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Vegetation and Fire History of a Ponderosa Pine-White Fir Forest in Crater Lake National Park

Abstract

This paper describes the structure and composition of the vegetation, and some of the environmental factors controlling it, on 7.5 km² of Crater Lake National Park, Oregon. It also gives the approximate dates and locations of most fires that burned in the area between 1750 and 1902. We sampled the vegetation in 64 plots. Wedges cut from 49 fire scars revealed the dates of fires at 24 locations.

Eight communities occur in the four recognized habitat types. Soil formed in alluvial parent material supports the relatively dry *Abies concolor/Symphoricarpos mollis* habitat type. Pumice parent material supports an *Abies concolor/Chimaphila umbellata* habitat type, an *Abies magnifica* var. *shastensis* habitat type, and most of a Mesic Species community. *Abies* saplings on alluvial soils have considerably greater plant moisture stress than those on pumice. The Mesic Species community occurs in areas with the water table near the surface in the spring, which provides enough moisture to stop some fires. Two communities of the *A. concolor/C. umbellata* habitat type occur above and below the Mesic Species community; differences between them are probably due to different frequencies of fire before 1902 as well as to the climatic changes with elevation. Fires occurred at sampling spots at intervals of three or less to more than fifty years, with the mean interval at a location ranging from nine to forty-two years. The mean interval between fires was generally longer at higher elevations. Areas on opposite sides of a canyon usually did not burn in the same year, and fire years do not correspond with drought years indicated by previous dendrochronological studies. The occurrence of a widespread fire appeared to reduce the intensity or size of fires occurring in the same area in the following ten years. Most trees now present on the study area started growing during the first forty years after the last fire in 1902; compositional change in overstory and understory, apparently due to fire exclusion, is obvious in several communities.

Introduction

Much recent literature has emphasized the importance of fire in many of the primeval coniferous forests in North America (Arno, 1976; Habeck and Mutch, 1973; Heinselman, 1973; Kilgore, 1973a; Martin *et al.*, 1976; Weaver, 1974; Wright and Heinselman, 1973). The absence of fire because of fire control has led to major changes in forest vegetation. Fire is being re-introduced in many ecosystems as a management technique; returning the vegetation in National Parks toward its primeval state is one of the recent uses of fire (Kilgore, 1973a). To use fire successfully in management, certain information is necessary about each individual area, since the effect of fire depends on such things as weather, topography, fuels, vegetation, soils, and the intensity and frequency of the fires. The purpose of this study was to determine the present vegetation structure and composition (with an estimate of that in the primeval forest) and the fire history for an *Abies concolor-Pinus ponderosa* forest in Crater Lake National Park. This background information was to be used in the introduction of prescribed burning. This information can also be used to find some characteristics of naturally occurring fires, and thus can contribute to an understanding of fire as a component of ecosystems and as a factor in evolution. The relationships of vegetation to fire and soils in the study area are probably representative of those over a considerable area in south central Oregon.

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The Study Area

The study area is about 7.5 km², located just inside the south boundary of Crater Lake National Park, Oregon, at the base of the east slope of the Cascade Mountains. Except for the 15 to 60 m deep, ravine-like canyon of Annie Creek (Fig. 1), it has a fairly even slope averaging 3.5 percent between 1340 m elevation at the southern end and 1550 m at the northwest edge.

Most of the area was covered by a glowing avalanche deposit of pumice from an eruption of Mt. Mazama about 7000 years ago (Olsson, 1970; Rubin and Alexander, 1960; Williams, 1942). This eruption resulted in deposits of sub-rounded pumice cobble and gravel in a sand matrix. The soils on the pumice resemble the Lapine (Dyrness and Youngberg, 1966) and the Steiger series (U.S. Bureau of Indian Affairs *et al.*, 1958).

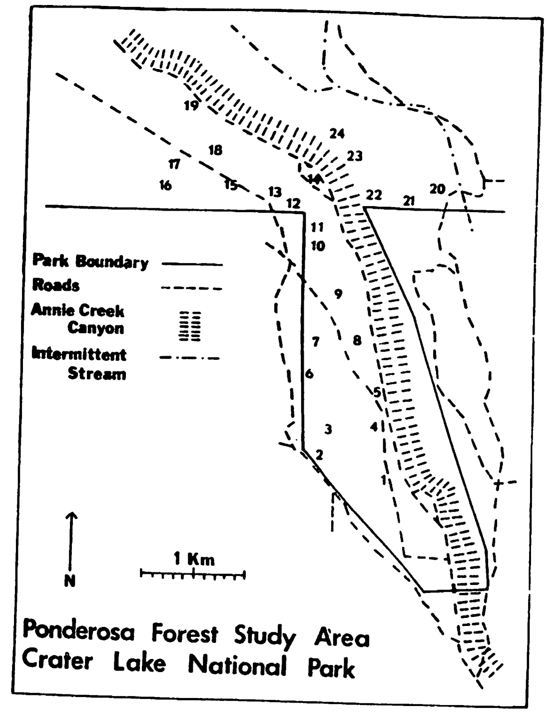

Figure 1. Spots where fire scars were sampled. The number refers to the data reported in Table 4. Two trees were sampled at each spot.

pumice particles give the soil an unusually high porosity: it holds an unusually large amount of water at low tensions for a coarse-textured soil (Youngberg and Dyrness, 1964).

The area lies on the strong climatic gradient east of the Cascade Mountains (Franklin and Dyrness, 1973). The mean precipitation is probably between 65 and 85 cm yr^{-1} (U.S. Dep. Agr., 1964). About 70 percent falls from November to March and less than 10 percent falls from June to August (Sternes, 1963). It is probably safe to assume that the soil is at field capacity shortly after snowmelt, and that soil moisture declines through the summer.

