Role of Fire in Restoration of a Ponderosa Pine Forest, Washington

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***Abstract**—Ponderosa pine forests in the Eastern Cascades of Washington support dense, overstocked stands in which crown fires are probable, owing to postsettlement sheep grazing, logging, and fire exclusion. In 1991, the Okanogan-Wenatchee National Forests began to apply long-term management techniques to reverse postsettlement changes in ponderosa pine forests. For 9 years, the effects of thinning and burning in a ponderosa pine/pinegrass forest were evaluated, using prescribed fire in fall 1997 in forest stands that had been thinned in 1996. Thinning and burning had little effect on the canopy layer of ponderosa pine, western larch, and Douglas-fir, but small grand fir trees, and nearly half of the saplings of all species, were killed. Shrubs in the middle forest layer were top-killed, but resprouted during the first postfire growing season, and increased dramatically after 3 years and 9 years. Frequency and cover maintained or increased for species in the lower forest layer in postfire years 1, 3, and 9. The thinning and fire treatments reduced the middle layer of small trees and shrubs in the first postfire year, but by the third and ninth postfire years tree seedlings, especially grand fir and ponderosa pine, and small shrubs were abundant in the understory. Thinning trees and removing excess fuels, coupled with low intensity late season prescribed burns, offers a promising management strategy for restoring the presettlement structure of the ponderosa pine/pinegrass community in Beehive Forest.*

Introduction

Historically, ponderosa pine (*Pinus ponderosa*) dominated forests depended on periodic fire to maintain or increase the frequency and density of low-growing plants (Armour and others 1984; Campbell and others 1977; Covington and others 1997; Leege and Hickey 1971; Old 1969; Ruha and others 1996; Tveten and Fonda 1999; Wilson and Shay 1990). In pre1900 fire regimes of the Eastern Cascade Mountains, Washington, ponderosa pine forests supported frequent low intensity fires (Agee 1993; Everett and others 1996, 2000; Weaver 1943, 1951, 1961, 1967). The periodic surface fires in these dry forests maintained an open, parklike structure of expansive, grassy understories and uneven-aged overstories formed by even-aged patches of trees <0.4 ha in area (fig. 1; Harrod and others 1999; Everett and others 1996, 2000). These disturbances resulted in a mosaic of pine stands on the landscape (Everett and others 2000), a pattern that was disrupted only when the patches became senescent or when diseased or insect-infested trees torched (Agee 1994).

The presettlement fire regime in the Eastern Cascades produced pine forests with three layers. Mature pine trees formed the upper layer, the discontinuous canopy of the forest that ranged from 15 to 30 m high (fig. 1). In contrast to forests in wetter regions, dry forests in the Eastern Cascades

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Figure 1—Ponderosa pine stand on the Okanogan-Wenatchee National Forests in the early 1900s (Forest Service photo). The parklike structure consists of widely spaced trees in the canopy layer, few shrubs in the middle forest layer, and grasses and forbs in the lower forest layer.

had large gaps among the groves of ponderosa pine maintained by periodic fire (Harrod and others 1999; Everett and others 1996). Although mature pines resisted fire, small pines often were killed by fire. Well-maintained pine stands had few saplings (Everett and others 2000). Little information is available on the structure of the middle layer, ~2 to 4 m high. It may have been a fragmentary mix of shrubs, most likely bitterbrush (*Purshia tridentata*), spirea (*Spiraea* spp.), and mountain balm (*Ceanothus velutinus*) (Franklin and Dyrness 1988; Weaver 1951). The mostly continuous lower layer, ~1 to 2 m high, was formed by grasses, forbs, and low-growing shrubs. Pinegrass (*Calamagrostis rubescens*), elk sedge (*Carex geyeri*), Idaho fescue (*Festuca idahoensis*), lupines (*Lupinus* spp.), hawkweeds (*Hieracium* spp.), and roses (*Rosa* spp.) were common members of the lower layer (Franklin and Dyrness 1988; Weaver 1951).

