Understanding the relationship between Fire and Dead Trees- A literature Review

ABSTRACT

A report to the Mendocino County Fire Safe Council evaluating the relationship between herbicide killed trees and fire behavior in coastal forests.

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Introduction

The assignment given to this project was to identify sources of scientific literature that could help a lay person understand the relationship between fire behavior and "*intentionally killed trees*" in Mendocino County. This assignment, and its focus on "*intentionally killed trees*", has some inherently difficult limitations that will require this author to expand the scope to include other sources of tree mortality (insects and disease) to fully address the issue of fire behavior. Additionally, the geographical focus on Mendocino County further limits and compounds the challenge as it limits the sources of information available. To augment this report this review will include sources of information from the "redwood region", the Klamath Mountains of northern California, and to a limited extent the Pacific Northwest to fully vet the topic.

A recent paper by Valachovic et.al. [15] provides the most comprehensive empirical data that directly addresses the topic. Other works by Stephens [14], Finney[5], and Giusti[8] will be used to supplement various important points pertinent to the topic.

Trees and Fire – What's the Connection

Trees and forests in the jargon of fire science are often categorized by 1) different fuel sources i.e. Aerial, Surface and Ground sources; and 2) the type of fuels found at these various structures.

If we look at trees as a source of combustible fuel we can break down the various components to better understand the flammability of the different parts. Tree parts like leaves, twigs, and small branches are generally lumped into a category of "fine" fuels. In addition, other non-tree vegetation components can add to the list of fine fuels i.e. grasses, small shrubs. Fine Fuels by definition = *Fuels with a high surface-area-to-volume ratio that dries readily and is rapidly consumed by fire when dry*."

The other commonly used term to describe fuel flammability is "coarse or rough fuels". Course fuels are defined "*as those limbs and branches usually greater that 3" in diameter lying on or near the surface of the ground, dead branch material, downed logs, bark, tree cones, and living plants of low stature. In natural ecosystems, fire generally is ignited in and carried by surface fuel [4]."*

For our purposes we consider wildland fire to be *combustible plant-derived material including grass, litter, duff, down dead woody debris, exposed roots, plants, shrubs, and trees. This plant-derived material can be dead or alive.*

Fire and its Environment – Another Connection

Fire, fire intensity, and fire behavior are all products of the conditions and elements of the environment. Parameters affecting fire include: compaction of fuels; horizontal continuity of fuels; vertical arrangement of vegetation; fuel moisture content; chemical properties of the vegetation; volatile substances found within different vegetation species; timelag; vegetation life cycle stage; ambient temperature; ambient humidity; terrain steepness and ordinal aspect.

Timelag – Is the moisture content in fuels that can change very rapidly, depending on the relative humidity of the air and precipitation. Moisture content changes in larger fuels, but at a much slower rate. Fire sciences has determined drying times for different size fuels and have designed a system to determine and record fuel moisture percents. We use the term time lag and have placed various sizes of fuels into convenient timelag categories or classes.

Timelag *is a measure of the rate at which a given dead fuel gains or loses moisture.*

The timelag categories are:

1 hour timelag fuels: less than 1/4 inch diameter

10 hour timelag fuels: 1/4 to 1 inch diameter

100 hour timelag fuels: 1 to 3 inch diameter

1000 hour timelag fuels: greater than 3 inch diameter

Fire and Fuels

From a fire's perspective the *source* of tree mortality; insects, disease, age, or herbicides makes little difference. What does matter is how each of these catalyst affect fuel *loading* and availability. All forests go through cycles that affect tree mortality at different rates. Insects can be episodic, localized or spread over a large geographic area; diseases can be species specific (Sudden Oak Death, *Phytophthora ramorum*) and limit its impacts to only one segment of the plant community; age will affect all species eventually; and herbicides can be localized, but individual applications can be widespread across the landscape. In the redwood forest type insects play a relatively small part in tree mortality, whereas disease and herbicide applications are primary drivers of mortality.

