Photopoint 13 1909

Eighty-Eight Years of Change in a Managed Ponderosa Pine Forest

Photopoint 13 1989

United States
Department
of Agriculture

Forest Service

**Rocky Mountain
Research Station**

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Abstract

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This publication gives an overview of structural and other ecological changes associated with forest management and fire suppression since the early 1900's in a ponderosa pine forest, the most widespread forest type in the Western United States. Three sources of information are presented: (1) changes seen in a series of repeat photographs taken between 1909 and 1997 at 13 camera points; (2) knowledge from 19 authors who have investigated effects of recent ecosystem-based management treatments; integrated with (3) findings of forest changes related to earlier treatments and to succession. The contributing authors discuss effects of historical silviculture and recent ecosystem-based management treatments, including an evaluation of various burning prescriptions in terms of tree response, undergrowth, soils, wildlife habitat, and esthetics and public acceptance.

Keywords: ecosystem-based management, forest succession, prescribed fire

Acknowledgments

The cooperation of numerous people on the Bitterroot National Forest, including current and now-retired employees, has been key to the success in maintaining and promoting the Lick Creek Demonstration/Research Forest. Some of those employees, along with researchers from both the Forest Service and The University of Montana, are contributing authors for this publication (see appendix A).

The manuscript reviewers gave invaluable comments and we extend our gratitude to them for working within our limited timeframe. They were: James K. Brown, retired from the Intermountain Research (now Rocky Mountain) Station, Missoula, MT; James R. Habeck, retired from The University of Montana, Missoula, MT; George E. Gruell, a Forest Service retiree who was employed by the Intermountain (now Rocky Mountain) Research Station in Missoula, MT, and then the Intermountain Region in Carson City, NV; and Penelope Morgan from the University of Idaho, Moscow, ID.

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Table of Conversions

Parameter	Multiply this unit	By this factor	To obtain this unit
Basal area	Square feet per acre (ft^2/acre)	0.2296	Square meters per hectare (m^2/ha)
	Square meters per hectare (m^2/ha)	4.3562	Square feet per acre (ft^2/acre)
Timber volume	Board feet per acre (bd ft/acre)	0.00583	Cubic meters per hectare (m^3/ha)
	Cubic meters per hectare (m^3/ha)	171.503	Board feet per acre (bd ft/acre)
Length	Feet (ft)	0.3048	Meters (m)
	Meters (m)	3.2808	Feet (ft)
	Inches (in.)	2.54	Centimeters (cm)
	Centimeters (cm)	0.3937	Inches (in.)
	Miles	1.6093	Kilometers (km)
	Kilometers (km)	0.6214	Miles
Area	Acres	0.4047	Hectares (ha)
	Hectares (ha)	2.4711	Acres

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Eighty-Eight Years of Change in a Managed Ponderosa Pine Forest

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Introduction

Stephen F. Arno

This publication displays and interprets changes in a managed ponderosa pine forest in western Montana based on a series of repeat photographs taken between 1909 and 1997 at 13 camera points. We also present information on:

- Pre-1900 conditions and ecological relationships in this forest.
- Historical harvesting treatments (beginning in 1906) and ensuing stand development.
- Changes associated with fire suppression and related forest succession.
- The initial effects of ecosystem-based management treatments carried out as a research and demonstration study in the early 1990's. Ecosystem-based management treatments are designed to benefit the ecosystem as a whole, rather than focusing on a few components such as timber production or big game habitat.

Our presentation is relatively nontechnical; for example, in the text we use only common names of animals and plants and direct the reader to appendix B for a list of scientific names. We intended this publication for a broad audience of people interested in forest conservation and management. The information should give readers insight to some of the outcomes associated with alternative management and protection strategies. Such knowledge is critical in view of major decisions currently being weighed by professionals, the public, and politicians regarding future management direction for most National Forest lands (for example, Haynes and others 1996).

Evaluations of ecosystem-based management treatments, although not comprehensive, do include responses of trees, undergrowth, fuels, soil nutrients, wildlife cover and forage habitat, and esthetic values. We also assess the effectiveness of the treatments as a first step in the process of restoring the ecological role of fire in perpetuating forests containing old growth ponderosa pine.

Our report is an update and expansion of Gruell and others (1982), which presented the 1909 to 1979 photo sequence. We describe historical changes in forest structure and some effects of ecosystem-based management treatments, but we do not include the descriptions of general wildlife relationships and livestock use (now relatively minor) provided in Gruell and others (1982). We have added photographs taken in 1989 and 1997 as well as one previously unpublished photo series and a newly discovered series from 1909 to 1937. The 1909 photographs were taken during the Lick Creek Timber Sale on the Bitterroot National Forest—a silvicultural partial cutting that constituted the first large ponderosa pine timber sale in what is now the Northern Region of the USDA Forest Service. In the 1920's the photopoints were relocated, permanently marked, and rephotographed. Thereafter, the photographs were retaken every decade. These photo series allow readers to witness changes in the forest. Accompanying captions provide interpretations of factors linked to visible changes—for example, harvest and thinning activities, tree mortality from bark beetle attacks, and advancing forest succession in the absence of fire.

Gruell and others (1982) was greeted with considerable interest by forest managers, biologists, and the general public because it illustrated the dynamic change that the forest underwent over time. The press run of 3,000 copies was exhausted in less than a year. The authors presented detailed evidence that prior to 1900, frequent low-intensity fires had maintained open stands of large ponderosa pines, still visible in the 1909 photos. The 1909 to 1979 sequences of photographs from each camera point showed that despite carefully guided partial cutting, cessation of fires often allowed development of a dense understory of small trees. Gruell and others (1982) concluded that the 1909 to 1979 successional trend was creating structural conditions that would increase susceptibility to severe wildfires, shifting composition toward the more shade-tolerant Douglas-fir and contributing to a loss of wildlife forage. To reverse these trends, the authors recommended reintroduction of low-intensity fires through the use of prescribed burning in conjunction with partial cutting and thinning.

To test the above recommendations, in 1989 the Bitterroot National Forest requested that the Intermountain Research Station (now Rocky Mountain Research Station) conduct research and demonstration studies at Lick Creek. In 1991, a series of replicated treatment studies was begun with a suite of silvicultural cutting and underburning. The goal was to maintain healthy pine-dominated forests containing large trees, desirable wildlife habitat, and low risk to severe damage by wildfire or epidemics of insects or disease. Cutting treatments were commercial thinning in a young stand, retention shelterwood in a 80-year-old stand, and single-tree selection in a stand containing some old-growth trees. Fire treatments (and no-burn controls) combined with the cuttings were conducted in both spring and fall and under contrasting levels of duff moisture.

We now report the initial effects of the experimental treatments, and also illustrate the appearance of the treatments at the historical photopoints. The 1989 retakes represent a pretreatment condition, and the 1997 retakes are 4 years after experimental treatments were conducted at some of these sites (see poster in pouch on back cover). We have also included an example photo series that was established in 1991 expressly to illustrate the treatments and year-by-year response. Coincidentally, the kinds of treatments that we report and illustrate are now widely recommended for large areas of ponderosa pine forests throughout western North America. These treatments fit the concept of ecosystem-based management that was embraced by the USDA Forest Service soon after this study began (Overbay 1992). Ecosystem-based management seeks to sustain desired conditions, uses, and values of wildland forests using management that works within the scope of natural processes that historically shaped these forests (Salwasser and Pfister 1994).

The success of the Lick Creek ecosystem-based management treatments led us to propose a much broader research and demonstration effort—the Bitterroot Ecosystem Management Research Project (BEMRP)—which was funded in 1994 by the Washington Office of the USDA Forest Service. BEMRP has been a 5-year project to help develop ecosystem-based management at the landscape level. Many researchers from the Rocky Mountain Research Station and The University of Montana have worked with National Forest personnel and communicated with interested publics. This publication has been produced just in time for the conference (May 1999) that culminates BEMRP, although as a result of its success another 5-year BEMRP with an updated mission has now been established.

In a broader sense, however, we are clearly just beginning the process of instituting ecosystem-based management on the Bitterroot National Forest and elsewhere in the ponderosa pine zone of the Inland West. The photo series and historical inventories and documentation at Lick Creek will be consulted as a basis for continual refinement of management that fits in with natural ecological processes. This publication is intended to serve as a reference for that long-term effort.

The Setting and Historical Background

Revised from Gruell and others (1982)

In much of forested North America, there is little reliable information on changes in vegetation over long periods. An exception is the Lick Creek drainage on the Bitterroot National Forest in west-central Montana, thanks to the foresight of USDA Forest Service personnel who have photographically recorded vegetation over the 88 years between 1909 and 1997. This photographic series provides a unique opportunity to visually interpret changes in a ponderosa pine/inland Douglas-fir forest. Changes depicted also allow an evaluation of how resource uses and activities have been influenced by logging and exclusion of fire. Similar changes have occurred over much of the ponderosa pine/Douglas-fir type in the Inland West, where shade-tolerant Douglas-fir would represent the potential climax were it not for disturbances such as fire and logging.

The photo study is near Lick Creek (latitude 46°5' N., longitude 114°15' W.), site of a 1906 ponderosa pine timber sale on National Forest lands. This area is 13 air miles southwest of Hamilton, MT, at elevations between 4,300 and 4,600 ft (fig. 1). The terrain is mostly 10 to 30 percent slopes except for localized northerly and southerly slopes of up to 70 percent. Soils are derived from granitic parent materials and are shallow to moderately deep. Some poorly drained areas and clay soils exist at the lowest elevations.

Weather data recorded 5 air miles southeast of the study area at Darby, MT (elevation 3,887 ft) suggest that the mean annual precipitation at Lick Creek is about 20 inches (USDA Soil Conservation Service 1977). Approximately 50 percent of this falls in the form of snow.

Because many years have passed since the original timber sale, records concerning USDA Forest Service participants are sketchy. Some of the people who are known to have been involved include Elers Koch, forest inspector and Bitterroot Forest Supervisor from 1906 to 1908; Wilford W. White, sale administrator and Bitterroot Forest Supervisor from 1909 to 1921; John Preston, Acting Deputy Forest Supervisor; Ranger Than Wilkerson; Earl Tanner; E. C. Clifford; Claget Sanders, the scaler; and "lumberman" C. J. Gregory. Gifford Pinchot, the first Chief of the USDA Forest Service, provided direction for this sale (Koch 1998). In a letter to Pinchot, Elers Koch (1937) wrote: "I consider this area [Lick Creek] one of the most satisfactory timber sale operations in the Region, and feel that your personal instruction in the early stages of the timber marking was largely responsible for the present splendid condition of the sale area." The Big Blackfoot Milling Company, a subsidiary of the Anaconda Copper Mining Company, purchased the timber and did the logging according to USDA Forest Service specifications. The company had a virtual monopoly in logging private lands in the Bitterroot Valley and expected no competition in bidding for the Forest Service sale; but unexpectedly an Idaho outfit, Hitt and Melquist, outbid them (Koch 1998). Later, the company bought the contract from Hitt and Melquist at considerable profit to the original bidder.

Because of the importance of the Lick Creek sale, a Washington Office photographer, W. J. Lubkin, was sent west to document the logging activity in 1909. Lubkin obtained excellent photos by using a 6.5 by 8.5 inch (17 by 22 cm) view box camera and glass plates. The camera points were not permanently marked because this was not part of the assignment. Fortunately, in November 1925, K. D. Swan, photographer for the USDA Forest Service Northern Region, accompanied W. W. White on a trip to the Lick Creek area to see if the camera points could be located. Swan (1968) recalled how White was able to locate the original photo points:

> The quest was extremely fascinating. White had a good memory and was able to spot, in a general way, the locations we were after. Peculiar stumps and logs were a great help. Just when we might seem baffled in the search for a particular spot, something would show up to give us a key. The clue might be the bark pattern on a ponderosa pine, or perhaps a forked trunk.
>
> The camera we were using duplicated the one used for the original pictures, and when a spot was once found it was a simple matter to adjust the outfit so that the image on the ground glass would coincide with the print we were holding. It was an exciting game, and we felt it was more fun than work.

In 1938, the temporary camera points located in 1925 were permanently marked with brass caps by Forest Supervisor G. M. Brandborg and Ranger C. Shockley (fig. 1). The original photographs were repeated in 1925, 1927, and 1937 to 1938 by K. D. Swan. He was followed by USDA Forest Service employees W. E. Steuerwald, 1948, 1958; Wyman Schmidt, 1968; and William Reich, 1979. Most of the retake photographs were made with 4 by 5 inch Crown Graphic cameras. Dennis Simmerman took the photographs in 1989 and 1997, using a Mamiya RB67 camera.

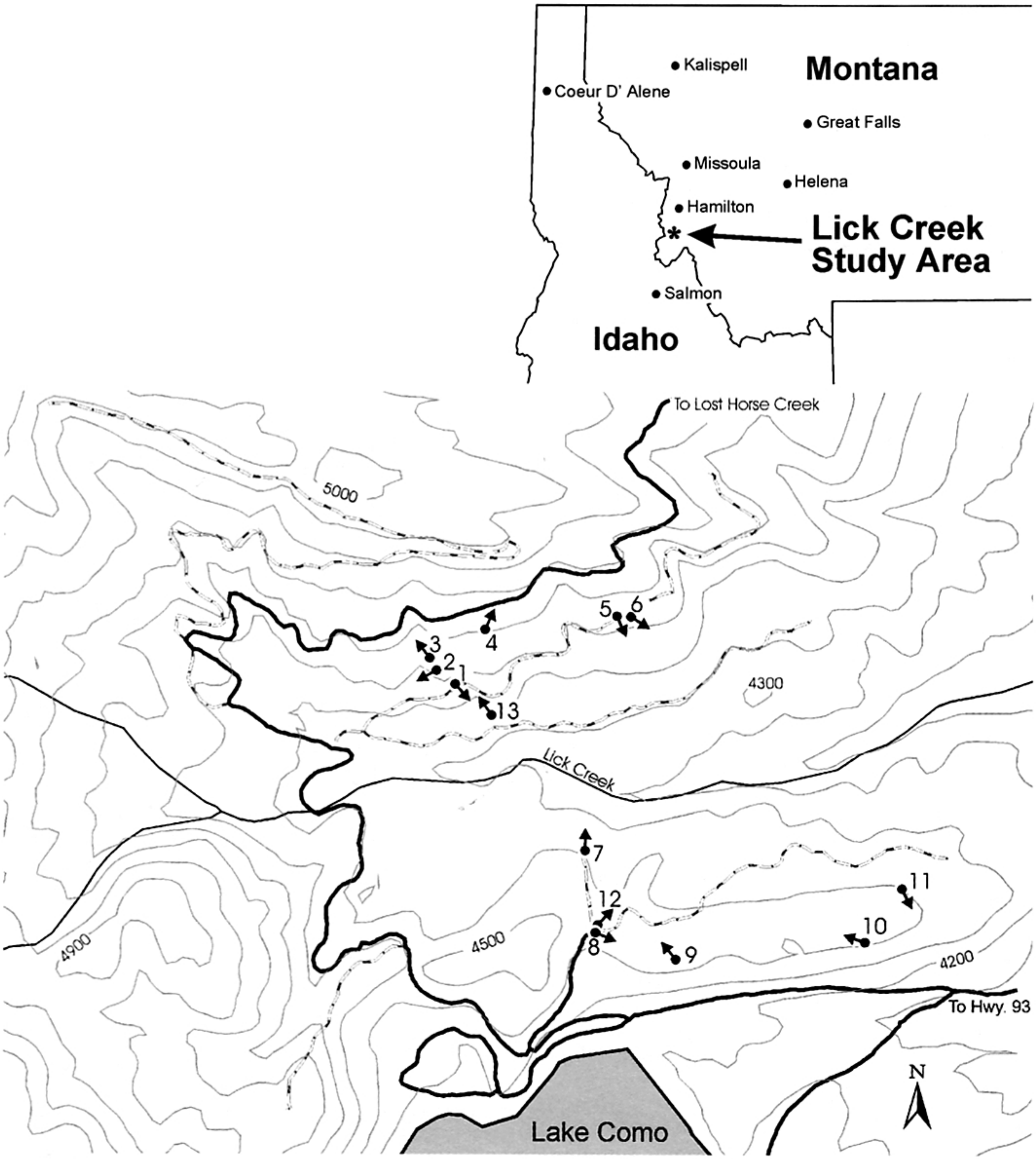

Figure 1—Lick Creek study area showing locations of photopoints.

Natural Forest Succession and Fire History

Modified from Gruell and others (1982)

"Succession" is the term applied to a change or sequence of vegetation on a given site through time following disturbance. For example, a succession of plant communities that follows clearcutting with broadcast burning of slash might be (1) grass-forb, (2) shrubfield, (3) saplings and shrubs, (4) pole-size trees, (5) mature forest, and (6) old-growth forest. Succession also applies to the sequence of species that dominate a general community type. Thus, a forest stand may initially be dominated by ponderosa pine (a shade-intolerant tree), which gives way to inland Douglas-fir (intermediate in shade-tolerance), and finally to grand fir (shade-tolerant) with increasing time since disturbance. Forest managers need to be able to understand and predict succession because vegetation change greatly affects management for livestock grazing, wildlife, timber, fire and fuels, watershed, and recreational values.

The Lick Creek photopoints present a rare opportunity to witness forest succession in managed stands through 88 years. But to assess this management-influenced succession, we should be aware of the kind of forest succession that preceded it and may have occurred if the stand was left unmanaged. The photopoints occur on two general types of sites or "habitat types," which support somewhat different vegetation and have different patterns of succession (Pfister and others 1977). A habitat type is a measure of site (physical environment), based upon the potential or "climax" vegetation—the type of plant community that represents the conceptual self-perpetuating endpoint of succession.

Fire and other disturbances usually intervene and prevent development of climax communities in these forests, but a knowledge of shade tolerances and successional trends allows us to identify the theoretical or potential climax on most sites. This ultimate vegetative type is a reflection of the overall physical environment. The potential climax vegetation can be used as clues to the site conditions (Pfister and others 1977).

All of the Lick Creek photopoints occur on sites where Douglas-fir is the potential climax dominant tree. The majority of points are located on two relatively dry Douglas-fir habitat types:

1. *Pseudotsuga menziesii*/*Calamagrostis rubescens* h.t., *Pinus ponderosa* phase (PSME/CARU-PIPO; Douglas-fir/pinegrass h.t., ponderosa pine phase).
2. *Pseudotsuga menziesii*/*Symphoricarpos albus* h.t., *Calamagrostis rubescens* phase (PSME/SYAL-CARU; Douglas-fir/snowberry h.t., pinegrass phase).

However, four photopoints are on moist Douglas-fir habitat types:

1. *Pseudotsuga menziesii*/*Vaccinium caespitosum* h.t. (PSME/VACA; Douglas-fir/dwarf huckleberry h.t.); and
2. *Pseudotsuga menziesii*/*Vaccinium globulare* h.t., *Arctostaphylos uva-ursi* phase (PSME/VAGL-ARUV; Douglas-fir/blue huckleberry h.t., kinnikinnick phase).

It is evident from the early photographs, accounts of early forest conditions (Leiberg 1899), and fire history studies (Arno 1976), that prior to logging and the advent of fire suppression in the early 1900's, the lower elevation forests of the Bitterroot Valley were made up of moderately dense stands of large ponderosa pine (fig. 2). Surface fires swept through these stands at intervals of between 3 and 30 years (Arno 1976), killing most of the smallest trees but causing little damage except for fire scars at the base of some, but not all, of the larger trees (Leiberg 1899). These fires killed the aerial portions of grasses and shrubs, but afterwards most of these species regenerated from underground organs. Tree seedlings also became established after the fires.

Lightning was a principal cause of these fires, but recent studies (Arno and others 1997; Barrett and Arno 1982) point out that Native American Indians (Salish and others) were also an important ignition source. Settlement by European-Americans became significant in the Bitterroot Valley below Lick Creek starting about 1860, but apparently this had little

Figure 2—Photo of unlogged forest at Lick Creek in 1909.

effect upon the role of fire until about 1900 (Arno 1976). Fire scar studies from similar sites in the Bitterroot Valley indicate that the pattern of frequent surface fires was in effect at least as early as 1500 (Barrett and Arno 1982).

In the spring of 1980, Arno and Gruell spent several hours searching the central portion of the photopoint study area for evidence of fire history. They found that large, old fire-scarred stumps (mostly ponderosa pine, but also some Douglas-fir on north-facing slopes) were common throughout the area. Evidently, most of these were the remains of trees cut in the 1907 to 1911 logging, and many of them were scarred by at least six to 12 fires in the 200 to 250 years prior to logging. Six of the best preserved and most complete fire-scar sequences, four from pitch-laden ponderosa pine stumps and two from live ponderosa pine, were cross-sectioned. The cross-sections were sanded and annual rings were counted under magnification to date the probable year of each fire scar. These fire-scar dates from the individual stumps and trees were then correlated and adjusted slightly to account for minor ring-counting errors as described by Arno and Sneck (1977). This produced a fire chronology for the stand as a whole. Table 1 presents the individual fire scar records and the fire chronology.

These records indicate that light surface fires swept through the forest at intervals averaging 7 years between A.D. 1600 and 1895. One of the cross-sectioned stumps (labeled "below photopoint 6" in table 1) shows 16 fire scars between 1752 and 1890 (fig. 3). For a more detailed discussion of the fire history for ponderosa pine forests on the Bitterroot National Forest see Arno and Petersen (1983).

Although the sites at Lick Creek are capable of supporting both ponderosa pine and Douglas-fir, the pre-1900 fire regime brought about development of uneven-aged stands of ponderosa pine. Douglas-fir saplings are readily killed by surface fires, whereas some ponderosa pine saplings often survive. (Small Douglas-fir are sensitive to fire because of the thin, photosynthetically active bark along with their small buds and fine branchlets. Ponderosa pine of comparable size have already developed a layer of corky outer bark and they have large, protected buds and thicker twigs.) Thus, there was a continual selection pressure against Douglas-fir. This phenomenon was acknowledged by W. W. White (1924). Figure 4 depicts relative abundance of these two conifers in both the overstory and the understory during the pre-1900 fire regime. If it had not been for frequent fires, the more shade-tolerant Douglas-fir would have been able to regenerate under the pine and eventually dominate the site, as shown in figure 5.

Field observations by Leiberg (1899) and historical accounts compiled by Weaver (1974) and Barrett (1981) state that many pre-1900 ponderosa pine/Douglas-fir forests had open, grassy undergrowth, and this is borne out by the 1909 photographs at Lick Creek. (See also Leiberg 1899.)

The native, dry grassland species—bluebunch wheatgrass, Idaho fescue, and arrowleaf balsamroot (identifiable in the early photographs)—formed the undergrowth on the drier sites (PSME/CARU-PIPO and PSME/SYAL-CARU). The undergrowth on moist habitat types (PSME/VACA and PSME/VAGL-ARUV) was primarily sod-forming (rhizomatous) woodland grasses—pinegrass and elk sedge—along with the low shrubs—kinnikinnick, snowberry, white spiraea, dwarf huckleberry, and blue huckleberry. On both dry and moist habitat types, understory conifers and large shrubs such as bitterbrush, willow, and serviceberry were scarce because of the frequent surface fires.

The 1909 photos, as well as the Leiberg (1899) photos, show that although the understories were open, the stands were "heavily stocked" with large ponderosa pine trees (modest growth rates and relatively high basal areas of tree stems per acre attest that these early stands were fully stocked or overstocked in terms of timber production). The trees had clear boles because the lower limbs had been shaded out and scorched by fire. In addition to fire, dominance of large pines contributed to a scarcity of tree regeneration and shrubs in the understory. Shrubs and small trees were probably also inhibited by tree root systems utilizing much of the soil moisture and nutrients.

