Old Growth Ponderosa Pine and Western Larch Stand Structures: Influences of Pre-1900 Fires and Fire Exclusion

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Old Growth Ponderosa Pine and Western Larch Stand Structures: Influences of Pre-1900 Fires and Fire Exclusion

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Research Summary

Historically, as a result of frequent fires, seral ponderosa pine and western larch trees dominated old growth stands in the Northern Rocky Mountains. We present detailed data on age structure and fire history of two remnant old growth stands on the Lolo National Forest in western Montana. These stands occupy contrasting sites; one is codominated by ponderosa pine and larch while the other is larch without ponderosa pine. Also, we compare age structures of eleven stands that represent a broad range of sites historically characterized by frequent fire regimes. These stands are located in western Montana, on the Bitterroot, Flathead, and Lolo National Forests. Three of the stands on moderately moist sites were distinctly even-aged. These reflected a variable fire regime of frequent nonlethal fires and infrequent stand replacement fires. Seven of the stands, including the drier sites and two moist sites with comparatively frequent fires, had highly uneven-age structures. The remaining stand, on a moderately dry site, had an intermediate age structure: uneven-age but with one very abundant age class. We interpret causal factors possibly linked to these variations in age structure, including aboriginal burning.

Ten of the 11 stands have now experienced an unusually long interval without fire (75 to 105 years). Related changes in stand structure between 1990 and the 1990's include large increases in basal area per acre (+50 to +150 percent) and in Stand Density Index per acre (+60 to -200 percent) except for two stands that have experienced large amounts of overstory mortality. We discuss implications for management to perpetuate old growth ponderosa pine and larch.

Acknowledgments

We thank the many individuals from the Bitterroot, Lolo, and Flathead National Forests who helped us find old growth stands suitable for sampling; in addition, Cathy Stewart, Vick Applegate, Vic Dupuis, Steve Slaughther, Sharon Klahhammer, and Margaret Doherty provided assistance in conducting the study. Mick Harrington, Intermountain Fire Sciences Laboratory, helped with study design and interpretation of data, and Todd Carlson and Roger Farnel carried out field sampling for study plot Lolo-4 (L-4). Manuscript reviewers provided many important suggestions. They were Carl Fidler and Kevin O'Hara from the University of Montana, Missoula; Phil Om and Jolie Gaudry, Colorado State University; Fort Collins; Phil Whisenhoop, Pacific Southwest Experiment Station, Redding, CA; Sue Heald, Bitterroot National Forest; Hamilton, MT; and Vick Applegate, Lolo National Forest, Missoula, MT.

Table of Conversions

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About the cover: View of Girard Grove from across the Clearwater River at the outlet of Seeley Lake, MT. Study plot Lolo-5 (L-5) is located in this highly uneven-age larch stand containing trees greater than 500 years old. This stand is a result of frequent fires prior to 1860.
Old Growth Ponderosa Pine and Western Larch Stand Structures: Influences of Pre-1900 Fires and Fire Exclusion

Richard P. Cohen

Introduction

Ponderosa pine (Pinus ponderosa) and western larch (Larix occidentalis) are long-lived fire-resistant trees of the North American interior and northwestern mountains. The pine is often seral and at a competitive disadvantage to interior Douglas-fir (Pseudotsuga menziesii var. glauca) and grand fir (Abies grandis) in the absence of fire or other major disturbance. Larch is always considered seral to coniferous and fir (Arno and others 1998; Pfister and others 1977). Historically, seral stands of old ponderosa pine and western larch dominated millions of acres. Lassen (1985) estimated that the historic ponderosa pine type covered about 25 million acres between central Montana and the Cascade Range in Washington and Oregon. Many of the pine and larch stands were maintained in an open park-like condition, having sparse understories, by frequent low-intensity surface fires at average intervals of between 5 and 30 years (Arno 1988). Old growth larch stands on sites too cold or moist for ponderosa pine generally had a history of either (1) mixed severity fires at intervals of 30 to 75 years, or (2) stand-replacement burning at mean intervals of 120 to 350 years (Arno and Fischer 1995).

Old growth stands of seral ponderosa pine and larch are essentially “fire-dependent” (Habekuck 1988). Remnant stands found today are highly valued as recreational and natural areas. Paradoxically, since the early 1900’s most stands have been under management that attempts to exclude fire. In contrast, recent management direction in many National Forests and other public lands often seeks to maintain or restore old growth pine and larch with the aid of prescribed fire. To accomplish this new management direction, better information is needed regarding how to restore and perpetuate seral old growth that was associated with frequent burning. Knowledge of how remaining old growth stands developed in conjunction with frequent fires of the past is critical. Consequently, we sought to obtain detailed age structure and fire history information for a range of pine and larch old-growth stands in western Montana that were historically associated with frequent burning. A previous study (Arno and others 1995) reported age structure information for nine ponderosa pine stands in the Bitterroot, Lolo, and Flathead National Forests, but only one of these was dominated by western larch. Here we present data from two additional old growth stands on Lolo National Forest representing habitats that contrast with the previous larch stand. One of the additional stands is a mixture of pine and larch on a steep upland slope and the other is larch dominated in a front-prone valley bottom evidently at the cold limits of ponderosa pine. We also synthesized our coniferous and larch data (BA, and Stand Density Indexes (SDI) for the entire range of old growth stands that we have sampled to represent the historical frequent fire types in western Montana.