Fire suppression in ponderosa pine forests in the Okanogan-Wenatchee National Forests (OWNF) began about 1910, and in the intervening years the fire regime changed from frequent, low intensity surface fires to infrequent, high intensity crown fires (Everett and others 1996, 2000). For example, two fires in OWNF, the Dinkleman fire in 1988 (22,275 ha) and the Tyee fire in 1994 (56,700 ha), burned with greater intensity and covered more area than they would have under presettlement fire regimes (Everett and others 1996, 2000). After nearly a century of fire exclusion, the forests now are ~10 to 12 fire-free intervals removed from historical conditions (Everett and others 2000), forest composition has shifted away from fire resisters and endurers (Agee 1993; Fonda and others 1998; Fonda 2001; Rowe 1983), and forest structure has shifted toward denser stocking of smaller understory trees in a dense, multicanopy arrangement (Everett and others 1996; Weaver 1961, 1967). Fire exclusion has had two consequences: (1) a continuous middle forest layer was created in an otherwise open forest by invading, drought sensitive trees (Everett and others 1996), which (2) died a decade or two after germination, adding to the total fuel loadings (Harrod and others 1999).

Weaver (1943, 1951, 1961, 1967) advocated management fires in these dry forests to reverse the changes in forest structure and composition. Using fire to reduce density of overstory species, however, presents challenges that must be managed carefully during the burn (Kilgore and Curtis 1987). Many ponderosa pine stands in the Cascades have dense canopies and continuous ladder fuels, so that torching of trees, spotting, and crown fires are possible. Thus, in today's forests prescribed surface fires might erupt into devastating crown fires (Everett and others 1996), unless the middle layer saplings and high density overstories are thinned to lower crown bulk density and remove ladder and dead woody fuels. Prefire management tactics that thin small trees to remove ladder fuels to the canopy and reduce fire intensity have come to be viewed as necessary in burning programs to restore presettlement forest structure (Agee 1991, 1996; Covington and others 1997; Scott 1998; Swezy and Fiedler 1996).

In 1991, the Leavenworth Ranger District of OWNF formed an interdisciplinary team to apply management techniques to dry forest stand to reverse postsettlement changes. The decision to thin and burn 865 ha in the Beehive Reservoir area was signed in December 1993. This project had six objectives: (1) improve forest health and develop stands of timber tolerant of disease, insect attack, drought, and wildfire; (2) develop/maintain park-like stands of ponderosa pine on slopes north of Beehive Reservoir; (3) maintain natural fire-dependent plant communities; (4) maintain/improve the health of large mature trees; (5) promote the development of wildlife habitats that require larger tree structure; and (6) use excess trees. The data in this study were gathered in conjunction with this forest management project, specifically objectives 2 and 3. In sum, the project was designed to rehabilitate and mitigate past disturbances that included sheep grazing from the 1880s to 1940, extensive logging in the 1920s and 1930s, and fire exclusion that became effective in the 1930s (Harrod and others 1999). The objectives above were expected to be achieved over a long period of forest management to restore forest structure to approximate the historical low intensity, low severity fire regimes described in many papers (Agee 1993; Everett and others 1996, 2000; Harrod and others 1999; Weaver 1943, 1951, 1961, 1967).

The first stages in the sequence to reach the desired future condition of the forest north of the Beehive Reservoir began with thinning in 1996. Our research began in September 1997 with the objective of assessing the first stages of the project. We wanted to know if a combination of thinning and burning could shift community structure toward parklike stands while maintaining composition of native species.

Materials and Methods

Study Site

The study site for this research was located in OWNF, 13 km southwest of Wenatchee, Washington, near Beehive Reservoir, in a ponderosa pine/pine-grass community that we call Beehive Forest for convenience (fig. 2). The overstory was dominated by large diameter ponderosa pine with clumps of small diameter Douglas-fir and grand fir. Western larch saplings were scattered throughout. The understory was dominated by grasses and forbs, namely pinegrass and broadleaf lupine (*Lupinus latifolius*). Bitterbrush, Scouler willow (*Salix scouleriana*), bittercherry (*Prunus emarginata*), and oceanspray (*Holodiscus discolor*) were important shrubs in the matrix of herbaceous species. The study site has a northeast aspect and gentle topography with 7° slopes. The site averages 590 mm of precipitation annually, with most falling as winter snow (Franklin and Dyrness 1988). Snow cover accumulates up to 3 m. Cumulative summer rain averages 44 mm, mostly from thunderstorms. Diurnal air temperatures fluctuate by more than 20 °C in the summer. Beehive Forest and the surrounding area (fig. 2) are part of the Wenatchee formation, which was created by fluvial and lacustrine processes in the lower Oligocene (Glesens and others 1981). Soils are Andisols (Meurisse and others 1991), and are derived from shale, siltstone, and sandstone (Glesens and others 1981).

