INTERRUPTION OF THE NATURAL FIRE CYCLE IN A GRAND FIR FOREST OF CENTRAL IDAHO: CHANGES IN STAND STRUCTURE AND COMPOSITION

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ABSTRACT

This study highlights the changes that have resulted from 96 years of fire exclusion in a 300-acre (120-hectare) area of grand fir (*Abies grandis*)-twinflower (*Linnaea borealis*)-blue huckleberry (*Vaccinium globulare*) habitat type in the Silver Creek drainage of central Idaho. I measured fire scars to establish the historic fire regime and established plots on a grid system to compare past stand conditions with those of the present. Historically, fire burned through this stand on an average of every 19 years. Most of the fires were low-intensity ground fires. The last fire burned in 1899. The advent of settlers, ranchers, and the U.S. Forest Service put an end to the fires which had maintained the site in an open stand of mostly ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). After 1900, lack of fire brought great changes to the overstory species composition, stand structure, and stand density. Today the old-growth ponderosa pine are not being regenerated. The Douglas-fir component has increased despite heavy mortality in the largest size classes. The importance of grand fir in the stand has increased substantially since 1900; in the absence of disturbance, it will soon dominate most of the stand. The stand is more diverse today due to a greater mix of tree species and greater overstory complexity but is more vulnerable to insects, disease, and destructive wildfire. In the 96 years since the last fire, the number of trees per acre has increased 363%.

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INTRODUCTION

Grand fir (*Abies grandis*) habitat types occur in central Idaho between the Douglas-fir (*Pseudotsuga menziesii*) and subalpine fir (*Abies lasiocarpa*) habitat types (Steele et al. 1981). Understanding of historic fire frequency and ecological function in the grand fir climax type is important for many reasons. First, these forest types are highly productive and provide the greatest silvicultural diversity compared to other forests of central Idaho (Steele et al. 1981). Historic disturbance regimes may provide insight on how to manage these forests in order to keep them productive and how to avoid insect and disease epidemics, as well as wildfires that are larger and more severe than those that burned prior to 1900. They can help biologists make inferences about historic wildlife, bird, or fish populations by reconstructing habitat characteristics. They can help hydrologists make estimates of historic stream flow and channel conditions. They can help us to understand the dynamics of forest succession and disturbance and how today's actions might influence the forests of the future.

Wildfire has played an important role in the forests of North America. Nowhere is this more evident than in the interior western United States. Historically, fire helped to cycle nutrients, decompose stored biomass, reduce accumulations of fuels, regulate species composition and stand densities, and often maintained forests of seral ponderosa pine (*Pinus ponderosa*) (Agee 1990, Arno 1976, Barrett 1988, Cooper 1960, Weaver 1974). However, fire regimes have changed drastically in the last 100 years.

Many investigators have studied historic fire frequencies in the dry ponderosa pine and Douglas-fir climax types. Fire-return intervals ranged from 5 years in Arizona (Dieterich 1980) to 38 years in central Oregon (Bork 1985). Steele (et al. 1986) found average fire-return intervals in the Boise Basin of central Idaho to range from 10 to 22 years. This was before Euro-American settlers introduced large herds of domestic livestock and fire control strategies. Research and historical documents and photos have shown that before the influences of modern settlement, much of these dry ponderosa pine and Douglas-fir climax forests contained more open stands of ponderosa pine and were dominated by grasses in the understory. Today, the tree densities in many forests have increased; ponderosa pine now shares the slopes with more shade-tolerant Douglas-fir. Furthermore, 80 to 100 years of fire exclusion in many of these forests has changed the fire regime from one of more frequent ground fires, to more intense and often lethal fires (Sloan *this volume*).