Study Sites and Fire History

Our eleven sample stands include eight locations (fig. 1). One location was sampled with three plots and another with five plots to compare spatial variation (Arno and others 1995). Collectively, those eight locations represent a range of contrasting conditions among western Montana pine and larch forest stands having had a history of frequent fire (table 1). Certainly, additional situations existed in natural stands. For instance, we were unable to locate any relatively low-intensity dry-stand ponderosa pine old-growth that had experienced no logging and could therefore represent short fire intervals (5 to 15 years) on a dry site. We did, however, sample one short-fire-interval ponderosa pine plot on a moist site (plot B-4) as well as a larch stand on a very moist site (plot L-5) that had relatively short fire intervals (table 1). Because these forest types have been logged, often for more than 100 years it was not possible to locate large unlogged stands and select sample areas using criteria that would ensure representativeness (Arno and others 1995). Our sample represents all of the remnant stands on both dry and moist sites that we were able to locate with a moderate amount of search and inquiry. Additional criteria were that stands needed to be large enough to easily contain our 2/4 acre sample plot and that they had experienced no logging, so that the original stand structure could be measured and aged. Unquestionably there are additional stands that could be sampled in western Montana, especially on dry high-elevation ridges in roadless areas, but this is the situation we have already sampled most heavily (plots B-1, 2, 3, and L-1, 2, 3 in table 1). Other situations have nearly all experienced some logging, heavy mortality, and successive replacement by Douglas-fir or grand fir.

Fire histories were determined for each plot from analysis of partial cross sections (wedge cuts) from the two to four trees in an immediately adjacent to the plot that had the most complete and least damaged sequences of multiple fire scars (Arno and Sneck 1977). A master fire chronology starting in the late 1500’s or early 1600’s (except plot F-2, table 1) was developed for each plot by correlating dates obtained from individual plats.

Our new sample stand L-5 represented an unusual challenge for obtaining fire history since ponderosa pine is rare and multiple fire scars on larch cannot normally be sampled using a partial cross-section (wedge). One of the larch trees in the vicinity of L-5 has multiple fire scars (fig. 2). Wedge sampling multiple scarred larch is inadvisable due to extensive rot and ring shake (separation along the growth rings) that cause the wedge to break in windstorms. Thus, dating multiple fire scars on larch requires felling the trees and taking full cross sections. Stand L-5 is in a recreation area land managers wanted to avoid felling old growth trees. We were able to obtain a reasonably good and complete fire history by a separate search with the maximum number (five) of undamaged fire scars observed; (2) wedge sampling fire scar sequences on one live and one dead tree.

Table 1—Summary of fire history and site characteristics of the 11 old growth stands representing eight different sites in western Montana, arranged according to increasing site moisture conditions. Sample plots L-4 and L-5 have not been previously reported.

<table>
<thead>
<tr>
<th>Sample area,</th>
<th>plot number</th>
<th>Habitat type*</th>
<th>Aspect, slope</th>
<th>Indecination</th>
<th>Site moisture</th>
<th>Old growth fire</th>
<th>Historic mean and (minimum, maximum) fireplace in years (about 1800-1900)</th>
<th>Stand replacement fires detected</th>
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</thead>
<tbody>
<tr>
<td>Bitterroot 1, 2, 3</td>
<td>PSME-CARU</td>
<td>SW, &lt;400</td>
<td>Very dry</td>
<td>X</td>
<td>49 (19, 97)</td>
<td>No</td>
<td></td>
<td></td>
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<tr>
<td>Lolo 1, 2</td>
<td>PSME-CARU</td>
<td>SW, &lt;400</td>
<td>Very dry</td>
<td>X</td>
<td>32 (17, 47)</td>
<td>No</td>
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<td>Lolo 3</td>
<td>PSME-CARU and VAGL</td>
<td>SW, &lt;400</td>
<td>Moderately dry</td>
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<td>28 (16, 49)</td>
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<td>Lolo 4</td>
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<td>NNW, &gt;400</td>
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<td>27 (17, 35)</td>
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<tr>
<td>Flathead 1</td>
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<td>Flat</td>
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<td>31 (8, 79)</td>
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<td>Flathead 2</td>
<td>PSME-VAGL</td>
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<td>Moderate</td>
<td>X</td>
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<td>Bitterroot 4</td>
<td>ABGRO/BO</td>
<td>E, gentle</td>
<td>Moderately moist</td>
<td>X</td>
<td>13 (9, 41)</td>
<td>No</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Other data included: Bitterroot 1, 2, 3: Bitterroot National Forest; Lolo 1, 2: Flathead National Forest; Flathead 1, 2: Lolo National Forest; Bitterroot 4: Bitterroot National Forest.