Forest Restoration

This study comprised burned and unburned treatments. Before the fire, all stands were treated to approximate historical stand structure and composition as described in the management plan. Stands were thinned in a range of size classes, but the treatment focused on the understory to reduce density and vertical fuel structure. Litter was raked from the bases of large trees, lower branches were pruned to remove ladder fuels, and logging slash was scattered. Mechanical harvesting units were used to thin trees more than ~1 m of snow, which prevented damage to understory plants and soil. Stands in the unburned treatments had been unburned for >20 years. After thinning, the stands fit fire behavior fuel model SB1, in which spread rate is moderate and flame length low (Scott and Burgan 2005). We selected a 14-ha unit in the thinned part of Beehive Forest for the unburned treatment.

The prescribed burn was intended to enhance the growth of large, fire-resistant trees, kill ~95 percent of all saplings <10 cm dbh, improve the vigor of grasses and forbs, and reduce surface fuel loadings. Fifteen ha of Beehive Forest, comprising the burn treatment, were underburned on 22 September 1997. The prescribed burn was a relatively low intensity surface fire with flame lengths generally <1.5 m. Approximately 80 percent of the area burned was blackened, and ~25 percent of the area consisted of white ash, suggesting higher burn intensity and complete litter consumption.

Vegetation Sampling

Postfire data for trees in the upper and middle forest layers, and taller shrub species in the middle forest layer, were gathered on six 20 x 50 m macroplots in each treatment. Two lines parallel to the 50-m side of the macroplot were located at the 5 m and 15 m marks on the 20-m side. Data on species in the lower forest layer were gathered on 20 1 x 1 m microplots placed every 5 m along these two 50-m lines. Data were gathered on the unburned plots in