Trappers first entered Klamath County about 1825, but there probably were no white settlements near the study area until about 1863, when a road was built through the area (Good, 1941). Crater Lake National Park was established in 1902, about the time the last fire burned in the area. The "panhandle," which includes much of the study area, was not added until 1932. Parts of this later addition had been logged between 1909 and 1927.

Methods

We sampled the vegetation in 64 plots, 50 of them randomly located along ten east-west transects, which had been selected in a stratified random manner. Fourteen plots were randomly located in vegetation units not adequately sampled on the transects. The data collected at each plot were similar to those of Daubenmire and Daubenmire (1968). All trees over 20 cm tall were tallied by diameter at breast height (dbh) class. Coverage of shrubs and herbs was recorded for each species in fifty 20 x 50 cm microplots. Classification was done in a manner similar to that described by Franklin, Dyrness, and Moir (1970). Nomenclature follows Hitchcock *et al.* (1955, 1959, 1961, 1964, 1969) and Peck (1961) for the few species not in Hitchcock *et al.*

The vegetation can be divided into habitat types based on what the climax dominants of each area appear to be (Daubenmire and Daubenmire, 1968). In the absence of climax forest, our best evidence of what the climax tree dominants probably would be is the density of small tress of the various species, their shade tolerance, and their apparent health. We assessed the probable shrub and herb dominants by the composition of the understory beneath a nearly closed canopy of the apparent climax dominants, *Abies concolor* or *A. magnifica* var. *shastensis.* The habitat types were sub-divided into communities with relatively homogeneous present vegetation.

Moisture stress of 1-2 m *Abies concolor* saplings was measured at one location in each of five communities before dawn on 17 September 1974, as the pressure potential of the xylem sap, using a pressure chamber (Scholander *et al.*, 1965).

A ground fire may kill a section of cambium at the base of a tree. The thin bark growing over the wound and the pitch which exudes from its edge make this tissue especially susceptible to damage by later fires. These fire scars were used to reconstruct the fire history of individual *Pinus ponderosa* trees. "Scar" or "fire scar" means the whole wound caused by several fires, and "sear" means the wound caused by an individual fire. Scars with a large number of sears were selected at 24 widely dispersed spots (Fig. 1). None were available in the logged area. At each spot two trees, usually within 100 m of each other, were sampled to insure that few fires would be missed, since not all fires sear all scarred trees (Arno, 1976). The fire history for each tree was found by cutting a wedge from one side of the fire scar and counting the rings outside the individual sears. There were problems with narrow, missing or indistinct rings, insect holes, decay, and later fires destroying evidence of earlier sears. Even the most accurate dates could be off 2 percent of the difference between the date of the fire and 1974. There were sometimes inconclusive indications of a sear; we recorded these. Since fires often reduce growth rate drastically for a few years (Keen, 1937), we also recorded sudden decreases in ring width which occurred during an unusually long interval between sears. We cross-dated the fires to determine the probable dates for individual sears. This system probably gives accurate dates for large fires, but smaller fires are more likely to be dated inaccurately; small fires may be inappropriately grouped with other fires by this method.

Ages of trees of selected sizes along transects in three communities were determined at 20 cm from the ground with an increment borer. In order to estimate the relationship between age and population density, we assumed the distribution of ages within a size class in the vegetation data corresponds exactly to the distribution of ages in the age sample for that size class. For instance, if the ages of four trees of a given species in a given size class were determined, a quarter of the trees in the size class were assumed to be the same age as each of the four trees. The number of age determinations for a given size class of one species ranged from ten for the more common size classes to one for the rare ones within each community.

Results and Discussion

Vegetation

Four habitat types, with eight communities, were recognized and mapped (Fig. 2, Tables 1 and 2). The communities can be separated along gradients of moisture, elevation, and succession, and by type of soil parent material (Table 3). These gradients are not completely independent. Logging and fire history, and relative abundance and sizes of *Pinus* and *Abies* were used to estimate the position of each community on the successional gradient (Table 3).

The *Abies concolor/Symphoricarpos mollis* habitat type appears to be the driest (Table 3). It is on soil formed from sandy alluvium deposited after the collapse of Mt. Mazama. The soil in much of the *Melica* community is similar to the soil in the pumice flow; however, non-pumice gravel is present, varying from almost none to almost all of the gravel. Much of the soil in the logged *Symphoricarpos* community has a darker, thicker A1 horizon with a generally lower proportion of pumice. It is questionable whether *A. concolor* would be the sole climax tree dominant in the logged *Symphoricarpos* community (Table 2). However, disturbance often favors plants from drier communities (Franklin and Dyrness, 1973), and the abundant *Carex pensylvanica* may slow tree establishment (USDA Forest Service, 1972).

The *Abies concolor/Chimaphila umbellata* habitat type occurs on soil derived from pumice flow deposits, and, as is the case with the other types on pumice, apparently experiences little moisture stress. This habitat type differs from the one on alluvium in that it has much more *Pinus contorta* and *Salix scouleriana*; several species, including *Symphoricarpos mollis*, *Senecio integerrimus*, *Melica aristata*, and *Hieracium* spp. are less common here (Tables 2 and 3). This habitat type is relatively large and occurs over

