Proceedings—Fire Effects on Rare and Endangered Species and Habitats Conference, Nov. 13-16, 1995. Coeur d'Alene, Idaho.

Fire Regimes and Management of Old-growth Douglas fir Forests in the Klamath Mountains of Northwestern California

Alan H. Taylor and Carl N. Skinner

Department of Geography, The Pennsylvania State University, 302 Walker Bldg., University Park, PA 16802
Tel. (814) 865-3433; Fax (814) 863-7943; E-mail ahtl@psuvm.psu.edu

USDA Forest Service, Pacific Southwest Station, Redding, CA 96061

Introduction

The vegetation of the Klamath Mountains of northwestern California is of exceptional biogeographical interest. Whittaker (1960, 1961) considered the region the historic center of floristic and vegetational development for forests in the western United States. The Klamath Mountains are floristically diverse and they have one of the highest concentrations of relictual and endemic species in California. For example, within one square mile of the sugar creek drainage in the Klamath National Forest seventeen conifer species are found, the greatest concentration of conifer species on earth.

Whittaker (1960) conducted a study of the vegetation of the Klamath (Siskiyou) Mountains in southern Oregon that documented population and community distributions along environmental gradients. He concluded that the complex species and community patterns in the Siskiyou portion of the Klamath Mountains were a product of exceptionally steep gradients in climate, topography, and parent material.

Since Whittaker (1960) developed his enduring model of vegetation-landscape relations ecologists and biogeographers have intensified research on the role of disturbance in shaping community structure and dynamics. Disturbances are now widely recognized as being common processes in forested landscapes that influence the distribution and abundance of species at stand and landscape scales. Moreover, environmental gradients influence disturbance gradients (e.g. Harmon et al. 1983; Veblen et al. 1992). In other words, landscape sale vegetation patterns are a composite of the superimposed patterns of species response to environment and disturbance.

The most common disturbance in the Klamath Mountains is fire. Yet little is known about fire regimes in this region, or how they may influence forest community structure and dynamics. Fire regime parameters that must be characterized to identify a fire regime include: frequencies, severities, sizes, and spatial distributions of fire. These parameters vary spatially and temporally due to variable patterns of stand development, fuels accumulation, climate, burning practices of native Americans and European settlers, and fire suppression activities.

European trappers first entered the Klamath Mountains in about 1810. Later, thousands of miners and prospectors converged on the area in 1850 when gold was discovered and they are reported to have set fires prodigally: unintentionally from neglected campfires, and intentionally to make travel easier, to clear ground for prospecting, for hunting, and for recreation. Miners are said to have set fires to enliven an evenings drinking with a mountain slope in flames and there is a report of miners driving game with fire successfully. The hunt bagged 18 Elk through destruction of 3 billion hoard feet of timber (Lieberg 1900; Forest Service 1940). There are few fire history data that can be used to evaluate these descriptions of settler fires in the Klamath Mountains and whether these fires altered the presettlement fire regime. Native Americans in the Klamath Mountains set fires to increase production of plants for food, basket material, and arrow shafts (Lewis 1993). Fire suppression began with the establishment of the National Forest System in 1905.

Objectives

The overall purpose of this study was to describe the fire regime in the north-central Klamath Mountains. Specific objectives included the identification of: 1) fire frequencies; 2) fire sizes; and 3) fire severities across environmental and vegetational gradients. An additional objective was to determine if and how European peoples influenced fire regimes in our study area.

In this paper, we describe the temporal and spatial variability of fire regime parameters for the period 1740-1992 and then discuss the implications of these data for management of late seral forest reserves in the Klamath Mountains.

Study Area

The study area encompassed 18 km^2, of steep dissected terrain in the north-central Klamath Mountains (Figure 1). The study site is a designated Late Successional Forest Reserve in the Klamath National Forest (HCA C-5) under option 9 (USDA 1994). Our study area is <30 km south of Whittaker's (1960) research site. Elevations in the study area range from 600-1600 m and forest types include Whittaker's (1960) low altitude *Pseudotsuga* (*Pseudotsuga menziesii*) evergreen forest, and the lower end of the montane *Abies concolor* zone.

Methods

Forest structure and composition were sampled in 75 plots distributed throughout the study area. Plot location was based on structurally and compositionally homogenous vegetation units that were identified on aerial photographs.