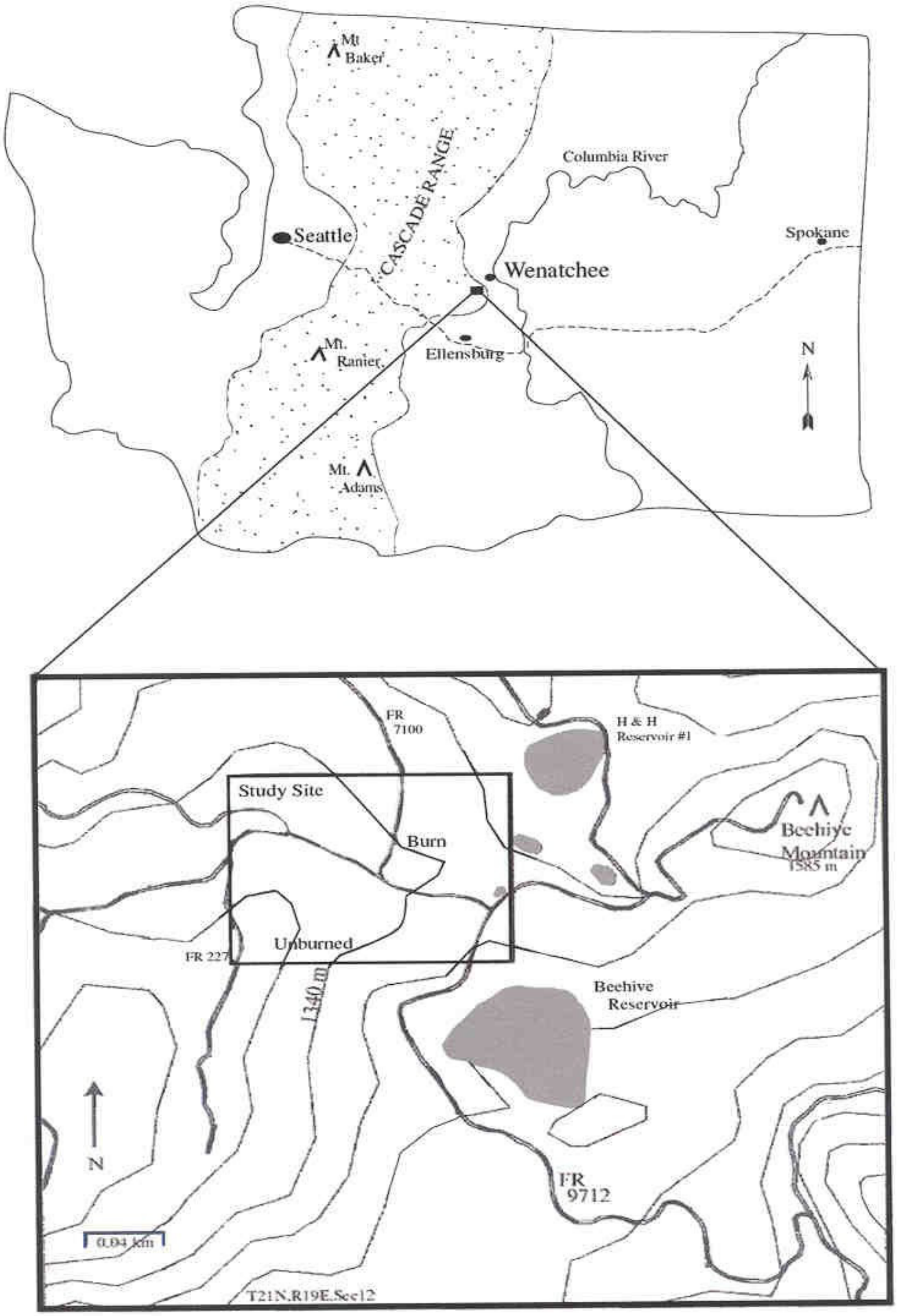

Figure 2—Location of the study site, ~13 km southwest of Wenatchee, WA. The area north of the Beehive Reservoir was thinned in 1996, and the burn treatment was applied in 1997.

summer 1998, and on the burned plots in summer 1997 (preburn), 1998 (burn +1), 2001 (burn +3), and 2006 (burn +9). The unburned plots were burned in October 1998, and thus were unavailable afterwards.

Density, basal area, and fire response (alive or dead) were recorded in 1998, 2001, and 2006 for all tree species >2 cm dbh on the macroplots. All tree seedlings were tallied on the macroplot. Crown scorch volume (CSV), the best indicator of postfire survivability/mortality (Peterson 1985, Wyant and others 1986, Ryan and Reinhardt 1988), was scored for each tree in 1998 using scorch classes: <1 percent, 1-5 percent, 6-25 percent, 26-50 percent, 51-75 percent, 76-99 percent, 100 percent. Mean CSV was calculated using midranges of each scorch class. Scorch evidence was gone by 2001.

Density of taller shrubs in the middle layer was recorded on the microplots. Fire response of the taller shrubs (alive/unharmed; top-killed/resprouted; or, dead) was tallied in 1998 on the macroplots. Because the trees and taller shrubs are woody, prefire density was easily reconstructed. We knew that all woody plants were alive before the fire, thus skeletons of dead and top-killed plants were created by fire.

Percent frequency and cover of herbaceous species were recorded on the microplots. Cover was scored to the nearest 1 percent for each species. Postfire data for herbaceous species were compared to the unburned plots because no prefire data were collected for herbaceous species on the burned plots. We judged fire responses according to the same frequency categories used by Tveten and Fonda (1999). Species whose frequency changed by <10 percentage points, compared to the unburned treatment, were maintainers. Those whose frequency changed by >10 percentage points, compared to the unburned treatment, were increasers or decreasers.

Four hawkweed species were present in the study site and could not be distinguished when young; their data were combined and reported as hawkweed spp. Likewise, the data for taxonomically and ecologically similar bristly Nootka rose (*Rosa nutkana* var. *hispida*) and baldhip rose (*R. gymnocarpa*) were combined and reported as rose spp. Botanical nomenclature follows Hitchcock and Cronquist (1973). Voucher specimens are deposited in the Biology Department Herbarium (WWB), Western Washington University.