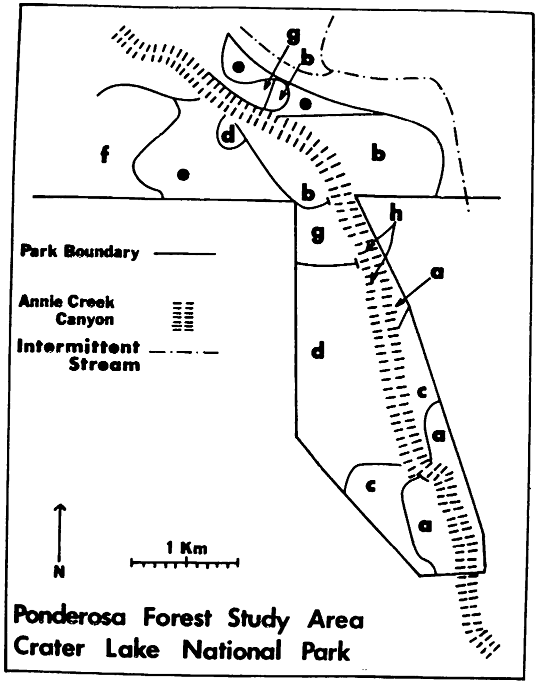

Figure 2. Location of plant communities and habitat types. *Abies concolor/Symphoricarpos mollis* habitat type: (a) Logged *Symphoricarpos mollis* community, (b) *Melica* community. *Abies concolor/Chimaphila umbellata* habitat type. (c) Logged *Chimaphila umbellata* community, (d) *Pinus lambertiana* community, (e) Closed *Abies concolor* community, (f) *Abies magnifica* var. *shastensis/Chimaphila umbellata* habitat type. *Abies concolor/* Mesic Species habitat type: (g) Mesic Species community, (h) *Castanopsis* community.

a greater range of elevation than the others. Differences in vegetation within it are probably caused by environmental differences as well as by differences in fire history. For example, *Arctostaphylos nevadensis* occurs only above *ca.* 1390 m, and *Apocynum androsaemifolium* rarely occurs above 1520 m. At lower elevations much of the *A. concolor* is in patchy, dense thickets of saplings, but at higher elevations it gradually becomes generally distributed. However, inferences about environmental causes are risky; elevation and disturbance are correlated, because the lowest elevations were logged, and the higher elevations were burned less frequently, giving it the aspect of a closed, relatively mature forest.

As one moves up in elevation within the *Abies concolor/Chimaphila umbellata* habitat types, the division between the *Pinus lambertiana* and the closed *Abies concolor* communities is approximately at the point at which understory dominants change from *Ceanothus velutinus* and *Arctostaphylos nevadensis* to mostly *Carex pensylvanica* and *Chimaphila umbellata* (Table 3). This division is also approximately where *Pyrola*

TABLE 1. Average density by species and community (trees/ha). Only trees taller than 20 cm are included.

		Habitat Type							
	dbh class (cm)	A. concolor/ Symphoricarpos		A. concolor/Chimaphila Community			Abies magnifica	A. concolor/ Mesic Species	
Species		Logged Symphoricarpos	Melica	Logged Chimaphila	Pinus lambertiana	Closed A. concolor	Abies magnifica	Mesic Species	Castanopsis
Populus	20-35	3							
tremuloides	10-20	63							
	0-10	872		129				128	
Calocedrus decurrens	0-10				16				
Pinus	95+				2				
lambertiana	55-75			4					
	20-35				2				
	10-20			4	9				7
	0-10			15	375				33
Pinus	35-55			11	4	16	18		
contorta	20-35			114	36	14	68	106	
	10-20			163	231	25	59	27	
	0-10			220	967	103	332		
Abies	95+						6		
magnifica	75-95						15		
var.	55-75						21		
shastensis	35-55					4	30		
	20-35					5	47		
	10-20				7	7	163		
	0-10		7		75	391	3970	10	
Pinus	20-35						3		
monticola	10-20					2	6		
	0-10					23	201	5	
Tsuga	10-20						3		
mertensiana	0-10				2	7	47		7
Pseudotsuga	95+								20
menziesii	75-95								26
	55-75								27
	35-55								14
	20-35								
	10-20					2			
	0-10				20				107
Pinus	95+		7		16	11	12	21	
ponderosa	75-95			4	11	14	9	10	

TARLE 1. (Continued)

Species	dbh class (cm)	Habitat Type							
		A. concolor/ Symphoricarpos		A. concolor/Chimaphila Community			Abies magnifica	A. concolor/ Mesic Species	
		Logged Symphoricarpos	Melica	Logged Chimaphila	Pinus lambertiana	Closed A. concolor	Abies magnifica	Mesic Species	Castanopsis
	55-75	27	7	19	7	2			7
	35-55	33		30	4			5	
	20-35	100		106	9				7
	10-20	170		99	4				7
	0-10	280		270	587	12			7
Abies concolor	95+				2	2	3		7
	75-95		7		2	5		3	27
	55-75	3	47			11	6	26	53
	35-55	27	87	15	7	68	16	70	7
	20-35	57	193	49	20	130	41	112	50
	10-20	213	247	137	209	338	98	373	86
	0-10	1282	2687	1003	2040	5118	3126	2592	1687

TABLE 2. Average percent cover and percent constancy of more important species. + = .05% or less. Only species occurring in more than two plots o with a mean cover of 0.1% are included. Data are presented as Cover/Constancy.

