EFFECTS OF ECOSYSTEM-BASED MANAGEMENT TREATMENTS

Prescribed Burn Weather, Fuel Moistures, and Fuel Reduction on all Cutting Units

Michael G. Harrington

The prescribed burn treatments were applied to reduce pre-existing and new slash fuel loadings, reduce understory tree density to lower crown fire potential, stimulate vigor of decadent understory vegetation, produce mineral seedbeds for seral species establishment, and increase availability of mineral nutrients. To test the feasibility of prescribed burning under a broad range of conditions without producing undesirable effects, several burn treatments were compared. Three contrasting burn treatments were applied in the shelterwood and commercial thinning studies and two burn treatments in the selection study. In the shelterwood study area, the three burning treatments conducted in May 1993 subsequent to the previous year's harvest were a low fuel consumption burn (wet burn), a high fuel consumption burn (dry burn), and a no burn. The wet and dry conditions were determined by moisture contents of the duff and large woody fuels. A single application of fire in the selection study, also in May 1993, took place under conditions intermediate to the wet and dry shelterwood treatments and was compared to a no-burn treatment. In the commercial thin units, a fall 1993 dry burn was compared to a spring 1994 wetter burn along with a no-burn treatment (table 5).

Woody fuels were measured before and after burning along 12 transects of 30 ft each in each of the three replicates of each treatment. In addition, 48 duff spikes were placed in each replicate to measure total duff depth and consumption. Litter, woody material, and duff samples were collected frequently during the burning for moisture content determination.

Because of the unusually hot, dry weather in mid-May 1993, the shelterwood and selection burns had to be conducted during the cool, early morning hours or after sunset to avoid excessive fire damage. Warm days for both the spring and fall commercial thin burns also dictated morning ignitions. With the exception of the start of one fall burn when the air temperature was in the mid-30's °F, all burns were conducted within the temperature range of 50 to 74 °F with relative humidities ranging from mid-30 to the mid-70 percent. Winds on all burns rarely exceeded 5 miles per hour. Strip head fires were used exclusively with the width of the strip dictated by a fire behavior goal of minimizing crown scorch in the large reserve trees.

Fuel moisture content is the primary characteristic that determines fuel consumption and, therefore, fire effects. Several types of fuel were sampled for moisture content during the burns because each has a somewhat different influence on fire behavior and fire impacts. Three key fuels on these sites were pine needle litter, decomposing humus or duff, and large woody fuels. The litter determines the rate and completeness of fire spread across the units, whereas the duff, which burns slowly, either dampens the fire impacts when wet or heightens the impact on soils or underground plant parts when dry. Consumption of large woody fuels can also cause severe damage to soil properties and underground plant parts, and also to cambium tissue and tree crowns.

Table 6 shows fuel moistures. The shelterwood units had the driest litter, which reflects the warm, dry weather in May 1993. The cool, damp mornings of the fall commercial thin burns resulted in relatively high litter moisture. The distinction between the wet, intermediate, and dry burns of the shelterwood and selection treatments is made by comparing duff and large woody fuel moistures, with the wet burn clearly having more moist fuels. To illustrate how rapidly fuels dry out on these relatively steep, southern exposures, note that in the 2 weeks between the shelterwood wet and dry burns, duff moisture dropped from 50 to 16 percent and large woody moisture from 100 to 30 percent.

Surface fuel loadings in these treatments would not generally be considered excessive, posing no severe wildfire hazard. However, because these south slopes dry out rapidly, completely, and regularly, the fuels that are present are easily ignited with a potential high rate of fire spread frequently during the fire season. Fuel loadings and percent reduction are shown in table 7.

Table 6—Fuel moisture contents for the Lick Creek prescribed burns.

	Treatment				
	Shelterwood		Selection	Commercial thin	
Fuel type	Wet	Dry	Int.	Fall	Spring
	Percent				
Litter	9	8	12	15	12
Duff	50	16	30	20	30
Large woody (>3 in.)	100	30	48	25	46

Table 7—Initial fuel amounts and percent reduction in Lick Creek burns.

	Treatment				
	Shelterwood		Selection	Commercial thin	
Fuel type	Wet	Dry	Int.	Fall	Spring
	tons/acre(percent reduction)				
Litter	1.4 (82)	1.9 (79)	2.1 (81)	1.2 (95)	1.2 (92)
Small woody (<3 in.)	4.5 (60)	5.3 (75)	4.5 (57)	3.1 (51)	3.6 (43)
Large Woody (>3 in.)	1.7 (75)	3.2 (80)	5.7 (93)	4.0 (87)	6.0 (66)
	inches (percent reduction)				
Duff Depth	1.1 (17)	1.4 (38)	1.7 (33)	1.2 (69)	0.9 (42)

Most of the litter and a significant portion of the woody fuels were consumed. The high consumption of large woody fuels in the selection units was likely due to the high percentage of rotten wood, which thoroughly burns when moderately dry. Duff layers were not thick in these stands, and only the fall burn resulted in a significant reduction. The low duff moisture content in the dry shelterwood burn did not result in high consumption, probably because of a rain shower near the end of the burn that dampened subsequent smoldering combustion and made the underlying soils moist.

In summary, a significant portion of the pre-existing and slash fuel were consumed by the prescribed fires, some of which were conducted during a record warm, dry period. None of the treatments, including those under very dry conditions, resulted in excessively negative impacts. Other fire impacts are reported in later sections of this paper. With closely controlled ignition and favorable weather, no control problems were encountered. Fuels consumed by the fires will continue to be replaced by those from fire damaged trees, natural litter deposition, and rapid plant establishment and growth. Therefore, prescribed fire should continue in the management of these forests.

Tree Response

Stand Structure Response to Harvesting and Prescribed Burning on Shelterwood Cutting and Commercial Thinning Units

Michael G. Harrington

The harvesting and prescribed burning treatments in the shelterwood and commercial thinning studies were designed to greatly reduce all sizes of Douglas-fir and thin ponderosa pine, primarily from the middle and smaller diameter classes. The harvesting was used to remove excess trees down to the merchantable limit, and the subsequent fire treatments were applied to reduce those in the submerchantable sizes. These activities were designed to reduce competition and the crown fire potential by thinning crown fuels. All measurements were made within 12 1⁄10 acre circular plots systematically located in each of the three replicates in the three treatments. Pretreatment stand density in the shelterwood units averaged 240 ± 52 trees per acre with a basal area of 117 ± 15 ft^2 per acre. Ponderosa pine constituted 72 percent of the trees (172 ± 45 trees per acre) and 82 percent of the basal area (96 ± 10 ft^2 per acre), with the remainder in Douglas-fir. In addition to these trees larger than 1 inch dbh, there were 60 seedlings per acre, 87 percent of which were Douglas-fir.

Following harvesting, an average of 92 ± 17 trees per acre (62 percent reduction) and 52 ± 5 ft^2 per acre (56 percent reduction) remained. Ponderosa pine was represented by 83 percent of the residual stand (76 ± 21 trees per acre) and 95 percent of the basal area (49 ± 4 ft^2 per acre). Douglas-fir was reduced to 16 ± 16 trees per acre and 3 ± 3 ft^2 per acre. Ponderosa pine density was reduced by 56 percent and basal area was reduced by 49 percent. This compared to 76 percent and 86 percent reductions in Douglas-fir. Figure 18 illustrates the extent of tree reduction in different size classes. Statistical comparisons were not conducted on these initial data, so only apparent treatment differences can be inferred.

Trees less than 7 inches dbh were killed by mechanical logging damage, and those greater than 17 inches dbh were removed only from clusters. Mortality of seedlings from mechanical damage averaged 35 percent, leaving about 39 seedlings per acre, 85 percent of which were Douglas-fir.

As expected and desired, there were apparent differences in tree mortality between the no-burn and burn treatments during the first 5 postburn years (fig. 18). For trees larger than 7 inches dbh, just over 2 percent died in the no-burn units either from bark beetles or wind damage. Comparatively, 10 percent of this size class in the low fuel consumption burn (wet) and 14 percent in the high fuel consumption burn (dry) died, primarily from significant fire injury. Some, however, were minimally damaged by fire but sustained high levels of beetle attacks. Within the burn treatments, smaller trees had notably higher levels of mortality than larger trees, which is a desirable objective of a thinning fire. Numbers of trees less than 7 inches dbh were reduced by only 6 percent in the no-burn units compared to about 65 percent in the combined burn units with most of these being less than 3 inches dbh. Mortality in the burn units decreased with increasing size as 13 percent of the trees less than 15 inches dbh died compared to 8 percent of the trees greater than 15 inches dbh. Additionally, over 90 percent of the Douglas-fir seedlings were killed by the fire treatments.

Four years after burning, the basal area for trees larger than 7 inches dbh had been reduced by less than 1, 4, and 6 ft^2 per acre for the no-burn, wet burn, and dry burn, resulting in final basal areas of 46, 39, and 44 ft^2 per acre, respectively. Remaining trees less than 7 inches dbh added another 4 ft^2 per acre for the no-burn treatment and about 2 ft^2 per acre for the burn treatments.