Researchers have conducted similar work in western subalpine forests. For instance, in lodgepole pine (*Pinus contorta*) forests researchers have discovered cycles that include even- aged stands, mountain pine beetle epidemics, and stand-replacing fire every 100 to 300 years and after intervening lower intensity fires (Arno et al. 1993, Barrett et al. 1991, Lotan et al. 1985, Romme and Despain 1989). In subalpine fir climax forests, the current stand conditions may not be much

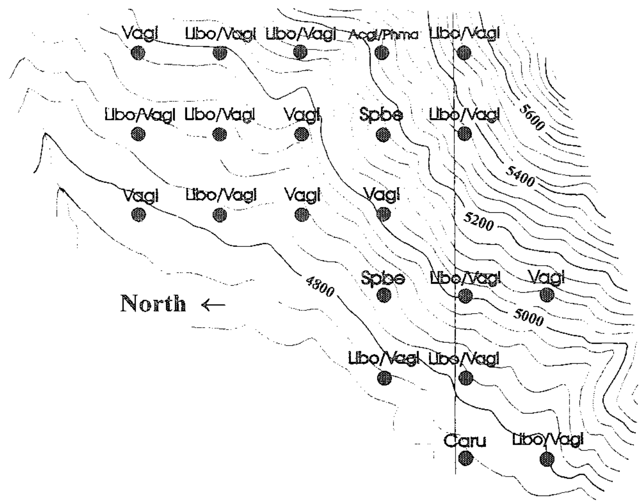

Fig. 1. Arrangement of plots within the sampled stand. Plots were located on a 500 meter grid. All plots fell in the grand fir (Abies grandis) climax type. Habitat types indicated are: Acgl/Phma—Abies grandis/Acer glabrum/Physocarpus malvaceus; Caru—Abies grandis/Calamagrostis rubescens; Libo/Vagl—Abies grandis/Linnaea borealis/Vaccinium globulare; Spebe—Abies grandis/Spiraea betulifolia; Vagl—Abies grandis/Vaccinium globulare.

different than they were during the last few thousand years.

There is little published information about historic stand conditions in the grand fir forest type. Hall (1976) observed that warm, dry grand fir associations with understory dominants such as elk sedge (*Carex geyeri*) or pinegrass (*Calamagrostis rubescens*) appear to have burned frequently in the Blue Mountains of western Oregon. Agee (1994) reported individual tree fire-return intervals of 50 to 200 years in a cool, moist grand fir-big huckleberry (*Vaccinium membranaceum*) habitat type in the Blue Mountains. On a grand fir-grouse whortleberry (*Vaccinium scoparium*) habitat type, he reported fire-return intervals of 66, 100, and 200 years.

STUDY SITE

The study site consisted of 300 acres (120 hectares) near the headwaters of Silver Creek on the Emmett District, Boise National Forest in central Idaho. Located on the Idaho Batholith, the soils are derived from granitic parent material, are low in silt and clay, and are weakly developed. Annual precipitation averages about 1000 millimeters, 65% of which falls as snow during the winter. Summers are typically hot and dry (Megahan et al. 1995). In general, the stopes face northwest but uneven terrain caused plot aspects to vary from 240° to 42°. Elevations ranged from 4600 to 5400 feet (1400–1650 meters).

The predominant habitat type is grand fir-twinflower (*Linnaea borealis* L.) in the blue huckleberry (*Vaccinium globulare*) phase; however, inclusions of other habitat types are common (Figure 1). Bordering the study site are Douglas-fir-ninebark (*Physocarpus malvaceus*) and several subalpine fir climax types.

Table 1. Severity of past fires. R = stand-replacing fire (no survivors, regeneration follows); M = mixed (many survivors, regeneration follows); N = non-lethal (nearly all trees survive, no regeneration). Values represent percent of plots in a fire category for each fire year.

Fire year	Number of plots	Fire severity				
		R	R/M	M	N/M	N
1899	21	0	0	10	0	90
1887	21	0	0	5	0	95
1862	21	0	0	14	10	76
1850	21	14	0	29	14	43
1810	18	0	6	22	28	44
1797	18	0	6	6	50	39
1787	17	0	12	12	59	18
1774	15	0	7	13	67	13
1759	13	0	15	8	62	15
1731	11	0	0	18	82	0
1707	9	0	0	0	100	0

Native Americans were the first inhabitants of the Silver Creek drainage to leave any record of their existence. The Northern Shoshone collected roots, seeds, and berries and were skillful hunters (Smith 1983). Miners came to the area in the late 1800's. By the early 1900's settlers brought large herds of livestock that grazed extensively on the area. In 1905 the Forest Service was established (Smith 1983). That same year, the Payette National Forest was created and sometime later a ranger station was built just west of Silver Creek. Today, Silver Creek is part of the Emmett Ranger District of the Boise National Forest.