The overstory pines often lived 300 to 600 years (Arno and others 1995). They evidently died and were replaced individually or in small groups. When openings occurred, new pines would generally grow and fill them. Some saplings would succumb to damage by the next surface fire, but others would survive.

Table 1—Fire chronologies for six fire-scarred trees and stumps at the Lick Creek photopoints, Bitterroot National Forest; X = an individual fire scar (42 fires between 1600 and 1900 yields a mean fire interval of 7 years).

Estimated fire year*	Live tree at photopoint 3 (cambium 1979)	Stump at photopoint 2 (cut about 1905)	Stump at photopoint 1 (Cut after 1903)	Live tree below photopoint 6 (cambium 1979)	Stump below photopoint 6 (cut about 1902)	Stump at photopoint 8 (cut about 1906)
1895		X		X		
1890		X		X	X	
1883			X			X
1875		X				
1871	X	X	X	X	X	X
1861			X	X	X	
1856				X		X
1850		X		X		
1846						X
1842			X			X
1838	X	X		X	X	X
1832						X
1828	X				X	
1821	X		X		X	X
1818		X	X		X	
1811					X	X
1806		X	X		X	
1798		X	X		X	X
1795	X		X			X
1790					X	X
1786			X			
1783		X			X	X
1780		X				
1776	X	X			X	X
1771					X	X
1758	X					X
1752	X				X	X
1744	X		X			X
1734			X			
1729						X
1719			X			
1713						X
1707			X			
1702(?)						X(?)
1693						X
1681						X
1672	X					
1657						X
1651						X
1646						X
1642						X
1618						X
1598						X
1586						X
1552						X
1545						X
1444						X
pith date	1648	1724	1617	rotten	rotten	1428

*These samples were not dendrochronologically cross-dated.

Occasionally, combinations of unusually dry years coupled with epidemics of yellow pine butterfly and pine beetles would cause substantial mortality as they did in some dry sites in the Bitterroot Valley during the early 1970's. C.A. Wellner (personal communication) noted that the beetle caused heavy losses at Trapper Creek and in some other areas of the Bitterroot in the mid- to late-1930's, which were dry years. Still, old-growth ponderosa pine forests with open understories perpetuated by surface fires evidently dominated the Lick Creek area for centuries prior to 1900 (see also Arno and others 1995, 1997).

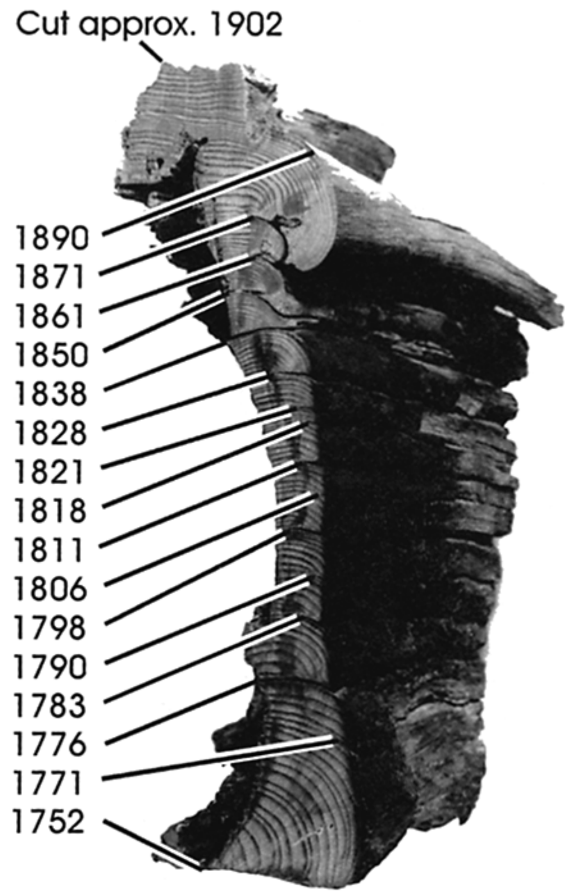

Figure 3—Cross-section from the ponderosa pine stump below photopoint 6 (see table 1) at Lick Creek, showing 16 fire scars between 1752 and 1890 (Gruell and others 1982).

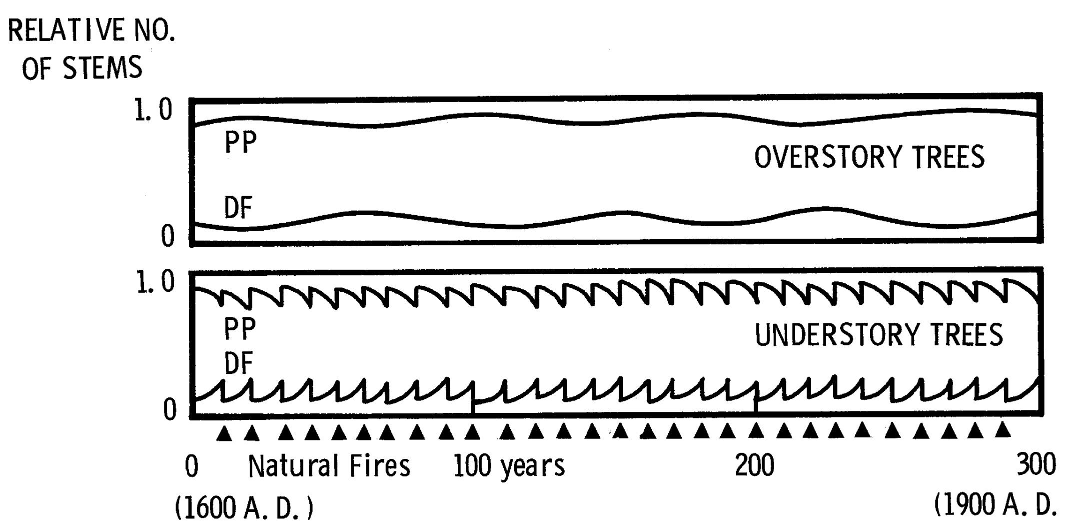

Figure 4—The effect of succession on relative abundance of ponderosa pine and Douglas-fir at Lick Creek: hypothesized succession with underburns at 5- to 15-year intervals (Gruell and others 1982).

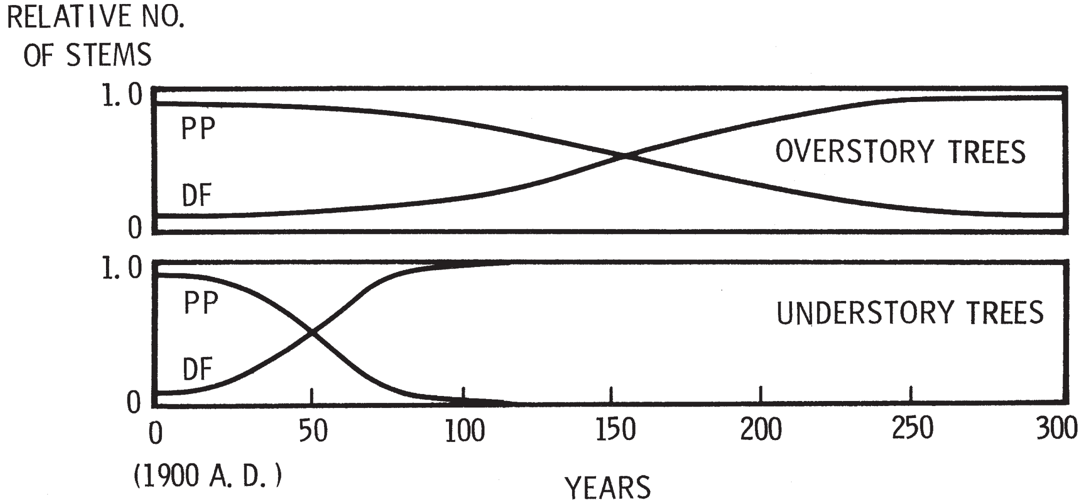

Figure 5—The effect of succession on relative abundance of ponderosa pine and Douglas-fir at Lick Creek: hypothesized succession with fire control and no cutting (Gruell and others 1982).

Historical Silvicultural Treatments

Early Silvicultural Story

Modified from Gruell and others (1982)

The Lick Creek timber sale of 1906 attracted much attention because it was the first large National Forest timber sale (2,135 acres) in the ponderosa pine cover type in the USDA Forest Service Northern Region. A total of 37,600,000 board feet (bd ft) was cut (White 1924).

Professional forestry and the USDA Forest Service were in their infancy in the United States and there was little research or experience on which to base silvicultural prescriptions for any of our forest cover types. Ponderosa pine was, and continues to be, a high-value timber species.

Frequent, low-intensity fires had favored ponderosa pine and had suppressed its more shade-tolerant associates (in this area, primarily Douglas-fir). Douglas-fir was economically less desirable than the large old ponderosa pine, so silvicultural practices were aimed at perpetuating pine and reducing the fir component. Autecological requirements of all species were just beginning to be understood; therefore, silvicultural treatments were based on limited knowledge.

Harvest Cutting Treatments, 1907 to 1911

James P. Menakis

The virgin stand contained chiefly medium and large ponderosa pine (fig. 2). Douglas-fir of inferior wood quality made up about 10 percent of the stand volume. A small amount of grand fir and spruce was included in the Douglas-fir volume. Total volume of sawtimber (10 inches diameter at breast height, dbh, and larger) of all species averaged 20,810 bd ft per acre. Tree ages ranged from 200 to 400 years, with potential site indexes for uncrowded trees averaging about 52 to 55 ft tall at 50 years for ponderosa pine and Douglas-fir (Pfister and others 1977).

Although original descriptions of the Lick Creek cuttings did not classify the silvicultural system, it could best be described as a selective cutting. Timber marking practices in this early cutting followed these criteria (Gruell and others 1982):

1. Leave 30 percent of the ponderosa pine volume for a future harvest 75 years later.
2. Leave ponderosa pine trees with good crown forms, or large trees if they were the best or only tree available.
3. Cut all Douglas-fir over 10 inches dbh.
4. Cut Douglas-fir heavily infected with witch's broom (caused by dwarf mistletoe).
5. Thin groups of small diameter ponderosa pine (this was later dropped because of dissatisfaction with the quality of the leave trees).

After the marking had started, Gifford Pinchot (first Chief of the Forest Service) inspected the site. Elers Koch, Bitterroot Forest Supervisor, described Pinchot's reaction to the marking. Pinchot "approved of most of what we had done, but felt we had been cutting too heavily, and made us go back and mark out some of the blazes on doubtful trees with red paint" (Koch 1998).

Actual cutting practices varied considerably during the 1907 to 1911 period (Gruell and others 1982). In a limited area, everything over 19 inches dbh was cut. Size class distribution of the residual stand was reported by White (1924) for the full cutting area and Menakis (1994) for 250 acres in the drier habitat types (table 2). The original stand contained an average of

Table 2—Estimated size class distribution of the residual stand by White (1924) and Menakis (1994).

Size class	White (1924)	Menakis (1994)
(inches)	*- - - - Number of trees per acre - - - -*	
2 to 4	—	14
6 to 8	2	10
10 to 12	6	11
14 to 16	6	7
18 to 20	5	6
22 to 24	3	3
26 to 30	2	2
32+	1	0

about 50 trees per acre (White 1924), with ponderosa pine representing about 87 percent and Douglas-fir about 13 percent in the drier habitat types (fig. 6) (Menakis 1994). Of these, an average of 25 trees per acre were cut in the 1907 to 1911 period (White 1924).

Estimates from approximately 250 acres of the original sale area indicate that about 22 ponderosa pine and three Douglas-fir per acre were cut (fig. 7). Average dbh of the pine cut was 23 inches, and for Douglas-fir, 20 inches (Menakis 1994). Most of the

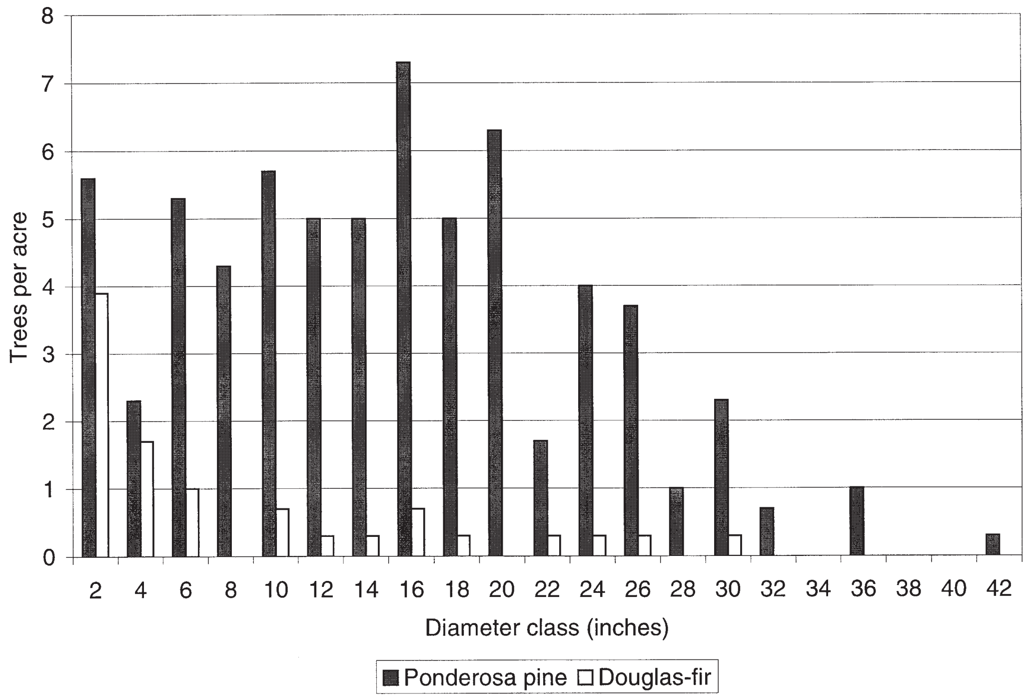

Figure 6—Estimated average diameter distribution for dry habitat type groups at Lick Creek in 1906, prior to logging (Menakis 1994).

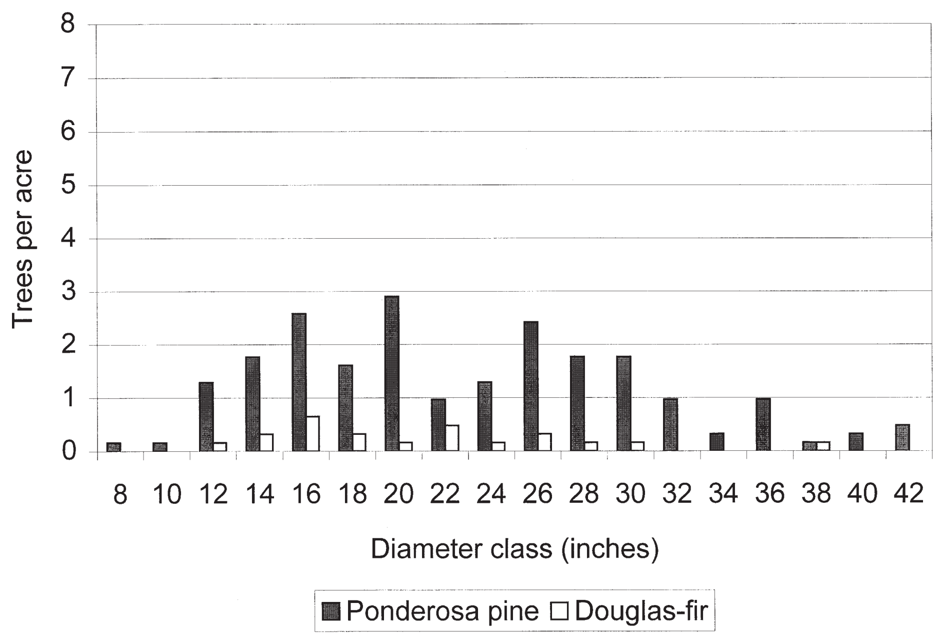

Figure 7—Estimated average diameter distribution of trees cut during the 1906 Lick Creek timber sale (Menakis 1994).

trees harvested were larger than the average of trees as a whole, so basal area remaining after logging averaged only 37 percent of the original 121 ft^2 per acre (White 1924), with ponderosa pine accounting for 97 percent of the remaining basal area in the drier habitat types (Menakis 1994).

Differences between White's and Menakis' diameter distributions could have resulted from different sizes and locations of the surveys, as well as different methodologies used. Boe (1948) observed that the residual basal area and volumes varied greatly over the cutover area, with ranges from about 5 to 50 percent of the original stand.

Of the 2,135 acres cut in the 1907 to 1911 period, 1,916 were of the ponderosa pine cover type and 219 were Douglas-fir, spruce, and grand fir (Gruell and others 1982). The potential vegetation for most of the area and all of the photopoints are within Douglas-fir habitat types (Pfister and others 1977). A grand fir habitat type, including some spruce trees, occurs in the moist sites along Lick Creek.

In addition to the thinning, an adjacent 320 acres of private land located along the southern borders of the Forest Service Lick Creek sale were clearcut in 1906. The clearcut was not part of the Lick Creek sale, but the land was later acquired by the Forest Service.

Residual Stand Growth Response

Modified from Gruell and others (1982)

An evaluation of the Lick Creek area 35 years after the 1907 to 1911 cutting showed that average stand volume of trees 10 inches dbh and larger had increased from 3,810 bd ft per acre in the residual stand in 1911 to 6,127 per acre in 1946 (Roe 1947a). This amounted to 66 bd ft per acre annual net growth. Fortunately, the residual stands that made up this average varied substantially and provided a basis to evaluate the effect of residual volume capital on subsequent growth. To make these evaluations, Roe (1947a) grouped the 1911 residual volumes into four broad classes averaging 627 residual bd ft per acre, 2,396 per acre, 4,655 per acre, and 9,089 per acre.

Largest net volume increments were made in the heaviest residual stands. Figure 8 shows that average annual increment ranged from 2 bd ft per acre where the reserve stand had averaged 627 bd ft per acre, to 126 bd ft per acre where the reserve stand had averaged 9,089 bd ft per acre. Most growth was made by merchantable-size trees reserved at the time of the

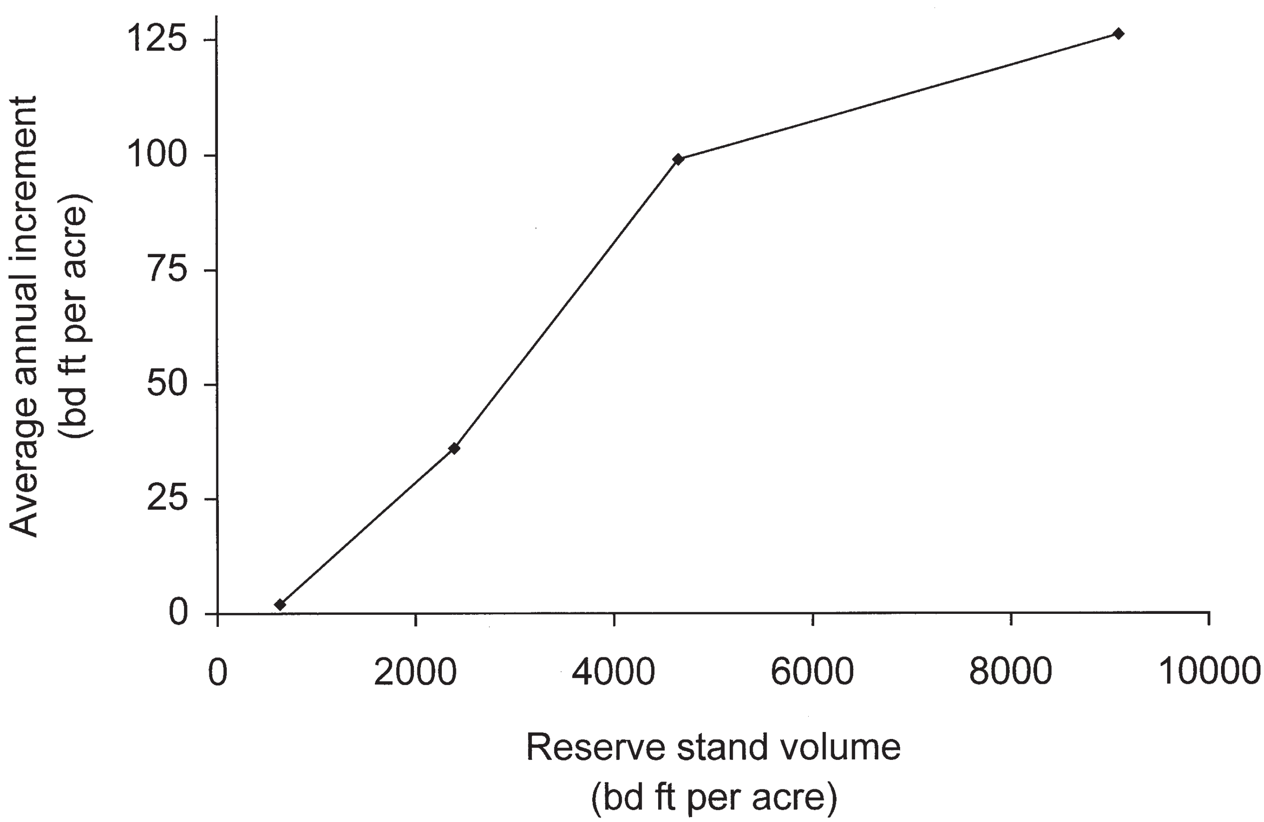

Figure 8—Average annual net volume increment for 35 years following harvest cutting in relation to reserve stand volume (Gruell and others 1982).

initial logging. Although the greatest per acre gains were in the heaviest residual volumes, on a percentage basis the most significant increases were in stands averaging 4,655 bd ft per acre (fig. 9) (Roe 1947b).

In the stands with the light residual volume, Douglas-fir contributed most to the ingrowth (trees less than 10 inches dbh at the time of the initial harvest that exceeded 10 inches dbh at the 35-year measurement). The opposite was true in stands with heavy residuals after the initial cutting. Here, nearly all of the 35-year growth was ponderosa pine 10 inches dbh and larger at the time of initial cutting. Intermediate reserve stand volumes resulted in intermediate response values in relation to both species composition and volume growth. Thus, stand volume capital played a role in evaluating the efficacy of reserving different levels of stand volume.

White (1924) described effects of release on individual ponderosa pine trees. He concluded: "It was noticed that the removal of one or more trees on the north seemed to have as much effect on increased growth as where the removal was on the south. This was so pronounced that the conclusion is reached that root competition in yellow pine stands is fully as important a factor as light."

Volume increment in stands with the heaviest residual volume increased rapidly. It peaked the second 5-year period after logging, remained relatively high for about 20 years, and then gradually declined (Roe 1947b). In stands with lighter residual volumes, the same trends were observed, except that ingrowth accounted for the increased increment growth.

Ingrowth played a relatively small part (in the residual stand growth) over all of the cutover area because there were few understory trees, seedlings, sapling, and poles in 1907. Frequent surface fires precluded survival of most understory trees before that time.

The reserve stand was apparently chosen with a good appreciation of tree vigor. Mortality averaged only 8 to 18 bd ft per acre annually for the 35-year period. No relationship of mortality rates to residual stand volume was detected. White (1924) concluded that most mortality was due to windfall shortly after the cuttings, but a small amount was due to bark beetles. About 90 percent of the wind losses occurred the first 3 years after cutting. Windfall was worst on the eastern and southeastern sides of large openings created by the logging. Western and northwestern winds were responsible for the wind losses.