*Based on Pfister and others (1977). Key to abbreviations: ABG = Abies grandis; grand fir; ABL = Abies lasiocarpa; subalpine fir; CARU = Cathagration rubescens; proregis; CLUN = Chrysothamnus pulchroides; DB = D. lutea; Klamath siskiyou; TW, PSME = Pseudotsuga menziesii; Douglas-fir: VAC = Vaccinium angustifolium; westlake; WAGL = Vaccinium-obtusum; var. obtusum; WAGL = Vaccinium-obtusum; var. obtusum. Bitterroot 1, 2, 3 also sampled any 2/4 acre plot within a 1.2 miles of geographic range limits of WL. Other locations included: Bitterroot 4 = 3.8 miles of geographic range limits of WL.
dead ponderosa pine, a rare species in this stand; and
(3) wedge sampling old fire scars from broken larch
snags. These fire history samples indicate that nine
fires occurred in the stand from about 1671 through
1859, with a mean fire interval of 24 years (fig. 3). Age
class cohorts of larch trees (discussed later) also sug-
gest the occurrence of fires in the 1630’s, the late
1500’s, and the early 1500’s. The common occurrence
of more than 500-year-old trees in this stand indicates
that none of the post-1500 fires were stand replace-
ment burns.

The other new sample stand, L-4, represented a
different kind of challenge for determining fire his-
tory. Several fire scarred ponderosa pine and larch
were available for dating the seven fires occurring
from about 1777 through 1919. Most of the old trees
became established in a single cohort during the late
1600’s, and there were no living trees with fire scars
old enough to record a fire that might have set the
stage for that regeneration event. However, a search
of the adjacent logged stand, immediately downslope,
revealed a well preserved stump of a huge ponderosa
pine that had been harvested in about 1919. This
pitch-permeated stump dated back to the early 1300’s
and had a continuous fire scar record from about 1594
including all of the fires recorded on the live trees,
except 1919 (fig. 3). The trees in plot L-4 and the stump
in the adjacent stand recorded 12 fires from about
1594 through 1889, with a mean fire interval of 27
years. As discussed later, the apparent stand-replacing
fire that gave rise to the even-age old growth
occurred in about 1663.

Methods of Stand
Reconstruction

Methods were similar to those used in the previous
study of nine old growth stands (Arno and others
1995). We placed a 100 m (328 ft) square plot within
each small sample stand in a location where topogra-
phy was relatively uniform. Our plot covered 1 ha (2.47
acres) on a flat site, but we did not enlarge it on sloping
topography and thus acreage was smaller on sloping
sites. Actual acreage was used in basal area cal-
culations for each plot. This plot size seemed adequate
to encompass age-group patterns found in other studies
of stand structure of coniferous forest in the inland
western United States (Bonn nieceken and Stone
1981; Cooper 1960; Stephenson and others 1991; West
1969; White 1965). We used this plot as a basis for inventory-
ing the current stand structure and tree ages, and
for reconstructing stand structure circa 1900. To do this
we (1) recorded species and diameter at breast height
d.b.h.) of each tree more than 4 inches in diameter, (2)
mapped each tree’s position, (3) number tagged all
trees more than 8 inches in diameter and took incre-
ment borings to determine total tree age, (4) invento-
rized all dead trees estimated to have been alive in
1900, and (5) tallied saplings less than 4 inches in
diameter by species on a representative 25 m square
subplot.

We chose 1900 as a basis for characterizing histori-
cal stand conditions because studies in mixed pondo-
rosa pine and fir forests generally indicate a disrup-
tion in the historical pattern of frequent fires shortly
after that time. Records of fire history in ponderosa
pine forests of western Montana show a consistent
pattern of frequent fire from 1800 back to about 1500
(Arno 1976; Barrett and Arno 1982); beyond that
threshold few living trees are available to sample
(Arno and others 1995).

The position of all trees more than 4 inches diameter
was recorded using a survey laser instrument (Crite-
ion 400, Laser Technology, Inc.). Beginning in one
corner, we made a closed-loop traverse through sev-
eral sighting points within the plot. The azimuth and
horizontal distance to each tree were then recorded
from one of the traverse points, allowing computa-
tion of the Cartesian position of each tree within the plot.