Vegetation was sampled in variable size plots so that each plot contained at least 20 trees. Sampling was conducted in both clearcuts and uncut forest. For each sample, the dbh and age of each tree were determined and the dates of radial growth releases and suppressions was identified because they may have been caused by fires. Fire scar dates were also recorded on ring- counted stumps.

Most fire dates were identified from fire scars in stem cross-sections (n=245) that were sanded and examined under a binocular microscope. Stand age data were also used to identify fire dates and to infer fire severity.

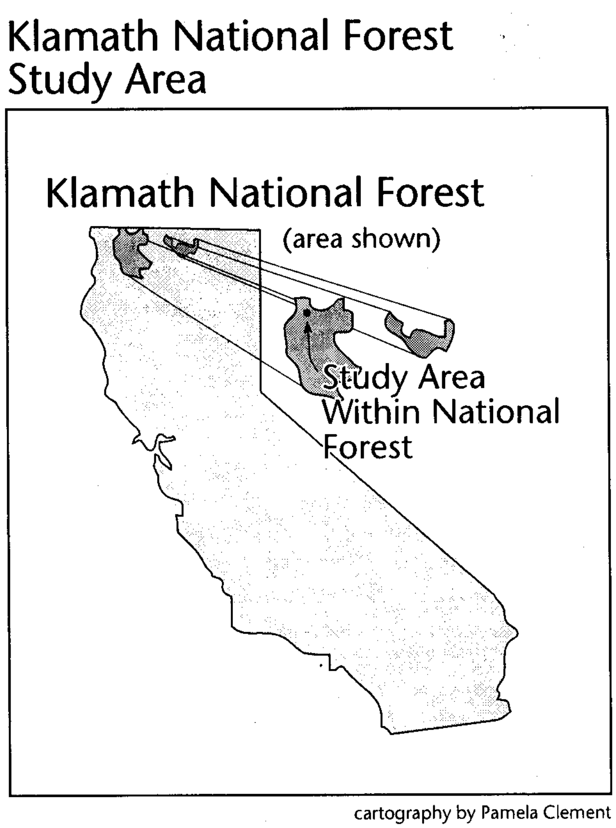

Figure 1. Location of study area within the Klamath National Forest.

Forest Vegetation

Ordination

Ordination of the 75 vegetation samples indicate that species abundance varies with elevation and potential soil moisture. Forests dominated by white fir (*Abies concolor*) occur at high altitude while mixed white fir/Douglas fir forests occur at slightly lower elevation, and in low elevation mesic coves. Douglas-fir is the sole conifer dominant on mid-elevation sites on all aspects. Mixed Douglas fir/sugar (*Pinus lambertiana*) forests occupy lower elevations on dry sites, and low xeric sites on west and southwest facing slopes are dominated by Douglas-fir/ponderosa pine (*Pinus ponderosa*) forests. Patterns of species dominance by elevation and site moisture conditions are similar to the forests described by Whittaker (1960).

Fire History

Identification of the fire suppression period

The number of sites recording fires in the study area for the period 1740-1992 indicates that fire suppression efforts by the Forest Service beginning in 1905 were only partially successful. There was a small decrease in fire occurrence around 1905. A large decline in fire occurrence did not occur until the mid 1940s. The most recent fire occurred in 1987 and burned through more than 70% of the study area. The virtual elimination of fire from the study area in the 1940s is consistent with fire records from the Klamath and adjacent Siskiyou National Forest in Oregon. Apparently, fire suppression did not become effective in this part of the country until fire suppression methods were mechanized in the 1940s.

Fire History

Forest vegetation types

Two patterns of variation in fire frequency were evident in the fire frequency data. First, fire frequencies decrease from low elevation xeric Douglas fir/ponderosa pine forests to more mesic white fir forests at high elevation (Table 1). Average fire frequencies were high at 7.6

Table 1. Average number of fires per century by forest type and time period. The number in parentheses is the average fire free interval in years.