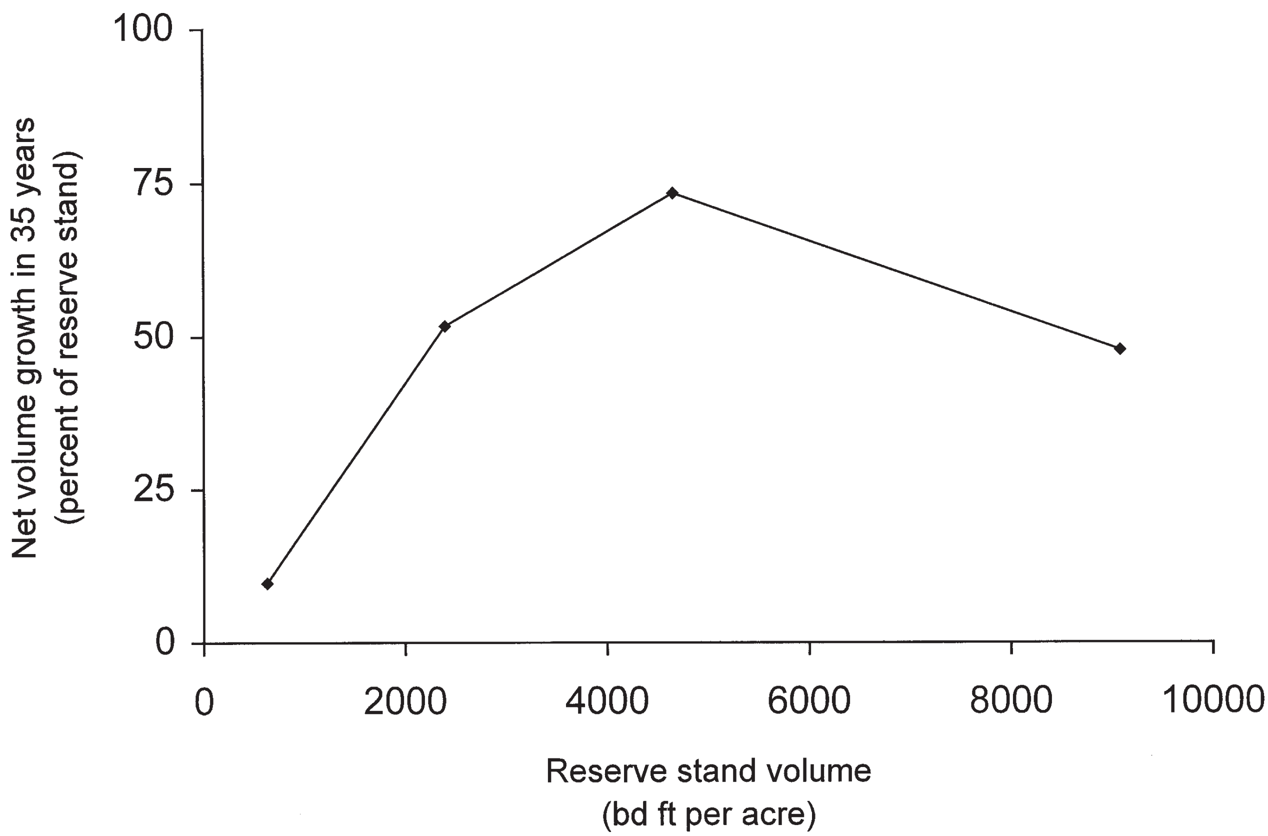

Figure 9—The 35-year net volume growth as a percent of the reserve stand volume (Gruell and others 1982).

Natural Regeneration Response to Initial Treatments

Modified from Gruell and others (1982)

During the 1907 to 1911 harvest, logs were transported to landings by means of log chutes, horse skidding, and steam donkey yarding. Slash was disposed of by piling and burning, which the purchaser considered to be an unnecessary practice (Koch 1998). Usually this type of logging and postlogging treatment results in relatively light site disturbance, and the photo series tends to corroborate this. Some advance natural regeneration, primarily Douglas-fir, was present in the stand prior to logging; most of it became established in the 10 years prior to logging (Boe 1948). However, opening of the stand, site disturbance of the logging, and apparent good seed crops resulted in adequate subsequent tree regeneration. White (1924) stated: "Along about 1912, there was a heavy yellow pine seed crop. That fall, in October, the area was grazed close by sheep." The most successful regeneration period was the first 10 years after logging, with a gradual decline in the second and third decades.

Total subsequent regeneration combining all species was best where reserve volumes averaged about 2,500 bd ft per acre. Lighter volumes resulted in lesser amounts of regeneration. Reserve volumes greater than 2,500 bd ft contributed little or no additional aid in seedling establishment except on southerly aspects where it enhanced Douglas-fir establishment. Apparently, reserve volumes of about 2,500 bd ft provided reasonably good conditions for all species, with an adequate seed source, and shade and moderate competition during the establishment period.

Some conclusions that came out of the evaluations of natural regeneration were (Boe 1948):

1. Douglas-fir reproduction tends to become established in advance of cutting, due to greater shade tolerance. The tendency is more pronounced on the cooler, moister north aspects where Douglas-fir predominates. Ponderosa pine generally regenerates after logging and predominates on the south slopes.
2. It took about 20 years after cutting to restock the area; however, the peak establishment occurred in the first 10 years.
3. Height growth of young ponderosa pine and Douglas-fir was about equal for the first 40 years, each averaging slightly more than 0.6 ft annually. Consequently, if both species become established at the same time, the danger of Douglas-fir crowding out the pine is greatly decreased.

Harvest Cutting Treatments and Thinning Study, 1952 to 1981

James P. Menakis and Gruell and others (1982)

Growth evaluations 35 years after the initial cuttings indicated that a second cutting was needed to better capitalize on growth potential of the site (Roe 1947b). So in the 1950's, additional cuttings were made on a limited portion of the original cutover area. The following cutting methods were imposed on 468 acres within the original 1907 to 1911 cutover area (2,135 acres):

- **Method A (approximately 223 acres)**—Remove old stand in four cuttings; the first in 1907 to 1911, and the other three at 10-year intervals starting in 1952.
- **Method B (approximately 98 acres)**—Remove old stand in three cuttings; the first in 1907 to 1911, half the old residual in 1955, and the other half in 1962.
- **Method C (approximately 147 acres)**—Remove old stand in two cuttings; the first in 1907 to 1911, and the remainder of the residual in 1955.
- **Method D (approximately 10 acres)**—A portion of the 320 acres clearcut in 1907 (private land then). This area is not included in the 468 acre figure as no further cutting was planned so it could be used for comparison purposes.

Crews installed 87 permanent research plots throughout the cutting units (Methods A-C) with the objective of determining which method would best capitalize on the growth potential of the site. In addition, 10 plots were installed in areas treated with Method D to compare the clearcutting to the selective cutting. The research plots were scheduled to be remeasured every 5 years. Figure 10 shows the diameter distribution in 1948 for the drier habitat types.

At the time of the second cutting in the 1950's, stand volumes averaged about 10,000 bd ft per acre. Method A removed about one-third of the residual volume (left after the 1907 to 1911 cutting) and was completed in 1952. Method B removed about one-half of the residual volume and was completed in 1956. Method C removed all of the residual volume but left one-third of the total volume and was completed in 1956 (fig. 11). The minimum dbh specifying the merchantability of a tree was 14 inches for method A, and 12 inches for methods B and C. Logs were mainly tractor skidded, with a pan under the front of the logs; however, there was some supplemental jammer skidding.

Marking practices to accomplish these partial cuttings were:

1. Remove high-risk trees (those which would not survive 10 to 20 years).
2. Remove damaged or defective trees, with special emphasis on one of the following: spiked tops, lightning scars, butt rots, and leans in excess of 20 degrees.
3. Remove poor quality, merchantable subordinates.
4. Remove extremely slow growing, overmature trees.
5. Release subordinates by removing merchantable overstory trees of lesser quality.
6. Remove all merchantable Douglas-fir.
7. Remove dominant trees from mature and overmature groups.

A stand improvement cut followed the first entries with the objective of providing fast growing, uniformly spaced second-growth ponderosa pine. Crop trees (4 to 9 inches dbh) were released from competing trees at an average spacing of 20 by 20 feet. Stand improvement cuts were completed in 1953 in method A and in 1956 in method B and C. Method A had additional stand improvements that included:

1. Pruning selected crop trees to 17 feet in height, but never removing more then 40 percent of the crown.
2. Thinning saplings (1 to 3 inches dbh) to a spacing that averaged 15 by 15 feet.
3. Removing unhealthy and defective trees 4 to 9 inches dbh (killed by poisoning).

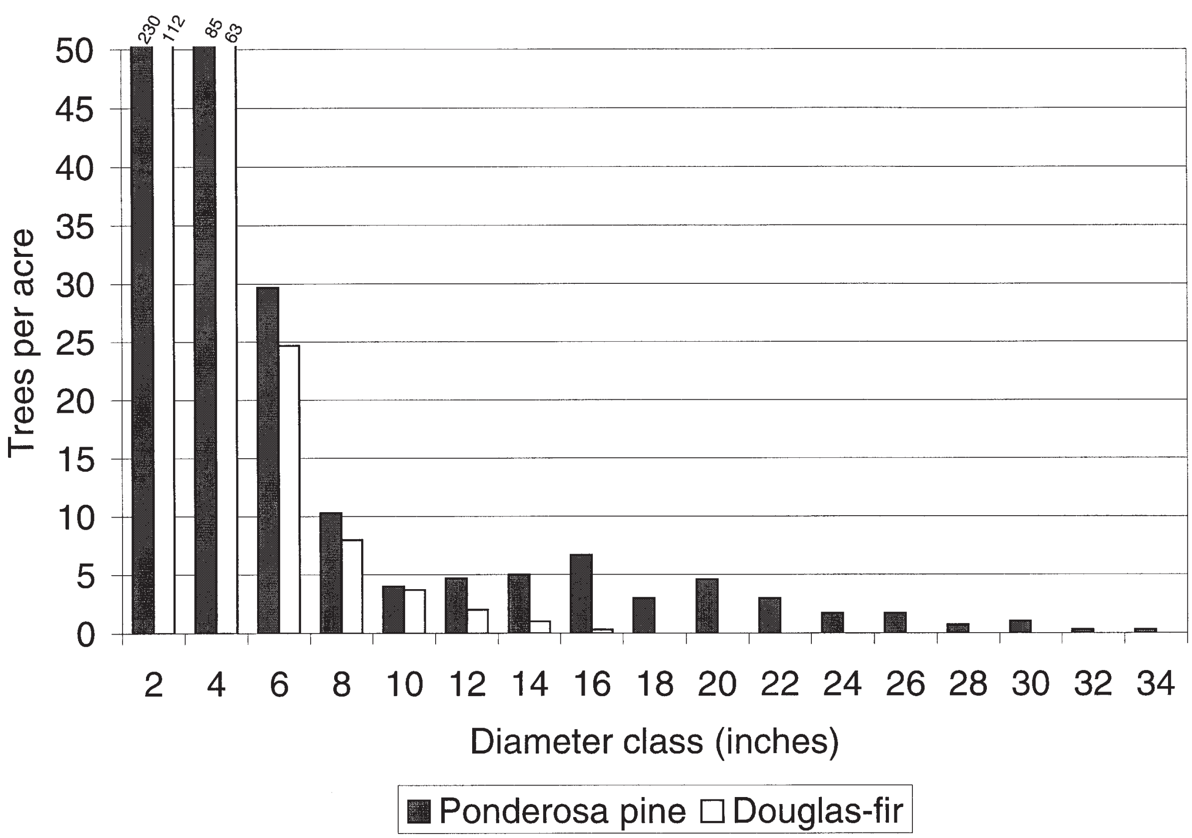

Figure 10—Estimated average diameter distributions for dry habitat type groups at Lick Creek in 1948 (Menakis 1994).

Figure 11—An example of method C before (1955) and 5 years after cutting. Photo at right (1998) shows recovery after 1950's and 1960's cuttings and 1994 underburning.

Response to 1950's Harvest Cutting

Modified from Gruell and others (1982)

Response following the 1950's cutting was similar to that after the original 1907 to 1911 cutting; greatest increases in merchantable volume were in stands with the largest reserve volumes. Net volume growth exceeded that following the original cuttings, ranging from about 150 bd ft per acre in stands with 2,000 bd ft per acre reserve volume to 235 bd ft in stands with 12,000 bd ft reserve stand volume. Ingrowth accounted for about 30 percent of the volume growth in the lightly stocked reserve stand and only about 3 percent in the more heavily stocked reserve stand. About half of the ingrowth was Douglas-fir, in spite of the attempts to enhance ponderosa pine and discourage Douglas-fir.

Lumber recovered from these second cuttings was similar in quality to that from virgin stands. Approximately 15 percent of the lumber was select, 60 percent in two and three common grades, and the remainder in lower grades.

Additional Treatments 1960 through 1981

James P. Menakis

A light stand improvement treatment was applied to method D in 1960. This treatment differed from other stand improvement treatments in that only a few 4- to 9-inch diameter trees were removed that were defective or unhealthy. The treatment was very light and patchy.

The third entry of Method A was completed in 1962. The harvest removed only one-third of the residual (1907 to 1911) trees, instead of the scheduled half, because many of the residual trees were growing well. The marking of trees followed the 1952 sale criteria except for emphasizing the removal of Douglas-fir heavily infected with dwarf mistletoe, and specifying minimum tree merchantability at a dbh of 9.6 inches. The thinning was followed 2 years later (1964) by a stand improvement cut aimed at removing smaller diameter Douglas-fir infected with mistletoe and additional thinning and pruning of crop trees remaining after the 1952 thinning.

Unfortunately, the thinning study was terminated in 1966 because of a restructuring of the USDA Forest Service Research Units. Future cuttings quickly deviated from the 1950's study design, creating several subdivisions in the original methods. Based on the new treatment boundaries (determined during the 1991 remeasurement) method A was subdivided into three groups (A1, A2, and A3), and methods B and C were each subdivided into four and three groups, respectively (labeling similar to method A) (fig. 12).

Methods B1 through B4 were thinned in 1967 following the guidelines in the 1950's study plan. Most of the remaining residual (1907 to 1911) trees were removed, as well as all of the merchantable Douglas-fir. A stand improvement cut, which also included

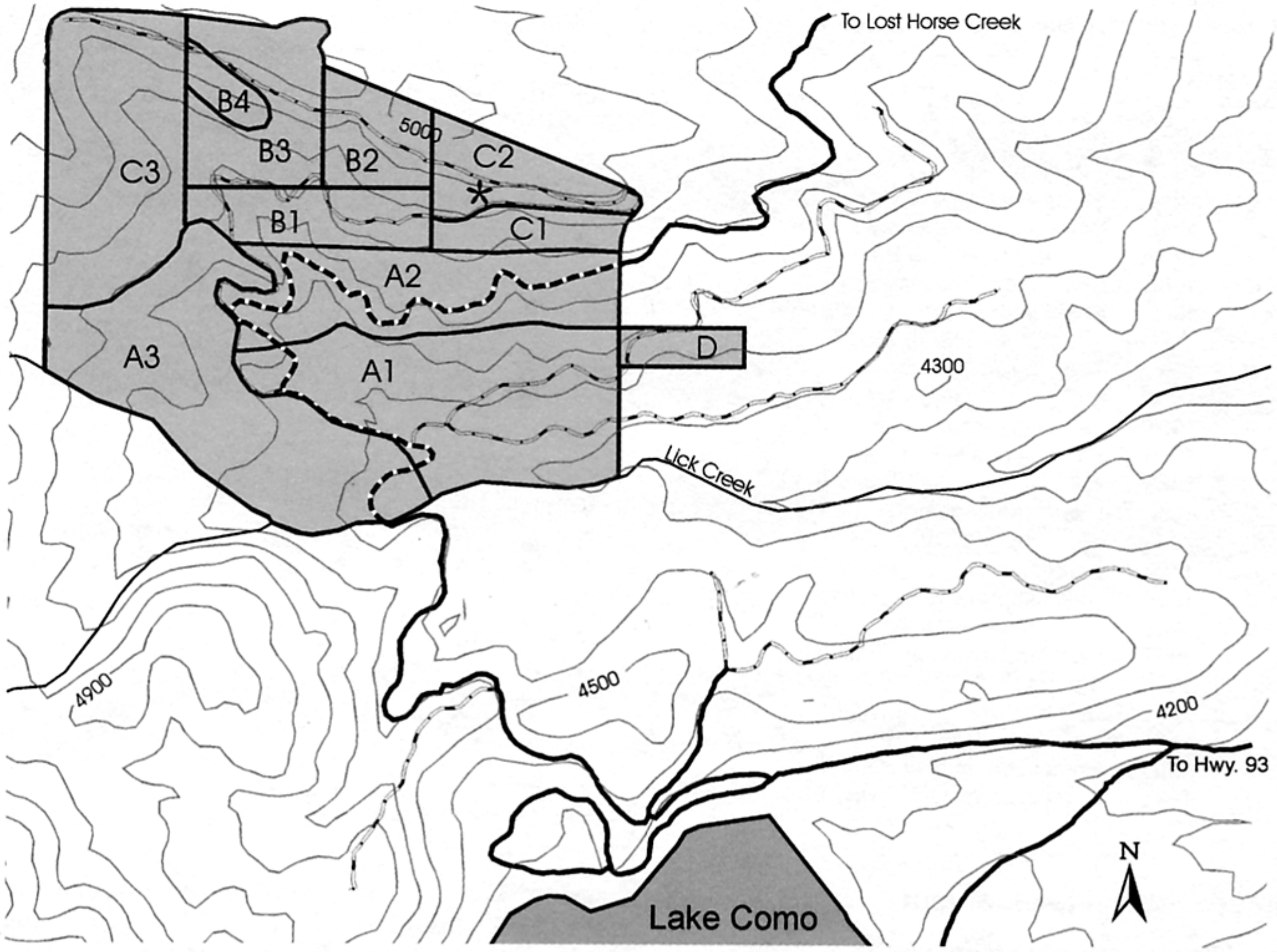

Figure 12—A map of the Lick Creek study area with methods A through D (described in text) delineated (Menakis 1994). Asterisk in area C2 shows location of photopoint for figure 11.

methods C1 and C2, followed the thinning with the objective of pruning and releasing crop trees.

In 1979, a large timber sale occurred on the west portion of the study area, affecting methods A3, B3, B4, and C3. The criteria for selecting trees were:

1. Release healthy, vigorous understory trees.
2. Salvage high risk and overmature trees.
3. Remove diseased and insect damaged trees to provide space for healthy trees.
4. Remove about 50 percent of the crown cover.

The minimum diameter to determine merchantability was 8 inches dbh. The sale was followed (in 1981) by a light and patchy underburn.

In 1980, a light stand improvement thinning was applied to methods A2, B1, B4, and C1. The objective of the thinning was to improve the growing space of sapling trees. The thinning was light and patchy, with saplings being hand piled. The exact extent of this treatment is unknown. Table 3 summarizes the history of the Lick Creek area by Methods.

Summary of Harvest Cutting Treatments

James P. Menakis

In 1991, the permanent plots established in the late 1940's and early 1950's were remeasured in an attempt to evaluate the different treatments. Unfortunately, because of the range of activities that took place and divided the original treatments, any comparison would be inconclusive. Table 4 stratifies methods by the number of commercial cuttings.

Despite the strong effort to limit the number of Douglas-fir trees in the Lick Creek area, by 1991 the percent of basal area per acre of Douglas-fir, when compared to total basal area, had increased by about 18 percent in the drier habitat types. The total number of trees per acre also increased by about four times during this period, with most of this increase in diameters less than 6 inches (fig. 13).

Table 3—Historical management activities by method (see fig. 12) (Menakis 1994).

Date			Method										
Month	Year	Activity	A1	A2	A3	B1	B2	B3	B4	C1	C2	C3	D
	1906	Clearcut											X
	1907	Selective Cutting Starts	X	X	X	X	X	X	X	X	X	X	
	1911	Selective Cutting Ends	X	X	X	X	X	X	X	X	X	X	
7	1948	Installation of Permanent Plots	X	X	X								
6	1952	Remeasurement of Perm. Plots	X	X	X								
6	1952	Commercial Thinning	X	X	X								
11	1953	Stand Improvement Cutting	X	X	X								
5	1955	Installation of Permanent Plots				X	X	X	X	X	X	X	X
12	1955	Commercial Thinning				X	X	X	X	X	X	X	
4	1956	Stand Improvement Cutting				X	X	X	X	X	X	X	
7	1957	Remeasurement of Perm. Plots	X	X	X								
9	1960	Stand Improvement Cutting											X
6	1961	Remeasurement of Perm. Plots				X	X	X	X	X	X	X	X
8	1962	Remeasurement of Perm. Plots	X	X	X								
10	1962	Commercial Thinning	X	X	X								
9	1965	Remeasurement of Perm. Plots				X	X	X	X	X	X	X	X
6	1966	Stand Improvement Cutting	X	X	X								
6	1967	Commercial Thinning				X	X	X	X				
10	1967	Stand Improvement Cutting	X	X	X	X	X	X					
8	1979	Commercial Thinning			X			X	X			X	
9	1980	Stand Improvement Cutting		X		X			X	X			
3	1981	Understory Burn			X			X	X			X	
5	1990	Remeasurement of Perm. Plots											X
11	1991	Remeasurement of Perm. Plots	X	X	X	X	X	X	X	X	X	X	

Immature Stand Management

Modified from Gruell and others (1982)

Cutting and other management of immature stands was started in the 1950's on the Lick Creek study area. More than 5,000 ponderosa pine crop trees (100 per acre) were released and pruned in the area cut with method A of the 1952 partial cutting. Trees were 4 to 9 inches dbh at the time. Release was provided by removing competitors in a 3- to 6-ft radius around the crown of each crop tree. To increase quality of the feature ponderosa pine crop trees, each was pruned to at least 17 ft. Cost of release and pruning at that time was about $0.50 per crop tree, broken down into $0.25 for pruning, $0.16 for release, and $0.09 for supervision, supplies, and transportation costs.

The 5-year evaluations of various intensities of pruning ponderosa pine showed a considerable

Table 4—Number of commercial and stand improvement cuts, and percentage of 1910 residual volume removed by method (Menakis 1994).

Method	Number of commercial cuts	Number of stand improvement cuts	Years of commercial cuts (% of 1910 residual removed)[+]		
A3	3	2	1952 (33)	1962 (22)	1979 (11)
B3	3	3	1955 (50)	1967 (25)	1979 (20)
B4	3	3*	1955 (50)	1967 (25)	1979 (20)
A1	2	2	1952 (33)	1962 (22)	
A2	2	3*	1952 (33)	1962 (22)	
B1	2	3*	1955 (50)	1967 (25)	
B2	2	2	1955 (50)	1967 (25)	
C3	2	0	1955 (100)		1979 (0)
C1	1	3*	1955 (100)		
C2	1	2	1955 (100)		
D	0	1*	No commercial cutting		

+ - Percent of residual volume removed was based on historical reports and general site estimates.
* - The last stand improvement cut was very light and patchy.