Data Analysis

This research was designed as a Randomized Complete Block ANOVA, with the significance level set at 0.05 before the research began. The years relative to fire constituted the treatments in the analysis: 1997 (preburn), 1998 (burn +1), 2001 (burn +3), and 2006 (burn +9). The six macroplots constituted the blocks. Because the postfire treatments were defined by a numerical component (+1, +3, +9), the data also could be analyzed by Linear Regression to identify possible functional relationships among the data with time since fire. We used ANOVA and Linear Regression to analysis relationships among percent cover in the lower layer, shrub and seedling density in the middle layer, and tree density and basal area in the tree layer.

Results

Overstory Response

Ponderosa pine was well represented on the burned plots in all prefire and postfire diameter classes, with the most young and mature trees of any species (fig. 3). Mean height of the canopy layer was 20 m. Douglas-fir, western larch, and grand fir were absent from diameter classes >40 cm. Douglas-fir was concentrated in the 11 to 40 cm diameter classes preburn and burn +1 year, but more trees were present in the <4-10 cm diameter classes after burn +3 and burn +9 years. Western larch was concentrated in the 11 to 40 cm diameter classes in all years. Grand fir had fewer trees in the smallest diameter classes after burn +1, but had a substantial increase in <4 cm trees

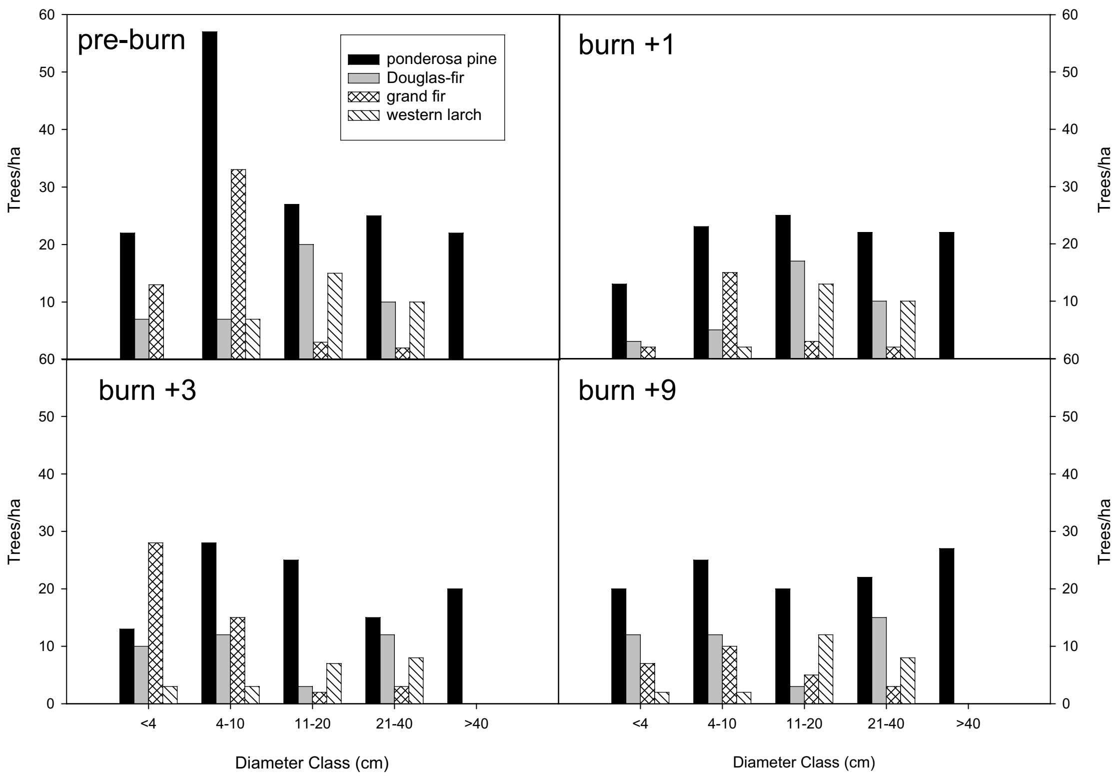

Figure 3—Prefire and postfire mean diameter distribution (trees/ha) for trees >2 cm dbh.

after burn +3. However, these trees were not maintained into burn +9 years. Few trees >11 cm of any species were killed by fire (fig. 3), but the smaller trees in the middle layer were most affected. Young trees of all species in the <4 cm diameter class were reduced by 43 percent by the fire.