Selective logging took place on the southern boundary during the 1970's. Firewood cutting has been conducted on the western boundary. Otherwise, the stand has not been visibly disturbed by human acts, except through altered natural fire cycles.

METHODS

The investigation of stand history consisted of two parts. The first part was a determination of fire history. I sampled the fire scars with the least amount of decay, and used the methods of Arno and Sneck (1977). The fire scars I sampled were well distributed throughout the stand. They came from nine ponderosa pine trees and one Douglas-fir. After cutting the partial cross section from the trees, I processed them according to Arno and Sneck (1977) and analyzed the data using the methods of Arno (Arno et al. 1993).

The second part of the investigation required measurement of sample plots laid out on a grid pattern in the stand and was based on the methods developed by Arno (Arno et al. 1993) for use in subalpine fir forests.

Circular plots were 0.1 acre (0.05 hectare). They were established on a north-south and east-west grid with a spacing of 500 feet (152 meters) between plots (Figure 1). The grid was anchored to a small creek gauging station we used as our primary reference point. The control line ran east from the reference point, up the slope. The transects ran north and south from the control line. We used colored flagging to mark the control line and transects. Each plot center

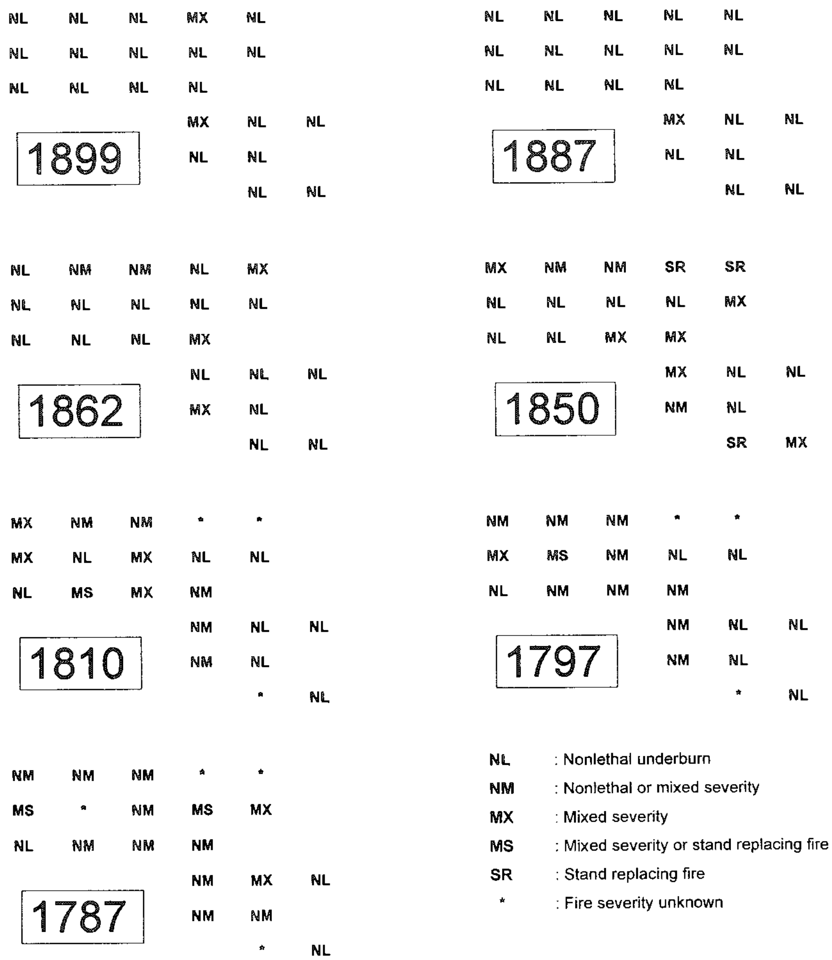

Fig. 2. Fire severity at each plot for the last seven major fires, based on dating fire scars on trees in the Silver Creek drainage, central Idaho.

was marked with a wire flag and labeled with transect and plot numbers.