Figure 2—Western larch at Lolo-5 (L-5) with
multiple fire scars.

Figure 3—Comparison of Lolo-4 (L-4) and Lolo-5 (L-5) fire histories.
PP = ponderosa pine, MFI = Mean Fire Interval.
Increment boring showed that most trees less than 8 inches diameter at breast height (d.b.h.) originated after 1900; therefore we sampled them less intensively. Ages of standing trees cut before 1900 were determined from increment borings taken approximately 12 inches above the ground line, or occasionally within a foot or so of the base. We used a power borer and bits up to 32 inches long (Scott and Arno 1992). We bored trees repeatedly, if necessary, in or near the stump, or as close to it as possible, until we found either very close to the top or the crown. Cores were mounted on grooved boards in the field (Arno and Snuck 1977).

Use of power borer increased sampling efficiency. It allowed time for repeated boring attempts in large old growth trees where root and off-center pit location necessitated several borings to obtain a usable sample (Scott and Arno 1992). Also, our experience has been that power boring results in less breakage of the expensive borer bits, probably because the bit is driven in and extracted from the core in contrast to the stop-and-go action of hand boring. To further reduce friction and breakage—especially important in larch, which has very dense wood—we applied beeswax to the borer bit prior to each drive. (Wax is conveniently applied to the warm or hot bit immediately after it is removed from a tree.)

Many of the core samples from old growth larch trees were highly fragmented due to ring shake and rot and required careful and reasonably sequenced placement on core boards in the field. Plastic drinking straws commonly used for holding cores would not work in this field situation.

We prepared the increment cores for measurement using an orbital sander with medium (80 grit) and fine (up to 400 grit) paper. Radii were counted under a 7 x 30 power binocular microscope. Total tree age was estimated by adding two correction factors to the count. The first was the estimated number of years the tree took to reach boring height, based on regeneration age data collected in past studies (Scott and Arno 1984). The second was the estimated time it took for the outermost core to be produced. We computed the estimated number of rings missed on a core that did not intersect the pith. This is computed as the product of the estimated distance to the pith from the innermost ring visible on the core and the average growth rate near the innermost ring. For example, 0.4 inches to the pith x 8 rings per inch = 3.2 years. The innermost ring to the pit was determined using a clear template with nested circles (Ghent 1955).

To improve estimation of cores bored the trees as low as possible, used longer borer bits, and made repeated attempts to intersect the pith. Fiedler and Shipton (1985) warned that increment cores from six of our previously sampled old growth stands and found that 67 percent of the innermost tree ring data determined from cores bored would be within 2 years of the actual age and the majority of the remaining ring data would be within 3 to 10 years of the actual age (Arno and others 1995). Considering the small errors associated with determining total age to the pith at ground line, we felt these estimates of total tree age were sufficiently accurate for characterizing stand age structure in the forest. (Stokes and Smiley 1968) would have been difficult in the numerous rotten and highly fragmented larch cores. Obtaining reasonable ages would require destructive sampling—that is, felling each tree and sectioning the stump at ground line.

To reduce occurrence of present overstory trees to estimate their circa 1900 d.b.h.'s, we could have subtracted two times the post-1900 radial growth as measured on the core. However, cores were generally taken lower on the tree, where diameter is larger than d.b.h. Also, individual radii reflected in cores are often wider or narrower than the mean reflected in a d.b.h. measurement. To overcome these problems we took the ratio of pre-1900 growth to the total radial growth of the tree on each increment core. For example, the increment core from a pre-overstory tree has a total radial growth of 14 inches and the post-1900 radial growth is 4.2 inches. The ratio of pre-1900 growth to total growth in this case is 70 percent (14/21 = 0.667). We multiplied 0.7 by the tree's measured d.b.h., 31 inches in this example, to arrive at a circa 1900 diameter of 21.7 inches. Using this method we were able to calculate an estimated basal area and a general stand structure for 1900.

Post-1900 dead trees were added to the circa 1900 stand based on their diameters at the time of death. Trees that apparently died since 1900 were recorded by hand boring and were assumed to have died after 1900. Fallen trees whose cores were largely disintegrated were assumed to have died before 1900. Similar states of decay of trees felled and left on the ground in the late 1800's have been examined previously in these forest types (Arno and others 1995).