Fire had little effect on density and basal area for total trees (table 1). The small trees killed by fire resulted in lower density, but these differences were not significant for any species across years. In addition, there were no significant differences among species for any postfire year, except in burn +9 year ponderosa pine was significantly greater than any other species (table 1). Ponderosa pine clearly dominated the canopy layer with significantly greater

Table 1—Mean tree density (trees/ha) and mean basal area (m^2/ha) at Beehive Forest, from 1997 (preburn), 1998 (burn +1), 2001 (burn +3), to 2006 (burn +9). No significant differences for a species across years for density and basal area and only ponderosa pine significantly different in burn +9 (in bold) when comparing species density.

	Preburn	Burn +1	Burn +3	Burn +9
Density				
Ponderosa pine	153	105	101	**114**
Grand fir	51	22	48	25
Douglas-fir	44	35	37	42
Western larch	32	25	21	24
Total	280	187	207	205
Basal area				
Ponderosa pine	7.84	7.60	8.05	8.73
Grand fir	0.26	0.22	0.06	0.09
Douglas-fir	1.06	1.00	0.64	1.25
Western larch	1.01	0.96	0.69	0.92
Total	10.17	9.78	9.44	10.99

basal area in each of the treatment years compared to grand fir, Douglas-fir, and western larch (table 1). Grand fir, Doulgas-fir, and western larch were not significantly different from each other in the preburn year or any postfire year. Basal area for a given species was not significantly different across the treatment years.

Trees <4 m had generally greater CSV than trees >4 m (table 2). Grand fir had greater CSV than any other tree species, and the differences among the larger ponderosa pine, Douglas-fir, and western larch were trivial.

Table 2—Postfire mean crown scorch volume (CSV) for all trees >2 cm dbh on the burned plots. Species are listed by order of increasing CSV in the >4 m tall category.

Species	>4 m tall	<4 m tall
Ponderosa pine	21	72
Western larch	23	1
Douglas-fir	45	53
Grand fir	80	86

Middle Layer Response

The most dramatic change in community structure was represented by new tree seedlings (<4 cm dbh) in burn +3 and burn +9 years (table 3). In 1998, two ponderosa pine seedlings (= 3/ha) were tallied postfire on the six macroplots in the burned treatment. No other species had individuals <2 cm dbh. By burn +3 years, seedlings of five species were present on the burned plots, with grand fir and ponderosa pine the most abundant, followed by Douglas-fir and western larch. After burn +9 years, ponderosa pine and Douglas-fir seedling density was not significantly different from burn +3 years, nor was there a significant change over time (table 3). Grand fir and western larch seedlings were not significantly different among sample years, but the increase over time was significant (regression coefficient for grand fir was b= 7.53 (that is, an increase of 7.53 seedlings per ha per year), and for larch b= 1.56).

Table 3—Composition of the middle layer, and changes by tree seedling and shrub density (per hectare) after fire. Means with the same superscript are not significantly different, by species.

Species	Postfire year 1	3	9	Regression relationship with time
Tree seedlings				
Ponderosa pine	3	410[a]	372[a]	Not significant
Douglas-fir	0	190[a]	125[a]	Not significant
Grand fir	0[a]	538[a]	713[a]	Significant
Western larch	0[a]	118[a]	150[a]	Significant
Total seedling density	3	1,256	1360	
Shrubs				
Shiny-leaf spirea	2,530[a]	870[a]	9982[a]	Not significant
Moutain balm	0	48[a]	57[a]	Significant
Oceanspray	15[a]	337[a]	238[a]	Not significant
Scouler willow	55[a]	63[a]	73[a]	Not significant
Bitterbrush	100[a]	87[a]	100[a]	Not significant
Serviceberry	0[a]	30[a]	48[a]	Not significant
Squaw currant	0[a]	7[a]	3[a]	Not significant
Total shrub density	615	617	10,501	

Shiny-leaf spiraea was the most abundant shrub species in the middle layer in all three postfire years (table 3). However, only moutain balm significantly increased density over time; postfire years +3 and +9 were significantly greater than the first postfire year. Other abundant postfire shrubs were oceanspray, Scouler willow, and bitterbrush, all of which readily resprouted in the first year postfire (78, 100, and 64 percent resprouted, respectively). Fewer than 14 percent of shrub individuals were killed on the burned plots, so shrub species were consider important endurers or maintainers.