In the commercial thin study area, the preharvest stand structure was represented by fewer and smaller trees than the shelterwood study area. The average stand density was 170 ± 29 trees per acre yielding 92 ± 10 ft^2 per acre basal area. Some 93 percent of the trees (159 ± 24 trees per acre) and basal area (86 ± 14 ft^2 per acre) were ponderosa pine, and

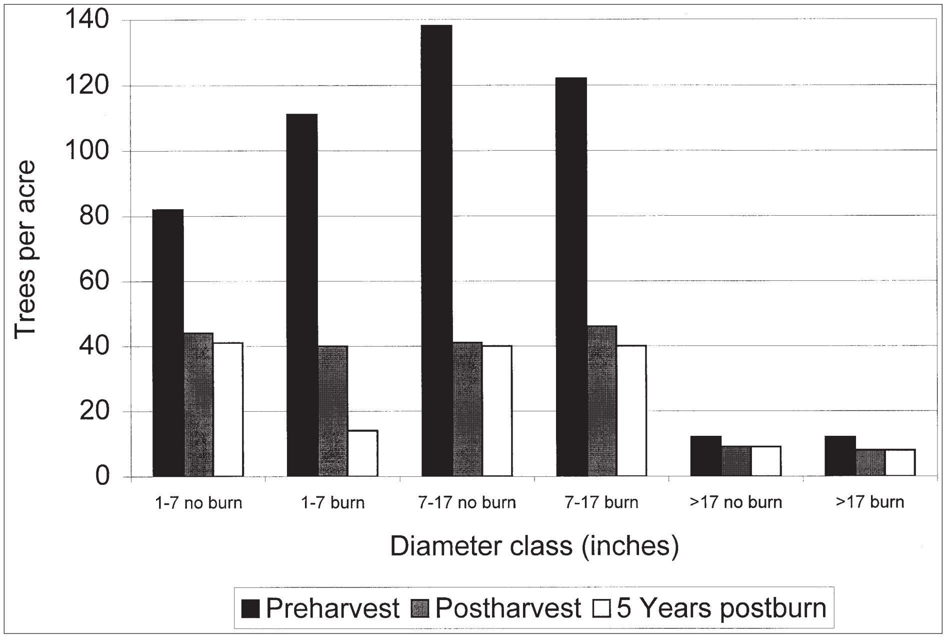

Figure 18—Tree reduction in the shelterwood no burn (a) and burn (b) treatments in three dbh classes.

the remainder were Douglas-fir. This indicates that after the harvesting in the early 1900's and again 40 to 50 years later, ponderosa pine regenerated better than Douglas-fir because of the warm, dry southern exposure and higher seed production.

Following the commercial thinning in 1992, an average of 112 ± 32 trees per acre and 61 ± 5 ft^2 per acre remained. Ponderosa pine made up 95 percent (106 ± 28 trees per acre) of the stand density and 98 percent (60 ft^2 per acre) of the basal area. Ponderosa pine density and basal area were reduced by about 30 percent, while Douglas-fir density was reduced by 50 percent and basal area by 80 percent, indicating that the largest Douglas-fir were preferentially removed.

The harvest focused on removing the smallest merchantable pines and most Douglas-fir because of their excessive numbers and, therefore, high demand on limited site resources, and because their continuous canopy increased crown fire potential. Figure 19 shows preharvest stand density and tree reduction within three diameter classes.

The objective of leaving the largest and healthiest trees was met as about 9 of 10 trees greater than 15 inches dbh remained. Numbers of trees less than 7 inches dbh were reduced by damage from logging equipment (fig. 19).

Within the 1⁄10 acre sample plots, 11 of the largest ponderosa pine were purposely girdled with fire or mechanically as a study of snag quality. We describe this study later. The stand characteristics were changed somewhat as a result of this activity. Snag production reduced ponderosa pine density by only 1 tree per acre, but basal area by 3 ft^2 per acre because only large trees were used for snags. Subsequent posttreatment basal area values reflect this reduction.

At 4 years after the prescribed burns, mortality of trees greater than 7 inches dbh was minimal. In the no-burn treatment, no trees died and only 3 percent were dead in both the fall and spring burn treatments (fig. 19). Of these about 70 percent were less than 10 inches dbh, indicating the selective thinning of smaller trees with this fire. Basal areas were reduced by only 1.4 and 0.7 ft^2 per acre in the spring and fall burns leaving 61 and 57 ft^2 per acre, respectively.

For trees 1 to 7 inches dbh, only 2 percent of those in the no-burn units died in the first 4 years after treatment, with insects or delayed mechanical damage as the mortality agents. In the spring and fall burn treatments, 57 and 59 percent of the small trees died, mostly from fire injury (fig. 19). Subsequent mortality will likely be insignificant as only a 1 percent increase occurred in the last 2 years.

In summary, the objective of the harvesting treatments in both the shelterwood and commercial thin study areas was to reduce basal area in the overstocked and smallest merchantable size classes (7 to 5 inches dbh) retaining 40 ft^2 per acre in the shelterwood and 50 ft^2 per acre in the commercial area to allow increased growth and health of residual large trees and a reduction in crown fire hazard. The harvesting in both areas was conservative, leaving an unplanned excess of about 10 ft^2 per acre. However,

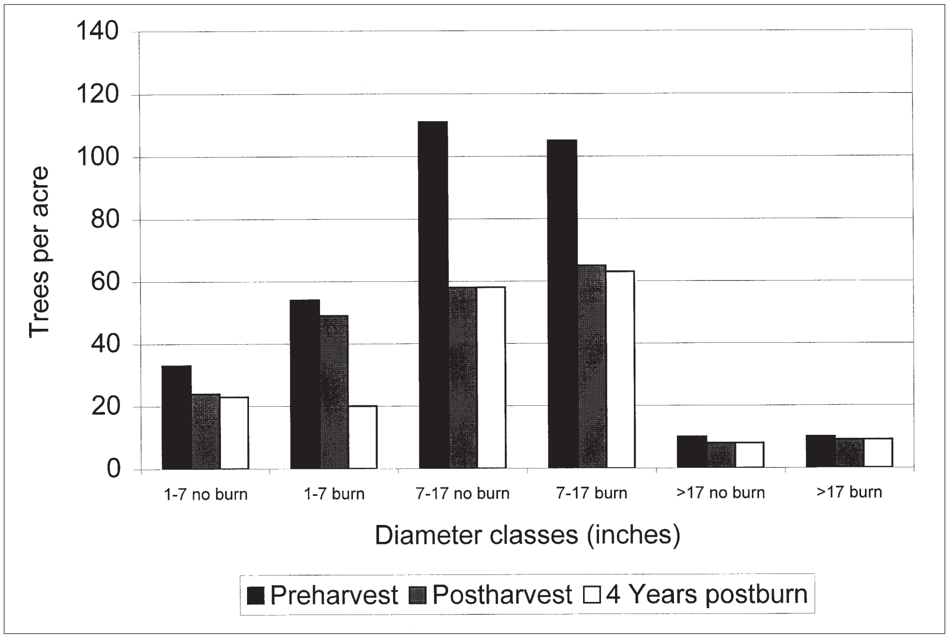

Figure 19—Tree reduction in the commercial thin no burn (a) and burn (b) treatments in three dbh classes.

small trees made up 4 to 5 ft^2 per acre of this excess. Fire mortality was expected and desired, especially in the smaller sizes in which about 60 percent of the trees were killed. Most of this size class, which were Douglas-fir or poor quality pines, remain in the no-burn treatment and continue to represent an undesirable condition in terms of competition and ladder fuels. Mortality of the larger trees averaged about 12 percent in the shelterwood and only 3 percent in the commercial thin study. This difference was likely due to greater fire injury due to warmer temperatures and more liberal ignition in the shelterwood units. Some overstory mortality was anticipated with burning, and in this case it further reduced the excess stand density.

Stand Structure in Response to Selection Cutting and Burning

Carl E. Fiedler

Prior to treatment, the selection cutting study area manifested a classic uneven-aged structure, with numerous small trees and decreasing numbers of increasingly larger trees (fig. 20). The pretreatment stand comprised about 200 trees per acre and 110 ft^2 of basal area per acre. Presence of occasional old-growth trees killed by the western pine beetle, pockets of mountain pine beetle mortality, and declining growth rings in nearly all trees indicated that the stand was overstocked.

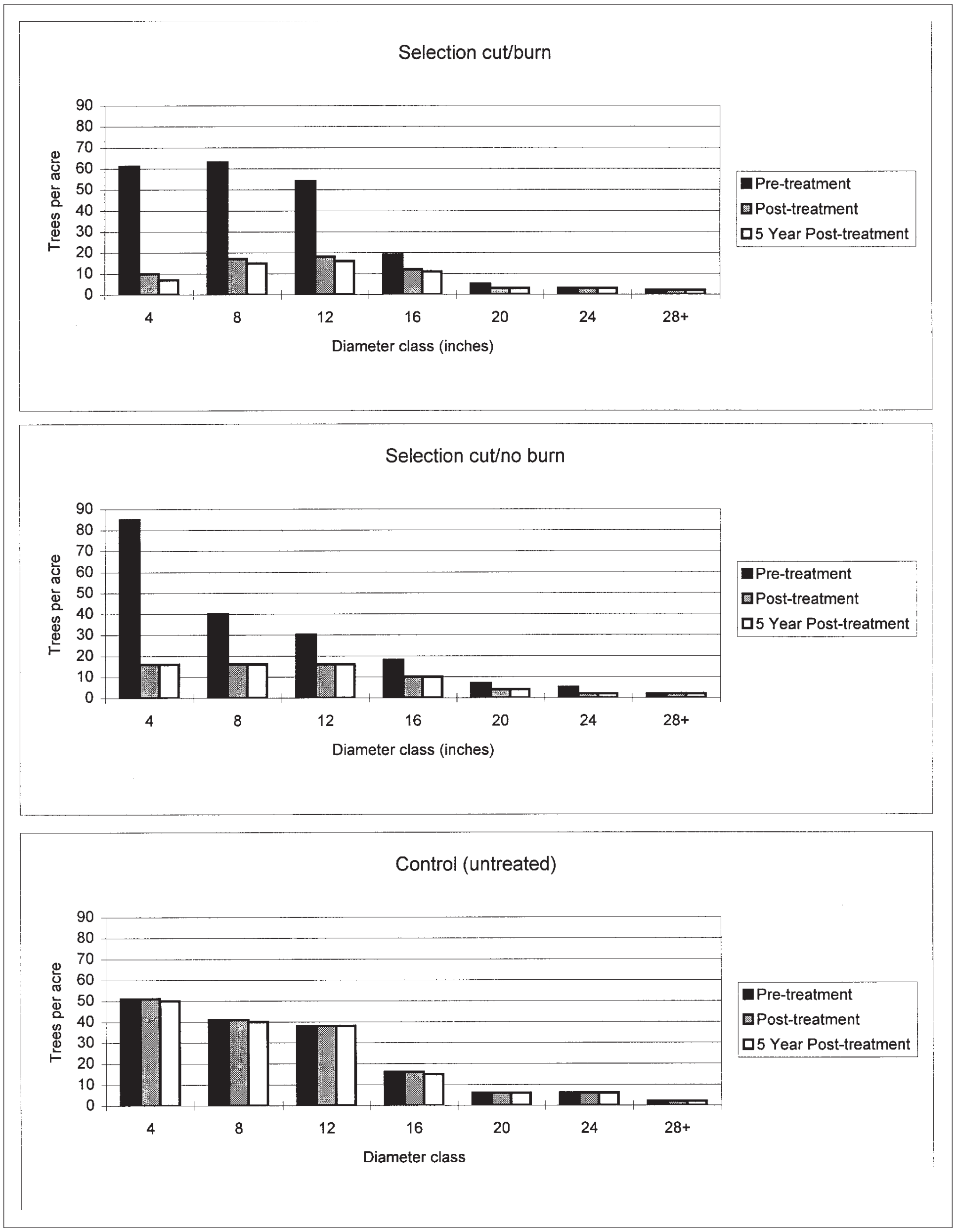

Figure 20—Trees per acre, by treatment and diameter classes, prior to, immediately after, and 5 years after treatment.