Both basal area and Stand Density Index (Reineke 1933) are measures of stand density, and therefore of site use. However, the Stand Density Index provides a more sensitive measure of site use or growing space occupancy than does basal area (Long and Dean 1986). The Stand Density Index adjusts for tree size, and thereby provides a superior estimate of density in uneven-age stands or stands with numerous larger trees (Fiedler and Shipton 1980, 1985). For example, the Stand Density Index associated with a square foot of basal area in 24 inch d.b.h. trees is only half that of a square foot of basal area in 4 inch trees (1.28 in 24 inch d.b.h. trees and 0.64 in 4 inch d.b.h. trees) (Fiedler and Shipton 1985), reflective of the much lower ratio of sapwood to total basal area in larger, older trees. The Stand Density Index may also provide a better estimate of density in old growth stands being considered for restoration treatments. The Stand Density Index for all 11 of our old growth stands was calculated for the current conditions and circa 1900 conditions. For greater accuracy, we calculated the Stand Density Index of our stands based on actual tree diameters instead of by d.b.h. classes or average stand diameter (table 2). This was done to calculate the basal areas from tree diameters, hence the figures presented for the nine previously sampled stands are slightly different than those published earlier (Arno and others 1995).

### Table 2—Summary of basal areas/acre and Stand Density Indexes for all 11 old growth stands comparing historic and modern levels.

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<td>137</td>
<td>168</td>
</tr>
<tr>
<td>B-2 1990</td>
<td>77</td>
<td>116</td>
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<tr>
<td>B-3 1991</td>
<td>176</td>
<td>292</td>
</tr>
<tr>
<td>B-4 1990</td>
<td>80</td>
<td>114</td>
</tr>
<tr>
<td>L-1 1991</td>
<td>131</td>
<td>202</td>
</tr>
<tr>
<td>L-2 1990</td>
<td>143</td>
<td>179</td>
</tr>
<tr>
<td>L-3 1991</td>
<td>135</td>
<td>206</td>
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<td>F-2 1990</td>
<td>138</td>
<td>220</td>
</tr>
<tr>
<td>L-5 1991</td>
<td>100</td>
<td>137</td>
</tr>
<tr>
<td>L-6 1990</td>
<td>80</td>
<td>137</td>
</tr>
</tbody>
</table>

Note: Basal area (BA) was calculated on actual tree diameters instead of by d.b.h. classes or average stand diameter (table 2). For example, we calculated on basal area from tree diameters, hence the figures presented for the nine previously sampled stands (table 2) are slightly different than those published earlier (Arno and others 1995).

### Results

#### Stand Age-4 Structures

Stand Age-4 (L-4) has a distinctly even-age structure among the pre-1900 trees (fig. 4a). Most of the pre-1900 ponderosa pine and larch regenerated within 35 years after apparent stand replacement in fire in about 1663. Curiously, seven larch (obviously small at the time) in the upper right portion of the sample plot (fig. 5a) survived this fire, whereas none of the pine (fig. 7b). The large ponderosa pine (pitch stump from about 1919 logging) that we sampled about 100 yards below the plot survived and remained (fig. 5b). All our data on age-class structure (fig. 4, 5, 7) represent trees still surviving. Many more trees probably regenerated but were killed, especially as saplings, by fires and other agents. Stand L-5 (L-5) has a highly uneven-age structure. It is dominated by larch established in every century starting with the early 1400's. There are apparent age classes of larch originating in the late 1800's and early 1900's. In the early 1800's an abundance of Douglas-fir became established and survived, perhaps as a result of a comparatively long (40+ years) larch establishment period before it became scarce after 1800, possibly because of larch's inability to compete with Douglas-fir (Pilster and others 1977). Douglas-fir survived the fires in about 1844 and 1859, and this final fire gave rise to an abundance of lodgepole pine regeneration (fig. 5b). The relatively short-lived lodgepole pine has produced small trees, averaging 9 to 10 inches in d.b.h. and 80 ft tall, which are now stagnated in growth and are succumbing to bark beetles.

We arrowed L-4, L-5, and our nine earlier sample stands in a progression from most even-age to most uneven-age structure (fig. 8). Stands were arrowed to intersect the overstory ponderosa pine and larch—the long-lived, fire-resistant and species itself (fig. 8). In the early 1800's, the associated ponderosa pine and lodgepole pine produced small trees, averaging 9 to 10 inches in d.b.h. and 80 ft tall, which are now stagnated in growth and are succumbing to bark beetles. Therefore, we sampled two of these fire originations during previous centuries (Arno and others 1995).