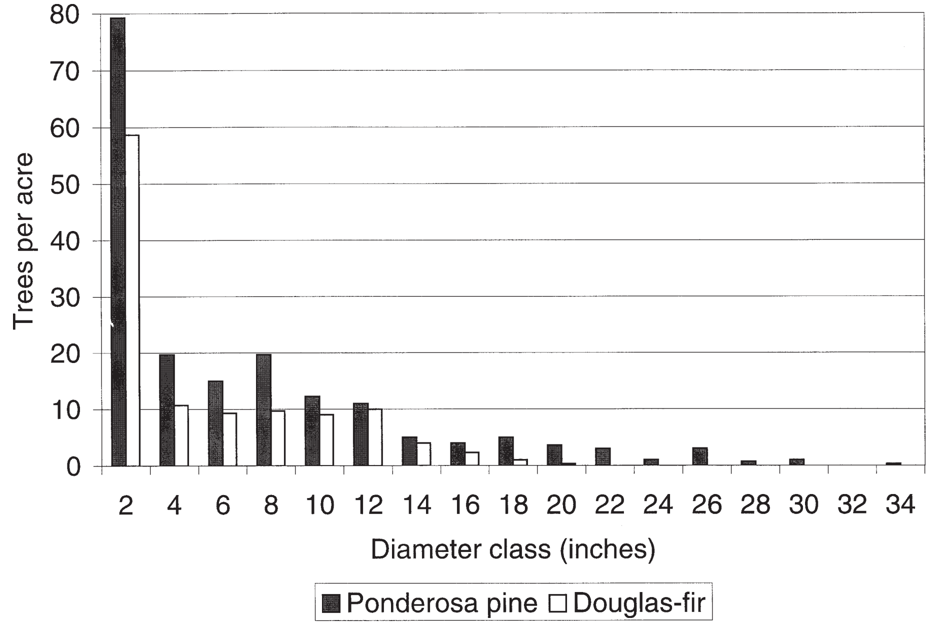

Figure 13—Average diameter distribution for dry habitat type groups by species and 2-inch diameter classes for 1991 (Menakis 1994).

reduction in dbh growth on the severely pruned trees, with proportionately less reduction on the lightly pruned trees (fig. 14). Height growth was not affected.

Cone stimulation studies were also conducted on this area. These studies showed that partial mechanical girdling of young ponderosa pine (50 years old) would substantially increase cone production (Shearer and Schmidt 1970). Older trees (140 to 220 years old), however, showed little additional cone production as a result of girdling treatments.

Summary

Modified from Gruell and others (1982)

In summary, a variety of silvicultural practices have been attempted in the Lick Creek area. The long case histories and observational data of partial cutting, release, pruning, and cone stimulation practices provide valuable clues for management of this important forest type.

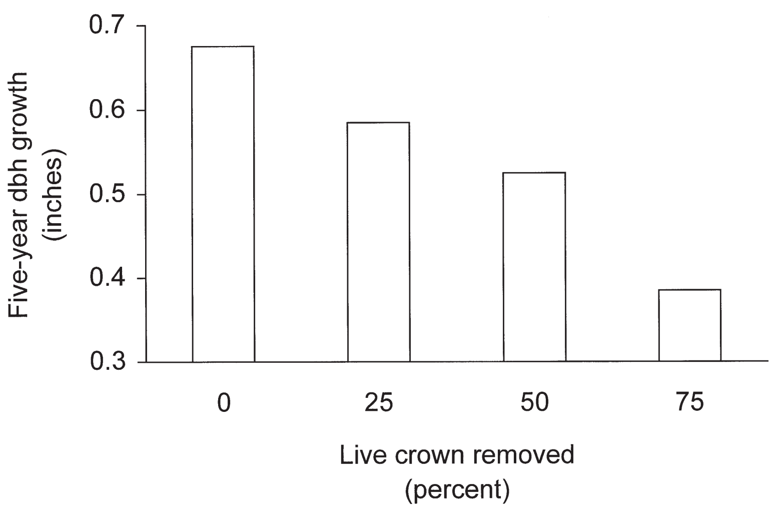

Figure 14—The 5-year diameter growth of 4- to 9-inch dbh ponderosa pine crop trees following release as related to amount of crown pruning (Gruell and others 1982).

Interpretations of Vegetative Change Through 1989: the Photopoints

Text modified from Gruell and others (1982)

Photo layout and design by Dennis G. Simmerman

The 1907 to 1911 logging operations and subsequent lack of surface fires dramatically changed the patterns of plant succession at Lick Creek. Large quantities of overstory pines were felled, creating sizable openings. Logs were skidded and slash was burned in piles (Koch 1998) locally scraping off or consuming surface vegetation, pine needle litter, and humus, and exposing mineral soil. The photo sequences covering the next 40 years show that tall shrubs (especially Scouler's willow) and tree regeneration became established in direct proportion to the amount of stand opening and soil surface disturbance. The response of tall shrubs and tree regeneration was most vigorous on the moist habitat types.

Even though overstory Douglas-fir were mostly removed in the 1907 to 1911 logging, Douglas-fir regeneration increased markedly thereafter. This regeneration is a result of (1) the absence of surface fires and (2) the opening up of the stand through logging. Figure 15 depicts the probable tree succession associated with fire control and partial cutting in this forest type. Note that this shows a speedup in the natural succession illustrated in figure 5. Douglas-fir regeneration increased markedly on the moist habitat types and under lighter cutting treatments. Pine regeneration was more successful in the dry habitat types and with greater stand opening and site disturbance.

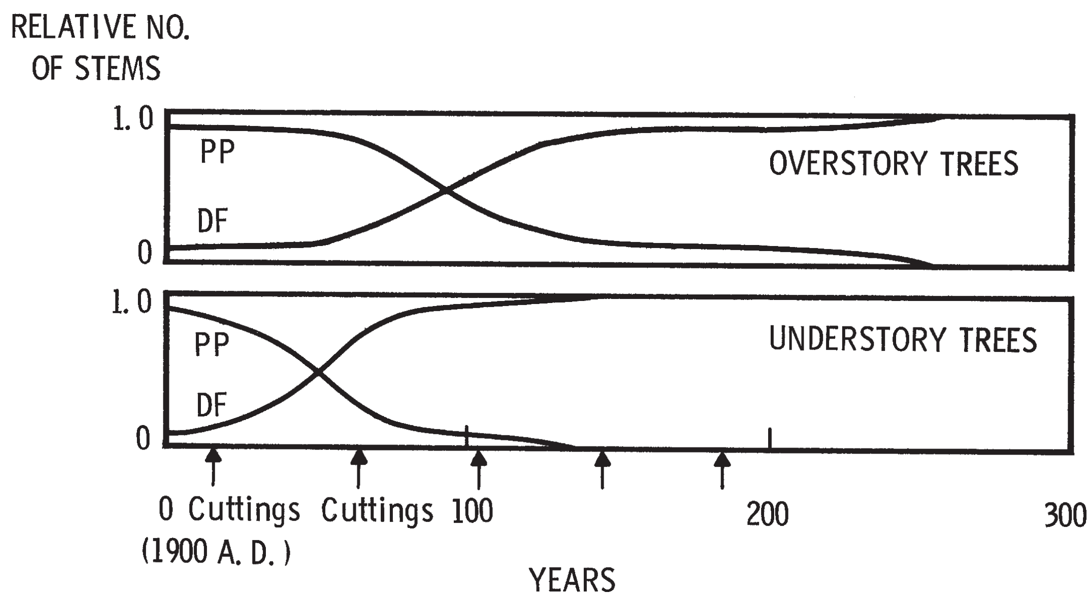

Figure 15—The effect of succession on relative abundance of ponderosa pine and Douglas-fir at Lick Creek: hypothesized succession with fire control and partial cuttings (Gruell and others 1982).

At some photopoints, several of the large pines left after early logging died from windthrow and mountain pine beetle attacks. This provided further opportunity for understory trees and shrubs to develop. Also, the photo sequences allow observation of the slow progression of death, downfall, and decay, including disintegration of stumps.

On dry habitat types, the original grassland type of undergrowth was replaced within a few decades by conifers and shrubs, including antelope bitterbrush. Often, dense pole stands developed after 30 to 40 years, tall shrubs began to be shaded out, and undergrowth, in general, became sparse. After thinning of the poles and removal of many of the remaining large pines in the 1950's and 1960's, the tall shrubs and other undergrowth became more dense. Where adequate thinning occurred, the remaining pole-size conifers generally show good vigor; otherwise, dense thickets of small trees developed. Composition has shifted toward mixed stands of ponderosa pine and Douglas-fir, and with continued partial cuttings and lack of surface fires, Douglas-fir increased dominance on many sites.

In general, the photos show that the dry habitat types have changed from original dominance by large ponderosa pine with bunchgrasses beneath to thrifty pole-size pine and Douglas-fir with scattered willow and undergrowth of species such as pinegrass, elk sedge, and snowberry. Bitterbrush occupies localized dry sites that were heavily scarified.

The transition shown on the moist habitat types begins with stands dominated by large ponderosa pines and with some Douglas-fir. These had open understories and ground cover composed of low shrubs and pinegrass. After the 1907 to 1911 logging and subsequent fire suppression, vigorous pole and tall shrub communities of Douglas-fir, ponderosa pine, and Scouler's willow developed, with a low shrub and pinegrass ground cover beneath. Thinning of the poles since 1950 kept the willow from becoming badly suppressed.

Photopoint captions contain interpretations of stand changes. These were taken from Gruell and others (1982) but updated by Helen Y. Smith, Stephen F. Arno, Michael G. Harrington, and Dennis G. Simmerman for 1989 and 1997 photos (Photopoints 1 through 14).

Ecosystem-Based Management Treatments

Stephen F. Arno

The Need for Ecosystem Management

At Lick Creek, from 1906 until the 1980's carefully guided harvesting had selectively removed large trees, retaining vigorous ones but allowing unmerchantable small trees to proliferate. The small trees were occasionally thinned by hand, but this was expensive and generated hazardous slash fuels. In contrast, for hundreds if not thousands of years prior to 1900, frequent low-intensity fires had shaped the forest by killing most of the small trees and maintaining a low level of fuel loadings (Agee 1993; Arno and others 1995, 1997). Thus, the silvicultural activities evaluated by Gruell and others (1982) contrasted with the pre-1900 natural forest succession in having no counterpart or substitute for frequent low-intensity fires.

To understand why traditional forestry treatments failed to account for the ecological role of fires, we must recognize that the art and science of forestry was developed in a humid region—Prussia, Germany, and northern France—where fires were uncommon and were considered destructive and unnecessary. At the beginning of the 20th century, European concepts became the basis for forestry in the United States, where, however, forestry was being applied in environments where natural fires had a vital role in establishing and maintaining certain desirable forest conditions, as was initially recognized by Gifford Pinchot (1899). Nevertheless, wildfires, many of which were set by careless humans, had become a serious hazard. Thus, the fledgling forestry profession in the United States soon advocated eliminating fire in the forest.

By the mid-1900's, undesirable effects associated with exclusion of fire were becoming apparent in ponderosa pine ecosystems. The first forester to publish the case for restoring a semblance of the fire process in ponderosa pine was Harold Weaver (1943). By the 1970's and 1980's many National Forests were interested in integrating prescribed fire into ponderosa pine management, but this was not a simple matter of re-introducing natural fires. Fire could not be allowed to spread across millions of acres of public and private land as it had done prior to 1900 (Barrett and others 1997). Even if confined to designated stands, fire would have to be re-introduced cautiously so as to avoid damaging too many trees. The forests were now too dense with understory trees, and surface fuels had accumulated to high levels as a result of 70 or more years of fire exclusion efforts.

Forest Planning Sets the Stage

In 1987, the newly completed forest plan for the Bitterroot National Forest suggested that management take into account natural ecological processes. Soon afterwards, the Darby Ranger District conducted an Integrated Resource Analysis for the Lick Creek area, obtaining input from a broad range of interested publics and natural resource specialists to define objectives for the area. This process, guided by the National Forest Management Act, resulted in a "desired future condition" for the area and a list of management activities that would begin moving the Lick Creek landscape toward that goal.

During the meetings to identify pertinent issues, the idea of making the Lick Creek area a demonstration/research forest took shape. The historical photo sequences and records of early silvicultural cuttings and tree growth response were recognized as a unique and valuable asset. The original stands at Lick Creek and elsewhere in the ponderosa pine zone of the Bitterroot National Forest contained large trees primarily in an open park-like structure (Leiberg 1899). They were uneven-aged and largely self-perpetuating as a result of frequent fires (Arno and others 1997; Gruell and others 1982). In the 1980's, despite several harvest cuts and thinnings, conifer stands were very dense and wildlife forage (grasses and shrubs) was reduced compared to conditions shown in the 1909 to 1938 photographs (Gruell and others 1982). By the 1980's, insects and disease were impacting forest health. Also, the growing risk of severe wildfire was demonstrated by several wildfires that burned in the ponderosa pine forests in the Bitterroot National Forest and elsewhere in the Northern Rockies (Williams 1995).

The challenge that was identified during planning meetings was to guide management of the Lick Creek area toward stand structures that would improve wildlife habitat, esthetics, and tree growth. To this end, the Bitterroot National Forest, the Intermountain Research Station, and The University of Montana entered into a cooperative agreement in 1991 to conduct studies to provide a basis for ecosystem management in Lick Creek and similar landscapes.

Considerations for Ecosystem Management at Lick Creek

Ecosystem management is a broad topic with many themes (Overbay 1992). For Lick Creek, which is representative of similar forests covering millions of acres of Northern Rocky Mountain landscapes, we elected to conduct studies that focus on a return to stand structures that are sustainable and consistent with historical fire occurrence in the area. In these studies we feature management of ponderosa pine, the long-lived seral species at Lick Creek in pre-1900 times. The idea is to develop stands that have a significant component of large-diameter pine trees, along with younger age classes and to maintain a large-diameter class indefinitely through time. Prescribed low-intensity fires would be scheduled periodically to regulate conifer regeneration, especially that of shade-tolerant Douglas-fir and grand fir.

Timber harvests scheduled coincident with the burning would be tailored to develop and maintain uneven-aged stand structures with a significant number of large trees through time. To accomplish this, new adaptations of traditional silvicultural systems (shelterwood and selection) would be used. Thinning and whole-tree removal of the smaller merchantable trees could help restore a more open stand structure that would allow for safer application of prescribed fire. Harvests could also generate funding necessary to finance treatments (Fiedler and others 1997). The first application of fire after long periods of fire exclusion might stress the leave trees and invite bark beetle attacks. However, if the largest and healthiest trees are retained, reducing stand density might improve their vigor before fire is applied.

To mitigate against the effects of fuel accumulation, fire could be applied early in a drying cycle, when the lower duff and large woody fuels were still moist (wet burn). Conversely, there is a need to test burning under drier conditions (dry burn) in order to expand the narrow window of opportunity for applying prescribed fire and obtaining satisfactory results. More specifically, we need to better understand the range of fuel moisture and weather conditions under which fire will consume an appreciable fraction of the fuelbed but will not damage leave trees, be difficult to control, or cause excessive smoke problems to nearby residents or communities.

The silvicultural cutting and prescribed burning treatments would be designed to benefit wildlife habitat (especially forage production), esthetics and recreation, timber production, and forest protection (fire, insects, and disease) by complementing the natural ecological processes. The form of timber harvesting conducted here would contrast with earlier harvests, a primary difference being the strong focus on the reserve stand in terms of density, structure, and species composition. This harvest is being used to reduce stand densities while retaining the most vigorous trees, to manipulate species abundance, and to prepare the stands for low-intensity fire.

Experimental Treatments

Three kinds of ponderosa pine/Douglas-fir stands at Lick Creek covered areas large enough to allow for the kind of multiple treatment units (replications) preferred for scientific testing (fig. 16). Tree density in all three stand types was high enough so that individual pines were growing slowly and were vulnerable to severe wildfire or insect damage. Douglas-fir made up no more that 20 percent of the overstory in each experimental stand, but Douglas-fir saplings were numerous. In cooperation with the Darby Ranger District, we developed a different kind of silvicultural cutting treatment for each of the three experimental stands consisting of 80 to 100 acres each. Within each silvicultural cutting system, we applied different underburning strategies as well as no burn treatments (table 5). Similar treatments were carried out operationally by the Darby Ranger District outside the experimental stands, so that the entire treatment area in the ponderosa pine forest at Lick Creek covered about 530 acres. This entire area was treated using a conventional timber sale. It produced 1.475 million board feet of sawlogs and plywood peeler logs and was purchased for $147,610 by Champion International Corporation of Missoula, Montana.

Leave trees were marked by National Forest crews with guidance from researchers. The harvesting was done in all three experimental stands in 1992 using conventional techniques—chain saw felling followed by winch yarding to designated trails and skidding by a crawler tractor. (Within a few years preferred logging techniques had changed to favor mechanical harvesting machines. Also, timber values had increased enough to allow use of low-impact harvesting equipment.) To control the amount of slash fuels created, limbs were left attached to the harvested logs. Limbs were removed, piled, and burned at roadside

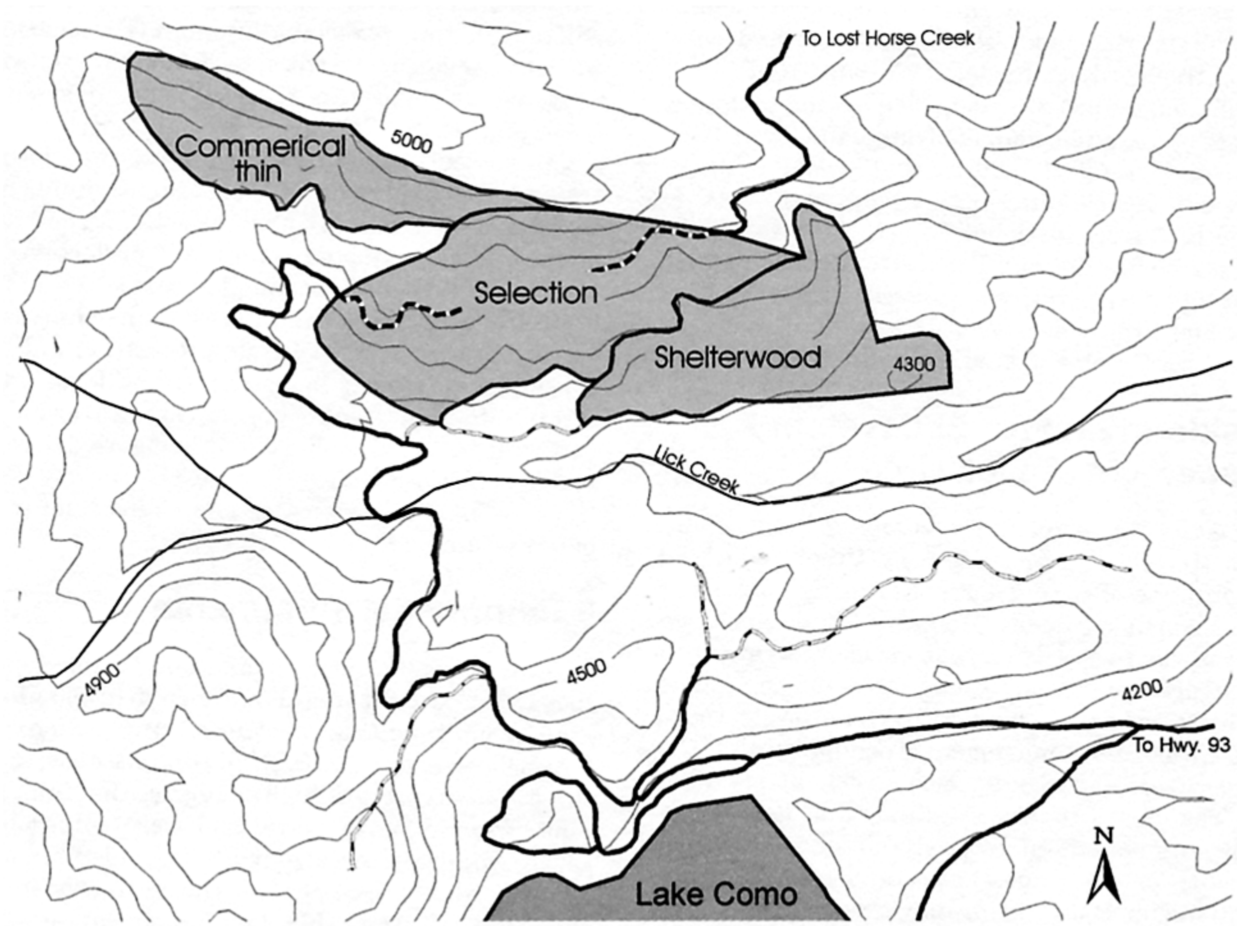

Figure 16—Location of 1990's ecosystem-based management treatment areas at Lick Creek.

landings. To provide an input of foliar nutrients and large woody debris to the soil, the tree tops—cut at about 6 inches in diameter outside the bark—were left on the site (Graham and others 1994). Broadcast underburns consumed the finer branches but not the green wood in the tops.

The following effects of the differential burn treatments were measured and compared: fuel reduction, tree mortality and growth response, undergrowth species response, tree regeneration, soil nutrients, and response of wildlife browse shrubs. Associated studies measured human visual preferences for different restoration treatments. Also, bird abundance and foraging behavior was measured in relation to shelterwood and underburning treatment, as was the comparative quality (for wildlife habitat) of snags

Table 5—Summary of experimental treatments applied within the shelterwood and selection cutting units and the commercial thin unit at Lick Creek.

	Shelterwood cutting	Selection cutting	Commercial thin
Control (no cut/burn)		X	
Cut/no burn	X	X	X
Cut/low consumption burn ("wet burn")	X		
Cut/intermediate burn ("intermediate burn")		X	
Cut/high consumption burn ("dry burn")	X		
Cut/fall burn			X
Cut/spring burn			X

created by fire versus mechanical girdling. A synopsis of study findings is reported in the next section, Effects of Ecosystem-Based Management Treatments.

Shelterwood Treatments

One of the experimental stands at Lick Creek was predominantly second-growth ponderosa pine 80 to 85 years of age that arose on what was originally private land. It is the area shown in photopoint 7, which was essentially clearcut in 1906 and later became part of the Bitterroot National Forest. By 1991, this stand was representative of many second-growth pine stands in the Northern Rocky Mountains. It supported an average of 240 trees and 120 square feet (ft^2) of basal area per acre. The dominant trees were mostly between 15 and 18 inches in dbh, and most of them were experiencing slow growth due to high tree density. Bark beetle mortality was occurring and might reach outbreak levels. Ladder fuels (patches of understory firs) and accumulating surface fuels were sufficient to create a risk of high tree mortality if a wildfire occurred. Many plants were being shaded out by dense tree cover.

The cutting treatment conducted in this experimental stand was a retention or irregular shelterwood in which the largest, healthiest pines were retained with a target stocking of 40 ft^2 basal area per acre. One goal of the cutting was to open the stand sufficiently to allow some successful regeneration of pine, which would then develop into a second age-class. In the future, periodic additional shelterwood cuts and underburns would be conducted, allowing more pine age classes to become established, until an uneven-aged stand with some large old trees had developed. At that point, a selection system could be applied to maintain the stand indefinitely into the future.

Three kinds of follow-up treatments were conducted, each on three separate experimental units of 4 to 10 acres. These were a “dry burn” (lower duff is dry), also referred to as a high consumption burn; “wet burn,” referred to as a low consumption burn; and a “no burn” treatment (fuels left untreated). All burns were conducted in the spring of 1993.

Selection Treatments

Another experimental stand at Lick Creek comprised primarily uneven-aged ponderosa pine ranging from seedlings to old-growth trees up to 40 inches dbh and 400 years of age. Younger trees in this stand, under about 18 inches dbh, became established in response to past partial cuttings. A modified individual tree selection cutting prescription, developed by Carl Fiedler of The University of Montana’s School of Forestry, was carried out in this stand in the fall of 1992. The stand had about 110 ft^2 of basal area per acre and was leave-tree marked to retain 50 ft^2 per acre of the most vigorous pines across the full range of diameters. Additionally, an average of one snag or potential snag per acre was retained for wildlife habitat. Scattered small openings of 1⁄4 to 1⁄3 acre were created in the marking process to provide conditions favorable for the regeneration of ponderosa pine. Approximately 20 percent more trees were left in each successively smaller (4-inch) diameter class to account for mortality over time and to ensure sufficient recruits into the larger size classes in the future. The long-term goal is to repeat selection cuttings at 25- to 30-year intervals for the purpose of regenerating ponderosa pine, adjusting species composition, and sustaining the uneven-aged structure.