After an examination of the vegetation, we identified the habitat type of each plot according to Steele (Steele et al. 1981). Site characteristics were recorded, including elevation, slope, and aspect. All living trees were tallied by diameter classes. Dead trees were recorded, and diameter at breast height (dbh) estimated. Further description of the stand included listing and cover of major understory species; species and vigor of the overstory trees; number of tree seedlings; previous overstories that are now dead; evidence of past disturbance in the stand (i.e., fire, insects, logging); fire history inferences from fire scars and charcoal on trees, logs, and stumps; litter layer accumulations; bark mound depth, especially under large ponderosa pine; branching habits of the dominant trees; and conditions in the larger stand around the plot.

Finally, it was important to obtain accurate age-class data to characterize stand structure. I collected increment cores at ground line from all of the large trees (20 inch or 50 centimeter dbh and larger) in the plot and all ponderosa pine using a power borer. When trees contained heart rot, I often cored them at dbh. Then I aged a sample of the other smaller trees in the plot, making sure to bore every size class. This usually required the boring of from four to ten trees in a plot.

Once the data were collected, I developed a landscape mosaic grid (Arno et al. 1993). Each plot is a mosaic pixel in the reconstruction of the history of the stand in relation to disturbance, composition, and structure. I used the fire chronology, the ages of seral species, and observations of fire history to construct fire severity maps for the stand.

For each sample point, I described the age-class structure of the current stand and estimated what it looked like in the past. To estimate past age-class structure, I used increment cores to determine which trees were present and estimated their size and growth rates. I chose 1900 as a comparison year because this date was early enough to represent the period prior to fire suppression. I used dominant species composition to classify the stand structure at each plot, then compared the two time periods by summarizing each stand type as a percent coverage of the landscape. Species dominance classification was based on current basal area and estimated basal area in 1900.

Diversity is an index developed from information theory (O'Neill et al. 1988, Turner and Ruscher 1988). Diversity is a measure of how many different stand

Table 2. Percent of the area dominated by each species: ponderosa pine (PP), Douglas-fir (DF), lodgepole nine (LP), grand fir (GF), shrubs (SH), and combination of 3 or more species (Mixed).

Dominant species	1900	1995
PP	52	0
PP/DF	14	24
PP/LP	5	0
PP/GF	5	0
PP/SH	5	5
TOTAL PP	81	29
LP	5	0
DF	10	10
DF/PP	0	5
DF/GF	0	10
DF/SH	0	5
TOTAL DF	10	30
GF	0	19
SH	5	0
MIXED	0	24

types are distributed on the landscape. It indicates difference, and is calculated based on species composition and stand structure:

$$-\sum_{k=1}^{m}(P_k)\log(P_k)$$

where P_k is the proportion of the landscape in stand type *k,* and *m* is the number of stand types present. Larger values indicate more diversity. I calculated diversity based on the stand types in 1995 and compared that to the diversity for the estimated stand types in 1900.

RESULTS AND DISCUSSION

Although the stand was classified as a grand fir-twinflower-blue huckleberry habitat type, we found much variability in the stand. One study plot fell into a grand fir-pinegrass (*Calamagrostis rubescens*) habitat type, two were in the grand fir-white spiraea (*Spiraea betulifolia*) habitat type, one in the grand fir-mountain maple (*Acer glabrum* var. douglasii (Hook.) Dippel)-ninebark habitat type, seven were in the grand fir-blue huckleberry habitat type, and ten were in the grand fir-twinflower-blue huckleberry habitat type. Grand fir-pinegrass represents the dry extreme of the group while grand fir-twinflower-blue huckleberry is at the moist end. The other habitat types can also be arranged on the moisture scale. Figure 1 shows the spatial relationship of the habitat types.