#### Post-1900 Structural Changes

Both stands L-4 and L-5, like the nine previously reported stands, have undergone structural change in structure and composition during this century. Stand L-4 was historically dominated by ponderosa pine and larch, with a small component (Douglas-fir (7a)), which was originally installed as long as the pine and larch. After the last fire in 1919, Douglas-fir saplings became established in great abundance along with a large component of young ponderosa pine (fig. 7b). By 1994 the stand had developed a Douglas-fir understory (fig. 8c) with more than 650 trees per acre, mostly to 5 inches in d.b.h. (fig. 7b). The larch and ponderosa pine regeneration has grown poorly in competition with Douglas-fir during this long fire-free period. The current fire interval is three times the period since the previous fire interval detected prior to 1900. Stand basal area (square feet per acre) has nearly doubled since 1900. The most dramatic element
Figure 4a,b—Approximate regeneration dates for individual overstory trees by species plotted against number of trees, (each symbol represents one tree’s establishment date) and approximate years of fire events for Lolo-4 (L-4) and Lolo-5 (L-5).
Figure 5a,b—Mapped position of overstory trees (established before 1900) by species and diameter size class on Lolo-4 (L-4) and Lolo-5 (L-5). Approximate ages are shown for individual trees from which quality cones were extracted. A symbol preceding an age indicates the minimum age for that tree; a symbol indicates the approximate age. PP = ponderosa pine; WL = western larch; DF = Douglas fir; LP = lodgepole pine; ES = Engelmann spruce; SAF = subalpine fir.
Figure 6 (Con.)

- Age class distributions based on tree establishment dates in 11 old growth ponderosa pine (PP) and larch (L) stands in western Montana. Years at left are midpoints of 20-year intervals. Stands are arranged from most even-age PP and L, shown on the left side of each graph, to most uneven-age PP and L. Data on right side of each graph represent other tree species. Data were taken from a 1 hectare plot in each stand as described in the text.
of this change is the 10-fold increase in basal area of Douglas-fir (fig. 9; table 3). Stand Density Index per acre has increased by a factor of 2.3 (table 2), largely as a result of the understory development. A comparison of density, structure, and species composition between 1900 and the 1990's (fig. 10a,b) illustrates the successional advancement of Douglas-fir in the understory. Meanwhile, the number of overstory pine and larch has declined by 10 percent during this century.

Changes in L-5 have been noticeable since the early 1800’s, when a prominent age class of Douglas-fir became established, followed after 1859 by an age class of lodgepole pine (fig. 4b). Since 1900, an additional 250 Douglas-fir per acre have become established, forming a patchy understory layer (fig. 11a,b; 12). Larch regeneration is almost nonexistent, with the youngest larch being more than 130 years old (fig. 4b). Stand basal area has increased 2.7 times since 1900, with Douglas-fir increasing by 73 square feet per acre (fig. 13). The Stand Density Index has increased three-fold in L-5 (table 2). Figures 14a,b illustrate structural changes during this century. The total number of trees on the plot increased 4.5 times since 1900, including dramatic increases in the numbers of Douglas-fir and lodgepole pine in the overstory.

In the comparison of post-1900 changes in Stand Density Index for all 11 sample stands, the increase in Stand Density Index has been slightly to moderately higher than the increase in basal area (table 2). The one stand (B-3) that showed a decrease in basal area during this century, due to major mortality of large overstory trees, still increased in Stand Density Index, due to continued ingress of Douglas-fir in the understory.

**Discussion**

The 11 stands on eight different sites sampled in western Montana represent a considerable range of site conditions and corresponding contrasts in topography from well-watered valley bottoms to droughty south-facing slopes on high ridges. All historically experienced frequent low-intensity fires, a condition that favored retention of the long-lived, fire-dependent, and fire-resistant species—ponderosa pine and western larch. Three of the stands also had occasional stand-replacing fires, and all of these stands had larch. Western larch sites are more moist and productive than many of the ponderosa pine sites without larch. Mixed severity fire regimes are generally associated with more moist sites, perhaps because drier sites (having nonlethal fire regimes) are receptive to burning for a longer time each year. The drier sites experience fires and their fuel reduction effects more often (Agee 1993). The natural distribution of western larch extends more to cooler and wetter sites than does ponderosa pine, and in these sites larch is a fire-dependent associate of mixed-severity and stand-replacement fire regimes (Arno and Fischer 1995). Historically, some dry ponderosa pine sites must have experienced occasional stand replacement fires, but this appears to have been relatively uncommon in western Montana.

Our new sample stands, L-4 and L-5, provide interesting examples and contrasts regarding influences of site conditions and other factors in determining the pre-1900 fire regime. Stand L-4 had a regime of frequent low-intensity fires and an occasional stand-replacement fire. This is understandable, given the moderately moist and productive habitat type and the stand’s location high on a steep, west-facing slope. Prevailing westerly winds would enhance the slope...
Table 3—Summary of overstory tree density, composition, and size, and comparison of current total basal areas with estimated basal area in 1900 for Lolo-4 (L-4) and Lolo-5 (L-5). (*+* signifies a value less than 1).