Forest type	Suppression 1905-1992	Settlement 1850-1904	Presettlement 1740-1849
White fir	4.1 (24.3)	2.7 (37.0)	2.7 (37.0)
White fir/Douglas fir	3.2 (31.2)	5.6 (17.8)	4.3 (23.2)
Douglas fir	2.9 (34.4)	6.9 (14.5)	4.7 (21.2)
Douglas fir/sugar pine	4.5 (22.2)	7.5 (13.3)	6.7 (14.9)
Douglas fir/ponderosa pine	3.4 (29.4)	7.5 (13.3)	7.6 (13.1)

fires per century in Douglas fir/ponderosa pine forests in both the settlement and presettlement periods. Fire frequencies during the settlement period in Douglas fir/sugar pine forests were similar to Douglas fir/ponderosa pine forests, at 7.5 fires per century. But the frequency was lower, at 6.6 fires per century during the presettlement period. Douglas fir forests had lower fire frequencies than forests with a pine component with 6.9 fires per century during the settlement period, and 4.7 fires per century during the presettlement period. Fire frequencies were lower in white fir/Douglas fir forests at 5.6 fires per century during the settlement period and 4.3 fires per century during the presettlement period. Only 2.2 fires occurred every century in high altitude white fir forests.

Second, the data suggest that fire frequencies were higher during the settlement than presettlement period and that fire frequencies declined alter 1905 by 30-230% depending on the forest type (Table 1). This suggests that European settlers may have influenced the fire regime by increasing ignitions.

Elevational patterns of fire frequency

Since elevation exerts strong control on the spatial patterning of forest communities and fire environments in our study area we examined patterns of fire frequency by slope position. Fires occurred most frequently in all periods on upper slopes (Table 2). The largest difference in fire frequency by slope position occurred during the presettlement period. Fire frequency was about 45% lower on low slopes than on mid and upper slope positions (Table 2).

Slope aspect patterns of fire frequency

Patterns of fire frequency also varied by slope aspect (Table 3). During the settlement and presettlement periods fires were most frequent on south facing slopes and less frequent on other slope aspects. In contrast, fires were least frequent on south slopes, compared to other aspects, during the suppression period.

Fire size and severity

Variation in fires sizes were analyzed by time period. Fire sizes for each year were crudely estimated as the product of the percentage of sites with fires and study area size (1800 ha). Fire sizes were then grouped into 100 ha size-classes by time period and their frequency distributions were compared using a Kolmogorov-Smirnoff two sample test. The frequency distribution of fire sizes were not different ($P>0.05$) during any of the periods (Table 4). Most fires were <300 ha and the largest fires occurred in 1987 (1260 ha) 1898 (530 ha), 1883 (580 ha), 1853 (365 ha), and 1783 (400 ha).

Fire severity

Fire severity is a measure of the degree to which fires alter vegetation on a site. Fire severity varies from low for surface fires that consume only forest litter to severe for stand replacing fires. Douglas fir in these forests establishes primarily alter moderate and severe fires so the frequency distribution of Douglas fir age-classes throughout the study area provides a rough indication of the timing of severe fires. In our study area, the frequency of Douglas fir age-classes increases in about 1880 suggesting that one or more severe fires occurred during the settlement period.

Table 2. Average number of fires per century by slope position and time period. The number in parentheses is the average fire free interval in years.

Slope position	Suppression 1905-1992	Settlement 1850-1904	Presettlement 1740-1849
Upper (>1275 m)	3.7 (27.0)	7.4 (13.5)	5.8 (17.2)
Middle (990-1275 m)	3.2 (31.3)	6.4 (15.6)	5.4 (18.5)
Lower (<990 m)	3.4 (29.4)	6.4 (15.6)	3.5 (28.6)

Table 3. Average number of fires per century by slope aspect and time period. The number in parentheses is the average fire free interval in years.

Slope aspect	Suppression 1905-1992	Settlement 1850-1904	Presettlement 1740-1849
North	3.2 (31.3)	6.0 (16.6)	5.1 (19.6)
East	3.4 (29.4)	7.0 (14.3)	3.9 (25.6)
West	4.1 (24.3)	6.5 (15.3)	5.8 (17.3)
South	2.4 (41.6)	7.3 (13.6)	6.0 (16.6)

Summary of fire history

Our data show that fire has been a common and important disturbance in old-growth Douglas fir forests in the Klamath Mountains and that there is spatial variability in the characteristics of the fire regime. Fires burned frequently during the presettlement period with 7.6 to 2.7 fires occurring every 100 years depending on forest type. Fires were most frequent in lower altitude Douglas fir/ponderosa pine forests on xeric sites and least frequent in higher altitude mesic white fir forests. Descriptions of increased and pervasive burning by miners, stockmen, and settlers after the area was settled in 1850 may be reflected in the fire frequency data. Fires were more frequent in Douglas fir/sugar pine, Douglas fir, and white fir/Douglas fir forests in the settlement than in the presettlement period. All forests, except white fir forests for which we had few (n=4) samples, show a decrease in fire frequency during the suppression era.