In the spring of 1993, three selection cutting units were underburned with a prescribed fire when fuel moistures were intermediate, between a “dry” and “wet” burn (cut/burn treatment) (fig. 17). Three selection cutting units were left unburned (cut/no burn treatment) and three units received neither cutting nor burning (control treatment).

Commercial Thin Treatments

The third experimental stand was dominated by pole-sized ponderosa pine about 70 years of age, that arose after past partial cutting. The stand was precommercially thinned in the 1960’s and slash left untreated. The trees responded to that thinning with rapid growth, and by 1991 the site supported an average of 85 to 100 ft^2 of basal area per acre. This is a high tree density for the steep, dry south-facing site; thus, by 1991 radial growth had slowed. The treatment was a commercial thinning with a goal of reducing the basal area to about 50 ft^2 per acre. This target basal area was calculated using the Growth Basal Area methodology (Hall 1987) to determine the basal area at which annual increment is predicted to be maximized. The merchantable tree boles, up to a 6-inch diameter top, outside the bark, were removed. The largest and most vigorous trees were retained. Thinning differs from a shelterwood harvest in that establishing pine regeneration is not a primary goal. Regeneration might be achieved regardless. If not, regeneration will be a goal after the next cutting, a retention shelterwood in 20 to 30 years.

Three thinning units were left unburned. To compare effects of the two different burning seasons, three units were burned in the fall of 1993 and three in the spring of 1994.

1992. Untreated second-growth (80-year-old) stand of ponderosa pine and Douglas-fir containing some older pines. Note large stump from 1907 to 1911 behind Douglas-fir in right front.

Figure 17—Example of ecosystem management treatements in the selection cutting unit at Lick Creek.

1992. Individual-tree selection harvest completed as described in the text. Douglas-fir in right front has been removed. Tree tops are left for nutrient cycling.

1994. One year later. Vigorous ground cover has developed.

1993. Two weeks after the prescribed burn to reduce slash fuel hazard. Note that herbaceous vegetation is beginning to emerge.

1997. Four years later. Percent ground cover has increased. Small pine seedlings (not visible) are present.

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

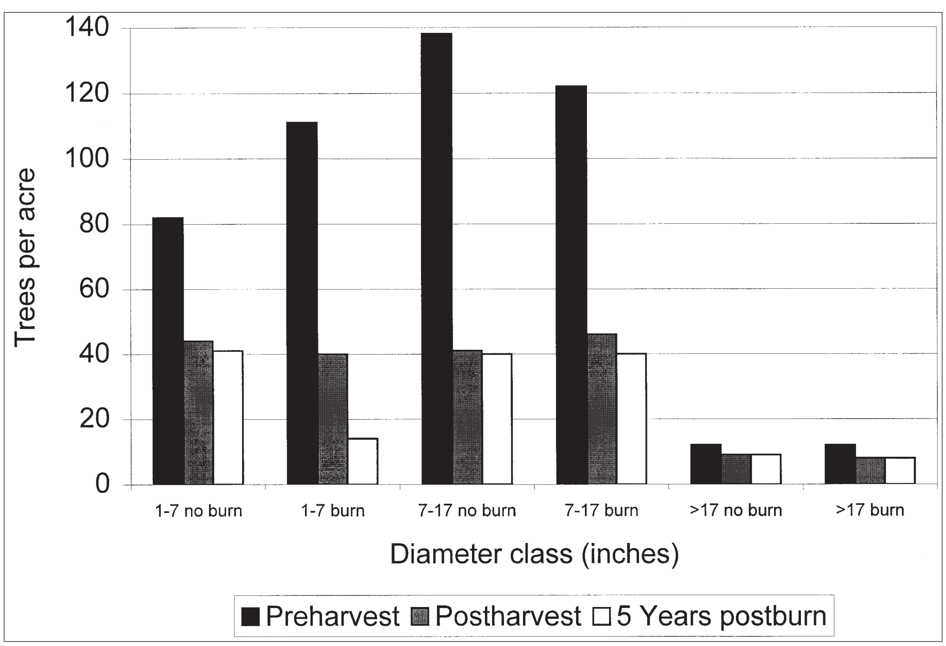

Figure 18—Tree reduction in the shelterwood no burn (a) and burn (b) treatments in three dbh classes.

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,

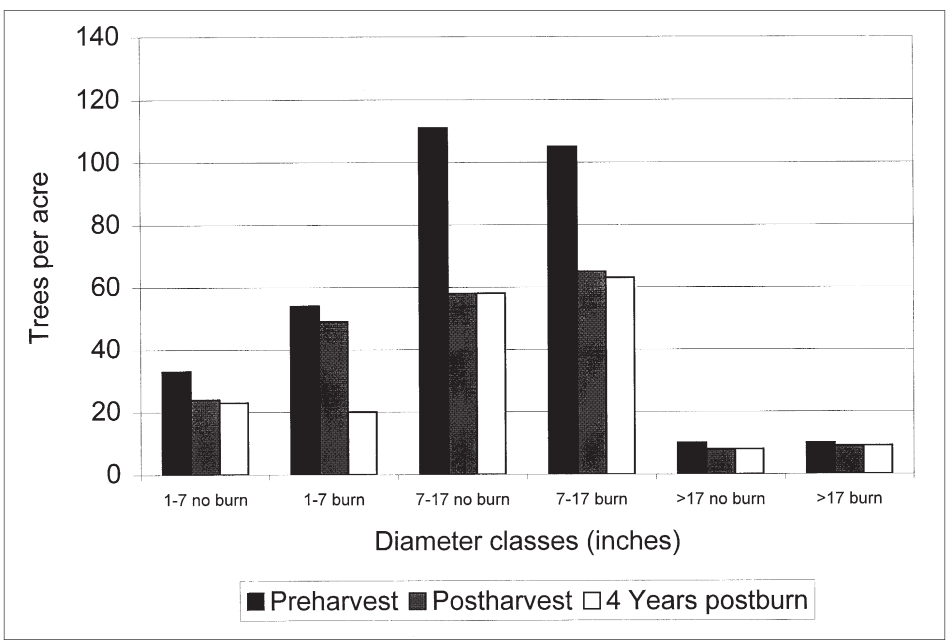

Figure 19—Tree reduction in the commercial thin no burn (a) and burn (b) treatments in three dbh classes.

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.

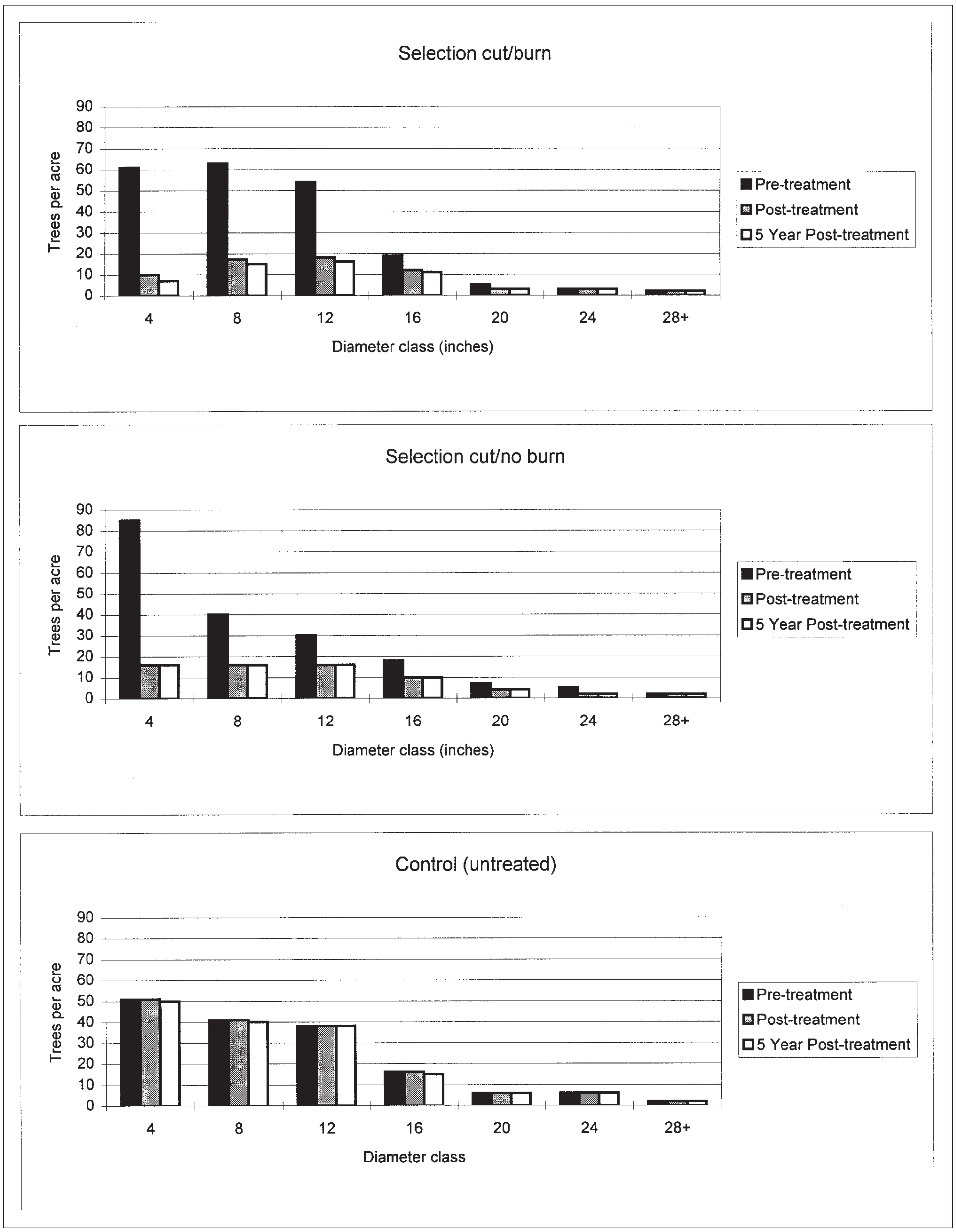

Figure 20—Trees per acre, by treatment and diameter classes, prior to, immediately after, and 5 years after treatment.

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.

All Causes: 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).

Fire: 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.

Beetles: 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).

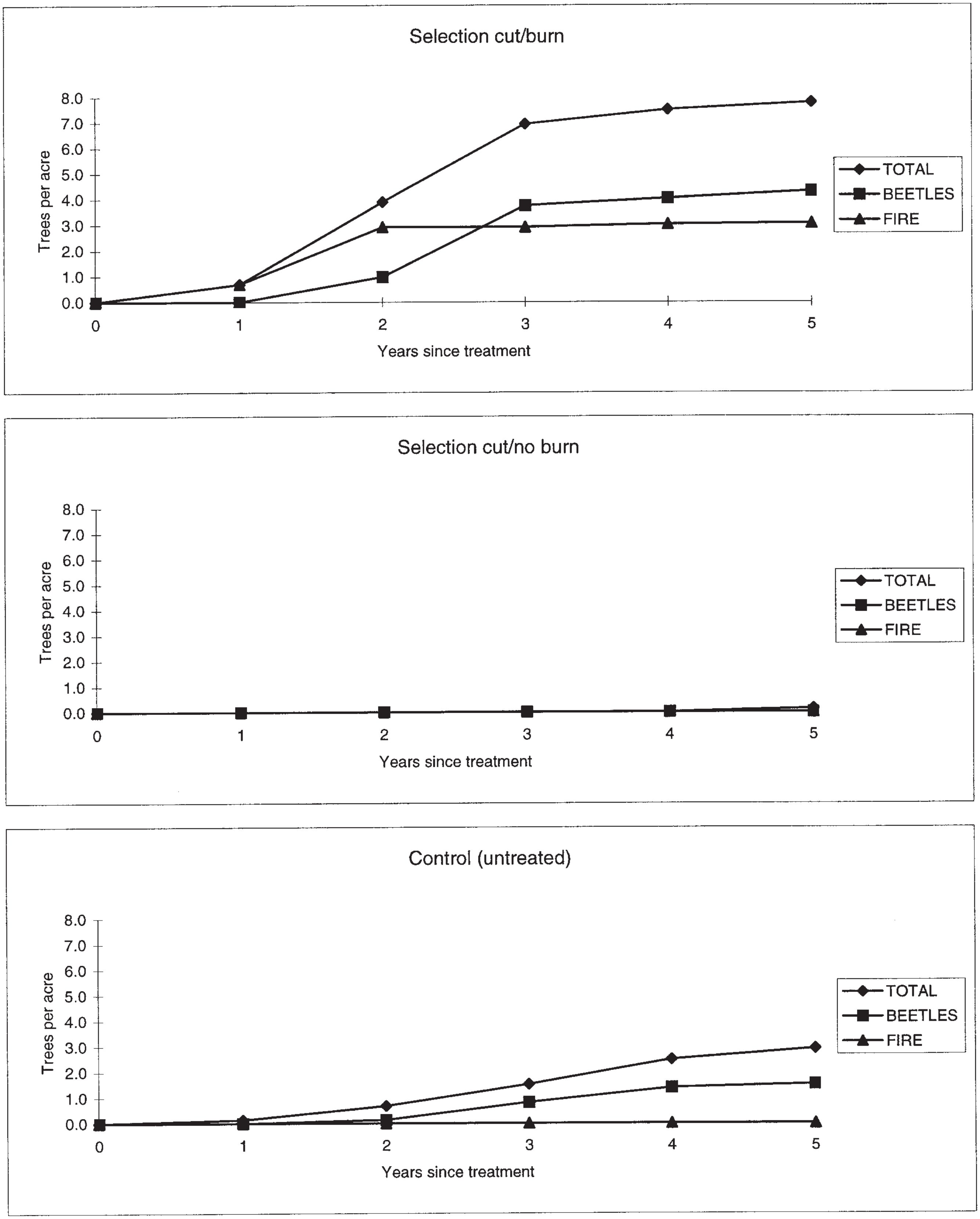

Figure 21—Cummulative annual mortality, by treatment and cause, for the 5 years 1993 to 1997.

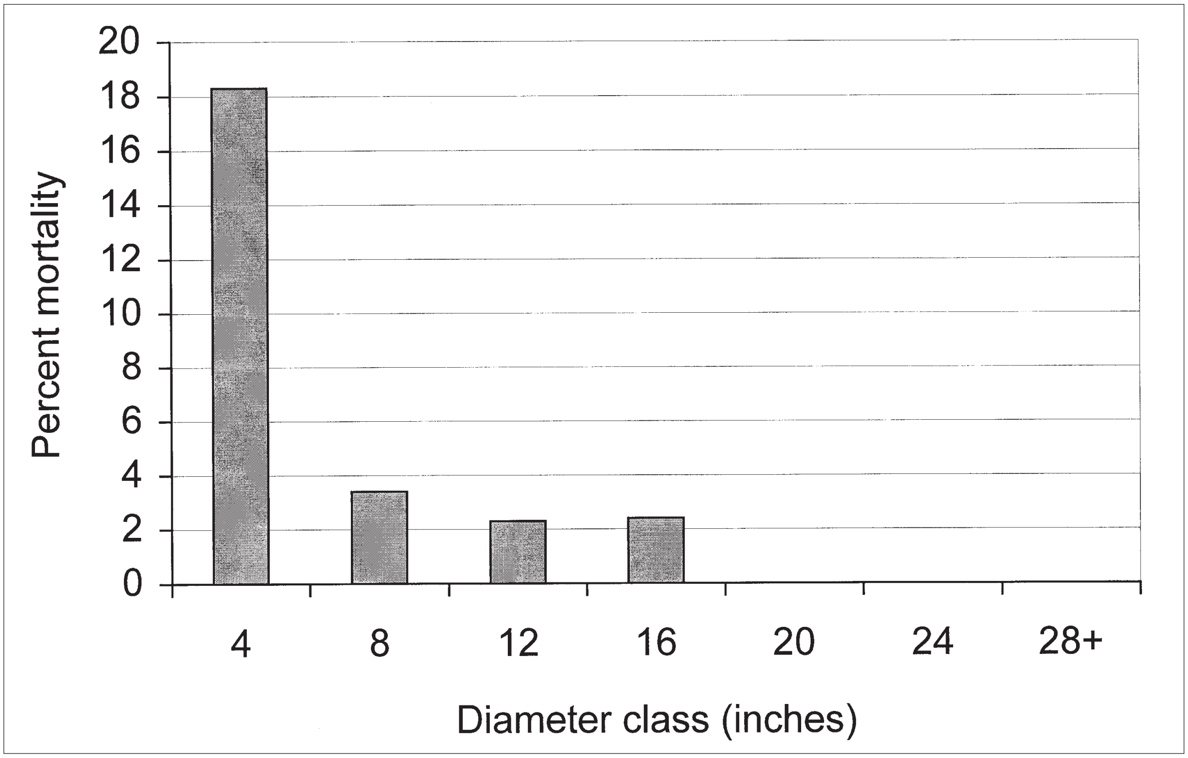

Figure 22—Fire caused mortality, by diameter class, for the 5 years 1993 to 1997.

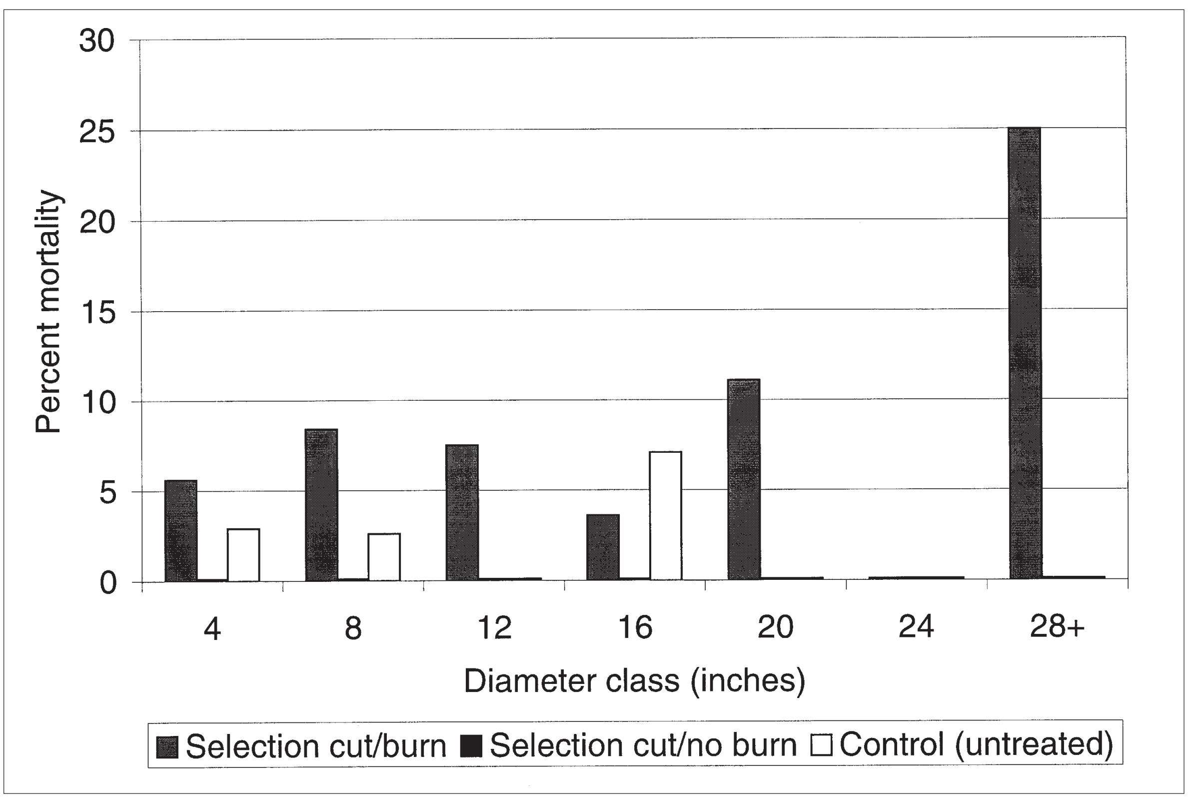

Figure 23—Beetle-caused mortality, by treatment and diameter class, for the 5 year period 1993 to 1997.

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.

Unit	Year 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

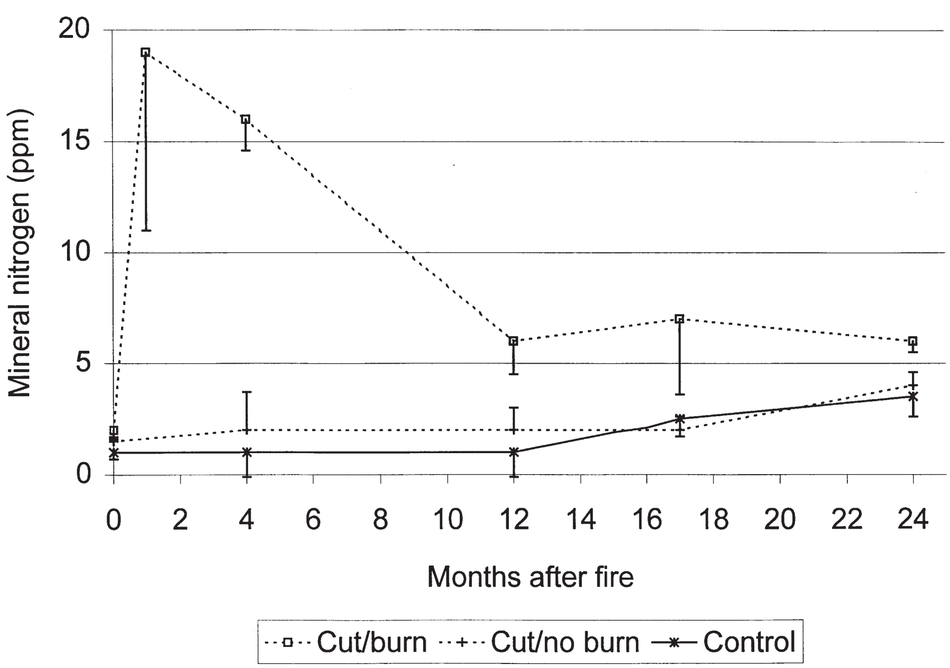

Figure 24—Effect of harvesting and prescribed burning on inorganic nitrogen in the surface 2 inches of mineral soil. ppm is parts per million.

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 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.

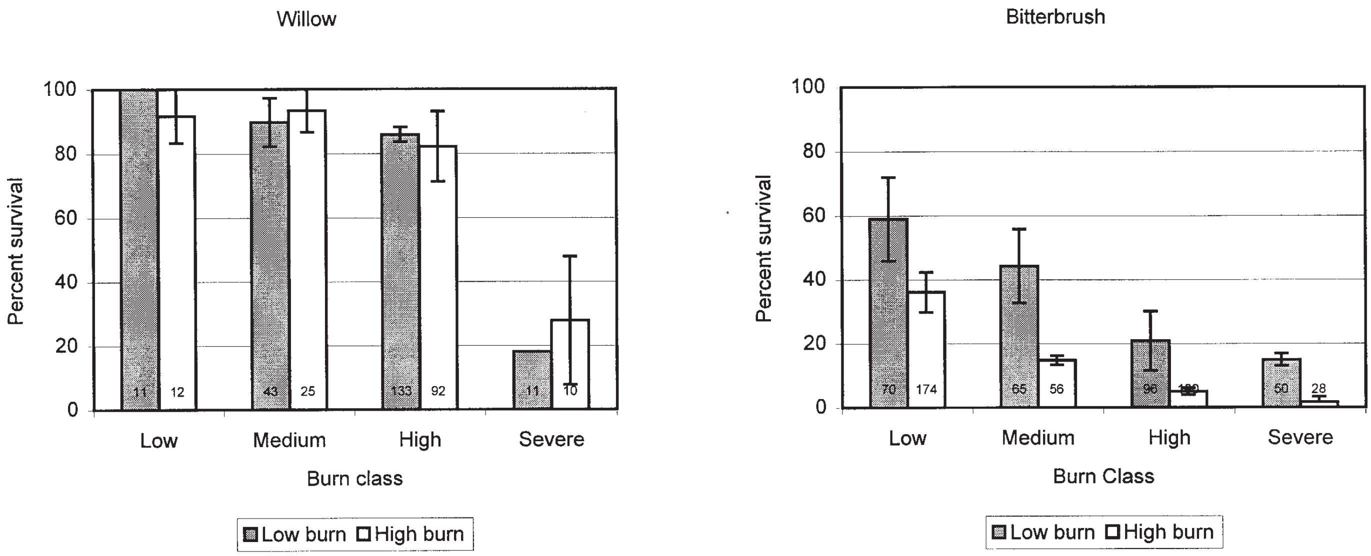

Figure 25—Percent survival of Scouler's willow and antelope bitterbrush by burn class.