Fire scar analysis was conducted for a 300-year period. The earliest fire record was from approximately 1707. The last fire to burn in the stand was in 1899. During that time period, I identified 11 fire years (Table 1). Fire frequency ranged from 10 to 40 years and the mean fire- return interval was 19.2 years. The greatest number of fire scars recorded on a sample was six; the least was two. The oldest trees I sampled fire scars from were 397 and 388 years old.

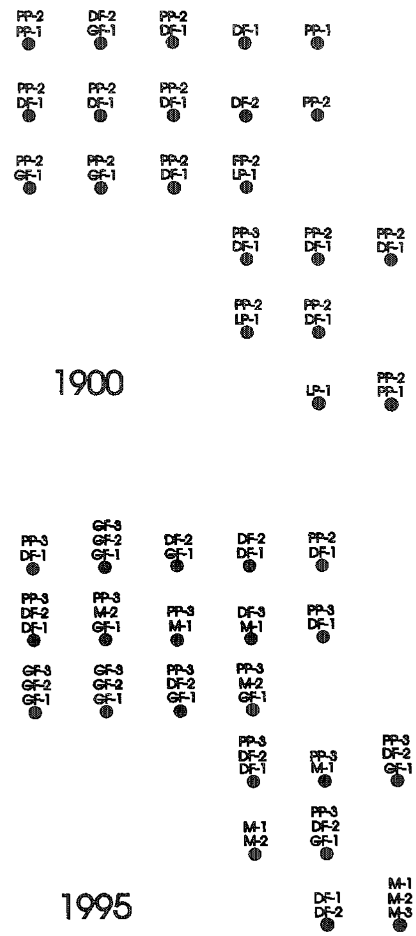

Fig. 3. Map of plots in sample stand showing the dominant species and stand structure in 1900 compared to 1995. Species codes: PP—ponderosa pine; DF—Douglas-fir; LP—lodgepole pine; GF—grand fir; M—mixed (dominated by two or more species). Stand structure codes: 1—young (saplings and poles); 2—mature; 3—overmature.

The fire scars showed that when fires burned, they covered much of the stand. This is not to say that each fire burned everywhere in the stand, however. The fires must have been somewhat patchy in the way they burned, based on the fact that some late seral species were able to survive. The broad coverage of the fire scar samples within the stand did not allow me to determine exact burn locations of the fires but the fire scars indicated that the fires were widespread throughout the stand.

The fires did not always burn through the stand with consistent severity (Table 1). Most of the fires were nonlethal under burns which did not kill overstory trees and did not stimulate regeneration of seral species. I will refer to these as nonlethal fires. A stand-replacing fire is one that killed all the overstory trees. We must go back to 1850 to find a stand-replacing fire and it influenced only 14% of the total area. There is a third category: the mixed-severity fire. It can be defined as a fire which kills some of the overstory trees but leaves survivors and stimulates regeneration. There was much less mixed fire than nonlethal fire. As the fire interval increased, so did the fire severity. The year

Table 3. Transition matrix. Values indicate percent change from one stand type to another.

1900	1995 Ponderosa pine	Douglas-fir	Grand fir	Mixed species
Ponderosa pine	35	18	18	29
Douglas-fir	0	50	50	0
Lodgepole pine	0	100	0	0
Grand fir	—	—	—	—
Shrub	0	100	0	0

1850 showed the most severe fire overall, and that came after the longest period without fire in the fire chronology.

As might be expected, the farther back in time, the more points on the landscape drop out of the analysis because the evidence to date fires did not go back that far. I started with 21 sample points providing data for 1899 and had only 9 plots with data for 1707. Also, when backdating more points fall into one of the either/or categories. Figure 2 shows the spatial arrangement of the different fire severity groups throughout the stand. In any given fire year, sometimes the plots with higher fire severity are clumped but often they are not. Fire severity maps before 1787 were not included in Figure 2 because most of the fire severity was uncertain. I found no relationship between fire severity and habitat type, probably because the spatial relationship of the stand was more important. Also, fire severity at each plot was not necessarily consistent between one fire and the next. Weather, fuel loads, and fuel conditions combine to determine fire severity.