Species			Community					
	Logged Symphoricarpos	Melica	Logged Chimaphila	Pinus lambertiana	Closed A. concolor	Abies magnifica	Mesic Species	Castanopsis
Poa nervosa var. wheeleri	0.5/75							
Stipa occidentalis var. californica	0.1/50							
Senecio integerrimus	+ /50							
Lonicera conjugialis	0.5/63						0.1/40	
Lupinus albicaulis	0.6/75							+ /50
Melica aristata	0.6/50	0.3/50						0.1/50
Smilacina spp.	+ /38	+ /50					0.8/100	0.1/100
Ozmorhiza chilensis	+ /38	+ /25					0.5/80	0.1/75
Elymus glaucus	0.3/38	0.4/50		+ / 8			+ /40	+ /25
Phacelia heterophylla	0.1/63	+ /25	+ /14					+ /50

TABLE 2. (Continued)

Species	dbh class (cm)	Habitat Type						
	A. concolor/ Symphoricarpos		A. concolor/Chimaphila Community			Abies magnifica	A. concolor/ Mesic Species	
	Logged Symphoricarpos	Melica	Logged Chimaphila	Pinus lambertiana	Closed A. concolor	Abies magnifica	Mesic Species	Castanopsis
Stephanomeria lactucina	0.1/75	+ /25	0.2/43		+ /13			+ /25
Symphoricarpos mollis	3.0/88	1.4/100	+ /14		+ /20		2.1/100	6.0/100
Hieracium albiflorum + H. cynoglossoides	1.4/100	+ /73	+ /29				0.1/60	+ /100
Amelanchier alnifolia	2.8/38	0.1/25	+ /14				0.2/60	2.6/100
Bromus spp.	2.3/75		+ /29				1.3/100	0.5/75
Collomia tinctoria	0.1/38		+ /14					+ /25
Cynoglossum occidentale	+ /75		+ /29					+ /25
Purshia tridentata	0.6/75		+ /14					
Haplopappus bloomeri	1.9/100		0.3/43					
Ribes cereum	2.5/88		4.5/86					
Sitanion hystrix	2.9/88	+ /50	2.4/86					
Fragaria virginiana var. platypetala	1.2/100	0.3/100	1.4/100	+ /42	+ /47		0.2/80	+ /25
Kelloggia galioides	1.1/88	0.2/100	0.3/86	0.1/53	0.1/60		0.1/40	+ /50
Apocynum androsaemifolium	0.1/25	0.6/75	0.1/100	1.7/83	0.4/60		+ /40	0.1/25
Stipa occidentalis var. occidentalis	4.7/75	+ /50	4.9/100	0.6/75	+ /20	0.1/33		
Ceanothus velutinus	11.9/75	1.2/50	24.4/100	15.3/92	1.6/60	+ /11		+ /50
Arctostaphylos patula	+ /13		0.1/43	+ /33	+ / 7			+ /25
Epilobium angustifolium	0.1/50	0.1/75	0.9/100	0.6/67	+ /13	+ /22	+ /40	
Pyrola dentata	+ /13	+ /50	+ /57	0.1/75	0.1/80	+ /33	+ /20	
Salix scouleriana			4.2/71	2.1/92	0.5/47	+ /11	+ /60	
Polystrichum juniperinum		+ /25	0.4/57	+ /25	0.1/67	0.1/67		
Arctostaphylos nevadensis		0.5/25		8.6/83	3.3/73	5.7/89		
Pyrola secunda		+ /50	+ /43		0.5/100	0.1/56	0.5/100	0.1/50
Goodyera oblongifolia					+ /53	+ /22	0.1/80	
Castanopsis sempervirens	+ /13			0.7/33	+ / 7	+ /11	+ /20	6.3/100
Adenocaulon bicolor		+ /50					0.3/100	– /100
Galium triflorum		+ /25					0.8/80	0.1/75

TABLE 2. (Continued)

Species (dbh class (cm))	Habitat Type: A. concolor/Symphoricarpos — Logged Symphoricarpos	A. concolor/Symphoricarpos — Melica	A. concolor/Chimaphila Community — Logged Chimaphila	A. concolor/Chimaphila Community — Pinus lambertiana	A. concolor/Chimaphila Community — Closed A. concolor	Abies magnifica — Abies magnifica	A. concolor/Mesic Species — Mesic Species	A. concolor/Mesic Species — Castanopsis
Ribes viscossissimum		+ /50		+ / 8			0.9/60	0.2/75
Clintonia uniflora							0.6/60	0.1/50
Ribes lacustre							0.1/60	+ /75
Rubus parviflorus							+ /40	0.8/100
Rosa gymnocarpa	+ /13						+ /40	1.1/100
Pteridium aquilinum	+ /13							2.7/75
Carex pensylvanica + C. brainerdii	39.8/100	27.2/100	16.5/100	6.3/58	7.1/100	5.0/89	0.4/60	0.8/50
Chimaphila umbellata	+ /13	0.4/75	0.3/100	1.0/100	5.4/100	4.9/89	3.9/100	2.1/100
Chimaphila menziesii	+ /50	0.2/100	+ /57	+ /58	0.2/87	+ /89	0.1/100	0.2/100
Pyrola picta	+ /38	+ /25	+ /43	+ /42	+ /33	+ /22	+ /60	0.1/100
Brachythecium leibergii + Pohlia nutans	+ /13	0.2/50	+ /71	0.1/67	0.4/80	0.2/100	0.2/80	0.6/100
Pterospora andromedea	+ /38	+ /50	+ /71	+ /25	+ /40	+ /44	+ /40	
Antennaria rosea	0.2/38							
Gayophytum nuttallii	0.8/13		+ /43					
Corallorrhiza spp.					+ /40	+ /11		
Listera caurina		+ /25			+ / 7	+ /11	+ /40	
Anaphalis margaritacea							+ /40	+ /25
Eriogonum umbellatum	+ /38							
Melica subulata	+ /13	0.1/50						
Ruellia ruellii		+ /25			+ /13	+ /11		+ /25
Number of Plots	8	4	7	12	15	9	5	4

TABLE 3. Position of communities on gradients of soil, moisture, elevation, and succession. ND means not determined.