Data on fire sizes suggest that fire sizes were similar during the presettlement, settlement, and early suppression periods. But age structure data suggest that fires may have been more severe during the settlement period. Many stands in our study area had Douglas fir age- classes that originated in the 1880s. Even-aged stands that established after severe fires in the late 1800s are also common in the nearby Siskiyou mountains. Settlers seem to have influenced the fire regime by increasing both the frequency and severity of fires. Warmer drier conditions during the late 1800s may also have contributed to the higher fire frequency and severity in the settlement period (Graumlich and Brubaker 1986; Graumlich 1987,1993; Fritts et al. 1979; LaMarche and Stockton 1974).

Our estimates of fire frequency are conservative. Low intensity fires rarely scar mature trees. So the observed geographical differences in fire frequency between our Douglas fir forests and those in Oregon and Washington are probably greater than the data suggest.

Table 4. Frequency distribution of fire sizes (ha) by time period.

Size-class	Suppression 1905-1992	Settlement 1850-1904	Presettlement 1740-1849
<100	4	4	7
100-199	5	3	15
200-299	-	6	6
300-399	1	3	2
400-499	3	-	1
500-599	-	2	-
>1000	1	-	-

Synthesis with other studies

Data on fire frequencies from other studies in the central Klamath Mountains include vegetation types identified by Whittaker (1960) that were not present or well represented in our study area. Low elevation Douglas fir/hardwood forests studied by Wills and Stewart (1994) had fire frequencies of 8.7 and 8.2 fires per century during the presettlement and settlement periods, respectively. Fire frequency was lower in the suppression era at 4.1 fires per century. Their data suggest that fire frequencies are higher in low elevation mixed evergreen forests than in the Douglas fir/ponderosa forests in our study area. Agee (1991a) estimated a fire rotation of about sixty years in mesic high elevation white fir forests which is consistent with the lower fire frequencies we found for white fir forests.

There are no fire history data for upper montane red fir forests in the Klamath Mountains but data from the Cascades and Sierra Nevada indicate that about 1.5-2.2 fires occur every century, on average, in this forest type (Pitcher 1987; Taylor and Halpern 1991; Taylor 1993). The gradient of fire frequency identified in our study area and from nearby sites parallels environmental and vegetation gradients in the region.

Management Implications

The structure and composition of late successional Douglas fir forests have been described in detail in the Washington and Oregon Cascades and Coast Ranges (e.g. Franklin et al. 1981). Key old-growth structural attributes include large live old trees, a large number of snags of various ages, a multilayered canopy, and moderate to high accumulations of logs or coarse woody debris on the forest floor. These forests developed under a fire regime of infrequent (20-50 yr) light surface fires, localized intense fires every 100-200 years and extensive stand replacing fires at intervals probably greater than 400 years (Stewart 1989; Morrison and Swanson 1990; Agee 1993).

Old-growth Douglas fir forests in our study area have a very different fire regime. Low and moderate severity fires are frequent and this has created patterns of forest structure and development that are different from those in more mesic Douglas fir forests in Oregon and Washington (e.g. Agee 1991b). In fact, the geographical differences in fire regimes are probably greater than the data suggest because our estimates of fire frequency are conservative. Low severity fires rarely scar trees.

One old-growth structural attribute that probably has been historically different in Klamath Mountains Douglas-fir forests than those in Oregon and Washington is the amount of coarse woody debris that accumulates on the forest floor. Low intensity fires in old-growth stands consume coarse woody debris (e.g. Thornburgh 1995). It is unlikely that coarse woody debris could accumulate to the levels found in mesic Douglas fir forests under a fire regime of frequent low and moderate severity fire.

A hands off approach to managing late successional forests under the current fire regime (suppression) in the Klamaths could be viewed as improving old-growth stands because coarse woody debris would increase on the forest floor. Moreover, shade tolerant species such as white fir would also invade increasing the vertical diversity of forests. In fact, 70% of the Douglas fir and Douglas fir-pine stands in our study area had a developing understory layer of white fir that established during the fire suppression era. Before fire suppression most white fir seedlings were killed by light fires. Our data suggest that continued fire suppression coupled with coarse woody debris accumulations and development of vertical fuel ladders will increase the probability of extensive severe fires in old-growth stands. Maintenance of old-growth stands may require use of prescribed fire and perhaps other fuel treatments to reduce the risk of severe fires and to maintain the processes responsible for old-growth forest development in the Klamath Mountains. Finally, our data suggest that promoting development of old-growth structures in adjacent younger stands should be examined critically. For example, increasing coarse woody debris in younger stands may increase fire risk and if these stands burn fire may more easily spread into old-growth remnants.