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

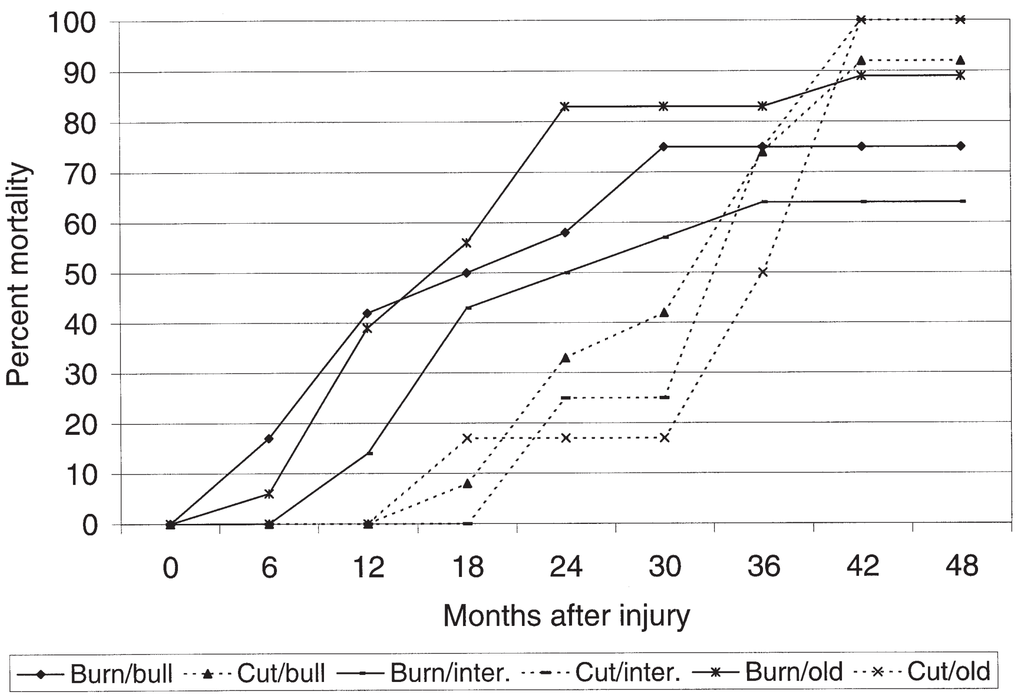

Figure 26—Percent mortality during the first 48 months after fire (burn) or saw (cut) girdling of ponderosa pine snag candidates. Three age classes are represented: bull pine, intermediate pine, and old-growth pine. See text for ages.

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.

Relevance of Lick Creek Ecosystem-Based Management Treatments to National Forest Management

Cathy Stewart

Treatments applied at Lick Creek were the first landscape-scale applications of ecosystem management on the Bitterroot National Forest. The coordinated effort between educators, researchers, resource managers, and the public helped gain acceptance and understanding of new approaches to management, both internally and externally. The longer skidding distances, high residual volume per acre, intensive marking guides, and underburning requirements all contributed to make the sale distinct from past sales and more difficult to sell and implement. However, if public land management is truly going to reflect ecosystem processes, structure and scale, these attributes will become the norm.

Not only do ecosystem-based management techniques meet many biological needs for species habitat, they also serve social needs. Large residual trees maintain visual quality and provide an aesthetically pleasing environment as well as watershed protection and wildlife cover and habitat. The application of prescribed fire reduces fuels and the threat of wildfire damage to neighboring homes and property. This is especially relevant on the Bitterroot National Forest, which surrounds the fastest growing county in Montana. Underburning also stimulates forage for big game, an important consideration because Lick Creek is a key winter range and spring calving area for elk.

With few old-growth ponderosa pine forests remaining relative to historical conditions, there will be fewer large-size pine logs produced from public lands. The Lick Creek sale allowed us to focus on removal of smaller material and highlighted the need to develop markets for this component. This will continue to be a need in the future as reduction of wildfire risk becomes more important.

Maintenance of the species composition over time may pose problems for some of the treatments. Due to the shade from the residual overstory, Douglas-fir will continue to out-compete ponderosa pine. Periodic application of fire can help ponderosa pine maintain dominance. However, the complex environmental and social conditions required for burning, as well as the added costs, may prevent application of fire on a regular schedule. Time will determine whether it is feasible to apply fire treatments frequently enough to maintain healthy multiaged stands of ponderosa pine at Lick Creek and on the millions of acres of similar forests elsewhere in the Inland Northwest.

Concluding Remarks

Stephen F. Arno and Michael G. Harrington

The 88-year photo sequences, descriptions of historical changes, and the initial results from ecosystem-based management treatments at Lick Creek portray a dynamic, ever-changing forest. The goals of ecosystem-based management at Lick Creek are to continuously maintain an open forest containing old growth as well as younger age classes of ponderosa pine. Half a century ago, Weaver (1943) and Biswell (1963) recognized that ponderosa pine forests were dependent on frequent low-intensity fires and that forest managers need to substitute prescribed fire for historical fires, often in combination with other fuel treatments and silvicultural thinning.

Evidence from Lick Creek shows that despite repeated silvicultural cuttings since the early 1900's, thickets of understory conifers (ladder fuels), down woody fuels, and litter fuels tend to increase in the absence of fire. Similarly, old-growth ponderosa pine/Douglas-fir stands show dramatic increases in understory conifers and fuel accumulation with fire exclusion (Arno and others 1995, 1997). At Lick Creek, the 1907 to 1911 and 1952 to 1980 partial cuttings were followed by vigorous regeneration of ponderosa pine. The 1990's ecosystem-based management treatments that included underburning have already been followed by natural regeneration of ponderosa pine with fewer Douglas-fir, whereas the cut/no-burn areas have a higher proportion of Douglas-fir regeneration, much of it established before the logging treatments.

In the early 1900's, foresters were concerned that an increase in Douglas-fir at Lick Creek would result in proliferation of dwarf mistletoe. Dwarf mistletoe outbreaks are not evident at the photopoints, probably because of frequent cuttings that deliberately removed a higher proportion of Douglas-fir. In contrast, in some stands at Lick Creek where Douglas-fir became abundant soon after the early 1900's cuttings, dwarf mistletoe has reached epidemic levels. Throughout much of this region, removal of large pines and exclusion of frequent fires has often resulted in second-growth forests dominated by Douglas-fir so severely infected that they appear incapable of producing large, long-lived trees. Dwarf mistletoe infestations produce bushy "witches brooms" that are highly flammable and increase the intensity of fires.

Another result of greater stand densities and increased proportions of Douglas-fir in this forest type has been increased defoliation by western spruce budworm (Anderson and others 1987). Tree mortality from root pathogens such as *Armillaria* spp., *Heterobasidion annosum* (formerly *Fomes annosus*), and *Philinus weirii* shows a similar trend related to the post-1900 structural and compositional changes in the ponderosa pine/Douglas-fir forest (Byler and others 1990). Comparable changes in stand structure and related forest health problems linked to fire exclusion have been identified in ponderosa pine forests throughout much of the Western United States (Clark and Sampson 1995; Covington and others 1997). Restoration treatments have been attempted in many areas, but usually the treatments and their effects have not been monitored and evaluated. Most research studies have examined only a narrow set of treatment effects. Prescribed burning has been studied, but usually not in combination with the cutting treatments necessary to restore a more natural stand structure before burning.

The observations and studies at Lick Creek are useful because they combine a long record of stand conditions and responses to a variety of silvicultural regeneration cuttings and thinnings, different burn prescriptions, and multidisciplinary studies of treatment effects. The 1990's treatments incorporated combinations of silvicultural cutting and prescribed fire carried out over a few hundred acres in an economical manner. The cut/no-burn treatments left large amounts of advanced regeneration of Douglas-fir, which will probably dominate the understory of the future stand. The low-, intermediate-, and high-consumption burns were successful in removing most of the small firs and in achieving significant fuel reduction with low levels of overstory tree mortality. The high-consumption burns were followed by moderate bark beetle-caused mortality that created additional small openings. The high-consumption burns represent the driest conditions usually acceptable for prescribed underburning.

A flush of available nitrogen followed cut and burn treatments. Some was evidently utilized by the postburn vegetation, which was then heavily grazed by deer, elk, and moose. Resprouting willow was browsed so heavily that it has been unable to grow vertically except where it was protected in wire cages. With so little of this burned lower elevation ponderosa pine forest available, and with high elk and deer populations, browsing use becomes concentrated on areas where nutritious browse is available.

It is a daunting challenge to restore the fire-dependent forest at Lick Creek after nearly a century of fire exclusion and having missed about a dozen natural fire cycles. Fuels have accumulated, trees may be experiencing growth stagnation related to overstocking and lack of sufficient nutrient cycling, and fine roots may be growing close to the soil surface and thus vulnerable to fire damage. Invasive nonnative plants are established and likely to increase with any disturbance. The evidence from Lick Creek and other areas, however, suggests that even well-designed silvicultural cuttings not accompanied by fire are inadequate for sustaining wildland ponderosa pine/Douglas-fir ecosystems. Prescribed fire can control the excessive number of saplings and reduce surface fuels, recycle nutrients in a semblance of natural processes, and reduce the risk of severe wildfire (Scott 1998).

"Preservation," protecting the stand from both cutting and fire, is another alternative, but this approach exacerbates problems of growth stagnation and vulnerability to severe damage from wildfire and insect or disease epidemics. Some people argue that preservation represents a conservative approach to maintaining a semblance of the natural ecosystem, but this fails to recognize that these ecosystems were historically dominated by plants and animals adapted to frequent low-intensity fires, not to fire exclusion. Moreover, preservation will likely eventually result in an unusually severe wildfire, which may have damaging effects, for instance, in triggering accelerated erosion or mass invasion of nonnative vegetation.

Because of the excessive stocking of mid-sized trees, returning fire without a prepatory silvicultural cutting would either be ineffective (failing to thin the stand) or too destructive (causing mass mortality) (Arno and others 1996). Once the initial restoration treatments have been completed, however, it should be easier to maintain the stand in some semblance of natural structure at low risk to severe wildfire or insect/disease epidemics by continuing use of prescribed fire, with or without silvicultural cuttings.

The ecosystem-based management treatments produced an array of changes from significant to subtle, from transient to long-term, some of which would be considered positive and some negative. Considered desirable are the open stand structure and removal of the Douglas-fir understory as designed by the cutting prescription and improved upon by the fire treatments. Natural conifer regeneration appears successful with the burn treatments producing microsites more favorable to ponderosa pine. The fire hazard has been reduced somewhat by consumption of surface fuels, but more important is the reduction of ladder fuels. However, burning of forest fuels means consumption of site organic matter and transformation of mineral nutrients. The short-term flush of available nitrogen following burning may have a brief fertilization effect, but a lessening of available nitrogen may subsequently result. The general increase in understory herbaceous and shrubby plant cover with treatments is also a positive response, with the exception of bitterbrush, a favored browse species that was moderately reduced by the harvesting and greatly reduced with the addition of burning. Regeneration of bitterbrush is now likely, however. Vigorous expansion of knapweed from all treatments could have deleterious impacts on native vegetation although it appears that knapweed increases following forest preservation and eventual severe wildfire as well. As with plant response, some bird species declined with treatments, some were unchanged, and others increased. These changes are likely to be temporary. An esthetic decline was indicated with harvesting and burning, but as the forest recovers, an increase in acceptance is expected.

Each of these individual responses to treatments at Lick Creek have been subjectively evaluated as favorable or deleterious. However, the most comprehensive appraisal of these treatments should look at responses collectively rather than individually. The prominent preharvest stand feature was excessive tree density that had resulted in reduced overstory vigor from competitive stress, diminished health and cover of understory vegetation, and rather continuous ladder and crown fuels that would support a stand-replacing fire. Thinning both the overstory and understory trees was essential for overcoming competitive stress among trees, rejuvenating understory vegetation, and reducing the threat of a severely damaging wildfire. The fire treatments reduced the fire hazard further and eliminated the opportunity for understory Douglas-fir to quickly grow into the overstory. Concurrent impacts of the thinning and burning activities were mortality of understory vegetation, soil disturbance that led to spread of knapweed, reduction of potentially mineralizable nitrogen, lessening of esthetic values, and reduction in habitat of certain birds. Many of these are temporary, but all are anticipated consequences that accompany activities to improve general health, diversity, and sustainability of this forest. The fire, wind, and insect disturbances that resulted in forest stability during past centuries likely caused temporary changes in individual site attributes that might be considered negative, such as those described in these studies. But in the long term, they created the vegetative and edaphic conditions that produce a forest represented by all aged, well-spaced trees with a diverse and vigorous understory that was resistant to catastrophic change. The seemingly negative specific responses described in the these ecosystem-based management studies can, therefore, be viewed as necessary consequences of forest restoration activities that impact site features in a manner thought to resemble that of historic fires.

It seems clear that ecosystem-based management projects of this scale—a few hundred acres being accomplished over 2 years—are attainable by the Forest Service and acceptable to the public. The ecosystem-based management treatments were well accepted by the visiting public, with the aid of educational efforts to explain the reasons and goals for treatments. This scale of treatment, however, is inadequate for restoring and maintaining any substantial fraction of the ponderosa pine forest on National Forest lands in this region. For instance, if average intervals for maintenance treatments were 25 years for 1 million acres of this forest type in western Montana, 40,000 acres would require treatment each year. The Interior Columbia Basin Ecosystem-Based Management Project evaluation calls attention to the need for large-scale restoration treatments, including prescribed burning (Quigley and others 1996). The long-term records from Lick Creek coupled with evaluations and research on the 1990's ecosystem-based management treatments should provide valuable insight for planning restoration efforts elsewhere in ponderosa pine forests. We suggest that these long-term efforts of treatment application, monitoring, and evaluation at Lick Creek continue into the future to build upon and adapt the knowledge already gained toward the goal of ecosystem restoration.

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Appendix B: Plants and Animals Names (Common and Scientific)

TREES

ponderosa pine	*Pinus ponderosa*
Douglas-fir	*Pseudotsuga menziesii*
grand fir	*Abies grandis*
spruce	*Picea engelmannii*
western larch	*Larix occidentalis*
aspen	*Populus* spp.
white fir	*Abies concolor*
blue spruce	*Picea pungens*

GRASS-LIKE

pinegrass	*Calamagrostis rubescens*
bluebunch wheatgrass	*Agropyron spicatum*
Idaho fescue	*Festuca idahoensis*
elk sedge	*Carex geyeri*
Ross' sedge	*Carex rossii*
wild rye	*Elymus glaucus*
Kentucky bluegrass	*Poa pratensis*

FORBS

arrowleaf balsamroot	*Balsamorhiza sagittata*
spotted knapweed	*Centaurea maculosa*
yarrow	*Achillea millefolium*
creeping dogbane	*Apocynum androsaemifolium*
fireweed (annual)	*Epilobium paniculatum*
bull thistle	*Cirsium vulgare*
Canada thistle	*Cirsium arvense*
thistle	*Cirsium* spp.
mullein	*Verbascum thapsis*
sheep sorrel	*Rumex acetosella*
horseweed	*Conyza canadensis*
lupine	*Lupinus* spp.

SHRUBS

snowberry	*Symphoricarpos albus*
dwarf huckleberry	*Vaccinium caespitosum*
blue huckleberry	*Vaccinium globulare*
kinnikinnick	*Arctostaphylos uva-ursi*
white spirea	*Spiraea betulifolia*
antelope bitterbrush (bitterbrush)	*Purshia tridentata*
Scouler's willow (willow)	*Salix scouleriana*
serviceberry	*Amalanchier alnifolia*
rose	*Rosa* spp.
Oregon grape	*Berberis repens*

INSECTS AND DISEASES

yellow pine butterfly	*Neophasia menapia*
mountain pine beetle	*Dendroctonus ponderosae*
western pine beetle	*Dendroctonus brevicomis*
bark beetles	*Dendroctonus* spp.
dwarf mistletoe	*Arceuthobium* spp.
western spruce budworm	*Choristoneura occidentalis*
Armillaria root rot	*Armillaria* spp.
Annosus root rot	*Heterobasidion annosum*
Laminated root rot	*Phellinus weirii*

ANIMALS

elk	*Cervus elaphus*
mule deer	*Odocoileus hemionus*
white-tailed deer	*Odocoileus virginianus*
moose	*Alces alces*
hairy woodpecker	*Picoides villosus*
black-capped chickadee	*Parus articapillus*
mountain chickadee	*Parus gambeli*
red-breasted nuthatch	*Sitta canadensis*
white-breasted nuthatch	*Sitta carolinensis*
brown creeper	*Certhia americana*
golden-crowned kinglet	*Regulus satrapa*

Appendix C: Summary of Vegetation Changes in Shelterwood Cutting Unit

Average percent cover for vegetation in the shelterwood cutting unit at Lick Creek by burn treatment.

		NO BURN					LOW CONSUMPTION BURN					HIGH CONSUMPTION BURN				
GENUS	SPECIES	Pre-Trt.	P1	P2	P3	P4	Pre-Trt.	P1	P2	P3	P4	Pre-Trt.	P1	P2	P3	P4
		Percent cover														
		1.8	3.7	4.1	2.3	1.4	1.9	7.8	8.0	4.7	2.5	1.6	9.0	8.9	4.3	1.8
SHRUBS																
Purshia	tridentata**	1.6	1.6	1.5	1.6	1.8	1.7	0.8	0.9	0.8	1.0	2.3	0.6	0.6	0.8	0.8
Rosa	species	1.4	1.0	1.0	1.3	1.9	0.6	0.6	0.5	0.8	0.9	0.9	0.6	0.7	0.9	1.0
Salix	scouleriana**	2.0	2.2	2.9	2.1	2.8	1.5	1.2	1.1	1.2	1.9	3.6	1.3	1.8	1.4	2.2
Spiraea	betulifolia	5.1	3.7	4.5	4.3	5.0	4.5	3.6	4.8	4.4	5.6	1.2	1.2	2.0	2.0	1.7
Symphoricarpos	albus	5.4	3.5	4.1	4.4	5.3	3.0	1.4	2.1	3.0	3.3	6.7	3.6	5.0	5.3	6.3
**Coverages from large shrub plots (1/300 acre)																
LOW WOODY PLANTS																
Arctostaphylos	uva-ursi	9.8	6.7	9.1	10.9	11.1	9.8	3.5	7.3	9.6	9.9	2.2	0.7	1.4	1.5	1.7
Berberis	repens	3.0	2.6	2.7	3.0	3.9	1.2	1.6	2.0	2.6	2.9	2.1	1.7	2.8	3.4	3.9
Vaccinium	caespitosum	1.0	0.5	0.8	0.9	0.9	1.8	0.6	1.1	1.0	1.8	0	0	0	0	0
GRASSES & GRASS-LIKE PLANTS																
Agropyron	spicatum	0.4	0.6	0.8	1.4	1.4	0.4	0.3	0.7	0.8	0.7	1.0	0.4	0.7	1.0	1.0
Calamagrostis	rubescens	7.4	4.8	8.1	7.7	8.2	7.7	5.4	9.9	10.1	9.9	6.1	3.5	7.0	6.9	8.2
Carex	concinnoides	0.1	0.1	0.2	0.2	0.2	0.4	0.4	0.8	1.0	1.4	0.1	T	0.1	0.3	0.4
Carex	geyeri	11.4	5.4	9.2	10.1	10.4	6.4	2.3	3.8	3.5	5.3	9.6	1.8	2.7	4.6	5.8
Carex	rossii	0.5	0.8	0.8	1.1	1.1	0.7	1.3	1.9	1.9	2.1	0.5	1.3	2.0	2.9	2.7
Festuca	octoflora	0	T	0.1	0.1	0.1	0.1	0.1	0.9	0.7	0.4	T	0.2	1.1	1.1	0.8
Koeleria	cristata	0.5	0.4	0.8	0.7	0.7	0.1	0.2	0.3	0.3	0.4	0.6	0.5	1.0	1.6	1.7
INTRODUCED GRASSES & GRASS-LIKE PLANTS																
Agrostis	species	0.3	0	1.0	1.3	0.7	0	0	0.2	0.7	0.7	0.1	0	0.2	0.4	0.4
Poa	species	0.1	0.4	1.6	2.7	2.1	0.2	0.1	0.3	0.3	0.2	0	0.1	0.2	0.5	0.6
OTHER HERBACEOUS PLANTS																
Achillea	millefolium	0.7	1.0	0.9	1.2	1.1	0.6	0.5	1.8	2.1	2.5	0.8	0.7	2.1	1.7	2.2
Apocynum	androsaemifolium	1.6	2.0	2.6	2.8	3.5	1.3	2.6	3.9	4.3	3.4	2.3	3.6	7.2	7.4	6.8
Arnica	cordifolia	2.8	2.0	1.7	1.9	4.2	1.4	1.2	1.1	0.8	1.5	0.8	0.9	0.6	0.4	0.8
Collomia	linearis	0.2	0.2	0.4	0.3	0.2	0.3	0.4	0.7	0.4	0.6	0.3	0.4	1.1	0.7	1.0
Epilobium	paniculatum	0.2	0.6	1.0	0.5	0.5	0.1	0.7	2.2	1.3	1.7	0.2	0.8	4.0	1.8	2.2
Fragaria	virginiana	0.7	0.7	1.0	1.1	1.5	0.4	0.5	0.9	0.9	1.3	0.3	0.4	0.7	1.0	1.2
Gnaphalium	species	0	0.1	T	0.1	0.1	0	0.1	0.2	0.2	0.5	0	0.1	0.3	0.7	1.1
Hieracium	species	0.4	0.5	0.5	0.6	0.8	0.6	0.6	0.8	0.8	1.6	0.4	0.5	0.7	1.1	1.3
Lupinus	species	1.1	0.9	1.8	1.8	2.7	0.6	1.1	3.5	4.8	6.6	3.2	3.0	3.5	3.3	4.0
Montia	perfoliata	0.1	0.2	0.1	T	0	T	0.2	0.2	T	0.1	0	0.8	1.0	T	T
Penstemon	species	0.3	0.3	0.7	0.8	1.0	0.4	0.4	0.6	0.7	1.4	0.1	0.1	0.2	0.3	0.4
Solidago	missouriensis	0.2	0.2	0.1	0.2	0.2	0.3	0.6	1.1	0.9	1.2	0.1	0.1	0.3	0.4	0.4
OTHER HERBACEOUS PLANTS-INTRODUCED																
Centaurea	maculosa	0.3	0.4	0.6	1.4	1.9	0.5	1.0	3.4	4.9	5.9	1.9	3.6	7.3	11.4	14.1
Cirsium	species	0	0.4	0.7	0.9	1.0	0	0.9	1.7	2.7	2.3	0	1.4	2.0	2.9	2.1
Conyza	canadensis	0	0	0.4	0	0	0	T	0.3	0.1	T	0	0	1.2	0.3	0
Rumex	acetosella	0	0.5	1.4	1.4	1.3	0.1	1.1	4.3	3.4	0.8	0	1.5	6.2	4.2	1.3
Verbascum	thapsis	0	0.4	0.8	0.3	0.1	0	2.7	3.6	1.6	1.2	0	3.2	4.9	2.2	1.3

(con.)