The selection cutting and broadcast burning treatments were developed to achieve several objectives. An improvement selection cutting was designed to: (1) reduce density to 50 ft^2 per acre to induce regeneration of shade-intolerant ponderosa pine (Fiedler and others 1988); (2) reduce the proportional composition of Douglas-fir; (3) increase vigor of reserve trees, making them less susceptible to mountain and western pine beetle attack; (4) increase the distance between tree crowns in the overstory to reduce the likelihood of stand replacement wildfire; and (5) promote rapid development of a large tree component (≥24-inches diameter). Another treatment objective was to reduce most of the excess sapling- and pole-sized trees (ladder fuels) that provide surface fires a means of torching into the overstory.

Following selection cutting, the treated units averaged about 60 trees per acre and 50 ft^2 of basal area per acre, which translates into a 70 percent reduction in trees per acre and 55 percent in basal area per acre. The bulk of the density reduction occurred in the smaller diameter classes (fig. 20).

Growth responses are compared among the three treatments described previously: (1) selection cutting with prescribed burning; (2) selection cutting without burning; and (3) control (no cutting or burning). Results are based on trees living at the end of the first 5 years of the study. Leave trees were marked in all units prior to randomly assigning the cutting and burning treatments. This approach ensured that posttreatment growth responses were compared among similar trees in each treatment.

Based on measurements of comparable trees in all three treatments, average annual diameter increment ranged from a low of 0.08 inch in the uncut control, to 0.10 inch in the cut/burn treatment, to a high of 0.13 inch in the cut/no-burn treatment.

Annual height growth varied little among the three treatments, averaging 0.6 ft in both the control and cut/burn treatments, and 0.7 ft in the cut/no-burn treatment.

Average annual basal area increment varied from 0.8 ft^2 per acre in the uncut control, to 0.7 ft^2 per acre in the cut/burn treatment, to 1.1 ft^2 per acre in the cut/no-burn treatment.

Average annual volume increments for 1993 to 1997 were also nearly identical for the control and cut/burn treatments. Annual cubic volume growth was 32 ft^3 per acre per year in the control versus 31 ft^3 per acre per year in the cut/burn treatment. Cubic volume growth was considerably higher in the cut/no-burn treatment, averaging 43 ft^3 per acre per year.

Trends in annual board foot volume growth by treatment mirrored those for cubic foot volume growth. For example, annual growth was 111 bd ft per acre per year in the control, 115 bd ft per acre per year in the cut/burn treatment, and 147 bd ft per acre per year in the cut/no-burn treatment.

The positive influence of density reduction on growth in the selection cut/no-burn treatment should have been realized in the cut/burn treatment as well because both received the same selection cutting treatment. However, the beneficial effects of reduced competition from cutting were apparently almost entirely offset by the short-term deleterious effects of reintroducing fire after nearly 100 years without frequent burning. Crown scorch, root damage, and cambial injury at the root collar may all have contributed to reduced tree stem growth in this treatment relative to the cut/no-burn treatment over the first 5 years of the study.

<u>All Causes</u>: Total 5-year mortality varied considerably among the three treatments but was highest in the selection cut/burn treatment (fig. 21). Virtually no trees died in the selection cut/no-burn treatment, whereas mortality in the control was intermediate to the other two treatments (fig. 21).

<u>Fire</u>: Fire was the major cause of mortality in the selection cut/burn treatment, killing 18 percent of the trees in the 4-inch diameter class, and 2 to 4 percent of the trees in the 8- through 16-inch classes (fig. 22). No trees larger than 16 inches died due to the effects of fire, and virtually all of the mortality attributed to fire occurred in the first 2 years of the study (fig. 21). The short-term deleterious effects of fire on individual trees may well be offset by mid- and long-term beneficial effects at the stand level (for example, stimulation of undergrowth forage species, hazard reduction, killing of small firs), which are primary objectives of prescribed burning. Furthermore, these objectives of burning likely cannot be achieved without at least some mortality of leave trees, particularly in the smaller diameter classes.

<u>Beetles</u>: Bark beetles were an important mortality factor in the selection cut/burn treatment, accounting for 4 to 12 percent mortality in the 4- through 20-inch diameter classes, and 25 percent of the trees ≥28-inches (fig. 23). In contrast, no trees of any size were killed by beetles in the selection cut/no burn treatment, and only sporadic mortality due to this factor was observed in the control treatment (fig. 23).

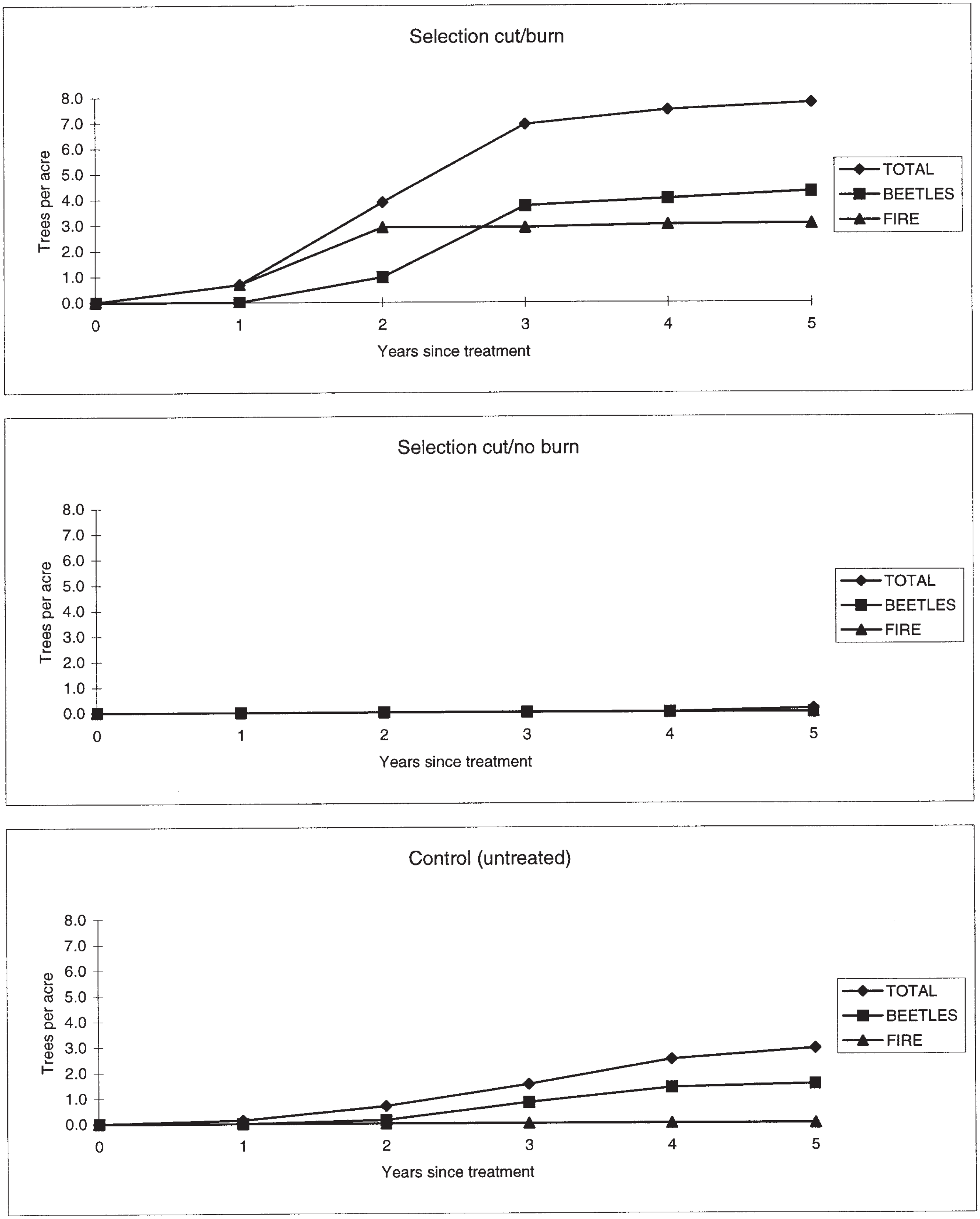

Figure 21—Cummulative annual mortality, by treatment and cause, for the 5 years 1993 to 1997.