<table>
<thead>
<tr>
<th>Number of overstory trees</th>
<th>Median d.b.h. of overstory trees</th>
<th>Total basal area</th>
<th>Total estimated basal area in 1900</th>
</tr>
</thead>
<tbody>
<tr>
<td>1904-1995</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolo-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolo-5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of overstory trees that died after 1900</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolo-4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolo-5</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Estimated number of overstory trees in 1900:

- Lolo-4: 28
- Lolo-5: 21
- Total: 49

Median d.b.h. of overstory trees in 1904-1995:

- Lolo-4: 10.2
- Lolo-5: 14.6
- Total: 12.4

Total basal area in 1904-1995:

- Lolo-4: 29
- Lolo-5: 11.4
- Total: 40.4

Total estimated basal area in 1900:

- Lolo-4: 83
- Lolo-5: 36
- Total: 119

Effect allowing fire to spread with greater intensity up an older stand was due to a higher fire intensity, but not to a higher fire intensity. The stand B-4 was more resistant to a higher fire intensity than the stand L-5. The stand B-4 had a higher fire intensity due to a higher fire intensity in the stand B-4 than in the stand L-5. The stand B-4 had a higher fire intensity due to a higher fire intensity in the stand B-4 than in the stand L-5.

Stand L-5 at Girard Grove along Seley Lake had a history of low to moderate intensity stand-replacing fires at comparatively high frequencies—mean fire interval of 24 years from about 1859 back to about 1671 based on fire scars (fig. 3), and apparently earlier than the early 1500's based on larch age-class cohorts (fig. 4b). In contrast, most forests away from the lake show evidence of historic replacement fires. The abundance of 500- to 600-year-old larch with multiple fire scars at Girard Grove and in much of the forest surrounding Seley Lake, based on examination of the stumps of early 1900's logging, suggests an absence of stand-replacing fires in many of these forests for at least 600 years. Koch (1945) examined ages of logged larch trees in stands bordering Seley Lake and reported that the oldest had become established soon after the year 1000 and in the early 1200's. The oldest of these was one of a few trees that had attained a diameter of 7 ft (Koch 1945). One such giant larch at Girard Grove is 84 inches d.b.h. and is listed as the co-champion largest known western larch (American Forests 1996). Considering this tree's size and girth, it is probably well over 600 years old, but is too large and probably too rotten for age determination.

Today, the undergrowth at Girard Grove (L-5) and surrounding stands is not as flammable and tends to burn poorly except under summer drought conditions, when severe wildfire fires occur (Margaret Doherty, personal communication). The virtual absence of ponderosa pine on this site further reduces sources of fuel for surface fires such as long pine needles. Paradoxically, at stands F-1 and F-2 in the same glacial trench or valley train about 25 miles north on a warmer and drier habitat type with abundant ponderosa pine, pre-1900 fire intervals were about the same or slightly longer (Arno and others 1995; Friedman and Habeck 1985).

Another anomaly in the relationship of fire frequencies to site moisture arises at site B-4 (table 1). This site had very frequent fires and is immediately adjacent to the Bitterroot Valley where an earlier study suggests that Indian burning played a major role in increasing fire frequencies on the landscape (Barrett and Arno 1982). Similarly, the historical fire regime at stand L-5 may have had an important component of Indian burning for hundreds of years. The U.S. Geological Survey, of what was then the Lewis and Clark Forest Reserve, made in the late 1890's (Ayres 1901) states:

There is no doubt that some of the fires, especially on the higher ranges, are due to lightning, but most of those in the valley seem to have been set by Indians and other hunting parties or by prospectors. The trails most frequently used by Indians, as the Jocko and Pend Oreille, are noticeably burned, especially about the camping places.

European-American travel in the valley was evidently rare prior to the late 1800's. Girard Grove, the site of stand L-5, is at the outlet of Seeley Lake and is
The much more open growing conditions associated with the historic stand structure at Girard Grove (fig. 14a; table 2), would have presumably favored a greasy undergrowth more conducive to burning than the current undergrowth more tolerant of fire with the historic vegetation more conducive to burning than the current undergrowth more tolerant of fire with the historic vegetation and disturbance history. It is likely that Douglas-fir understory has increased basal area from a moderate 84 square feet per acre in 1900 to 137 square feet in 1994 (fig. 9; table 3). Additionally, the 10-fold increase in basal area of the Douglas-fir understory to 36 square feet per acre produces an evident stress on all trees. Foliage of both ponderosa pine and larch crowns is noticeably thin and sparse. The Douglas-fir understory is heavily infected with dwarf mistletoe (Arceuthobium douglasii) and Douglas-fir radial growth is very slow. Some post-1919 understory Douglas-fir and larch already have advanced bole rot, apparently from Phellinus pini. Post-1990 radial growth of overstory ponderosa pine and larch averaged only 0.4 inch in the last 20 years. These are symptoms of severe growth stress related to overstocking.