Community	Soil parent material	Predawn moisture stress (bars)	Elevation (m)	Relative successional stage
Logged Symphoricarpos mollis	Alluvial	-19	1340-1430	Early
Melica	Alluvial	-17	1430-1520	Late
Logged Chimaphila umbellata	Pumice	-7	1340-1410	Early
Pinus lambertiana	Pumice	ND	1370-1520	Middle
Closed Abies concolor	Pumice	-7	1480-1550+	Late
Abies magnifica	Pumice	-6	1510-1550+	Middle
Mesic species	Alluvial and Pumice	ND	1450-1550+	Late
Castanopsis	Alluvial	ND	1340-1450	Middle

secunda and *Goodyera oblongifolia* begin to occur, where *A. concolor* greater than 35 cm dbh become more important, and where small *Pinus ponderosa* almost disappear (Tables 2 and 3). Several understory plants, such as *Epilobium angustifolium* and *Salix scouleriana*, are less important at higher elevation. These changes are not sudden, and there are exceptions to the generalizations.

At higher elevations *Abies magnifica* var. *shastensis* becomes progressively more important. Where the *A. magnifica* var. *shastensis* less than 10 cm dbh outnumber *Abies concolor* of the same size, we recognize the *A. magnifica* var. *shastensis/Chimaphila umbellata* habitat type. Uncertainty about successional relationships of the two *Abies* necessitates the use of such an arbitrary distinction. Generally the understory is similar to the upper parts of the *A. concolor/Chimaphila* habitat type, with the sparse cover contributed by only a few species, except in some patches in which large *Pinus ponderosa* are located and *Arctostaphylos nevadensis* and *Carex pensylvanica* are fairly abundant (Table 3).

The *Abies concolor*/Mesic Species habitat type occurs in an area with the water table near the surface during the spring and in Annie Creek canyon. It contains several species that indicate moist conditions, such as *Smilacina* spp., *Adenocaulon bicolor*, *Galium triflorum*, and *Clintonia uniflora* (Table 3). The Mesic Species community separates the *Pinus lambertiana* and closed *Abies concolor* communities (Fig. 2). *Abies concolor* is the most important tree, but small areas have important components of *Pinus contorta* or *Picea engelmanni*, and there is a small meadow-like area. The *Castanopsis* community lies in Annie Creek canyon. *Pseudotsuga menziesii* is more important here than elsewhere. The top of the canyon often resembles the *Abies concolor/Symphoricarpos mollis* habitat type, and the vegetation becomes more mesic down into the canyon.

The vegetation is described in more detail by McNeil (1975); some communities recognized here result from combinations of the smaller ones he described.

Fire History

Fires rarely burned both east and west of Annie Creek during the same year (compare spots 20-24 with others in Table 4). The Mesic Species community stopped some fires from moving farther north (e.g., 1892, 1841, 1812), but did not stop others (e.g., 1902, 1879, 1846, 1818). So the area can be divided into three parts with different fire his-

TABLE 4. Fire incidence at different spots, 1748-1902. For spot locations, see Fig. 1. A. Each spot includes sears on two trees, usually within 100 m of each other. x = sear formed; (x) = possible sear formed—usually a growth rate decrease and some hint of sear present; map = sears at nearby spots indicate a fire may have burned this one also; interval = usually long interval without a fire; GR = decrease in growth rate that coincided with a fire year; . = date before the first sear on one tree at the spot; | = date before the first sear on both trees at the spot. B. Mean interval between fires, using (1) only definite sears, and (2) all indicators of fire occurrence.

A.	Panhandle									Northwest part										Northeast part				
Spot:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1902		x	x			map	x	x	x	x	x	x	x		x									
1897								x						x										.
1892	x	map	x	x	x	x	x	x	x															.
1889																								.
1883	x	x	x								x									x	x	x	map	x
1879				x	x	x	x	x	x	x		x	x											x
1877																			x					.
1870	x		x						x											x	x	x	x	x
1864	x	x	x	map	x	x	x	x	x	x	x	x	x	x	x			map	x		.			.
1859																					.			.
1855									x											x	GR		x	x
1849		x																			.	interval		.
1846	x			x	GR	GR	x	(x)	x	map	x	x	x	x	x	x	x	x	x		.			x
1841	x	x	x	x	x	x	x	x	x		.			x	.						.			.
1831											.				.						.			.
1829	x										.				.					interval	x	x	x	x
1826					GR	GR		x	x		.	x			.		x				.			.
1818	x	map	x	map	x	map	x	map	x	x	x	x	x	x	x	x	x	x	x		.			.
1815															.	.					.			.
1812	x	x	x	x	x	x	x	x	x		|				.	.					x			(x)
1804	(x)										|	x	x		.	.		x			.	x		
1800	x										|				.	.		.	x		.			(x)
1798									interval		|				.	.		.			.			.
1797	x	x	map	x	x	x	x				|				.	.		.		x	x	x	x	.
1791							x	x			|	x	x	x	x	.		.	x		.	.		.
1788											|		.	x	.	.		.			.	.		.
1786											|		.		.	.		(x)			x	map	x	x
1782-84	x		x		x	x	x		x	x	|	x	x		x	x	x	.				.		|
1779					.					.	|		.	x	.	|		.			x	.		|
1776	GR	x		interval	x			x		.	|		.		.	|		.			.	.		|
1775					.					.	|		.	x	.	|		.	x		.	.		|
1773					.			x		.	|		.		.			.	.	(x)	x	.		|
1771					.					.	|		.		.			.	.		.	.		|
1770					.					.	|	x	x		.		x	.	.		x	.		|
1769	x	x	x	x	x	x			GR	.	|		.		.			.	.		.	.		|
1762			.		.					.	|		.		(x)			.	.		.	.		|
1759	x		x		x	map	x	x	x	.	|	x	x	x	|		x	.	.	x	x	x	x	|
1755	x		.	x	|					.	|	.	.		|		.	.	.		.	.		|
1751			.		|				.	|	.	.		|		.	.	.	x	x	x	x	|
1748			.		|	x	x	x	x	x	|	x	.		|		x	x	x		.	.	.	|
B. Mean interval between fires.																								
(1) Sears only	9	14	15	15	15	18	12	14	13	30	19	14	18	15	28	42	22	33	18	22	—	23	22	—
(2) All indicators	9	12	13	12	12	12	11	12	12	24	19	14	18	15	28	42	22	24	18	19	—	18	20	—