Fire in the Redwood Forest Community

Fire studies in redwood forest demonstrate that fire is a recognized historical disturbance [1, 3, 13] that is influenced by the geographic location of the north-south and west-east distribution of redwoods. Coastal sites had fire intervals of 150-200 years [16] while inland sites experienced fire on an average of 33-50 years. Fires in Sonoma County redwood stands were shown to occur every 6-23 years [6]. In another study fuel depth and load where shown to affect fire intensity and duration [13] while elevation, relative humidity and fuel moisture influenced ease of ignition and rates of spread. The occurrence of past fires is readily visible in redwood stands through the presence of charred bark and trunk hollows (goose pens). In a separate report Giusti [9] provides an ecological comparison between fire and mechanical impacts to redwood stands and shows that careful and thoughtful mechanical impacts can mimic and serve as a surrogate for addressing the challenges facing management in this time of aggressive fire suppression.

In yet another study the authors show that Douglas-fir-tanoak forests have the greatest potential for individual tree torching and canopy fire spread. Douglas-fir-tanoak forests tend to occur on dry, upper slopes that can result in higher intensity and severity fire than more fire-resistant grasslands and oak woodlands, and in contrast to the typically lower-slope coast redwood systems that sustain low-severity fires [6, 12].

Fuel Loading and Herbicides

Information on this topic is extremely limited and best summarized in a study by Valachovic and others [15]. In their paper they evaluated fuel loading across Humboldt, Mendocino and Sonoma Counties to serve as surrogates to understand fuel loading being caused by *P. ramorum*. In their study they evaluated fuel loading 2-5; 5-8; and 8-12 years post treatment. They selected Douglas-fir-tanoak stands between 40-60 years old as these represent the most typical stands where herbicide treatments would be applied. They collected data on fuels across the timelag spectrum as well as litter and duff layer depths on the forest floor.

Tanoak Densities and fate in different forest types

In pre-treatment sites Giusti [9] found tanoak densities to be 533 trees/acre on a redwood dominant site in northwestern Mendocino County while Valachovic found tanoak densities averaged 446 trees/acre in Douglas-fir-tanoak dominant stands. In another study conducted in Jackson Demonstration Forest Jameson and Robards [11] found 9 years after timber harvest, the combined density of hardwood and brush species was 1,816 and 2,307 stems/acre. In another Unit, which was not burned, the density of hardwood and brush stems was 277 stems/acre. In the Valachovic study tanoak densities were reduced to 84 trees/acre following herbicide treatment. Over time, the treated sites rebounded to an average of 185 trees/acre following subsequent sprouting or germination of new tress. They further found that on average dead tanoaks began to fail and fall into the surface fuel complex (5-8 years). However, they further found that not all trees had failed by the late stage (8-12 years).

Herbicide treatments increase surface fuels over time [15]. As would be expected 1-, 10- and 100-hour woody fuels increased slightly in the early stage (2-5 years) post treatment. By the end of the late stage (8-12 years) surface fuels nearly doubled in treated sites when compared to a control. As trees shed leaves, and limbs fuel bed depth doubled in the early stage peaked at the middle stage (5-8 years). A similar study conducted at Point Reyes National Seashore (Marin County) found similar increases in fuel loads in stands of tanoak that progressively impacted by Sudden Oak Death disease [7] . These studies show a positive relationship exists between dead tanoak basal area and surface fuels.

Fire Behavior and Fuels

The availability of fuels does not necessarily insure that a fire will occur. All fires need an ignition source e.g. lightning, camp fire, spark(s) from machinery, a discarded cigarette, etc. In Mendocino County, lightning fires are uncommon but do occur; the principle source of wildland ignitions are human-caused. Additionally, if a fire should start it is not necessarily "*drawn*" to an area of dead trees. As previously explained, fire movement is affected by slope, climate, wind, and terrain. If an area of dead trees should be in the path of a moving fire that is when fire behavior can be affected.