GENUS	SPECIES	NO BURN Pre-Trt.	NO BURN P1	NO BURN P2	NO BURN P3	NO BURN P4	LOW CONSUMPTION BURN Pre-Trt.	LOW CONSUMPTION BURN P1	LOW CONSUMPTION BURN P2	LOW CONSUMPTION BURN P3	LOW CONSUMPTION BURN P4	HIGH CONSUMPTION BURN Pre-Trt.	HIGH CONSUMPTION BURN P1	HIGH CONSUMPTION BURN P2	HIGH CONSUMPTION BURN P3	HIGH CONSUMPTION BURN P4
		Percent cover														
TOTAL UNIT PERCENT COVERAGES AND NUMBER OF SPECIES PRESENT BY VEGETATION TYPE																
Shrubs		15.8	12.1	14.2	13.9	17.0	11.7	7.6	9.6	10.2	12.9	14.9	7.3	10.1	10.4	12.2
	Number of species present	8	7	7	8	7	7	8	7	7	7	8	6	7	8	8
Low woody plants		13.8	9.9	12.5	14.7	16.1	12.8	5.7	10.4	13.6	14.6	4.3	2.3	4.1	4.9	5.6
	Number of species present	4	3	4	4	4	4	3	3	3	3	2	2	2	2	2
Grasses and Grass-like plants																
	Native species	21.4	13.3	21.2	23.3	23.6	15.9	10.3	18.6	19.1	20.9	18.0	7.8	14.8	18.8	20.9
	Number of species present	15	16	15	16	14	11	11	12	12	13	12	10	12	13	13
	Introduced species	0.4	0.9	2.8	4.1	3.0	0.2	0.2	0.8	1.2	1.0	0.1	0.4	1.1	1.9	1.8
	Number of species present	2	3	5	3	3	1	4	5	4	4	1	6	6	7	6
Other Herbaceous plants																
	Native species	12.2	11.8	15.0	15.5	20.7	8.9	11.5	20.9	20.1	25.9	11.8	14.8	25.5	22.0	24.9
	Number of species present	44	40	41	46	43	38	39	42	40	38	33	32	34	34	35
	Introduced species	0.7	2.4	4.9	4.8	4.7	0.8	6.1	13.8	13.1	10.8	2.0	10.2	22.6	21.7	19.7
	Number of species present	5	8	10	8	7	6	9	11	9	9	3	9	12	12	10
Total undergrowth cover	64.3	50.3	70.6	76.3	85.0	50.2	41.3	74.0	77.3	86.0	51.2	42.9	78.2	79.6	85.0	
	Number of species present	78	77	82	85	78	67	74	80	75	74	59	65	73	76	74

T = Trace amounts (<0.1% cover).

Other plant species found only in trace amounts (<0.1%):

SHRUBS
Alnus incana, Amelanchier alnifolia, Crataegus douglasii, Juniperus communis, Prunus virginiana, Rubus idaeus, Rubus parviflora, Rubus species, Vaccinium globulare

LOW WOODY PLANTS
Clematis columbiana, Linnaea borealis, Lonicera ciliosa

GRASSES AND GRASS-LIKE PLANTS
Bromus species, Calamagrostis purpurascens, Carex aurea, Carex species, Danthonia intermedia, Danthonia species, Danthonia unispicata, Elymus glaucus, Festuca idahoensis, Festuca occidentalis, Juncus species, Juncus tenuis, Luzula campestris, Stipa occidentalis, Stipa richardsonii, Stipa species, Trisetum species

INTRODUCED GRASSES AND GRASS-LIKE PLANTS
Agropyron intermedium, Agropyron species, Agrostis scabra, Bromus inermis, Bromus tectorum, Dactylis glomerata, Dactylis species, Phleum pratense

OTHER HERBACEOUS PLANTS
Allium cernum, Anaphalis margaritaceae, Antennaria anaphaloides, Antennaria luzuloides, Antennaria microphylla, Antennaria neglecta, Antennaria racemosa, Arabis species, Arenaria macrophylla, Aster conspicuus, Aster laevis, Aster species, Balsamorhixa sagittata, Brodiaea douglasii, Calochortus species, Campanula rotundifolia, Castilleja species, Cerastium arvense, Chimaphilla menziesii, Chimaphilla umbellata, Collinsia parviflora, Corallorhiza maculata, Corallorhiza species, Crepis atrabarba, Crepis species, Dodecatheon species, Epilobium angustifolium, Eiplobium species, Epilobium watsonii, Equisetum laevigatum, Equisetum species, Erigeron divergens, Erigeron species, Erigeron speciosus, Erythronium grandiflorum, Frageria vesca, Galium boreale, Galium triflorum, Geum macrophyllum, Goodyera oblongifolia, Hedysarum species, Hedysarum sulphurescens, Heucheria cylindrica, Lithospermum ruderale, Lomatium species, Lomatium triternatum, Microseris nutans, Montia linearis, Osmorhiza chilensis, Polygonum douglasii, Prunella vulgaris, Pterospora andromedea, Ranumculus acriformis, Sedum stenopetalum, Senecio integerrimus, Silene menziesii, Stenanthium occidentale, Thalictrum occidentale, Urtica dioica, Veronica americana, Viola adunca, Viola orbiculata

OTHER HERBACEOUS PLANTS-INTRODUCED
Cryptantha affinis, Erigeron strigosus, Filago arvensis, Lactuca serriola, Myosotis micrantha, Plantago major, Taraxacum species, Tragopogon dubium, Trifolium species

RMRS
ROCKY MOUNTAIN RESEARCH STATION

The Rocky Mountain Research Station develops scientific information and technology to improve management, protection, and use of the forests and rangelands. Research is designed to meet the needs of National Forest managers, Federal and State agencies, public and private organizations, academic institutions, industry, and individuals.

Studies accelerate solutions to problems involving ecosystems, range, forests, water, recreation, fire, resource inventory, land reclamation, community sustainability, forest engineering technology, multiple use economics, wildlife and fish habitat, and forest insects and diseases. Studies are conducted cooperatively, and applications may be found worldwide.

Research Locations

Flagstaff, Arizona
Fort Collins, Colorado*
Boise, Idaho
Moscow, Idaho
Bozeman, Montana
Missoula, Montana
Lincoln, Nebraska
Reno, Nevada
Albuquerque, New Mexico
Rapid City, South Dakota
Logan, Utah
Ogden, Utah
Provo, Utah
Laramie, Wyoming

*Station Headquarters, 240 West Prospect Road, Fort Collins, CO 80526

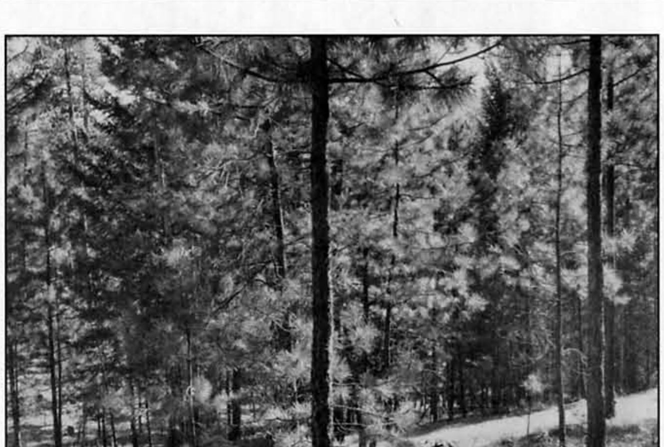
PHOTOPOINT 1
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Camera faces southeast toward Lick Creek scalers' cabin and clearcut on private land in distance. Ground cover is largely herbaceous species with high incidence of lupine. Scattered patches of low shrubs are also evident (PSME/SYAL-CARU h.t.). Scattered willows occupy the more moist sites below Ranger Earl Turner. A few widely scattered young conifers are also evident. (USDA FS Photo 86467)

1925. 16 years later. Establishment and growth of conifers has resulted in a marked change in the understory. Snag at right center was a living tree in 1909. (USDA FS Photo 204817).

1937. 28 Years Later. Former view is almost entirely screened by young ponderosa pine. The herbaceous understory does not appear to be as luxuriant as formerly. Willows in opening at left are considerably larger. (USDA FS Photo 354395)

1948. 39 Years Later. Continued growth of conifers has resulted in complete closure of understory in midground. Snowberry shrubs are evident. (USDA FS Photo 452646)



1958. 49 Years Later. Construction of system road has altered the soil surface in foreground. Shelterwood cut in 1952 is not apparent because of screening by young pine. (USDA FS Photo 487741)

1968. 59 Years Later. A selection cut in 1962 and precommerical thinning in 1966 have opened the stand and allowed appreciable growth. Willows can be seen below road. (USDA FS Photo 518769)

1979. 70 Years Later. View is once again screened by growth of young pines in foreground that became established on scarified soil following logging. A stand of bitterbrush, not pictured, behind camera point also regenerated as a result of disturbance. (USDA FS Photo).

1989. 80 Years Later. Young pines and Douglas-fir now almost entirely block view of larger ponderosa pine trees in center and right background (seen well in 1968 photo). (USDA FS Photo)

1997. 88 Years Later. No treatment is evident in this area since the 1960s. The young pines and Douglas-fir have now grown tall enough to allow some sight of larger trees in the background. The pines appear very spindly and overcrowded with the Douglas-fir being more dominant than in 1989. (USDA FS Photo)

PHOTOPOINT 2
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

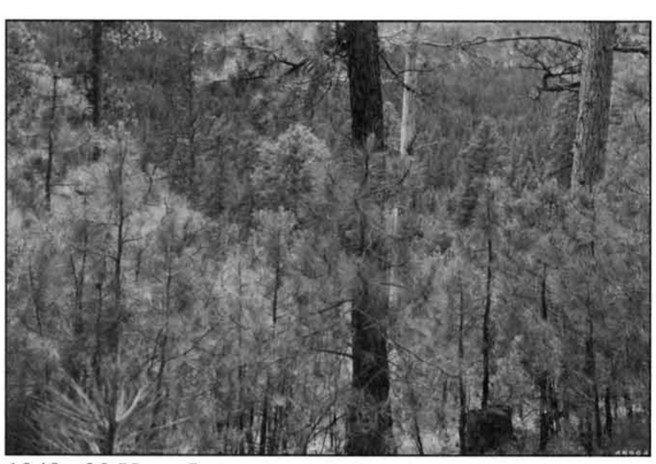
1909. Looking southwest across open ponderosa pine dominated slopes from a point 75 yards above photopoint 1 (dry extreme of PSME/CARU-PIPO h.t.). Original stand apprears to have been quite open before logging. A deeply incised skid trail is evident in midground. A few widely scattered young conifers and willows are growing on slopes below. Recent analysis of stump at feet of Ranger Tanner shows evidence of 5 different wildfires prior to logging. (USDA FS Photo 86475)

1927. 18 years later. Pine regeneration screen view, while some mature trees have fallen to the ground. An unidentified shrub now occupies site at right corner of photo. (USDA FS Photo 221277).

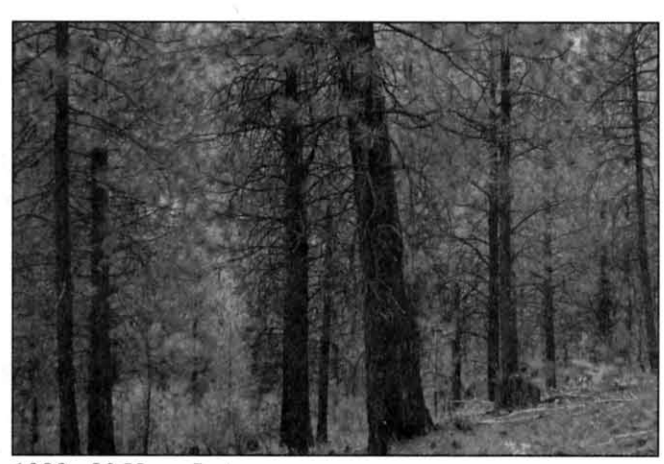
1968. 59 Years Later. Wyman Schmidt views selection cut in 1962 that removed the mature pine that had been present in left corner of photo since 1909. Precommercial thinning in 1966 has opened up foreground. Ground fuels have increased by addition of slash. Thinning has allowed leave trees to put on good growth. (USDA FS Photo 518776)

1937. 28 Years Later. View is completely screened by heavily over-stocked young pines. Pine at right center has died. Suppressed shrub at right corner of photo persists beneath canopy of young pines. (USDA FS Photo 354396)

1979. 70 Years Later. Thinning of the young pine stand has resulted in establishment of bitterbrush in left foreground and to right of old stump. Willows are also evident in foreground. Growth of young pines is accelerating. (USDA FS Photo).

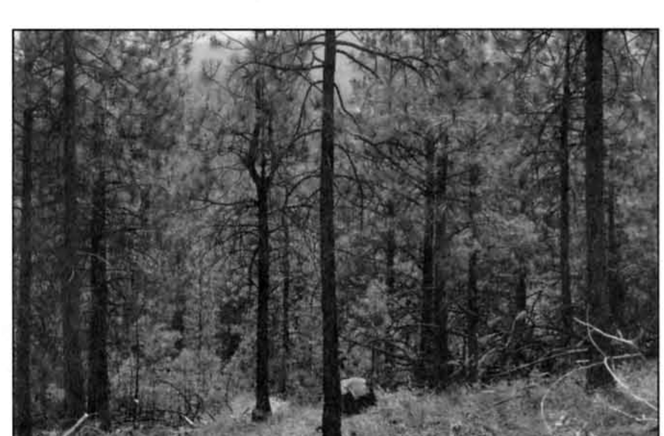


1948. 39 Years Later. Heavy stocking of young pines appears to have stagnated. Note fire mosaic on far slope that apparently occurred in 1875. Pine at left center has died. (USDA FS Photo 452645)



1989. 80 Years Later. Young pines continue to fill the understory. Willow in the foreground is barely visible and the bitterbrush seen in the 1979 photo is undetectable. (USDA FS Photo)

1958. 49 Years Later. A shelterwood cut in 1952 removed tree at right and snag is also gone. Young pines have grown modestly despite heavy overstocking, while buildup of ground fuels is evident. (USDA FS Photo 487742)



1997. 88 Years Later. Harvesting in 1992 removed the mature pine present since the 1909 photo, along with the smaller pine to the left. No burning was conducted in this area in 1993. Undergrowth is primarily elk sedge. (USDA FS Photo)

PHOTOPOINT 3
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. A northwesterly view of cleanup operation following cutting in an open-grown ponderosa pine (PSME/CARU-PIPO h.t.) stand. Although slash piles obstruct clear view, the understory apparently lacks shrubs. Perennial grasses and forbs predominate. (USDA FS Photo 86466)

1927. 18 years later. Young Douglas-fir and ponderosa pine have become established in the background. A few young pine are also scattered through foreground. Willows 4-6 feet in height now occupy site at right midground of photo. Others of similar growth form are also evident. Kinnikinnick predominates at base of tree at right foreground. Litter is beginning to accumulate. (USDA FS Photo 221278).

1968. 59 Years Later. A selection cut in 1962 and precommerical thinning in 1966 opened up the area considerably. Note decomposition of larger materials. Large willows at right contain many dead branches, but removal of young conifer competition has provided inproved growing conditions, A bitterbrush shrub has become established near tree in right foreground. (USDA FS Photo 518768)

1937. 28 Years Later. Ponderosa pine and Douglas-fir regeneration continues to close the understory in background. Growing conditions for young trees and willow have been enhanced by mortality and windthrown standing timber. Note growth of willow in right midground. Litter continues to accumulate. (USDA FS Photo 344401)

1979. 70 Years Later. Overstory canopy is more closed as a result of the tree growth. Willows at right show some new growth. New willows are evident in foreground, while the one in front of tree at left which became established between 1909 and 1927 is slightly larger than in former years. Note the increased size of the bitterbrush plant. (USDA FS Photo).

1948. 39 Years Later. Growth of understory now obstructs view of background. Willow at right midground is obscured by young pines. (USDA FS Photo 452643)

1989. 80 Years Later. The willow (center/right with the bitterbrush in front of it) appears to have fewer leaves and more dead limbs. Note the increased size of the bitterbrush stems (right foreground) and the absence of the leaning tree from the center of the stand. (USDA FS Photo)

1958. 49 Years Later. A shelterwood cut was made in this general area in 1952 but its influence is not evident. Continued growth of young conifers has resulted in a thicker understory. The large willows at right are becoming senescent. Litter buildup is heavy. Debris may be the result of 1952 logging outside view of photo. Kinnikinnick continues to predominate at base of tree at right. (USDA FS Photo 487746)

1997. 88 Years Later. Harvesting in 1992 removed the large ponderosa pine at the right. This site was not underburned in 1993. Although the willows appears dead in the photo, they are alive at the base as is the bitterbrush (in the logging slash). Note the flush of lupine (Lupine spp.) in the foreground. Additional ground cover is primarily kinnikinnick, elk sedge, and pinegrass. (USDA FS Photo)

PHOTOPOINT 4
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Looking northeast through a more heavily stocked ponderosa pine stand at a point about one-half mile northeast of photopoint 3. The ground cover around C. H. Gregory (in distance) and W. W. White is predominately herbaceous species with a high incidence of balsamroot (PSME/CARU-PIPO h.t.). The dark low-growing shrub around White appear to be snowberry. Large willows are evident on left edge of photo and in front of White. (USDA FS Photo 86469)

1927. 18 years later. The two willows in the 1909 scene have grown considerably and now contain many dead branches. Other willows have become established in midground, while young ponderosa pine can be seen in localized areas. The herbaceous ground cover persists. Taken later in the season, this view pictures balsamroot at a cured stage of growth. Note fire-scarred stump on right. (USDA FS Photo 221280).

1968. 59 Years Later. A 1962 selection cut and 1966 precommerical thinning have resulted in a more open landscape with increasing slash on the ground. The bitterbrush plants are more evident, while willows in the midground have been favorable influenced by removal of young conifers. (USDA FS Photo 518770)

1938. 29 Years Later. Young pine growth is beginning to occupy localized sites in understory. A tree on right has blown down, and the willow in foreground that was present in 1909 has become senescent. In foreground, the low shrub component is less evident, but this may be a seasonal difference. (USDA FS Photo 354400)

1979. 70 Years Later. Rapid establishment and growth of new conifers has screened the open view of 1968. Growing conditions for bitterbrush and willow have deterioated because of competition from conifers for sunlight and moisture. Partial cutting and thinning in 1952, 1955, 1962, and 1966 have allowed more conifer regeneration than the early, light 1906-09 cut. (USDA FS Photo).

1948. 39 Years Later. Two mature pines have fallen to ground. Growth of young pines are closing in portions of understory. Young pine at right foreground is screening senescent willow. Herbaceous plants and snowberry in foreground have put on good growth. (USDA FS Photo 452641)

1989. 80 Years Later. The small trees established shortly before the 1979 photo have grown into a thicket of saplings. (USDA FS Photo)

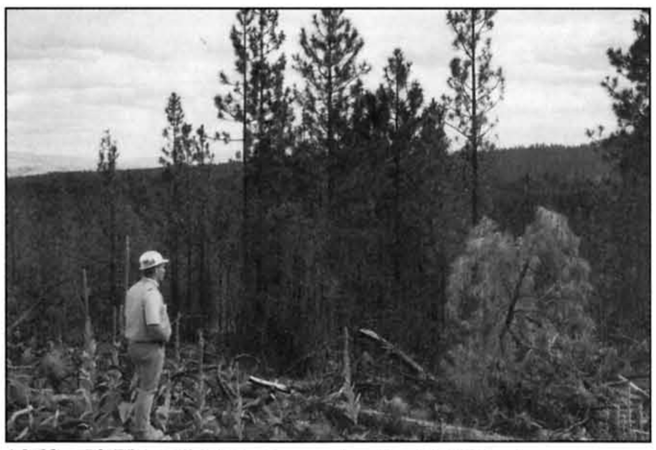
1958. 49 Years Later. A shelterwood cut in 1952 removed several of the merchantable trees and left slash on the ground. Plants occupying sites near left edge of photo appear to be bitterbrush. (USDA FS Photo 487747)

1997. 88 Years Later. This stand was not subject to management activities in 1992 and 1993. Note the rapid growth of the Douglas-fir trees in the foreground since 1989, masking the view of the slower growing ponderosa pines in the background. Undergrowth is primarily pinegrass and dogbane. (USDA FS Photo)

PHOTOPOINT 5
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

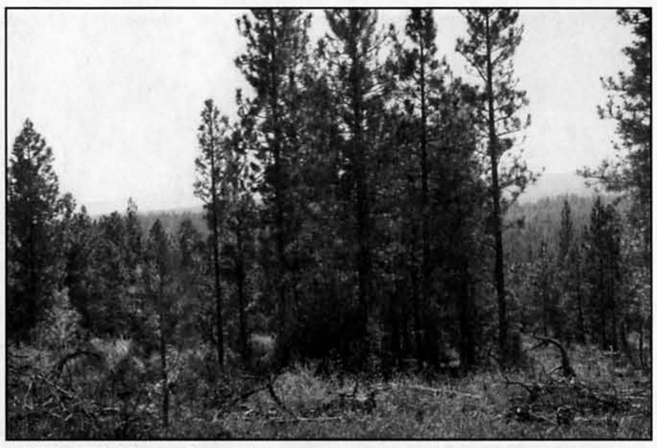
1909. The camera faces south-southeast into the Lick Creek drainage. Camera location for Photopoint 6 is below and to the left. E. C. Clifford examines partial cut which opened up the ponderosa pine stand (PSME/CARU-PIPO h.t.).(Note clearcut in distance pictured in photopoint 6) Understory is predominatly perenial grasses with high incidences of balsamroot. A low-growing willlow can be seen at left foreground, while other widely scattered willows are evident in background. (USDA FS Photo 86473)

1927. 18 years later. Ponderosa pine regeneration is profuse in midground. Willow in forground has grown considerably as has another on the left edge of photo behind tree. Down trees and brokes-top pines (center and right) evidently resulted from wind damage after stand was opened. (USDA FS Photo 221281).



1968. 59 Years Later. Construction of road in 1967 and overstory removal in 1968 resulted in considerable site modification. The willow in foreground of 1909 scene in front of William Chord had persisted despite heavy pine competition and is now of large growth form with little foliage near the ground. Mullein in foreground seeded in on disturbed soil. (USDA FS Photo 518774)

1938. 29 Years Later. Young ponderosa pine growth continues at a modest rate. Although willow at left has not leafed out, it appears to contain dead branches. Gradual loss of overstory trees continues. (USDA FS Photo 361707)



1979. 70 Years Later. Opening of stand in 1968 allowed good growth of pines and release and establishment of willow. The large willow in foreground shows new growth near ground level from suckering. Spotted knapweed dominates site in foreground. Far slope that was clearcut in 1909 is now covered by pole-size conifers. (USDA FS Photo).