TABLE 4. Fire incidence at different spots, 1748-1902. For spot locations, see Fig. 1. A. Each spot includes sears on two trees, usually within 100 m of each other. x = sear formed; (x) = possible sear formed—usually a growth rate decrease and some hint of sear present; map = sears at nearby spots indicate a fire may have burned this one also; interval = usually long interval without a fire; GR = decrease in growth rate that coincided with a fire year; . = date before the first sear on one tree at the spot; | = date before the first sear on both trees at the spot. B. Mean interval between fires, using (1) only definite sears, and (2) all indicators of fire occurrence.

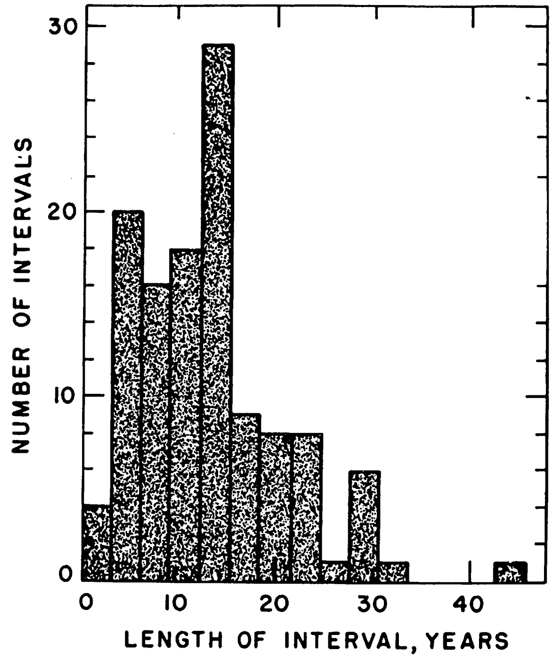

Figure 3. Frequency distribution of intervals between sears on fire scars in the panhandle area.

tories: 1) the panhandle; 2) the northwest part; and 3) the northeast part. The difference between the "long" and "short" estimates for the mean interval between fires at a spot (Table 4) is small when compared with the variance of intervals between fires (Fig. 3). These means are comparable to those found in other parts of Central Oregon (Keen, 1937; Sherman, 1969; Soeriaatmadja, 1965) and somewhat longer than in the mixed conifer forest for the Sierra Nevada (Wagener, 1961; Kilgore, 1973a). In order to maintain a "natural" mosaic of communities with prescribed fire, it may be necessary to imitate the frequency distribution rather than just the mean interval. For instance, intervals of 15 years or more without fire were not uncommon (Fig. 3). These spots may have provided refuge for species poorly adapted to fire—for example, those which require that long to reproduce.

Fire frequency and vegetation are correlated to some extent. Fire incidence decreases with increased elevation toward the northwestern part of the study area (Table 4, Fig. 1). It is somewhat lower in the Mesic Species community than immediately above or below. *Ceanothus velutinus* is dominant only where the mean interval between fires was 15 years or less, and it is almost absent where the interval was greater than 20 years. Others have noted that fire history can cause important differences in vegetation in this region (Dyrness and Youngberg, 1966; West, 1969).

Comparison of the dates of the fires with Keen's (1937) dendrochronological record for south central Oregon indicates that there is little relation between the years that fires occurred and those in which *Pinus ponderosa* growth was less than average, which Keen concludes are the drier years. Of forty fire years, sixteen had growth less than average; eighteen had better than average growth; the other six were very close to average. Of seventeen years with extensive fires (those which left sears at more than half the spots in one of the three parts of the study area), seven had greater than average growth. The inference that fires are not limited to the driest years is supported by the occurrence of fires in different years on the two sides of Annie Creek (Table 4). Years dry enough to allow extensive fire appear to have been fairly common.

One factor controlling the intensity and size of a fire is the fuel accumulation since the last fire. Evidence for its effectiveness occurred in our data. The upper limit to the percentage of trees seared by a major fire increases with time since the last large fire (Fig. 4). This effect can be seen by comparing the panhandle and the northwest part for the 1846 and 1818 fires (Table 4): these fires were apparently less intense, scarring fewer trees, in the panhandle where a large fire had recently burned.