In a paper addressing mountain pine beetle mortality the authors determined stand level fire behavior models suggest that bark beetle-induced tree mortality increases *flammability* (emphasis added) of stands by changing canopy and forest floor fuels, but they further found that the effect of beetle infestation on the area burned in years of extreme fire appears negligible. Contrary to the expectation of increased wildfire activity in recently infested stands, they found no difference between observed area and expected area burned in stands during three peak years of wildfire activity. To synthesize, the authors concluded that fire pathways were not driven by standing dead trees. However, when a fire did enter a stand of dead trees then the condition of the trees affected fire behavior at the site [10].

If a fire should enter a stand of dead trees then the condition of the standing trees can influence fire behavior. In this illustration Valachovic shows how time affects tree condition, and how tree conditions affect fire behavior following herbicide induced mortality. The illustration shows clearly how time influences fuels and how flammability is affected. This demonstrates that flammability and time have a direct relationship between herbicide application and tree decline. As her paper demonstrate, 8-12 years post treatment would be a time of highest flammability due to the condition of the available fuels.

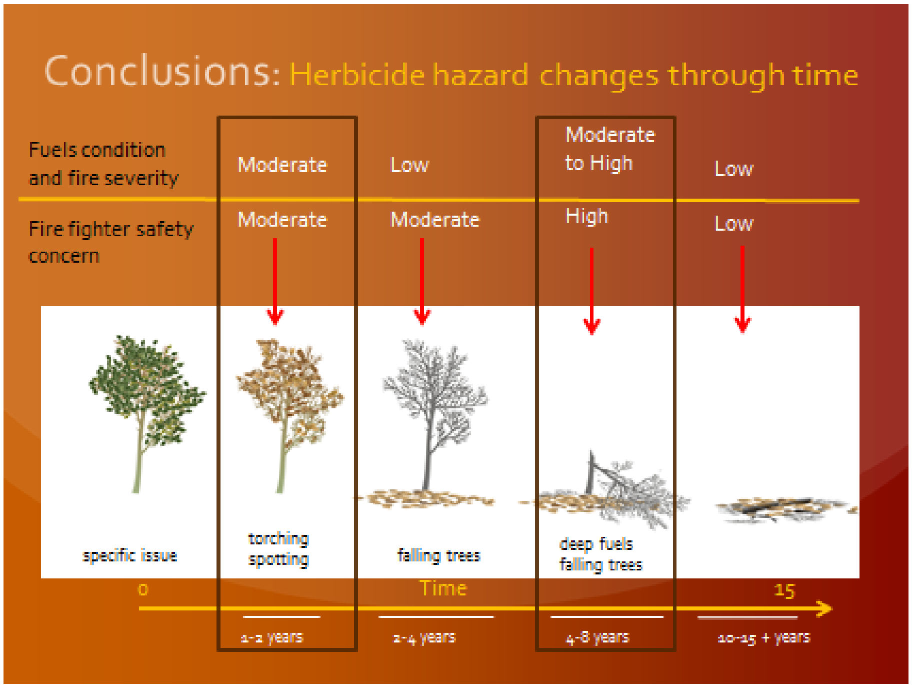


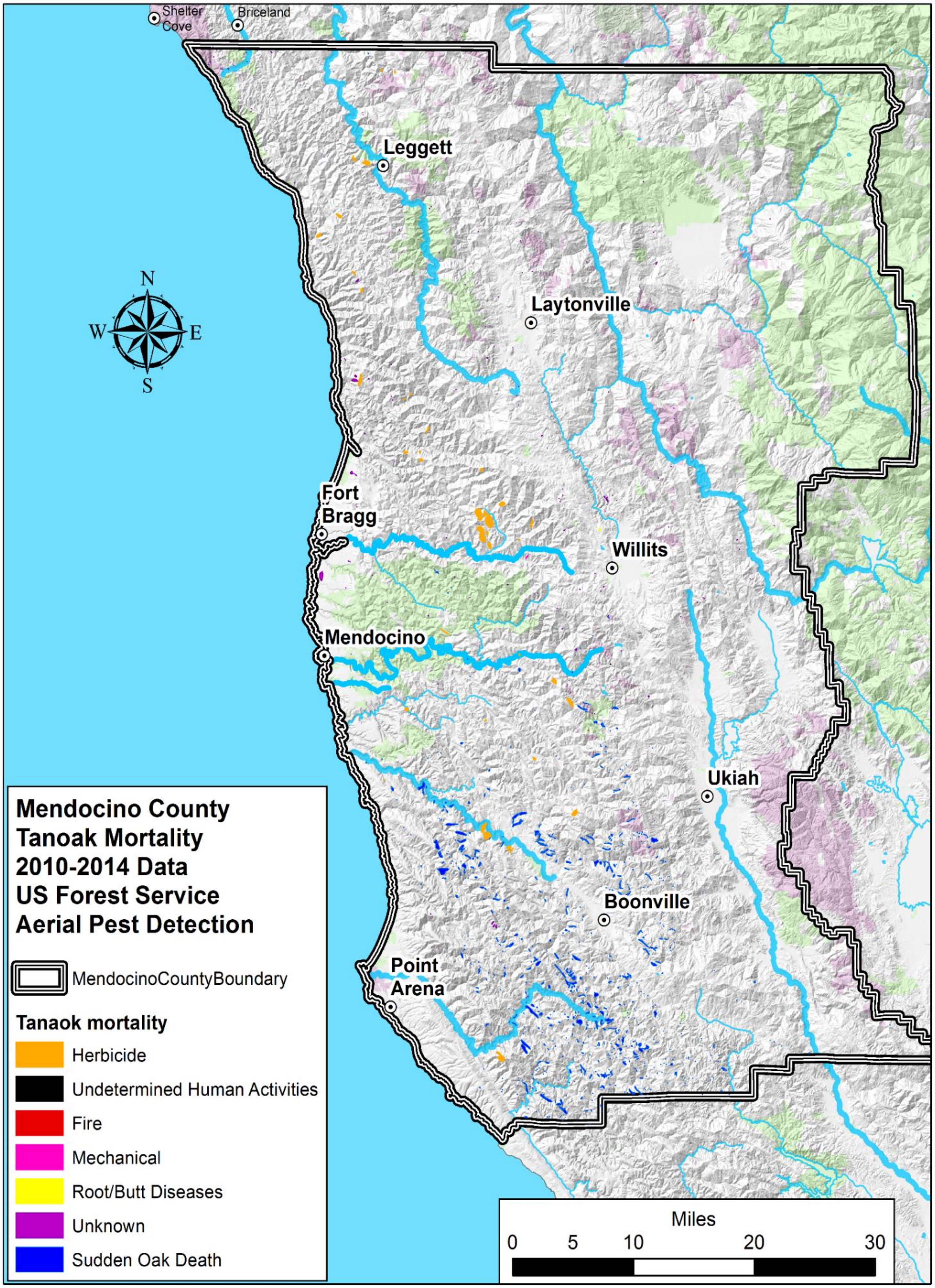
Fig. 1. Graphic showing the progression of fuel loading following herbicide treatments.

Time and Space

In the previous paper by Hart evaluating fire movement and behavior in stands killed by beetles they stressed the need to take a spatial view of standing dead trees to appreciate what factors moved a fire toward dead standing trees. They make the very strong statement "*Contrary to the expectation that an MPB outbreak increases fire risk, spatial overlay analysis shows no effect of outbreaks on subsequent area burned during years of extreme burning across the West….. our results demonstrate that the annual area burned in the western United States has not increased in direct response to bark beetle activity"*. To synthesize, they put forward the proposition that having dead standing trees has no impact on where and when a fire will occur.