**Implications for Stand Management**

The historical interaction of frequent fire with ponderosa pine and larch in our 11 old growth stands helped produce a variety of age-class structures, although most stands probably had a similar physical (open, parklike) appearance. This historical evidence suggests that a range of management alternatives is possible while restoring some semblance of pre-1900 composition, structure, and disturbance history. Such restoration is a general goal of national forest management in western Montana (Losekany 1989) due to a variety of esthetic and ecological values associated with old growth ponderosa pine and larch. The greatest challenge in restoration management will be dealing with radical alterations in stand structure, live and dead fuels, and the shift of seed sources in favor of the shade-tolerant conifers.

It seems probable that silvicultural removal of understory trees, which constitute the "ladder fuels" that allow fires to crown out, will be necessary preceding any reintroduction of fire (Pfeiffer 1996; Harrington 1996). The current stand structure and condition of overstory trees in stand L-4 exemplifies a need for tree removal. Growth of the ponderosa pine and larch overstory has increased basal area from a moderate 84 square feet per acre in 1900 to 137 square feet in 1994 (fig. 9; table 3). Additionally, the 10-fold increase in basal area of the Douglas-fir understory to 36 square feet per acre produces an evident stress on all trees. Foliage of both ponderosa pine and larch crowns is noticeably thin and sparse. The Douglas-fir understory is heavily infected with dwarf mistletoe (Arceuthobium douglasii) and Douglas-fir radial growth is very slow. Some post-1919 understory Douglas-fir and larch already have advanced bole rot, apparently from Phellinus pini. Post-1990 radial growth of overstory ponderosa pine and larch averaged only 0.4 inch in the last 20 years. These are symptoms of severe growth stress related to overstocking.

**Effective application of fire without prior removal of understory trees would be difficult since any burn sufficient intensity to kill understory trees would probably damage the already stressed overstory. A stand replacement fire today (unlike the one in about 1863) probably would not result in significant natural regeneration of ponderosa pine, due to depletion of seed source in the area as a result of past logging and succession to Douglas-fir. Successional studies on comparable sites suggest that Douglas-fir and possibly larch would become dominant after a stand replacement fire (Arno and others 1985; Jacobsen 1986). Given the advanced successional state of the vegetation at this relatively high-elevation site, any strategy to perpetuate ponderosa pine will probably require planting in small openings. Such openings could be created by harvesting or slashing understory trees and burning them in natural openings when there is little likelihood of fire spreading appreciably.
Stand L-5, Girard Grove at Seeley Lake, represents an easier opportunity for restoration management. Condition and growth of the overstory is reasonably good, and the understory of Douglas-fir is less dense than in stand L-4. Flat terrain and easy access contrast with the steep slope at stand L-4, and would facilitate removal of understory trees as well as application of prescribed fire.

Perhaps the most difficult question in designing restoration management for Girard Grove is establishing a conceptual goal for such management. It appears that the parklike, uneven-age larch stand at Girard Grove—and probably extending along much of the immediate vicinity of Seeley Lake—was a product of aboriginal burning. Regardless of the ignition source, however, the frequent low-intensity fires produced an open stand of very large and long-lived larch represented by many different age classes. This contrasts with patchy larch-lodgepole pine stands with 1 to 3 age classes that are typical of this forest type and habitat type (Antos 1977; Barrett and others 1991; Davis 1980). Due to occasional replacement fires, most larch-lodgepole pine forests did not develop extensive areas dominated by 300 to 600-year-old trees. At Girard Grove the frequent fire regime and its effects are relatively clear. If these effects are considered desirable, they could be simulated through the use of understory removal cutting and prescribed burning.

Conclusions

Recent ecological and anthropological evaluations suggest that aboriginal burning was an important component of many historical fire regimes in western and central North America (Barrett and Arno 1982; Botkin 1981; Davis 1980; Denny 1982; Finney and Martin 1991; Gruell 1985; Lewis 1985). Moreover, trying to partition out and remove the effects of aboriginal ignitions to define a conceptual "natural" condition without human influence would no doubt be a highly speculative endeavor.

A common perception in American society is that old growth forests can be perpetuated by leaving them alone—let nature take its course without human interference. This concept has serious shortcomings in forest ecosystems evolved under the influence of fire and where preservation continues the practice of excluding fire. The problem of preservation is further compounded in old growth stands historically associated with a frequent fire regime, because fire exclusion has drastically altered these ecosystems (Agee 1993; Covington and Moore 1994; Habeck 1986; Moir and Dieterich 1986; Swetnam and Dietrich 1985). We hope that this information on the relationship of stand structure to fire history will provide useful background for designing strategies to restore and maintain old growth ponderosa pine and larch.

References


Keywords: forest health, forest succession, fire dependent forest, uneven age management, aboriginal burning
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