Lower Layer Response

Although postfire responses of the lower forest layer components were pronounced on burned plots, the postfire community structure and composition did not change substantially compared to the unburned plots. Based on changes in frequency, most of these species responded as maintainers or increasers in an intact lower layer after burn +1, burn +3, and burn +9 years (table 4). Mean cover of each species was not significantly different among the unburned site and any postfire year. In fact, nearly all grasses, forbs, and shrubs were endurers. The understory dominant and fire maintainer, pinegrass, was uniformly distributed and had the highest cover of any understory species (table 4). One of the latest flowering understory species, pinegrass had abundant, tall flower stalks after burn +1 in August.

Broadleaf lupine was a uniformly distributed, dominant species and fire maintainer, but it had about half of the cover of pinegrass (table 4). Lupine flowered in early summer and set seed by mid-July. It was completely senesced by August when pinegrass became prominent. The remaining maintainers, with low frequency and cover, were structurally unimportant (table 4).

Table 4—Unburned and postfire percent frequency and mean percent cover of grasses, forbs, and shrubs in the lower forest layer. Species listed have at least 1 percent cover in one treatment. Mean cover for each species did not differ significantly among the four treatments.

	Frequency				Cover			
	Unburned	Burn +1	Burn +3	Burn +9	Unburned	Burn +1	Burn +3	Burn +9
Maintainers in all postfire years								
Pinegrass	86	81	84	84	23.3	23.3	26.8	20.7
Broadleaf lupine	82	75	75	73	12.1	13.8	14.4	8.4
Hawkweed spp.	43	41	53	38	3.8	1.4	3.0	1.7
Sharptooth angelica	13	16	6	12	0.6	<0.1	0.4	0.4
Yellow penstemon	12	15	10	16	0.9	1.0	0.6	0.8
Increaser by burn +9								
Kinnikinnick	26	21	31	37	8.1	3.8	7.0	10.3
Decreaser in burn +1 and burn +3, maintainer by burn +9								
Elk sedge	68	45	50	67	8.7	6.2	3.4	8.2
Decreasers by burn +9								
American vetch	26	28	20	10	3.0	2.8	1.0	0.1
Northwest sedge	18	28	13	1	2.5	1.5	0.3	0.2
Increaser in burn +1 and burn +9								
Heart-leaf arnica	22	37	18	33	2.3	4.1	0.9	1.0
Increaser in burn +1 and burn +3, decreaser by burn +9								
Fireweed	12	34	28	0	1.5	2.5	1.7	0
Increasers in burn +3								
Yarrow	53	58	68	63	5.2	3.9	3.2	1.9
Idaho fescue	9	14	27	3	0.6	1.5	1.5	0.2
Decreaser in burn +1 and burn +9								
Rose spp.	49	38	42	33	5.6	5.1	3.8	1.8

American vetch (*Vicia americana*) and northwest sedge (*Carex concinnoides*) were decreasers by burn +9 and contagiously distributed (Whittaker 1975) within the pinegrass-lupine matrix (table 4).

There were five increasers (table 4). Kinnikinnick (*Arctostaphylos uva-ursi*) commonly formed extensive mats, which contributed strongly to sustaining fire on the burned plots. Heart-leaf arnica (*Arnica cordifolia*) was an increaser after burn +1 and burn +9 years. Fireweed (*Epilobium angustifolium*) was an increaser in the first two postfire year measurements, but disappeared by burn +9. Yarrow (*Achillea millefolium*) and Idaho fescue were increasers into the third postfire year. They were prominent in late summer, often in flower with pinegrass.

Rose spp. response was variable over time, but were decreasers in burn +1 and burn +9 years. Elk sedge was a consistent decreaser in burn +1 and burn +3 years and cover for this species was less than 50 percent of the unburned cover. However, elk sedge was a maintainer by burn +9.