In another study assessing tree mortality and fire severity a study by Bond and others[2] in southern California make a similarly bold statement by writing "*We found no evidence that pre-fire tree mortality influenced fire severity*". Once again, they talk about evaluating fire behavior and severity over the landscape matrix. In their paper they site another study wherein a regional analysis of 303 fires beetle-affected stands did not burn at higher severities than unaffected stands in fires occurring several decades after the outbreaks.

Fig. 2. USDA – Forest Service map of Mendocino County showing distribution of tanoak mortality across the forest matrix addressing the spatial context of mortality.


Mendocino County
Tanoak Mortality
2010-2014 Data
US Forest Service
Aerial Pest Detection
MendocinoCountyBoundary
Tanaok mortality
Herbicide
Undetermined Human Activities
Fire
Mechanical
Root/Butt Diseases
Unknown
Sudden Oak Death
Miles
0 5 10 20 30
N
S
E
W
Shelter Cove
Briceland
Leggett
Laytonville
Fort Bragg
Willits
Mendocino
Ukiah
Boonville
Point Arena

Bringing the discussion back to Mendocino County one needs to look at the spatial distribution of dead trees distributed across the landscape. The map shows the distribution of tanoak mortality in Mendocino County between 2010-2014. Sudden oak death disease is the primary cause of tanoak mortality across the county concentrated along the Hwy 128 corridor and the southwest corner of the County. Acreage totals reported by USDA – Forest Service aerial surveys estimate acres affected by SOD to be:

2011: 8,000 acres	2013: 45,500 acres	2014: 28,700 acres

Herbicide mortality is distributed sparingly throughout the commercial timberlands. Other mortality factors include non-SOD diseases, other human land-use practices, and fire. The same USDA-FS aerial survey estimated that approximately 3,165 acres of tree mortality were caused by herbicide applications.

The map shows how dead stands of trees are distributed across the landscape. It also shows how much of the forest matrix is not dominated by dead trees thereby serving as a buffer between the dead stands that, depending on their state of decay, are relatively more flammable. Given this spatial context the work by Hart[10] and others predicts that the dead stands provide no greater risk of fire than living stands given the other factors that affect fire behavior and ignition. They boldly state: "*These results refute the assumption that increased bark beetle* (tree mortality) *activity has increased area burned*".

Fire and fire behavior is the sum of many parts. Of particular importance is the forest matrix being evaluated as one type of forest type (Douglas-fir/Tanoak) is considered relatively more at risk from fire than a redwood stand which is considered less flammable. Additionally, the stand of dead trees needs to be viewed in the context of the entire forest matrix as juxtaposition of dead stands, and contiguity of dead trees can play a role in fire behavior.

Summation

Key points identified in this review are summarized. They are:

1) Different fuel types (fine vs. coarse) ` different fire behavior;
2) Fuel types are measured by a term coined "lag time" which is a ratio between moisture content in wood and the time required for the wood to lose moisture over time;
3) Wildland fires are affected by climate, weather, slope, aspect and fuel availability and condition;
4) Fire behavior is not dependent on the cause of mortality;
5) Douglas-fir/Tanoak forests tend to be relatively more flammable than redwood forests;
6) Herbicide treatments, like tree diseases, increase surface fuels over time – a positive relationship exists between dead tanoak basal area and surface fuels;

7) Dead trees affect flammability but do not necessarily affect fire behavior across the entire forest matrix;
8) Dead stands need to be evaluated spatially to determine fire risk in context of the forest matrix.