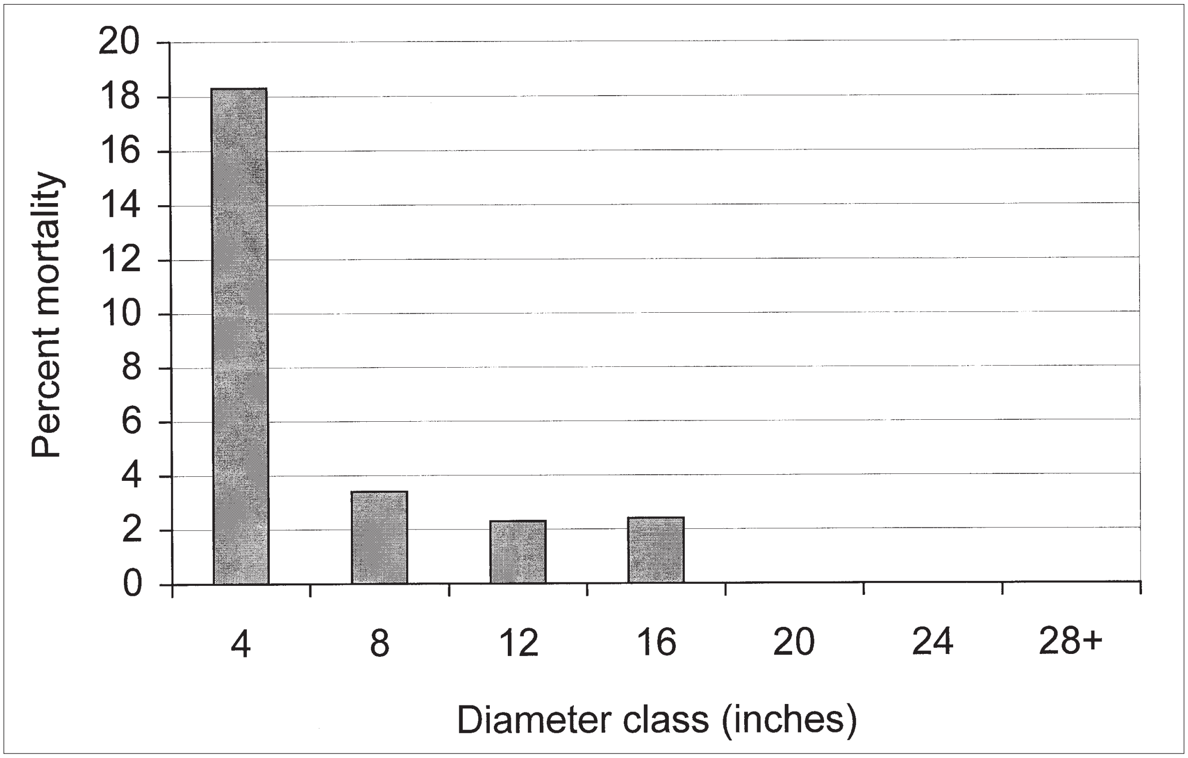

Figure 22—Fire caused mortality, by diameter class, for the 5 years 1993 to 1997.

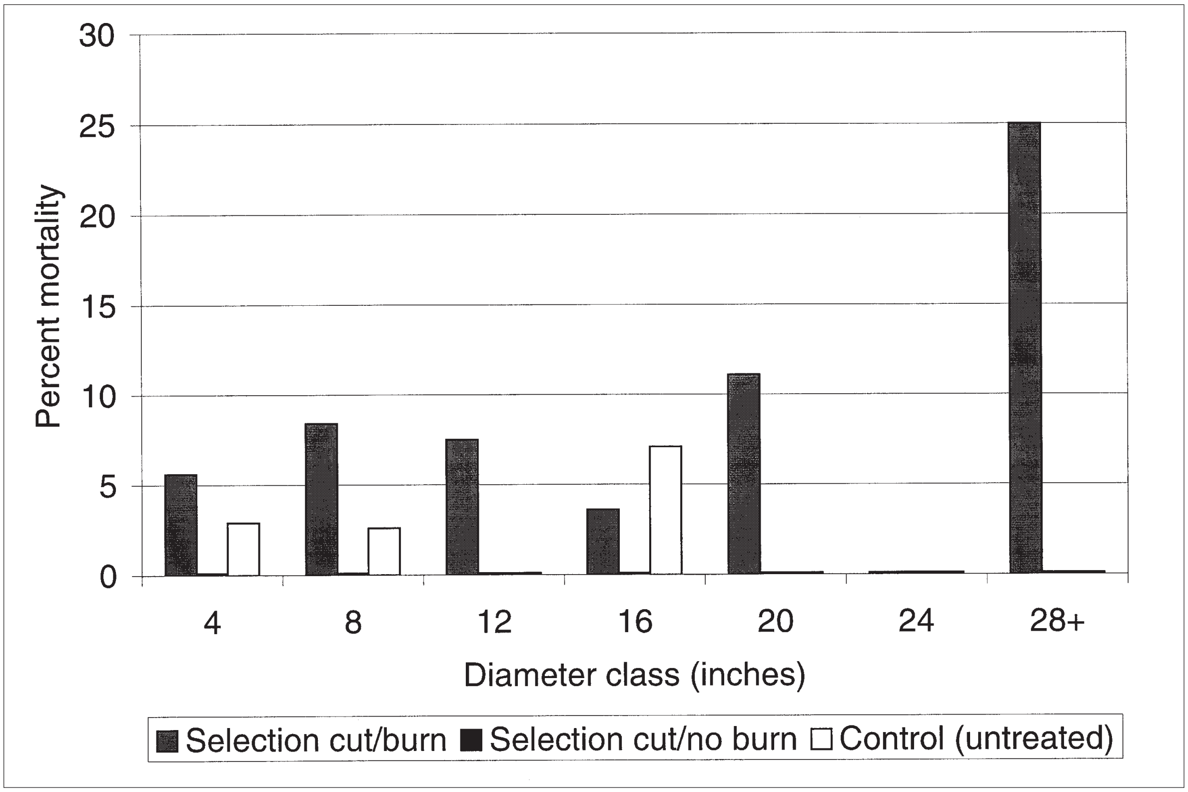

Figure 23—Beetle-caused mortality, by treatment and diameter class, for the 5 year period 1993 to 1997.

Tree Regeneration

Natural Regeneration, Shelterwood Cutting Unit

Stephen F. Arno

One of the challenges in attempting to perpetuate a ponderosa pine/Douglas-fir forest using partial cuttings rather than clearcutting is that the more shade-tolerant Douglas-fir tends to regenerate more successfully than the pine under conditions of partial shade. Therefore, it was important to track the success of naturally regenerated ponderosa pine and Douglas-fir in relation to the experimental cutting and burning treatments. Natural regeneration often requires several years after treatment to become established. In the shelterwood cutting units at Lick Creek we have data for regeneration as of the fifth year following cutting and burning treatments (table 8). Treatments were shelterwood cut reducing basal area of the overstory from an average of 117 to 52 ft^2 per acre followed by either a high fuel consumption burn, a low consumption burn, or no burn.

Tree regeneration was tallied on 48 1 m^2 vegetation plots, which were systematically placed in each of three replicates per treatment. Ponderosa pine and Douglas-fir saplings in their second to fifth year of growth in July 1998 and that were in relatively good vigor were considered as established posttreatment regeneration. Such regeneration of ponderosa pine averaged 281 trees per acre in the no-burn and both-burn treatments of the shelterwood unit (table 8). Average posttreatment regeneration of Douglas-fir was greater in the no burn (309 trees per acre) than in the burn treatments (84 trees in low consumption and 56 in high consumption). Advance regeneration that had survived treatments was entirely Douglas-fir and was abundant in the cut/no burn treatment where it averaged 1,321 trees per acre, but absent from the burned units.

A definitive evaluation of the effectiveness of natural regeneration would require delineating openings in the shelterwood stands and quantifying their occupancy by saplings, which we have not done. However, some trends are clear. An appreciable amount of natural regeneration of ponderosa pine is associated with all three treatments, but in the cut/no burn treatments this is exceeded by competing Douglas-fir regeneration, most of which became established more than 5 years before and survived the treatment. It seems likely that natural tree regeneration will continue to increase, especially in burned units and on skid trails within units that were not burned.

Artificial Regeneration, Shelterwood Cutting Unit

Ward W. McCaughey, Leon J. Theroux, and Clinton E. Carlson

It may sometimes be necessary to plant ponderosa pine to restore this shade-intolerant species in stands where competing Douglas-firs have become

Table 8—Lick Creek regeneration summary, 5 years posttreatment in the shelterwood cutting unit.

	Trees per acre by treatment		
	2-4 year old trees combined		**Advance regeneration (>5 years old)**
Replicate	**Ponderosa pine**	**Douglas-fir**	**Douglas-fir**
	No burn		
1	337	84	1856
2	84	337	506
3	422	506	1603
Ave/Treatment	281	309	1321
	Low consumption burn		
1	253	0	0
2	0	84	0
3	590	169	0
Ave/Treatment	281	84	0
	High consumption burn		
1	253	0	0
2	169	169	0
3	422	0	0
Ave/Treatment	281	56	0

abundant as a result of fire exclusion. The same may be true for western larch, which is another early seral, fire-dependent and fire-resistant species that often accompanies ponderosa pine on relatively moist sites. Western larch—a long-lived tree with high value for wildlife habitat, aesthetics, and forest products—occurs naturally in forests 15 miles north of Lick Creek and extends throughout much of the Inland Northwest.

We designed experimental plantings of ponderosa pine and western larch within the shelterwood units at Lick Creek to determine survival and growth of planted ponderosa pine and western larch under a retention shelterwood cut followed by a high consumption burn, low consumption burn, and no burn. Growth of surviving seedlings will be evaluated through long-term monitoring of study trees. We want to determine how well western larch will grow on sites, such as Lick Creek, that are slightly beyond the limits of their current natural range. This species has the potential to enhance biodiversity in forests currently occupied by only two tree species—ponderosa pine and Douglas-fir.

Plantations of ponderosa pine and western larch were replicated three times in lower slope treatment units where moisture and soils were most suitable for western larch. Forty seedlings of each species were randomly planted at 5- by 5-foot spacing, for a total of 360 containerized seedlings of each species planted.

Survival of ponderosa pine and western larch slowly declined over the first 4 years following planting (table 9). Survival of ponderosa pine is consistently near 65 percent with either burn treatment, while survival of western larch is higher than pine on the dry burn and lower on the other treatments. Growth rate has been generally good for both species although it was necessary to use mesh seedling tubes to protect pine and larch seedlings from browse damage by elk.

Table 9—Early percentage survival of ponderosa pine and western larch planted in 1993 in the wet burn, dry burn, and control treatments of the shelterwood unit at Lick Creek. Percentages are based on a total of 360 seedlings of each species planted in each treatment.