References

Agee, J.K. 1991a. Fire history along an elevational gradient in the Siskiyou Mountains, Oregon. Northwest Science 65:188-199.

Agee, J.K. 1991b. Fire history of Douglas-fir forests in the Pacific Northwest, pp. 25-33, In, Ruggiero, L.F. et al. (Technical coordinators) Wildlife and vegetation of unmanaged Douglas- fir forests. USDA Forest Service General Technical Report PNW-GTR-285.

Agee, J.K. 1993. Fire ecology of Pacific Northwest Forests. Island Press, Covelo.

Forest Service 1940. Map of Siskiyou National Forest Oregon and California. USDA Forest Service.

Franklin, J.F., K. Cromack, W. Denison, A. Mckee, C. Maser, J. Sedell, F. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. USDA Forest Service General Technical Report PNW-118.

Fritts, H.C., G.R. Lofgren, and G.A. Gordon. 1979. Variations in climate since 1602 as reconstructed from tree rings. Quaternary Research 12:18-46.

Graumlich, L.J. and L.B. Brubaker. 1986. Reconstruction of annual temperature (1590-1979) for Longmire, Washington derived from tree rings. Quaternary Research 25:223-234.

Graumlich, L.J. 1987. Precipitation variation in the Pacific Northwest (1675-1975) as reconstructed from tree rings. Annals of the Association of American Geographers. 77:19-29.

Graumlich, L.J. 1993. A 1000-year record of temperature and precipitation in the Sierra Nevada. Quaternary Research 39:245-255.

Harmon, M.E., S.P. Bratton, and P.S. White. 1983. Disturbance and vegetation response in relation to environmental gradients in the Great Smokey Mountains. Vegetatio 55:129-139.

LaMarche, V.C. and C.W. Stockton. 1974. Chronologies from temperature sensitive bristlecone pines at upper tree line in the western United States. Tree-Ring Bulletin 34:21-45.

Lewis, H.T. 1993. Patterns of Indian burning in California: ecology and ethnohistory, pp. 55-116, Before the wilderness: environmental management by native Californians, edited by T.C. Blackburn and K. Anderson. Ballena Press, Menlo Park, California.

Lieberg, J.B. 1900. Cascade Range and Ashland forest reserves and adjacent regions. USGS Annual Report 21, 1899-1900, Part 5-Forest Reserves, pp 209-498.

Morrison, P.H., and F.J. Swanson. 1990. Fire history and pattern in a Cascade Range landscape. USDA Forest Service General Technical Report. PNW-GTR-254.

Pitcher, D.C. 1987. Fire history and age structure in red fir forests of Sequoia National Park, California. Canadian Journal of Forest Research 17:582-587.

Stewart, G.H. 1989. The dynamics of old-growth *Pseudotsuga* forests in the western Cascade Range, Oregon, USA. Vegetatio 82:79-94.

Taylor, A.H. and C. Halpern. 1991. Structure and dynamics of *Abies magnifica* forests in the southern Cascade Range, USA. Journal of Vegetation Science 2:189-200.

Taylor, A.H. 1993. Fire history and structure of red fir (*Abies magnifica*) forests, Swain Mountain Experimental Forest, Cascade Range, northern California. Canadian Journal of Forest Research 23:1672-1678.

Thornburgh, D.A. 1995. The natural role of fire in the Marble Mountains Wilderness, pp. 273-274; Proceedings: symposium on fire in Wilderness and Park Management. USDA Forest Service General Technical Report INT-GTR-320.

USDA 1994. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. U.S. Government Printing Office: 1994-589-111, Washington D.C.

Veblen, T.T., T. Kitzburger, and A. Lara. 1992. Disturbance and forest dynamics along a transect from Andean rainforest to patagonian shrubland. Journal of Vegetation Science 3:507-520.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon, and California. Ecological Monographs 30:279-338.

Whittaker, R.H. 1961. Vegetation history of the Pacific coast states and the "central" significance of the Klamath Region. Madroño 16:5-22.

Wills, R.D. and J.D. Stewart. 1994. Fire history and stand development of a Douglas-fir/hardwood forest in northern California. Northwest Science 68:205-212.