Parts of the closed *Abies concolor* community have not burned since 1846, probably

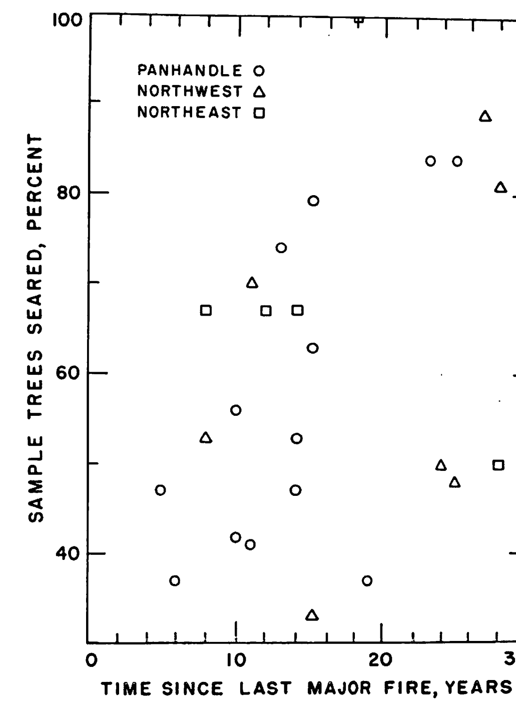

Figure 4. Relationship between years since last major fire and the proportion of sampled trees that were scarred, for all major fires between 1748 and 1902.

accounting for its high density of *Abies* and its sparse understory. The fact that fire did not occur here from 1846 to 1902 and that there are few 10-55 cm dbh *Pinus ponderosa* may indicate that this area would become dominated by *A. concolor* even without fire control.

Because of the small size and irregular shape of the study area, little can be said about the size of the fires. The large fires burned outside the study area, so their area is more than the 400 ha west of Annie Creek. Many of the small fires may also have burned outside the study area. From 1800 to 1902 there were about 15 fires that seared three or more adjacent spots; however, 12 to 16 or more fires seared only one or two spots that were well separated from any other spots seared the same year. This large number of small fires is somewhat surprising, because between 1930 and 1974 only two lightning fires were recorded in the study area (Fire Atlas, Crater Lake National Park). However, in each of the two years of this study we observed one large *Pinus ponderosa* killed by lightning, so lightning strikes probably are fairly common.

Effects of Fire Exclusion

Figure 5 shows the tree age-density relationships for one community. These and similar data from other communities indicate that most of the trees over 20 cm tall germinated within 30 or 40 years after the last fire; since then establishment of trees has decreased. It appears that *Abies concolor* may have become established more rapidly after the last fires than *Pinus ponderosa* or *Pinus contorta*, but this finding may be an artifact resulting from difficulty of counting rings in these severely suppressed *Pinus*. Repeated fire would have favored *Pinus* (Kilgore, 1973b; Lunan and Habeck, 1973), probably because of the thick bark of some species (Franklin and Dyrness, 1973) and their low shade tolerance (Atzet and Waring, 1970). Other changes are taking place in the understory due to increased shade or litter accumulation; for example, dead shrubs of *Ceanothus* and *Arctostaphylos* are common in areas where a closed *Abies* canopy has recently been established.

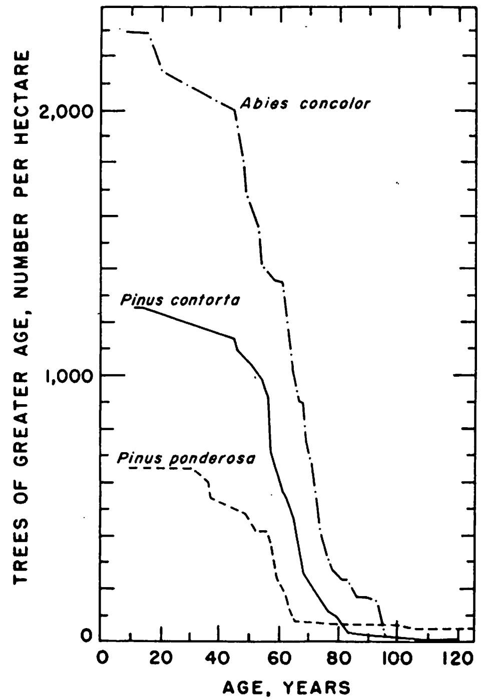

Figure 5. Estimate of the relationship between tree age and density for major trees in the *Pinus lambertiana* community. The position of the line for a given year represents the density of all trees that age and older.

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Literature Cited

Arno, S. F. 1976. The Historical Role of Fire on the Bitterroot National Forest. USDA Forest Serv. Res. Paper INT-187. 29 pp.

Atzet, T, and R. H. Waring. 1970. Selective filtering of light by coniferous forests and minimum light energy requirements for regeneration. Can. J. Bot. 48:2163-2167.

Daubenmire, R., and J. Daubenmire. 1968. Forest Vegetation of Eastern Washington and Northern Idaho. Washington Agr. Exp. Sta. Tech. Bull. 60. Washington State Univ., Pullman. 104 pp.

Dyrness, C. T., and C. T. Youngberg. 1966. Soil-vegetation relationships within the ponderosa pine type in the central Oregon pumice region. Ecology 47:122-138.

Franklin, J. F., and C. T. Dyrness. 1973. Natural Vegetation of Oregon and Washington. USDA Forest Service General Tech. Report PNW-8. Pacific Northwest Forest and Range Exp. Sta., Portland. 417 pp.

———, ———, and W. H. Moir. 1970. A reconnaissance method for forest site classification. Shinrin Richi 12:1-14.

Good, R. A. 1941. History of Klamath County, Oregon: Its Resources and Its People. Klamath Falls, Oregon. 604 pp.

Habeck, J. R., and R. W. Mutch. 1973. Fire dependent forests in the northern Rocky Mountains. Quaternary Res. 3:408-4245.

Heinselman, M. L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Res. 3:329-382.

Hitchcock, C. L., A. Cronquist, M. Ownby, and J. W. Thompson. 1955, 1959, 1961, 1964, 1969. Vascular Plants of the Pacific Northwest, Parts 1-5. Univ. Washington Press, Seattle, 5 vols.

Keen, F. P. 1937. Climatic cycles in eastern Oregon as indicated by tree rings. Monthly Weather Rev. 65:175-188.