I suspect sources of ignition originated from a combination of human factors and lightning strikes. The fires probably burned in the late summer when conditions were the driest. Most of these habitat types tend to be too moist to burn in the early summer and fall although that may not have been true in drought years. The burning patterns were probably patchy and variable in intensity. The fire scars showed the fires were widespread across the stand; however, which fires made a record in which tree seemed to be more arbitrary. I often observed patterns of compressed growth rings from some trees which corresponded to the dates of fire scars on other sampled trees. This I attributed to crown scorch and used it as further evidence that the fires burned throughout the stand, not just in isolated locations. Crown scorch can reduce tree ring width for a few years after a fire by reducing the photosynthetic base of the crown which will reduce growth of the tree.

What are the likely implications of these frequent fires? Frequent low-intensity burns promote seral species like ponderosa pine, which is especially adapted to that fire regime. The fires kill some of the weak trees, expose mineral soil for regeneration of seral species, and kill most of the more shade-tolerant species which do not have thick bark. Frequent fires promote understory vegetation, such as perennial grasses (pinegrass), and shrubs that can regenerate from sprouting [blue huckleberry, Scouler willow (*Salix scouleriana*), and mountain maple], and a fairly open stand structure (Crane and Fischer 1986).

Table 4. Percent of the study area covered by the three stand types based on structural age of the ponderosa pine. "Immature" stands contain seedling[1], sapling, and pole classes. "No immature" stands contain only mature ponderosa pine. "Mixed" stands contain both.

Stand type	1900	1995
Immature	14	5
Mixed	52	10
No Immature	33	86

[1] Seedlings = trees up to 4 feet (1.2 m). Saplings = trees 0–4 inches (10 centimeters) dbh. Poles = trees above 4 inches dbh in the rapid growth stage. Mature = trees with good vigor but growth slowing. Overmature = trees of reduced vigor and growth.

In the summer of 1995, when this study was conducted, fire had not burned in this forest for 96 years. This represents exclusion of fire for five of the average fire cycles. This lack of fire has changed the forest (Table 2). In 1900, 81% of the stand was dominated by ponderosa pine. In 1995, only 29% of the stand was still dominated by pine. Further, 52% of the 1900 forest was dominated by ponderosa pine alone. In 1995, none of the forest was dominated by ponderosa pine alone. A very small part of the stand was dominated by lodgepole pine in 1900, but today none of it is. On the other hand, in 1900 there were no parts of the stand dominated by grand fir or a mix of three or more dominant species. In 1995, grand fir dominated 20% of the stand while mixed species dominated 25% of it. Douglas-fir has also increased.

In the forest today, the overstory is more complex than it was in 1900 (Figure 3). Where mature and immature layers were common in the forest of the past, an overmature layer of ponderosa pine has developed. Where there was once a single overstory layer, a second layer has now developed.

The transition matrix (Table 3) shows how the stands that were dominated by a species in 1900 have changed in 1995. Some of the pine has given way to Douglas-fir, some to grand fir, and some to a mix of species.

In 1900, half of the sample plots contained a mix of immature and mature early seral trees (ponderosa and lodgepole pine) and another 14% supported only immature pine (Table 4). Ninety-five years later, 86% of the area supports no immature ponderosa pine. Pole-sized ponderosa pine used to be present on one third of the area (Table 5). Today, they are not present

Table 5. Ponderosa pine age classes. Values are percentage of the area in a given class.

PP Structural age class[1]	1900	1995
Poles	33	0
Mature	76	5
Overmature	5	71
Ponderosa pine absent	14	29

[1] Seedlings = trees up to 4 feet (1.2 meters). Saplings = trees 0–4 inches (10 centimeters) dbh. Poles = trees above 4 inches dbh in the rapid growth stage. Mature = trees with good vigor but growth slowing. Overmature = trees of reduced vigor and growth.

Table 6. Transition matrix for changes in ponderosa pine. Values indicate the percent change from one stand type to another.

	1995				
1900	Immature	Mixed	Mature	Overmature	Absent
Immature	0	0	100	0	0
Mixed	0	40	20	40	0
Mature	0	0	0	75	25
Overmature	0	0	0	0	100
Absent	0	0	0	0	100

at all. The area where ponderosa pine is absent has grown from 14% in 1900, to 29% in 1995. Likewise, the transition matrix (Table 6) shows the ponderosa pine component that is still present in the stand is aging. Where the ponderosa pine was mature or a mix of mature and immature, it is now overmature or absent.