	Year			
Unit	**1994**	**1995**	**1996**	**1997**
Wet burn	- - - - - - - - - *Percent survival* - - - - - - - - -			
Ponderosa pine	78	73	70	65
Western larch	88	76	58	54
Dry burn				
Ponderosa pine	74	70	68	67
Western larch	92	80	77	74
Control				
Ponderosa pine	98	95	92	88
Western larch	85	61	53	51

Undergrowth Response, Shelterwood Cutting Unit

Stephen F. Arno

One of the goals of ecosystem-based management is to enhance biodiversity of native undergrowth species, including early successional plants important as wildlife forage or habitat. However, little is known about the response of undergrowth species to partial cutting and prescribed burning treatments. When the pattern of frequent, low-intensity fires is suppressed for a long time in ponderosa pine/Douglas-fir forests, tree canopy coverage expands greatly and duff and litter increase. These changes are unfavorable to many native undergrowth plants that require periodic disturbances and do not grow well in the shade of a dense tree canopy. In the long term, dense stands may experience a severe, stand-replacing fire, which may further reduce already stressed native species and allow invasive non-native species to make major advances. Some non-native species, such as spotted knapweed, are already abundant at Lick Creek; hence, there is concern about how they will react to management treatments.

Canopy coverages were estimated for each species of shrub or herbaceous plant on 48 1 m^2 plots placed systematically within each of the three replicates of each treatment in the shelterwood cutting unit. Tall shrubs were measured on 12 larger circular plots (2 m radius) in each treatment unit. We measured coverages of each undergrowth species prior to the shelterwood cut and burn or no-burn treatments. We measured these permanent plots again during years 1 through 4 after treatments were completed. Appendix C presents data for the plants that had more than minor coverages (>0.1 average percent cover) either before or after treatments.

The no-burn, low-consumption, and high-consumption burn treatments presumably represent a progression of increasing heat treatments to the soil that contains seeds, rhizomes, and other regenerative organs. Burn treatment severity is indicated indirectly by the consumption of woody fuels that ranged from zero in the no-burn treatment to around 80 percent in high consumption burns for the shelterwood cutting unit (table 7). Another indicator of disturbance intensity is the amount of mineral soil exposed by the treatment. Posttreatment mineral soil exposure averaged 4 percent in the no-burn, 8 percent in the low-consumption burn, and 9 percent in the high-consumption burn treatments (appendix C).

In all three of the treatments, total plant cover 1 year following treatment was 15 to 20 percent lower than pretreatment cover (appendix C). Undergrowth coverage surpassed pretreatment levels by the second postburn year. Compared to preharvest levels, plant coverage increased over pretreatment levels more in both burn treatments than in the no-burn treatments. This greater increase in undergrowth is presumably an effect of the fire, probably linked to enhanced soil nutrient availability due to burning (Hungerford and others 1991).

As would be expected, responses of individual plant species in relation to type of treatment followed divergent patterns (Arno and others 1985; Steele and Geier-Hayes 1995; Stickney 1990). Minor changes in coverages of individual plants were associated with shelterwood cut/no-burn treatments. In contrast, the high-consumption burns often elicited major and divergent responses from different species. Responses to low-consumption burns were generally intermediate. The plant responses at Lick Creek have generally mirrored those recorded at four other study areas where we have measured response to thinning and burn treatments in similar forests in Idaho and western Montana (data on file at the Intermountain Fire Sciences Laboratory, Missoula, MT).

Bitterbrush and kinnikinnick coverage decreased after high consumption burns. Rose and snowberry retained similar coverage after burn treatments. Shrubs whose coverage increased after high consumption burns were Oregon grape and spirea (appendix C). Scouler's willow has increased after burn treatments in other study areas, but at Lick Creek it was severely hedged by big game and was able to grow vertically only where protected in wire mesh cages.

Increased coverage was largely due to vigorous sprouting from rhizomes in snowberry and spirea and from sprouting root crowns in the willow. Responses to low consumption burns for shrubs and low woody plants were similar in trend to those of high consumption burns, but of lesser magnitude (appendix C).

Among grass-like plants, elk sedge often decreased in coverage with increasing severity of treatment. Conversely, pinegrass and Ross' sedge increased after the burns (appendix C). None of the broadleaved herbaceous plants commonly associated with ponderosa pine forests throughout the Northern Rocky Mountains consistently declined in cover after treatments. Two common forbs, yarrow and creeping dogbane, increased proportionately with intensity of treatment. The annual fireweed is widespread in these forests and increased dramatically after the burn treatments. It is an off-site colonizer (Stickney 1990) that is established from wind-transported seeds.

Bull thistle and Canada thistle—both introduced forbs—often became abundant after burn treatments, but their coverages appeared to be declining after year 3. A similar pattern was noted with mullein, sheep sorrel, and horseweed at Lick Creek. This pattern suggests that as the native species expand their coverage in the posttreatment environment, they squeeze out some of the non-natives that require open microsites. A more serious concern is spotted knapweed's pattern of continuous expansion through the 4-year posttreatment record at Lick Creek. Spotted knapweed has become more abundant in the Lick Creek area than on many other sites we have examined in ponderosa pine/Douglas-fir forests of western Montana and Idaho. The species is apparently well adapted to compete on coarse sandy soils and southern exposures. The photo sequences show that knapweed increased noticeably during the 1960's and 1970's, probably as a response to dozer scarification during partial cutting and harvesting of large pines and aided by big game and livestock use. Even the 1992 harvesting resulted in dozer scarification of about 11 percent of the area, in designated skid trails, which evidently encouraged spotted knapweed. Use of rubber-tired equipment and harvesting on snow or frozen ground could potentially reduce scarification. Burning, especially high consumption, seems to favor an increase of knapweed. Paradoxically, protection from disturbance that leads to fuel accumulation and severe wildfire would also probably favor expansion of knapweed. We are continuing studies of the ecological factors related to spotted knapweed's invasion and methods of its control.

The problem of excessive wildlife use of treated (especially burned) areas might be mitigated by treating areas of at least several hundred acres at a time. This also would have the advantage of dramatically reducing per acre burning costs.

Influence of Selection Harvest and Prescribed Fire on Soil Nitrogen

Initial Response of Mineral Nitrogen, Selection Cutting Unit

Michael G. Harrington

Both harvesting and prescribed fire result in the removal of accumulated live and dead organic matter. Large numbers of trees, which represent live organic matter, intensely compete for limited site resources and develop into ladder and canopy fuels. Normally cast litter and woody material along with created slash represent dead organic matter. Whereas this organic matter represents a resource sink and flammable forest fuel, it is also an important source of carbon and inorganic nutrients following death and decomposition for maintenance of site productivity. With management activities as conducted here, a concern arises for the transformation and potential loss of site nutrients.

A pilot study was conducted to determine initial impacts of harvesting and burning on extractable mineral nitrogen—ammonium (NH_4^+) and nitrate (NO_3^-)—which is typically limiting in Inland West forest soils. In each of the three replicates of the three treatments in the selection study, five soil samples were collected at two depths, 0 to 2 inches and 2 to 6 inches. The three treatments were harvesting (fall 1992) with no burning, harvesting with burning (spring 1993), and a control. Samples were collected just before burning, 4 days after burning, and 4, 12, 17, and 24 months after burning. The first samples were collected randomly, and each subsequent sampling was done near the preburn collection microsites.

Figure 24 shows the changes in extractable mineral nitrogen (N) over a 24-month period in the upper 2 inches of mineral soil. Before burning, all treatment sites had similarly low levels of N. Immediately after the burn, N levels increased to about 20 parts per million and were still at 16 parts per million by the end of the first growing season. This immediate postfire N increase has been reported elsewhere (Harrington and Kelsey 1979; Ryan and Covington 1986; White 1986). N in the no-burn and control treatments remained virtually unchanged during this first season. Over the next 8 to 12 months, N in the burn treatment decreased as it was likely sequestered by plants and microorganisms as well as leached to lower soil depths. By 17 months the burn treatment N was still over twice that of the others. This difference had diminished by the start of the second year after treatment.

In the 2 to 6 inch soil layer, changes were expectedly less dramatic (Covington and Sackett 1992). N in the burn treatment continued to increase incrementally from about 1 part per million before burning to a high of 3 parts per million 24 months later. In the other treatments, N was also measured at 1 part per million before burning but increased to only about 1.5 parts per million during the subsequent 24 months.

These measurements indicate a short-term transformation of organic N into mineral N, which may have a transitional fertilization effect. Harrington and Kelsey (1979) reported large, vigorous ponderosa pine seedlings on burned sites compared to unburned site, and Harris and Covington (1983) found greater biomass and N content in understory grasses following burning. To understand longer term impacts, potentially mineralizable N and microbial biomass N should be evaluated. The response of these and other soil attributes are presented in the next section.

Microbial Response and Nitrogen Availability, Selection Cutting Unit

Kristin L. Zouhar and Thomas H. DeLuca

In the summer of 1995, we initiated a study of soil nutrient relationships in the selection harvest units

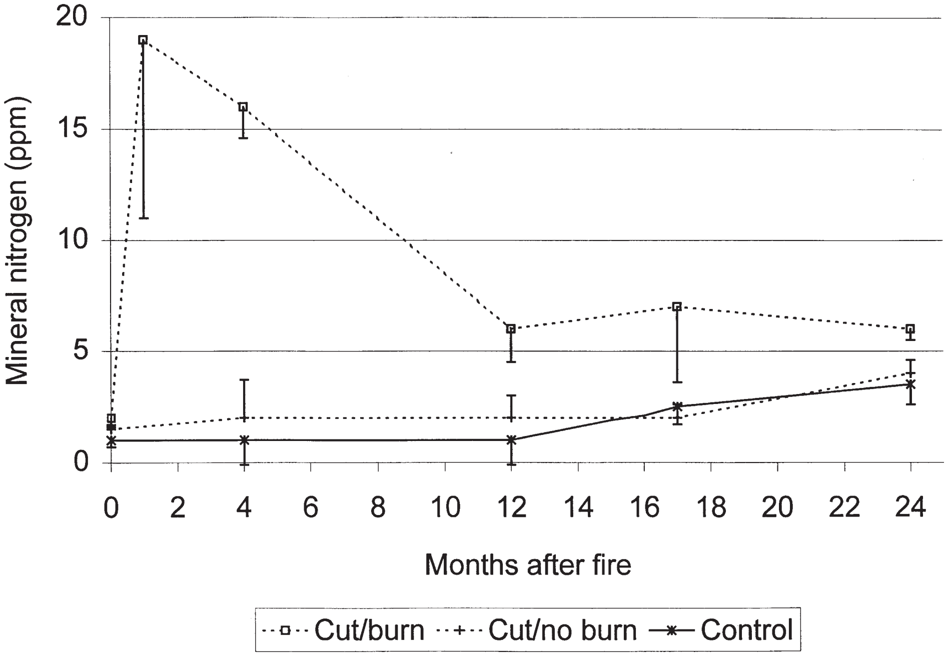

Figure 24—Effect of harvesting and prescribed burning on inorganic nitrogen in the surface 2 inches of mineral soil. ppm is parts per million.