Kilgore, B. M. 1973a. The ecological role of fire in Sierran conifer forests—its application to National Park management. Quaternary Res. 3:496-513.

———. 1973b. Impact of prescribed burning on a sequoia-mixed conifer forest. Proc. Tall Timber Fire Ecol. Conf. 12:345-375.

Lunan, J. S., and J. R. Habeck. 1973. The effects of fire exclusion on ponderosa pine communities in Glacier National Park, Montana. Canadian J. Forest Res. 3:574-579.

Martin, R. E., D. D. Robison, and W. H. Schaeffer. 1976. Fire in the Pacific Northwest—perspectives and problems. Proc. Tall Timbers Fire Ecol. Conf. 15:1-24.

McNeil, R. C. 1975. Vegetation and Fire History of Ponderosa Pine-White Fir Forest in Crater Lake National Park. Oregon State University, Corvallis, M.S. thesis. 171 pp.

Olsson, I. U. 1970. Plate IV. *In* Olsson, I. U. (ed.) Radiocarbon Variations and Absolute Chronology. Proc. Twelfth Nobel Symp. John Wiley & Sons, Inc. N.Y. 654 pp.

Peck, M. E. 1961. A Manual of the Higher Plants of Oregon. 2nd ed. Binsfords and Mort, Portland. 936 pp.

Rubin, M., and C. Alexander. 1960. U.S. Geological Survey radiocarbon dates. V. Amer. J. Sci. Radiocarbon supplement 2:129-185.

Scholander, P. F., H. T. Hammel, E. D. Bradstreet, and E. H. Hemmingsen. 1965. Sap pressure in vascular plants. Science 148:339-346.
Sherman, R. J. 1969. Spatial and Developmental Patterns of the Vegetation of Black Butte, Oregon. Oregon State University, Corvallis, Ph.D. thesis. 80 pp.
Soeriaatmadja, R. E. 1966. Fire History of the Ponderosa Pine Forests of the Warm Springs Indian Reservation, Oregon. Oregon State University, Corvallis, Ph.D. thesis. 123 pp.
Sternes, G. L. 1963. Climate of Crater Lake National Park. Crater Lake Natural History Association and National Park Service. Crater Lake. 12 pp.
U.S. Bureau of Indian Affairs, USDA Soil Conservation Service, and Oregon State College. 1958. Soils of the Klamath Indian Reservation, Interim Report. 324 pp.
U.S. Dept. Agr., Forest Service. 1972. Vegetation-site Key and Description of Least-Disturbed Plant Communities within the Pumice Deposition Zone, Winema National Forest. Report on file at the Winema National Forest, Klamath Falls, Oregon.
U.S. Dept. Agr., Soil Conservation Service. 1964. Normal annual precipitation, 1930-1957, State of Oregon. Map.
Wagener, W. W. 1961. Past fire incidence in the Sierra Nevada forests. J. Forestry 59:739-748.
Weaver, H. 1974. Effects of fire on temperate forests: Western United States, pp. 279-320, *in* Kozlowski, T. T., and C. E. Ahlgren (eds.). Fire and Ecosystems. Academic Press, New York. 542 pp.
West, N. E. 1969. Successional changes in the montane forests of the Central Oregon Cascades. Amer. Midland Nat. 81:265-271.
Williams, H. 1942. The Geology of Crater Lake National Park, Oregon. Carnegie Institution of Wash. Publ. 540. Washington, D.C. 162 pp.
Wright, H. E., Jr., and M. L. Heinselman. 1973. The ecological role of fire in natural conifer forests of western and northern North America—introduction. Quaternary Res. 3:319-328.
Youngberg, C. T., and C. T. Dyrness. 1964. Some physical and chemical properties of pumice soils in Oregon. Soil Sci. 97:391-399.

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A Listing of Reports on Black-Footed Ferrets in Wyoming (1851-1977)

Abstract
One hundred and forty-eight black-footed ferret (*Mustela nigripes*) reports from Wyoming (1851-1977) are recorded, complete with an evaluation of each.

Black-footed ferrets (*Mustela nigripes*) are one of North America's rarest mammals (Cahalane, 1954; Linder and Hillman, 1973; Clark, 1976). In states which are undergoing rapid change through energy and mineral development and mushrooming human population, information is imperative on rare, threatened, and endangered species for distribution to the largest possible audience. From knowledge of the distribution and precarious situation of this species, plans can be made to minimize human impacts on them. Comprehensive ferret listings for several states have been published, but none currently exists for Wyoming. The first listing of eight Wyoming ferret reports was by Long (1965). Hershkovitz (1966) reported seeing a ferret in central Wyoming. Clark (1973) gave 18 additional reports. The first major effort to collect and evaluate ferret reports in Wyoming was initiated in 1973 (Clark, 1978). The increased number of reports in recent years does not reflect an increase in ferrets, but instead a growing concern for the animal's decreasing numbers. The following list of 148 reports gives ferret information from 1851-1977.

The following table gives all those ferret reports which appeared to be positive or probably so. Each report was classified as: 1) *Positive*—if the observer showed physical evidence (*e.g.*, skin, photograph or ferret trenches); or if he was a biologist or professional field-oriented worker (*e.g.*, geologist, range manager), if the region had a documented history of ferret sightings, and if the habitat was characterized by abundant ground-dwelling sciurids (especially prairie dogs). If the sighting was in white-tailed prairie dog habitat, presence of suitable alternate prey during winter was required. 2) *Probable*—if the observer gave an accurate description, identified a ferret from a series of mustelid pictures, and characterized the animal's behavior in detail. The report had to be supported by other independent sightings, or other evidence of ferrets in the immediate area.

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