Discussion

The forest structure achieved by thinning and burning suggests that Beehive Forest approached the conditions established by the management objectives in the first postfire year. The data for postfire shrubs, however, indicate that more time and treatments will be needed before the forest reaches the structure depicted in figure 1. Few plants in Beehive Forest were completely killed by fire, and species composition, comprising maintainers and a few increasers, were stable after burning. This is a similar finding to thinning and burning treatments in ponderosa pine-Douglas-fir in northeastern Oregon, where understory vegetation was largely unchanged (Metlen and others 2004). As in the northeastern Oregon study, individual species response at Beehive to thinning and burning treatments was consistent their life history characteristics. Most grasses, forbs, and shrubs were endurers that maintained the low forest layer through rapid resprouting and postfire growth. Resisters and endurers commonly are maintainers, occasionally increasers, whose frequency or density does not change substantially after fire. The postfire responses of plant species in Beehive Forest were similar also to species on Fort Lewis, WA, where dominant species in fire-maintained Idaho fescue prairies and Garry oak (*Quercus garryana*) woodlands were maintainers whose frequency changed by <10 percentage points from prefire conditions (Tveten and Fonda 1999). Few native species on Fort Lewis or in Beehive Forest were increasers or decreasers.

Prefire thinning and burning initially opened the middle layer in Beehive Forest, primarily by top-killing at least 50 percent of taller shrubs and secondarily by killing sapling trees. About 13 percent of individual shrubs were killed by fire; all survivors were endurers that resprouted <6 weeks after the fire. Densities of smaller ponderosa pine and Douglas-fir, and grand fir of all sizes, in the middle layer were reduced by fire in the first postfire growing season. The current forest structure now fits fire behavior fuel model 2, in which low intensity surface fires are carried through fine herbaceous fuels (Anderson 1982). Developing and maintaining parklike stands by changing the structure of this middle layer with a combination of thinning and burning was a management objective. Third and ninth year data on tree seedlings and shrubs indicate that community structure has shifted only slightly toward parklike stands while maintaining native species on the site. The low percentage of total killed seedlings and shrubs indicates that more thinning and fire will be needed before the goal is achieved.

The canopy layer remained intact on the burn site. Mature ponderosa pine, western larch, and Douglas-fir were resisters. Mature Douglas-fir in the canopy layer resisted the direct effects of fire. If the desired forest structure requires lower Douglas-fir density, future management efforts may focus on mechanical thinning of Douglas-fir, rather than low intensity fires, to achieve that structure.

Prescribed fire objectives usually define acceptable values for overstory mortality. Because CSV of >80 percent invariably indicates mortality in conifers (Ryan and Reinhardt 1988), many burn programs use low intensity surface fires to avoid burning the canopy. For instance, mean flame lengths in a thinned stand of ponderosa pine in Arizona were ~15 cm, with occasional flareups to ~64 cm (Covington and others 1997), compared to 1 to 2 m flame lengths for Beehive Forest. The fires in Beehive Forest did involve the canopy, with good results. Mean CSV for grand fir (avoider) exceeded 80 percent, whereas ponderosa pine (resister) was <80 percent (table 2). Furthermore, successive fires enhance the resister strategy of ponderosa pine by raising the height to live crown, thereby reducing potential CSV and postfire tree mortality in the future.

Conclusions

The treatments in Beehive Forest have started the process to restore forests of widely spaced groves of large ponderosa pine trees with scattered western larch and Douglas-fir, a grassy understory with sporadic clumps of young trees, and light surface fuel loadings (Agee 1993; Everett and others 1996, 2000; Harrod and others 1999; Weaver 1951). Ponderosa pine forests in the Cascades have missed 10 to 12 fire episodes (Everett and others 1996, 2000), and one thinning and burning treatment will not restore presettlement conditions. The restoration process has started in Beehive Forests, and no counterindications exist that suggest management objectives cannot be achieved. Prescribed burning alone fails to restore ponderosa pine forests to presettlement conditions, since forest structure has changed so drastically with fire exclusion (Agee 1996; Covington and others 1997; Everett and others 1996, 2000; Fiedler 1996; Harrod and others 1999; Scott 1998; Swezy and Agee 1991). Consequently, thinning trees and removing excess fuels, coupled with low intensity late season prescribed burns, offers a promising management strategy for restoring the presettlement structure of the ponderosa pine/pinegrass community in Beehive Forest.

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