Table 10—Total C and N, extractable K, Mg and Ca, and pH of mineral soils in the selection cutting unit at Lick Creek.

Unit	Total C	Total N	C:N	K	Mg	Ca	pH
	- - - - - - - - - - - - - - mg/kg - - - - - - - - - - - - - -						
Control	2.07	0.11	19.42	169.40	161.00	416.70	4.68
Cut/no burn	2.13	0.11	18.65	161.40	74.40	799.30	4.87
Cut + 2yr burn	1.95	0.11	18.02	195.60	93.30	623.10	5.31*
Cut + 1yr burn	2.15	0.11	18.70	155.60	86.90	661.70	4.98*

*Differs significantly from control as determined by t-test of five replicates at $p < 0.10$.

at Lick Creek. The four study treatments were: a single tree selection harvest (fall 1992), single tree selection harvest (fall 1992) with a broadcast burn (spring 1993), single tree selection cut (fall 1992) with a broadcast burn (spring 1994), and an untreated control. The soils are shallow to moderately deep, derived from highly weathered granitic parent material, and classified as Totelake series, sandy-skeletal, mixed, frigid, Typic Ustochrepts.

Five transects were placed along the contour of the slope and soil samples were taken from four randomly located points along each transect. Samples were taken from two depths (0 to 3 inches and 3 to 6 inches) with the litter layer removed. Sampling was repeated in the fall, spring, and following summer. Because nitrogen (N) availability is driven by microbial activity, soil samples were returned to the laboratory and analyzed for short- and long-term N availability as well as indices of microbial activity.

Total carbon (C) and N and concentrations of extractable base cations—potassium (K), magnesium (Mg), and calcium (Ca)—in soils at Lick Creek were not greatly influenced by selection harvest with or without prescribed fire. The pH of both 1-year-old and 2-year-old underburned plots was significantly higher than in the untreated control plot presumably as a result of ash deposition in the burn plots (table 10).

Levels of extractable mineral N (NO_3^- and NH_4^+) were low and variable and demonstrated no differences between treatments on either summer sample date. The initial flush of mineral N described in the previous section had apparently dissipated. The concentration of NO_3^- and NH_4^+ in the mineral soil has been shown to increase immediately following burning (Covington and Sackett 1992; DeLuca and Zouhar 1998; Kovacic and others 1986). This increase may last anywhere from 30 days (Kovacic and others 1986) to 1 year (Covington and Sackett 1992). The spring burn at Lick Creek was "spotty" resulting in charred patches across the ground surface. Our sampling approach included both burned spots and unburned areas on prescribed fire plots. This provided us with a value for the plot as a whole but may have missed any temporary increase in mineral N.

Levels of labile N were measured as potentially mineralizable N (PMN), microbial biomass N and resin

Table 11—Potentially mineralizable N (PMN), microbial biomass N, 3-day basal respiration rates, ninhydrin reactive (NRN), and anthrone reactive C (ARC) in mineral soils at Lick Creek during summer periods.

Unit	PMN	Biomass N	Respiration	NRN	ARC
	- - - - - - - - g/kg/day (parts per million) - - - - - - - -				
1995					
Control	10.36	15.55	0.22	1.85	6.63
Cut	12.03	13.88	0.16	1.53	4.51
Cut+2yr burn	4.70*	12.91	0.14*	1.61	1.98*
Cut+1yr burn	5.07*	12.10*	0.12*	1.75	2.29*
1996					
Control	6.38	12.34	0.12	2.21	10.98
Cut	6.00	7.80*	0.10	2.38	9.43
Cut+3yr burn	4.91	5.48*	0.13	1.70**	11.31
Cut+2yr burn	4.56	6.10*	0.10	1.86	8.72

*Stastically significant at $\alpha = 0.10$.
**Statistically significant at $\alpha = 0.01$.

extractable N. PMN and microbial biomass N were significantly reduced by prescribed fire (table 11); however, microbial biomass N was also reduced in the selection harvest alone.

Microbial respiration rates and soluble sugars—measured as anthrone reactive carbon (ARC)—were also significantly higher in control plots as compared with both burn plots in 1995. This difference was probably due to the greater organic matter (litter in control plots and slash in burn plots) remaining on the control and harvest/no-burn plots where there was no fire-induced volatilization of labile C from the mineral soil or forest floor.

In the second summer, fewer differences occurred among treatment plots. The 1996 field season was the driest date on which soils were sampled. Soil moisture contents were approximately 20 percent of soil water holding capacity (at –30 kPa) compared with around 80 percent the previous summer.

Monleon and others (1997) found that net N mineralization rates in the mineral soil surface were unchanged in plots underburned 4 months prior to sampling, and decreased in plots underburned 5 years prior to sampling. This agrees with our measurement of less PMN in the burned plots as compared with control on both summer sample dates, 1 to 3 years postburn at Lick Creek and up to 12 years at another site in western Montana (DeLuca and Zouhar 1998). Monleon and others (1997) speculate that the change in N mineralization rates is a result of decreased soil organic matter quantity after 5 years.

Ratios of PMN/total N were generally higher in the control plot than in burned plots both summers, suggesting a lower percent of the total organic N is in an available form in the mineral soil of the burned plots. Similarly, biomass N/total N was consistently higher in control than either the cut or burned plots, with the cut-only plot being intermediate in value. These ratios were unchanged between summers in the control and cut-only plots, while they decreased substantially from one year to the next in the burned plots. Microbial biomass dropped proportionately less in the harvest only and control plots, perhaps because the less disturbed surface organic layer provides insulation and a more stable microenvironment less affected by changes in moisture availability and temperature (Entry and others 1986).

The answer to the question of how these treatments affect N availability is implicit in what we know about the factors that affect mineralization and immobilization (that is, the quality and quantity of organic substrate, temperature, and moisture), and how these factors are altered by the treatments. It is also explicit in the results of research aimed at quantifying and predicting this change in certain ecosystems. In the case of Oregon studies under ponderosa pine in pumice-derived andisols with an inherently low site index, productivity was decreased as a result of prescribed fire and vegetation removal (Busse and others 1996; Monleon and others 1997). In contrast, Arizona studies on more productive high organic matter mollisols have demonstrated improved N fertility following fire, and improved ecosystem health (Covington and others 1997). How these effects are expressed in the climate of western Montana on moderate productivity incepticols remains uncertain. However, it appears that the pool of mineralizable N may be reduced by the combination of selection harvest with prescribed fire. It is not clear whether this reduction in PMN may ultimately have an adverse effect on site productivity or if this drop in available N balances nutrient availability. For example, the control plots have the highest levels of PMN and relatively low levels of exchangeable K^+. It is possible that a low K^+:PMN ratio might actually enhance insect and disease activity as noted in forest fertilization programs where fertilizer N applied without K^+ increased tree mortality rates on low K^+ sites (Mandzak and Moore 1994). In a forest where fires have been suppressed, most of the available K^+ can be found in the foliage of trees and understory plants. Fire reduces mineralizable N and liberates the K^+ from understory plants and heat killed and damaged trees, thereby increasing the K^+:PMN ratio.

Antelope Bitterbrush and Scouler's Willow Response, Shelterwood Cutting Unit

Donald J. Bedunah, Michael G. Harrington, and Dayna M. Ayers

The Lick Creek study site, like many western Montana ponderosa pine forests, is an important winter/spring range for wild ungulates such as elk, mule deer, white-tailed deer, and moose. These forests supply a critical forage resource, but browse species become decadent as forest cover increases over time. At the Lick Creek study area, two browse species, Scouler's willow and antelope bitterbrush, were selected for monitoring their response to treatments. Specifically, our objectives were to monitor these plants' survival, vigor, and use by ungulates following cutting and burning treatments and to determine variables influencing survival and vigor.

Within the shelterwood study area, 1,856 bitterbrush and 871 willow plants were permanently located before harvesting within 36 circular plots of $\frac{1}{10}$ acre each established in each of the control and shelterwood cut with no-burn, low-consumption burn, and high-consumption burn treatments. Immediately after the shelterwood cut, all bitterbrush and willow plants were relocated to determine the degree of mechanical damage. Following prescribed burning, the level of fire damage to bitterbrush and willow plants was determined. Each shrub was then monitored in the summers of 1993 and 1994 to document survival and vigor. In each treatment, percent canopy cover of willow and bitterbrush was estimated in 36 circular plots of 350 ft^2 each.

The shelterwood cut and prescribed burn treatments resulted in modest willow mortality, substantial bitterbrush mortality, concurrent decreases in cover, but increased plant vigor (table 12). The loss of plants was greatest in the treatments associated with the combined effects of harvesting and burning. Mortality of willow (14 percent) and bitterbrush (35 percent) associated with harvesting alone (table 12) was moderate and kept from being excessive by the low amount of severe ground disturbance as only 11 percent of the area had skid trails. Distances between skid trails were maximized in order to minimize the impact of the skidding operation.

Willow plants sustained less mechanical damage and significantly less mortality than bitterbrush (table 13). Of the bitterbrush plants receiving any mechanical damage, almost 70 percent sustained severe damage and 86 percent of those died. Willow survival was greater than 94 percent, except for those plants severely damaged on skid trails, where survival decreased to 58 percent. Differences in mortality and resprouting between bitterbrush and willow subjected to similar mechanical injury result from their different morphologies. The deep root system and multistemmed growth of willow allow for higher tolerance of disturbance than that of bitterbrush. Willow often resprouts after surface disturbance from a subterranean root crown (Lyon 1966), whereas bitterbrush can only resprout from a surface caudex (Guinta and others 1978), which is more easily removed or injured by disturbance.