1948. 39 Years Later. Understory is now dominated by young ponderosa pine. The pine in center foreground that was apparently dead in 1938 has lost its bark, while the two trees to the right have toppled. Opening of the overstory may have improved conditions for herbaceous plants. (USDA FS Photo 452650)

1989. 80 Years Later. Rapid growth of understory is evident. Note the difference in size of the young ponderosa pine at the left compared to 1979. Willow is still visible in the foreground. (USDA FS Photo)

1958. 49 Years Later. Photo was taken too far to the left, but it does show that young ponderosa pine have grown well, considering that they are heavily overstocked. The increased canopy in foreground appears to be restricting growth of herbaceous plants. (USDA FS Photo 487743)

1997. 88 Years Later. Thinning in 1992 and a high consumption burn in 1993 have opened this stand. The burn was intended to thin the overstory trees (see text). The ground cover is dominated by spotted knapweed. (USDA FS Photo)

PHOTOPOINT 6
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. The camera faces southeast in a ponderosa pine stand (PSME/CARU-PIPO h.t.) that has been selectively logged. W. W. White assesses the work. Understory vegetation is largely comprised of herbaceous species with balsamroot evident. Low shrubs in immediate foreground cannot be identified. Note clearcut on private land in distance. (USDA Forest Service Photo 86471)

1925. 16 years later. Ponderosa pine seedlings have become established while willow is evident, particularly in area formerly covered by slash pile at right. Blowdown has occurred in foreground while distant slopes (in the clearcut) support tall shrubs and conifer regeneration. (USDA FS Photo 204818).

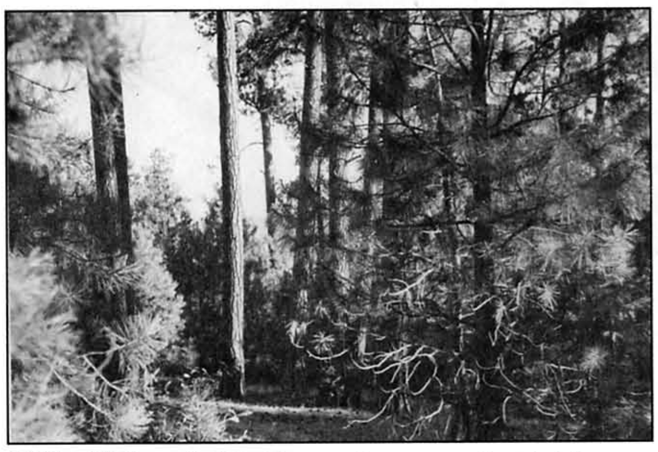
1968. 59 Years Later. Overstory removal in 1968 resulted in a landscape that is dominated by young ponderosa pine. Foreground has been heavily scarified by tractor skidding. After 59 years, willow on edge of stand at left center of photo contain much dead material. (USDA FS Photo 518772)

1938. 29 Years Later. The open park-like appearance of the understory has been replaced by dense patches of young ponderosa pine. Willows have grown appreciably, but are not yet leafed out in this April scene. Blowdown of an occasional overstory pine is resulting in reduced crown cover. (USDA FS Photo 361708)

1979. 70 Years Later. Ponderosa pine growth response to overstory removal has been very good despite poor condition of some trees in 1968. Scarified soil in foreground allowed establishment of pine seedlings, bitterbrush, willow, pinegrass. and knapweed. (USDA FS Photo).

1948. 39 Years Later. Growth of young ponderosa pine masks much of former view. Ground cover around Kenneth Boe is largely herbaceous species. Clearcut in distance now supports a developing conifer stand. Willows are suppressed. (USDA FS Photo 452648)

1989. 80 Years Later. Understory pines have grown considerably. The willows do not appear as vigorous. (USDA FS Photo)



1958. 49 Years Later. The camera has swung too far to the left. Increased development of the pine understory has created ladder fuels. Shading and litter accumulation apparently has inhibited herbaceous growth. (USDA FS Photo 487744)

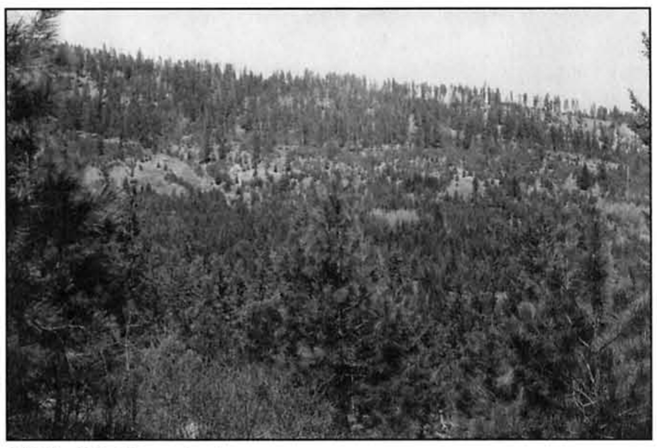
1997. 88 Years Later. Shelterwood harvesting in 1992 and a high consumption burn in 1993 opened the stand. Small pines in left foreground and some in midground were killed by fire and beetle attacks (see text). Willows in the right and left foreground sprouted following the fire and are still alive, but have been heavily browsed. Spotted knapweed and dogbane are the primary ground cover with some mullein. (USDA FS Photo)

PHOTOPOINT 7
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Looking north across part of 1906 clearcut on private land. Photopoints 5 and 6 are in conifers at right in distance. Foreground supported ponderosa pine and a higher complement of Douglas-fir than on other sites in the photo series (PSMA/VAGL h.t.). Residual conifers below are mostly Douglas-fir. Scattered patches of aspen and willow have been released following logging. Slopes below support luxuriant ground cover of pinegrass and low shrubs. (USDA FS Photo 86479)

1925. 16 years later. Conifer regeneration has developed more rapidly on north slope and valley bottom than on the distant south slope. Douglas-firs are mostly represented. Aspen and willow have grown profusely. Note large willow in foreground. (USDA FS Photo 204830).

1968. 59 Years Later. Precommerical thinning was carried out in 1968, but photo indicates insignificant removal on this site. Willows in foreground are leafed out and therefore more evident. (USDA FS Photo 518778)



1938. 29 Years Later. Conifers now dominate slope below and valley bottom. Ponderosa pines that were not visible in 1925 are now apparent in immediate foreground. Most of south-facing slope in view now supports vigorous young forest except for a few openings, especially on convex slopes. Large willow in foreground has not leafed out. (USDA FS Photo 361705)

1979. 70 Years Later. Canopy appears less dense than in 1968. (USDA FS Photo).

1948. 39 Years Later. The original scene is now almost completely screened by vigorous young conifers. Willows in foreground are still in a healthy condition. (USDA FS Photo 452638)

1989. 80 Years Later. Mid-story trees have grown to fill in the upper canopy. One willow shrub is still evident in the left midground. (USDA FS Photo)

1958. 49 Years Later. Conifers show further height and diameter growth, whereas willow is declining. (USDA FS Photo 487749)

1997. 88 Years Later. The stand seems more dense even though 3 overstory pines have fallen as a result of bark beetle attacks. These trees have created a fuel accumulation on the ground. The willow (left midground) is no longer detectable, but a willow to right is now visible. Douglas-fir regeneration is evident. (USDA FS Photo)

PHOTOPOINT 8
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Looking east-southeast at a selection cut in primarily ponderosa pine (PSME/VACA h.t.). Pole-size Douglas-fir can be seen at right. Ground cover is herbaceous species with low shrubs and scattered small willows and snowberry. A large willow is growing in foreground on left. Charred log at the foot of W. W. White (center) and snag at left center of photo attest to past wildfire. E.C.Clifford, the first planting specialist in the Northern Region, is seated on a charred log. (USDA FS Photo 86470)

1927. 18 years later. Willows are now a conspicuous part of the understory in midground, while foreground has taken on a more grassy appearance. Douglas-fir and ponderosa pine regeneration are contributing to a much more developed understory than before. (USDA FS Photo 221285).

1937. 28 Years Later. Young conifer are beginning to dominate the understory; willow has grown appreciably in midground. Litter accumulation is evident in foreground, while the tree canopy on the skyline is less dense because of mortality and windthrow. (USDA FS Photo 354397)

1948. 39 Years Later. Willows are beginning to die back. Competition from young conifers is becoming intense. Litter accumulation in foreground includes a high incidence of pine cones. (USDA FS Photo 452649)

1958. 49 Years Later. The open understory of 1909 has been replaced by a dense growth of young conifers. Willows are not leafed out, but nonetheless contain many dead branches. Altough grasses persist in foreround, their growth seems to be inhibited because of accumulative litter. (USDA FS Photo 487748)

1968. 59 Years Later. Precommerical thinning and pruning were carried out in 1968. The removal of trees in foreground, dozer scarification, and deposition of material from road construction resulted in establishment of mullein, thistle, and many ponderosa pine seedlings. Young willows can be seen at left center of photo. (USDA FS Photo 518771)

1979. 70 Years Later. Photo documants how ponderosa pine can successfully regenerate on a disturbed (scarified) site. The ground cover in immediate vicinity is largely knapweed, dogbane. and Canada thistle, which are disturbance indicators. (USDA FS Photo).

1989. 80 Years Later. Pines have grown considerably since 1979 photo. (USDA FS Photo)

1997. 88 Years Later. Lower branches were scorched during burn treatment in 1993. Under growth is dominated by wild rye and spotted knapweed with dogbane and rose present in lesser quantities. Willows, although not obvious, are still alive but heavy browsing has kept them suppressed. (USDA FS Photo)

1909. A northwest view back toward previous camera points. Ground cover is comprised of herbaceous species including balsamroot and low-growing snowberry and spiraea (PSMA/SYAL-CARU h.t.). Young Douglas-fir can be seen in understory. (USDA FS Photo 86478)

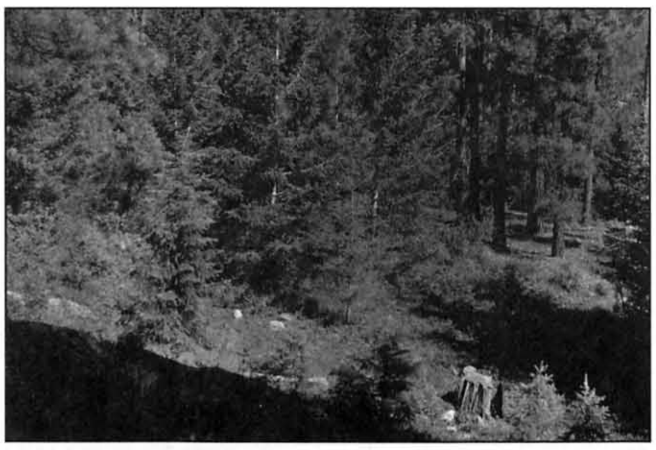
PHOTOPOINT 9
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1927. 18 years later. Willows are now predominant in opening at left in midground and are also evident in foreground. A few bitterbrush plants are also present in foreground. Douglas-fir regeneration is well established. (USDA FS Photo 221284).

1968. 59 Years Later. Precommerical thinning in the 1960's resulted in improved conditions for willow, bitterbrush. and other understory plants. Slash has increased ground fuels. (USDA FS Photo 518777)

1938. 29 Years Later. Douglas-fir growth is competing with willow and bitterbrush. Both shrubs have grown considerably, but dead branches are particularly evident within the canopy of several willows. Note amount of dead material in willow at right edge of photo. (USDA FS Photo 361701)

1979. 70 Years Later. Growth of Douglas-fir screens view. These ladder fuels are beginning to create a hazard to second growth timber and the few trees left from the original stand. (USDA FS Photo).



1948. 39 Years Later. Young Douglas-fir stand has overtopped much of the shrub complement. A few bitterbrush and willow plants persist in openings, while snowberry is growing vigorously. (USDA FS Photo 456326)

1989. 80 Years Later. Canopy has now become very dense, screening out the large pine in the center midground. (USDA FS Photo)

1958. 49 Years Later. Early skyline view has been completely screened by growth of conifers. Closure of understory has resulted in further deterioration of large shrubs. Note dead willow at left center of photo. (USDA FS Photo 487739)

1997. 88 Years Later. Thinning in 1992 has opened the stand. Underburning in 1993 was light and spotty resulting in most small conifers surviving. Rose bushes are more vigorous, surrounding the willow in center midground. (USDA FS Photo)

PHOTOPOINT 10
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Facing nearly due west from ridge northeast of Como Lake. Light selection cut in open ponderosa pine. Ground cover is comprised of perennial grasses and forbs, including balsamroot (PSME/CARU-PIPO h.t.). A few low-growing bitterbrush plants can be seen in the vicinity of horses and in distance on left. A group of willows can be seen behind horseman at left center. (USDA FS Photo 87357)

1925. 16 years later. Bitterbrush plants on left and willow in distance, more evident in the winter scene, have increased in size. Young conifers are beginning to fill in the understory in the background. (USDA FS Photo 204815).

1968. 59 Years Later. Precommerical thinning and pruning in 1968 removed mature pines and opened up young pine stand. This benefited some bitterbrush plants (reference to other photo sequences), but those in left foreground under and near leave trees show further deterioration. Slash has added to heavy fuels, while down material is more decomposed. (USDA FS Photo 518767)

1938. 29 Years Later. Several pines in foregorund have been cut, some have died, and others have fallen to the ground. Ponderosa pine and Douglas-fir regeneration is profuse, while the willow in distance is larger. Bitterbrush has increased, but regeneration appears minimal. Slash and windfall have resulted in an increase in heavy fuels. Mullein can be seen in left foreground for the first time. (USDA FS Photo 361704)

1979. 70 Years Later. Understory is dominated by increased pine growth that is shading out bitterbrush. Past disturbance has allowed knapweed to predominate in foreground. (USDA FS Photo).

1948. 39 Years Later. Former open view is screened by growth of young conifers. Bitterbrush plants have continued to grow, but are beginning to receive competition from conifers for space. Willow in distance has been overtopped by conifers. Dead trees have toppled, adding to fuel load. Slash in foreground has decomposed somewhat, while balsamroot is not evident and mullein has increased in occurrence. (USDA FS Photo 452639)

1989. 80 Years Later. Growth of trees in the foreground has reduced the view. A few bitterbrush plants can be seen in the center of the stand, along with some grasses. (USDA FS Photo)

1958. 49 Years Later. Growth of young ponderosa pine and Douglas-fir dominate skyline, thereby obscuring view of the few remaining mature ponderosa pine in distance. Competition by young pines in foreground has apparently caused several of the bitterbrush plants to deteriorate. Heavy ground fuels show considerable decomposition. (USDA FS Photo 487738)

1997. 88 Years Later. Thinning in 1992 has created large openings throughout the stand. Only mid- and back-ground received burn treatment in 1993 resulting in loss of small trees. Bitterbrush in unburned foreground looks more vigorous than others in burn area. Ground cover is dominated by spotted knapweed, elk sedge, and bluebunch wheatgrass. (USDA FS Photo)

1909. View is south-southeast through an open ponderosa pine stand selectively cut in 1907 or 1908 (PSME/SYAL h.t.). Luxuriant grass/forb cover reflects prelogging conditions. Note fire-scarred ponderosa pine and lone Douglas-fir seedling immediately to the left of W. W. White. A low-growing bitterbrush plant con be seen between White and stump. (USDA Forest Service Photo 86480)

PHOTOPOINT 11
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1927. 18 years later. Douglas-fir regeneration has resulted in marked change in understory. Grass/forb ground cover persists, but now bitterbrush and snowberry are more evident in foreground. Pine stand is somewhat less dense because of cutting or windfall. (USDA FS Photo 221282).

No record of photos taken in 1958, 1968, 1979.

1938. 29 Years Later. Douglas-fir understory continues to increase in size and density. Some overstory trees continue to die. (USDA FS Photo 361703)

1989. 80 Years Later. This scene has changed considerably since the 1948 photo. Heavy thinning, probably in 1968, resulted in good regeneration of ponderosa pine. Willows are doing well in the center and right midground. Undergrowth is primarily Kentucky bluegrass (Poa pratensis) and pinegrass. (USDA FS Photo)

1948. 39 Years Later. Original view is now screened out by growth of young Douglas-fir. Ground cover in foreground now has considerable numbers of low shrubs. Snowberry appears to predominate. (USDA FS Photo 452640)

1997. 88 Years Later. Young ponderosa pine in right midground have grown. Harvesting in 1992 removed overstory trees in background. Burning treatment in 1993 was very light as evidenced by surviving pine saplings and uncharred litter in foreground. Willows that were vigorous in 1989 are heavily browsed. (USDA FS Photo)

PHOTOPOINT 12
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Prior to harvest, the stand was fairly dense, dominated by pine (as evidenced by the stump and slash piles) with a few Douglas-fir (PSME/VACA). Undergrouth was primarily herbs and grasses. Note the willow to the right of the men. (USDA FS Photo 86472)

1925. 16 years later. Douglas-fir and ponderosa pine regeneration is fairly heavy in patches. Note that the 2 large ponderosa pine in the center midground have been harvested. Willows have increased. (USDA FS Photo 204820).

1958. 49 Years Later. Douglas-fir continues dominance over the pine. (USDA FS Photo)

No record of photos taken in 1968 or 1979.

1937. 28 Years Later. Dense thicket of ponderosa pine and Douglas-fir has developed. Willows not visible in this photo. (USDA FS Photo 354398)

1989. 80 Years Later. Heavy thinning in 1968 favored retention of the pines. Regeneration is visible in foreground. Willows are visible in right/center foreground (not visible since 1925 photo). (USDA FS Photo)

1948. 39 Years Later. Large ponderosa pine in left center is almost obscured by thick understory. Young Douglas-fir are gaining dominance over the pines. (USDA FS Photo 452642)

1997. 88 Years Later. This stand is now more open due to the thinning in 1992 and underburning in 1993 which removed much of the conifer regeneration seen in 1989 photo. Undergrowth is mostly pinegrass and kinnikinnick. (USDA FS Photo)

PHOTOPOINT 13
1909 - 1997
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. Open, park-like stand of ponderosa pine trees (PSME/VACA). Light cutting at the time is evidenced by the few stumps and small slash piles. Undergrowth is largely herbaceous with low shrubs such as kinnikinnick and dwarf huckleberry. [People are (L-R): Mrs. W.W. White, Charley Gregory (lumberman), W.W. White] (USDA FS Photo 86476)

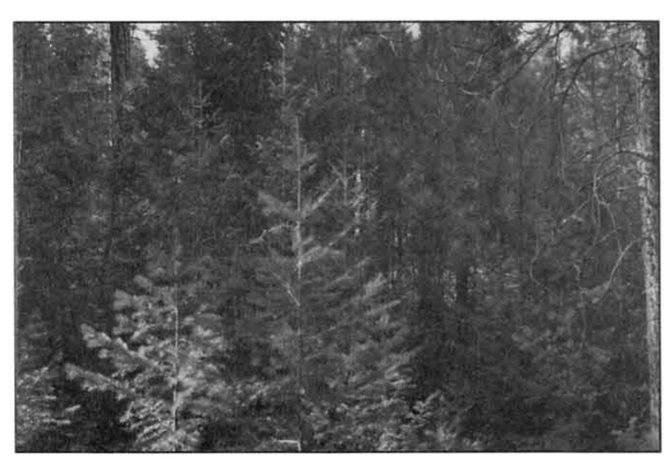
No record of photo taken in 1925 or 1927.

1968. 59 Years Later. Fairly heavy thinning of understory trees and perhaps some overstory tree removal occurred during selection cut in 1962. Regeneration of ponderosa pine following the thinning is seen in the foreground. (USDA FS Photo 518775)

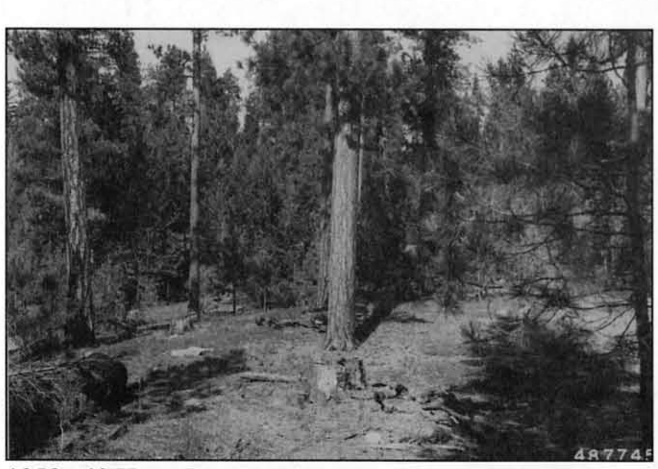
1938. 29 Years Later. Overstory ponderosa pine remains about the same. Small pine and Douglas-fir growing in scattered patches. Note the willow in right/center midground and the less dense undergrowth (photo possibly taken late in season). (USDA FS Photo 361706)

1979. 70 Years Later. Remarkable development of understory into dense thickets of ponderosa pine and Douglas-fir has occurred. (USDA FS Photo).

1948. 39 Years Later. Understory trees are more abundant with small openings in the forest. Pine in center has been marked (at base) for cutting. Undergrowth vegetation still fairly sparce. (USDA FS Photo 452647)



1989. 80 Years Later. Continued development of understory thickets is seen with Douglas-fir increasing and becoming more dominant over the pines. (USDA FS Photo)



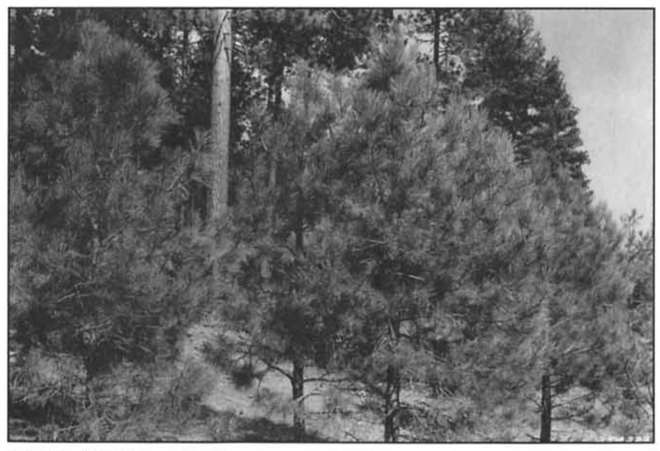
1958. 49 Years Later. Harvesting removed the large pine in the center of the photo and the one to the left/center, as well as some others in the background. Understory Douglas-fir has become more conspicuous. Undergrowth still appears sparse. (USDA FS Photo 487745)

1997. 88 Years Later. Some overstory ponderosa pine were removed during 1992 selection harvesting. Patchy underburning in 1993 killed some conifers in the thickets. Ground cover is kinnikinnick, dwarf huckleberry, and pinegrass. The view to the left and right of photo is much more open, similar to 1909. The stand is now multi-aged with a patch of large snags killed by beetles during the 1990s. (USDA FS Photo)

PHOTOPOINT 14
1909 - 1937
LICK CREEK DRAINAGE
BITTERROOT NATIONAL FOREST, MONTANA

1909. This recently discovered photoseries was evidently located northwest of photopoint 4 near the present-day Lake Como-Lost Horse Loop Road. (It has not been relocated since 1937.) Photopoint is "300 yards north of cabin" in photopoint 1, and view is east. Stand was open-grown large ponderosa pines with a groundcover of bunchgrass and arrowleaf balsamroot. (USDA FS Photo 86474)

1927. 18 years later. Late-September view with patches of saplings, willow shrub behind large tree at left, small bitterbrush shrub in left center, and a larger bitterbrush or willow in right-center. (USDA FS Photo 221279)



1937. 28 Years Later. Late-September view largly obscured by the developing young pines. (USDA FS Photo 354399)

88 Years of Change in Ponderosa Pine Forest

1909

1948

Large pine cut ~ 1952

1968

1989

1997

Adjacent Forest 1997

Photos taken from one point show changes resulting from fire exclusion, removal of large pines and ecosystem management treatments in the 1990's.

Photo point location, Bitterroot National Forest ~ Produced by the Fire Effects Unit, Rocky Mountain Research Station, Missoula, Montana ~ for General Technical Report-RMRS-GTR-23, March 1999