Literature Cited

1. Abbot, L. L., 1987. The effect of fire on subsequent growth of surviving trees in an old growth redwood forest in Redwood National Park, California. Master's Thesis. Humboldt State University, Arcata, Calif.
2. Bond, M. L., D. E. Lee, C. M. Bradley, C. T. Hanson. 2009. The open Forest Science Journal. 2:41-47.
3. Brown, P. M. and T.W. Swetnam, 1994. A cross-dated fire history from coast redwood near Redwood National Park, California. Canadian J. of Forest Research. 24:2131.
4. Debano, L.F., D. G. Neary, P.F. Folliott. 1998. Fire's Effects on Ecosystems. New York, NY: J. Wiley and Sons.
5. Finney, M. A. 1991. Ecological effects of prescribed and simulated fire on coastal redwood (Sequoia sempervirens) [D. Don] Endl.). PhD diss. University of California, Berkeley.
6. Finney, M. A., R. E. Martin. 1992. Short fire intervals recorded by redwoods at Annadel State Park, California. *Madrono* 39:251-262.
7. Forrestel, A. B., B. S. Ramage, T. Moody, M. A. Moritz, S. l. Stephens. 2015. Disease, fuels and potential fire behavior: Impacts of Sudden Oak Death in two Coastal California types. Forest Ecol. and Mngt. 348: 23-30.
8. Giusti, G. A. 2013. Ecological assessment of biomass thinning in coastal forests – A literature review. 24 pp. http://cemendocino.ucanr.edu/files/195828.pdf
9. Giusti, G. A. 2014. Ecological assessment of biomass thinning in coastal forests – Phase II: Pre and post-harvest stand assessment of woody biomass harvesting. 8 pp. http://cemendocino.ucanr.edu/files/195829.pdf
10. Hart, S. J., T. Schoennagel, T. T. Veblen, and T. B. Chapman. 2015. Area burned in the western United States is unaffected by recent mountain pine beetle outbreaks. PNAS 112 (14) 4375-4380.
11. Jameson, M. J. and T. A. Robards. 2007. Coast Redwood Regeneration Survival and Growth in Mendocino County. West. J. Appl. Forestry 22(3) 171-175.
12. Lorimer, C. G., D. J. Porter, M. A. Madej, J. D. Stuart, S. D. Veirs, S. P. Norman, K.L. O'Hara, W. J. Libby. 2009. Pre-settlement and modern disturbance regimes in coast redwood forests; implications for the conservation of old-growth stands. Forest Ecol. and Mngt. 258:1038-1054.

13. Nives, S. L. 1989. Fire behavior on the forest floor in coastal redwood forest, Redwood National Park. Master's Thesis, Humboldt State University, Arcata, California.
14. Stephens, S. L., J. J. Moghaddas. 2005. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. Forest Ecol and Mngt. 215:21-36.
15. Valachovic, Y. S., C.A. Lee, H. Scanlon, J. M. Varner, R. Glebocki, B.D. Graham, and D. M. Rizzo. 2011. Sudden oak death – caused changes to surface fuel lading and potential fire behavior in Douglas-fir/Tanoak forests. Forest Ecol. and Mngt. 261: 1973-1986.
16. Viers, S. D. 1980. The role of fire in northern coast redwood forest dynamics. Pp. 190-209 in *Proceedings, conference on scientific research in national parks*. Vol. 10, Fire Ecology. San Francisco. Ca., Washington D. C. National Park Service.

Links for further reference:

National Wildfire Coordinating Group (NWCG). 2005. Glossary of Wildland Fire Terminology. [Online]. http://www.nwcg.gov.

CalFire Fire Hazard Severity Zone Maps –

http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones

University of California Center for Forestry Wildland Fire link:

http://ucanr.edu/sites/forestry/Wildfire/

USDA Forest Service Fuels classifications:

http://ocw.usu.edu/Forest__Range__and_Wildlife_Sciences/Wildland_Fire_Management_and_Planning/Unit_2__Fuels_Classification_2.html

USDA Forest Service Tree Mortality maps:

http://www.fs.usda.gov/Internet/FSE_DOCUMENTS/stelprd3841372.pdf