For willow and bitterbrush with burn damage, mortality was clearly associated with the degree of burn severity (burn class) (fig. 25). Bitterbrush was notably impacted by any level of fire damage, whereas willow was not markedly affected until it suffered severe charring of the root crown (fig. 25). Of the 639 bitterbrush plants that received burn damage, only 28 percent survived, and these were predominantly in the low and medium burn classes (fig. 25). Bitterbrush mortality by burn class was greater for the high consumption burn compared to the low consumption burn. Although fire can cause high mortality of bitterbrush, its regeneration strategy apparently requires

Table 12—Percent cover reduction, mortality, and plants with high vigor for antelope bitterbrush and Scouler's willow by treatment in the shelterwood unit at Lick Creek, 1994. Changes are relative to pretreatment conditions. Average pre-treatment canopy cover was 0.94 percent for bitterbrush and 0.77 percent for willow.

	Bitterbrush			Willow		
Treatment	Cover reduction	Mortality	High vigor plants	Cover reduction	Mortality	High vigor plants
	percent					
Control	2	4	28	1	3	15
Harvest only	75	35	70	33	14	60
Low consumption	83	62	88	62	22	71
High consumption	92	68	78	58	26	69

Table 13—Influence of mechanical damage class for the shelterwood cut and burn treatments on survival of Scouler's willow and antelope bitterbrush for plants receiving no burn damage at Lick Creek, 1994.

	Mechanical damage class				
Species	None	Low	Medium	High	Severe
	percent survival				
Scouler's willow	89 (66)[a]	95 (42)	94 (51)	94 (34)	58* (115)
Antelope bitterbrush	94 (289)	88 (77)	92 (79)	81 (41)	14* (432)

[a] Numbers in parentheses are total numbers by class.

*Significantly different ($p < 0.05$) from all other classes.

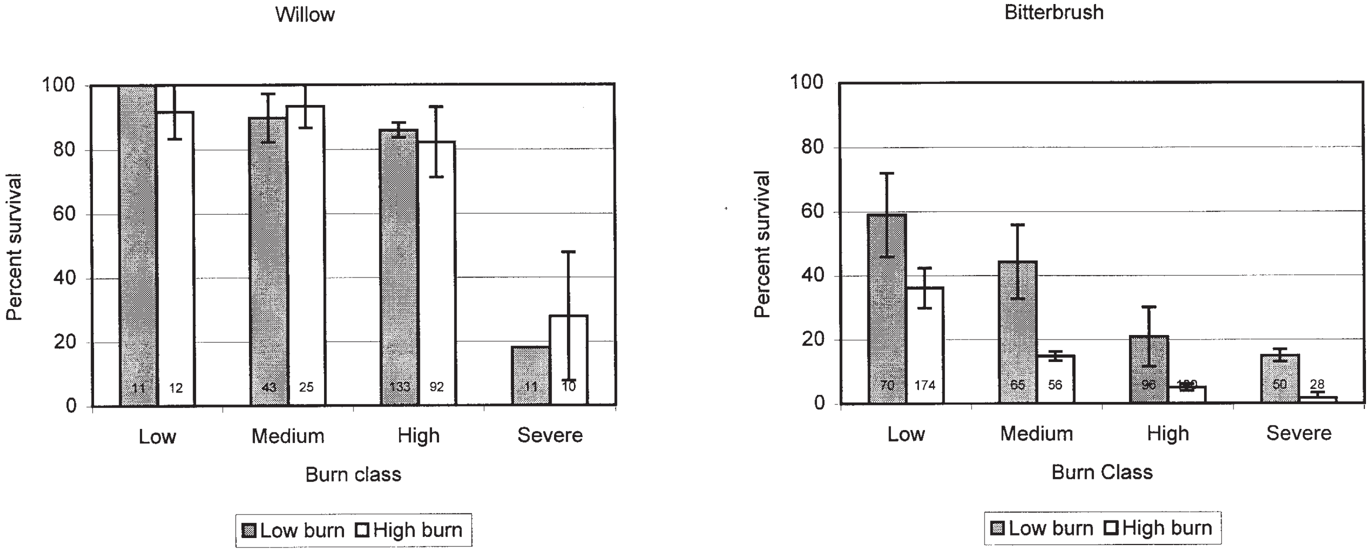

Figure 25—Percent survival of Scouler's willow and antelope bitterbrush by burn class.

almost competition-free, mineral seedbeds, naturally caused by fire, for seed germination from rodent caches (Sherman and Chilcote 1972; Clark and others 1982).

Of the 337 willow plants with burn damage, 80 percent survived and there was no difference between the burn treatments (fig. 25). Vigorous resprouting is consistent with other research (Leege and Hickey 1971; Leege 1979) and willow has been reported to increase in both biomass and vigor by as much as 100 percent following a burn (Leege 1969; Mueggler 1965; Noste and Bushey 1987).

For surviving bitterbrush and willow, the proportion of high vigor plants in the burn and the harvest-only treatments greatly increased compared to the control (table 12). Bitterbrush responded most favorably to the unburned shelterwood treatment, whereas willow had higher mean vigor within both burned treatments in the growing season immediately following the burns. Yet surprisingly, the proportion of high vigor willow plants was not significantly greater in the burn treatments over the harvest-only treatment 2 years posttreatment. This is most likely related to heavy browsing in the growing season following the treatments, resulting in loss of new growth and subsequently lower vigor for these plants.

In summary, these results show that despite significant bitterbrush mortality and modest willow mortality from overstory removal and prescribed burning, surviving willow and bitterbrush were more vigorous following treatments. If one considers fire as a natural disturbance, then the loss of a proportion of the bitterbrush population to fire may not be ecologically detrimental. In fact, the high preharvest bitterbrush numbers relative to pre-1900 may have originated from disturbance from the early 1900's logging, subsequent fire suppression, and low deer and elk populations due to unregulated hunting also in the early 1900's. Also, even though the most severe fire treatment caused 68 percent reduction in bitterbrush, there were still 68 plants per acre in which greater than 78 percent had high vigor. By reducing impacts of harvesting with widely spaced skid trails, using low-impact equipment, and prescribing low fuel consumption burns with variable fire coverage, plant mortality should be minimized, especially for bitterbrush. With the return of open stand conditions, mineral seedbeds, and more vigorous plants, the potential for natural regeneration to replace fire-killed plants is high (Gruell 1986). The current harvesting and prescribed burning treatments appear to have been a positive stimulus to willow productivity. Survival was greater than 75 percent, and the percentage of high vigor plants increased from 15 percent pretreatment to 70 percent posttreatment.

Heavy browsing of the vigorous shoots by wild ungulates was probably a detriment to flower and seed production on the study area (Canon and others 1987). Treatment areas need to be large enough to reduce browsing impacts on plant vigor, and with dispersed ungulate browsing, seed production and seedling establishment potential should be greater on the mineral seedbeds in the open stands.

These restoration treatments have increased bitterbrush and willow vigor in spite of heavy ungulate browsing on treated areas. However, frequent underburning would likely be detrimental, especially to bitterbrush. In areas where both willow and bitterbrush occur, resource managers interested in maintaining or enhancing browse need to consider understory composition and species-specific responses to management practices before applying treatments. A no-management option would temporarily eliminate mortality of individual shrubs, but population fitness would decline dramatically as overstory density increases, and the threat of wildfire may increase. A wildfire could be highly destructive to bitterbrush specifically, and to the forest in general.

Effects of Logging and Burning on Birds During the Nonbreeding Season, Shelterwood Cutting Unit

Elizabeth A. Beringer, Sallie J. Hejl, and Lynn Bacon

Shelterwood logging and prescribed burning can potentially restore mature second-growth ponderosa pine/Douglas-fir stands to “old-growth” forests in the Northern Rocky Mountains, but it is unknown how logging and burning affects birds that use these forests, especially during the nonbreeding season. We counted birds in two mature second-growth ponderosa pine/Douglas-fir sites in the Lick Creek drainage during the autumns of 1992 through 1994. One site was logged in 1992 using a shelterwood cut and prescribed burned in spring 1993. The other site was not treated. Before treatment, the sites were similar in vegetative composition, elevation, and previous logging history (originally logged in the early 1900’s). Eight count stations were located on each site, with two stations randomly established in each of the four treatment types, which were (1) logged followed by a high consumption burn, (2) logged followed by a low consumption burn, (3) logged and left unburned, and (4) neither logged nor burned. We sampled birds each week from October 13 to December 9 each year.

We noted 29 species on these sites during the three fall seasons, and 20 of these species were found on both sites. In general, the numbers of species and individuals within species were low, but seven species (Hairy Woodpecker, Black-capped Chickadee, Mountain Chickadee, Red-breasted Nuthatch, White-breasted Nuthatch, Brown Creeper, and Golden-crowned Kinglet) were found on both sites in all 3 years. The presence of kinglets was noteworthy as they are rarely found in these forests during the breeding season.

Treatment effects varied among species. Some species (such as Red-breasted Nuthatch, Golden-crowned Kinglet) were more abundant at the untreated site, which potentially indicates negative effects of logging or logging and burning. Other species (such as Downy Woodpecker) were not obviously affected by logging and seem to be positively affected by burning following logging. Indeed, woodpeckers as a group were more abundant in the low-consumption burn areas, as compared to the unlogged/unburned areas or logged/unburned and logged/high consumption burned areas, particularly in the second year after the burns.

Most of these results are similar to what one might expect based on earlier studies examining the effects of silviculture on birds in the breeding season (Hejl and others 1995). Red-breasted Nuthatch and Golden-crowned Kinglet are usually less abundant in recently logged areas than in unlogged ones across habitats within the Rocky Mountains (Hejl and others 1995). Much less is known, however, about the effects of prescribed burning on birds. The fact that woodpeckers in general may be positively affected by shelterwood logging followed by low-consumption burning treatments (which attempt to recreate natural conditions in this habitat, Hejl 1992) is encouraging since many human-induced treatments (primarily intensive logging) are known to negatively affect many woodpecker species (Hejl and others 1995). In Arizona, Hairy Woodpeckers also were more abundant in burned forests, even partially logged ones, than in unburned ones, during the nonbreeding season (Blake 1982). In contrast to the Lick Creek study, the burned forests in Arizona resulted from a wildfire. In addition, the fact that woodpeckers in the Lick Creek area were potentially responding to small scale disturbances (3 to 11 acres) is noteworthy. Because both the logging and burning treatments were applied to the treated site, and the treatment areas were small and in proximity, the birds may not be responding to individual treatments but to the treated landscape as a whole. In fact, the woodpeckers may be responding to the effects of fire, and not the logging, but the research design did not completely isolate the burning treatments from the logging treatment. We suggest that future investigators examine the effects of logging and burning both independently and together, and at several spatial scales.

