.; Mastro, V.C. 1995. **Invasion by exotic forest pests: a threat to forest ecosystems.** Forest Science Monograph 30 41(2): 1-49.
- Lindquist, J.L.; Palley, M.N. 1963. **Empirical yield tables for young-growth redwood.** Bulletin 796. California Agriculture Experiment Station; 47 p.
- Oliver, C.D.; Stephens, E.P. 1977. **Reconstruction of a mixed-species forest in central New England.** Ecology 58: 562-572.
- Rizzo, D.M.; Garbelotto, M. 2003. **Sudden oak death: endangering California and Oregon forest ecosystems.** Frontiers in Ecology 1(5): 197-205.
- Spencer, M.; O'Hara, K.L. 2006. **A Multiple Logistic Regression Model for Predicting the Development of *Phytophthora ramorum* symptoms in Tanoak (*Lithocarpus densiflorus*).** In: Standiford, R.B.; Giusti, G.A.; Valachovic, Y.; Zielinski, W.J., technical coordinators. Proceedings of the Redwood Region Forest Science Symposium; 2004 March 15-17; Rohnert Park, CA Gen. Tech. Rep. PSW-GTR-194. Albany, CA: Pacific Southwest Research Station. USDA Forest Service; [this volume].
- Swiecki, T. 2002. **Restoration of oak woodlands impacted by sudden oak death.** California Oak Mortality Task Force Executive Committee; 9 p.
- Tappeiner, J.C., II; McDonald, P.M.; Roy, D.F. 1990. ***Lithocarpus densiflorus* (Hook&Arn.) Rehd.: Tanoak.** In: Burns, R.M.; Honkala, B.H., technical coordinators. Silvics of North America. Volume II. Hardwoods. Agric. Handb. 654. Washington, DC: U.S. Department of Agriculture; 22 p.
- Zinke, P.J. 1988. **The redwood forest and associated north coast forests.** In: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. Exp. ed. Sacramento, CA: California Plant Society Press; 679-699.