Wildlife Snag Production, Commercial Thinning and Shelterwood Cutting Units

Michael G. Harrington

Because of past cutting of low vigor trees and firewood gathering, few quality wildlife snags existed in the Lick Creek research area. Therefore, an opportunity arose to study the efficacy of artificially producing snags. Fire, along with insects, disease, lightning, and wind (topping), has always been a primary agent for mortality of trees for wildlife use. Therefore, fire was used to mortally injure snag candidates compared with mechanically injured trees in a study to observe longevity and quality of artificially created snags.

Recognizing that wood quality likely influences decay rates and, therefore, snag longevity, three different age classes presumably with different heartwood to sapwood ratios, growth rates, and pitch content were selected for study. The youngest were second growth, referred to as bull pine, which were mostly 57 to 85 years old and had become established after the 1907 to 1911 harvesting. The third class consisted of the oldest trees in the stand, primarily between 240 and 400 years old, referred to as old-growth pine. Between these two groups was a class of intermediate-aged trees mostly from 120 to 180 years old. In each age class 12 trees were located in the no-burn units and mechanically girdled by removing a 3-inch wide strip of bark and cambium completely around the tree. In each age class 12 trees were similarly located in burn units and slash (including several logs) was piled around the tree bases. These piles were ignited during the prescribed burn treatments. A total of 72 trees, all greater than 15 inches dbh, were measured and treated for study.

At 4 years after the mechanical girdling, only one bull pine remained alive and all intermediate and old-growth trees were dead (fig. 26). Of the 36 fire-girdled trees, 10 were still alive including three bull pines, five intermediates, and two old growth. A few of these may still die but most probably will survive. There were no additional changes 5 years after girdling.

Four trees have fallen. Two bull pines fell 4 years after mechanical girdling and two intermediate pines fell 4.5 years after fire girdling. This indicates that decay is occurring and additional falling should be imminent. A few of the new snags have recent bird cavities, which also indicates the presence of sapwood decay.

Monitoring will continue for 10 to 15 years to follow changing tree characteristics, standing longevity, and bird use.

The Effect of Management Activities on Esthetics, All Cutting Units

Robert E. Benson

When people visit forest lands their impression of the area is largely influenced by the scenic quality of the place. Part of their impression is set by nature—the topography of the land, the type of vegetation, and the presence or absence of features such as mountains, lakes, or streams. Visual impressions are also influenced by management activities that may enhance or detract from the esthetic quality of the scenery.

In the Lick Creek logging studies initiated in 1992, scenic quality of different treatments was analyzed using several techniques: (1) viewers were shown color slides and asked to rate them on a numerical like/dislike scale, (2) viewers were shown sets of color print photos and asked which photos they most preferred and which they least preferred, and (3) a mathematical model was used which predicted viewer preferences

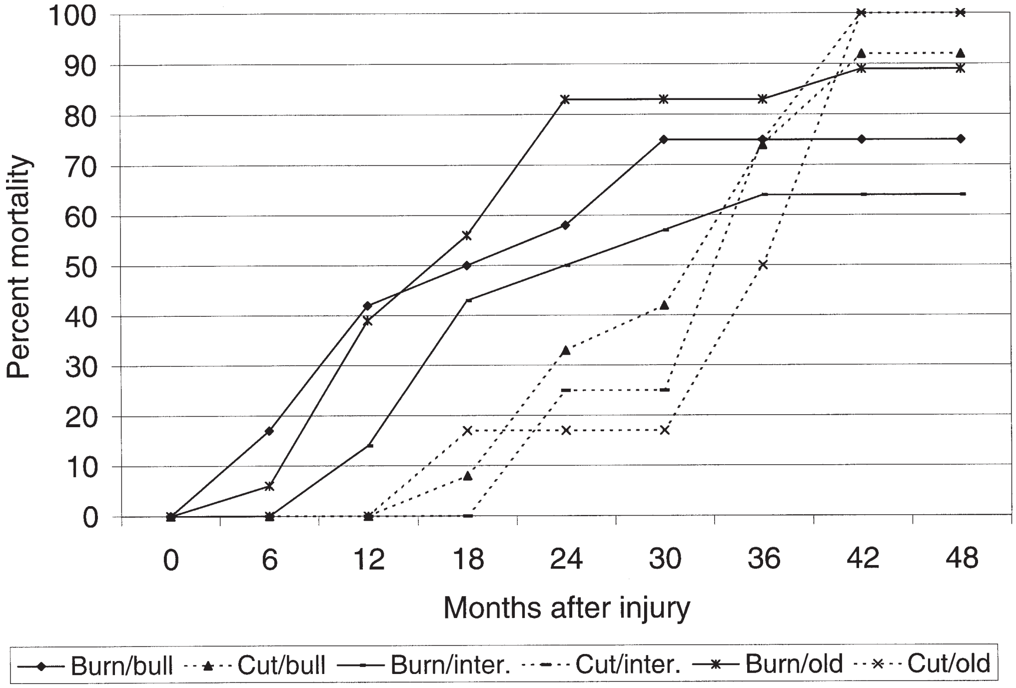

Figure 26—Percent mortality during the first 48 months after fire (burn) or saw (cut) girdling of ponderosa pine snag candidates. Three age classes are represented: bull pine, intermediate pine, and old-growth pine. See text for ages.

based on various features in the photo that had been found in other studies to influence preferences.

These studies showed that the most preferred was the preharvest selection stand, typically open and park-like with large yellow-barked pine. Viewers also liked the preharvest scenes in areas that were shelterwood cut or thinned, but their preferences were not as distinct. Least preferred scenes were postharvest areas where slash remained or where there was evidence of recent burning such as partially burned slash or charred trees. The results were essentially the same from all three of the techniques used, especially in identifying the most and least preferred scenes.

These viewer ratings were made two growing seasons after harvest, but the results are similar to several other studies that focused on esthetic quality following harvest and during different stages of subsequent stand development. As vegetation develops and covers the disturbances left from logging, esthetic ratings generally increase. But there is also evidence that ratings drop if stands become overly dense and brushy looking, or if they become decadent with large amounts of dead and down trees (Arthur 1977; Benson 1995; Benson and Ullrich 1981; Daniel and Boster 1976). An earlier evaluation of photos taken in Lick Creek since the early 1900's estimated that as the old growth and open stands such as in 1909 were gradually filled in with thickets of young trees, the esthetic quality declined (Gruell and others 1982).

From a management standpoint it appears that efforts to return stands to conditions similar to those in the early part of the century will result in more visually pleasing scenery than if overstocked thickets develop. Management activities such as logging or burning may temporarily detract from visual quality, but if they are done with care the amount and duration of disturbance can probably be limited.

Educational Value

Jane Kapler Smith and Rick Floch

In 1991, Lick Creek was officially designated a Demonstration/Research Forest (Carlson and Floch 1996). The purpose of this designation was to provide a place where innovative researchers could both test and demonstrate different techniques for managing ecosystems. Researchers, natural resource managers, and the public have been able to observe and learn about the consequences of different management treatments at Lick Creek. In 1994, Lick Creek was designated a Learning Site for the Western Montana Ecosystem Management Learning Center Program. Centered among towering pines at the Wood's Cabin on the shores of Lake Como, the Learning Center focuses on demonstrating the influence of fire and timber harvesting on lower elevation ponderosa pine-dominated ecosystems of western Montana. In addition, a 7-mile long self-guided auto tour through the Demonstration/Research Forest was developed to provide visitors with information about fire ecology, forest management, cultural history, and wildlife habitat. With the development of these three informational platforms, the Lick Creek area has become a frequently used outdoor classroom for environmental education.

Local schools schedule several outdoor field trips into the area annually, studying wildlife, plants, forested ecosystems, riparian habitats, and other biological topics. Public field trips are also conducted that focus on sharing the results of recent research in the Demonstration/Research Forest. College classes from as far away as Oklahoma State and researchers and resource managers from Australia, Argentina, and Russia have toured the area. Because many of the treatment boundaries lie along roads, visitors can easily see the results of various treatments and compare them with untreated forest.

Forest succession is a gradual process, impossible to observe directly in the field. In 1996, photos were used to make a 15- by 25-inch poster entitled "80 Years of Change in a Ponderosa Pine Forest." (This is the same photo point used for the poster in this volume.) We distributed the posters at training sessions and meetings for managers, silviculturists, and fire management officers. Their response was enthusiastic. When viewers could trace a single location through time, noting single trees that remained standing or grew taller from one photo to the next, the concept of succession became clear. The photos vividly display the development of ladder fuels over time, a concept crucial for understanding the change in fire hazard that accompanies succession in ponderosa pine forests in the absence of disturbance. When a presenter points out the change from ponderosa pine dominance to Douglas-fir, viewers also find the concept of species change easy to grasp.

Within a year of its publication, 1,800 copies of the "80 Years of Change" poster were distributed. It has been useful not only in western Montana, where Douglas-fir is replacing ponderosa pine through succession, but also in Idaho, Washington and Oregon, where grand fir and Douglas-fir both replace ponderosa pine; in California, where white fir and coastal Douglas-fir are the replacement species; in the central Rocky Mountains, where blue spruce is the major replacement species; and in New Mexico and Arizona, where white fir and blue spruce are replacement species (Oliver and Ryker 1990).

With its long history of research, remarkable photographic record, abundance of natural resources, cultural history, proximity to a major recreational complex (Lake Como), and easy access by a Federal highway (U.S. 93), the Lick Creek area provides opportunities for many kinds of environmental education. It is a showcase example of an integrated approach to ecologically sustainable and environmentally sensitive forest stewardship.