The number of ponderosa pine trees on the plot has declined by about one third since 1900 (Figure 4). Lodgepole pine numbers have declined by more than half. The more shade-tolerant species have increased during this century. Douglas-fir has tripled its abundance, subalpine fir has increased 800%, Engelmann spruce (*Picea engelmannii*) has increased 1100%, and the number of grand fir today is almost 20 times greater than it was in 1900. Even though Douglas-fir has increased substantially in number since the turn of the century, there has also been a great deal of mortality in the large size classes. This is based on the presence of numerous Douglas-fir snags and downed logs throughout the stand.

All species included, there were about 84 trees per acre in 1900 (Figure 5). One tenth of that number was represented by grand fir and most were small trees. Almost 40% of the trees were Douglas-fir and of these, some were big trees and some were small. Ponderosa pine trees composed one fourth of the total in 1900 but most of them were large trees. In 1995, there were about 304 live trees per acre on average throughout the stand. This means there are 363% more trees in 1995 than there were in 1900. Half of the trees in 1995 are grand fir. One third of the trees are Douglas-fir, and only 5% of the trees are ponderosa pine.

Diversity is often considered to be a good thing in forest ecology; however, this idea may need to be reconsidered. The forest on my study area today is more diverse than is was in 1900, based on our species composition and stand structure data. The diversity index for 1900 is 2.05 out of a maximum 2.39 possible. In 1995 the diversity is 2.40 out of a possible 2.48. The importance of diversity under historic conditions may have come at the landscape level rather than at the stand level.

If fire exclusion continues to be successful, Figure 6 gives an estimated outcome. Grand fir is by far the most successfully reproducing tree species. Although a small amount of ponderosa pine is present, most of the seedlings are suppressed and will not succeed in producing a mature tree. Barring any major disturbances, this stand will become a climax grand fir forest with a small component of Douglas-fir, subalpine fir, and Engelmann spruce. Ponderosa pine relics may persist for many years to come but most will succumb to the stresses of increased competition. The resulting stand will be at risk for spruce budworm, tussock moth, dwarf mistletoe, root rot epidemics, and stand-

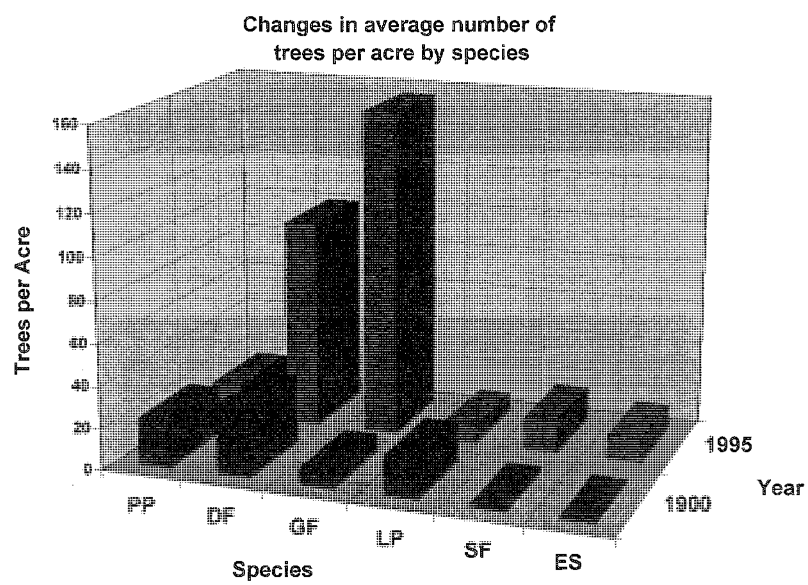

Fig. 4. Average number of trees per acre by species for 1900 and 1995 including all trees one inch at dbh and larger. Species codes: PP-ponderosa pine; DF-Douglas-fir; LP-lodgepole pine; GF-grand fir; SF-subalpine fir; ES-Engleman spruce.

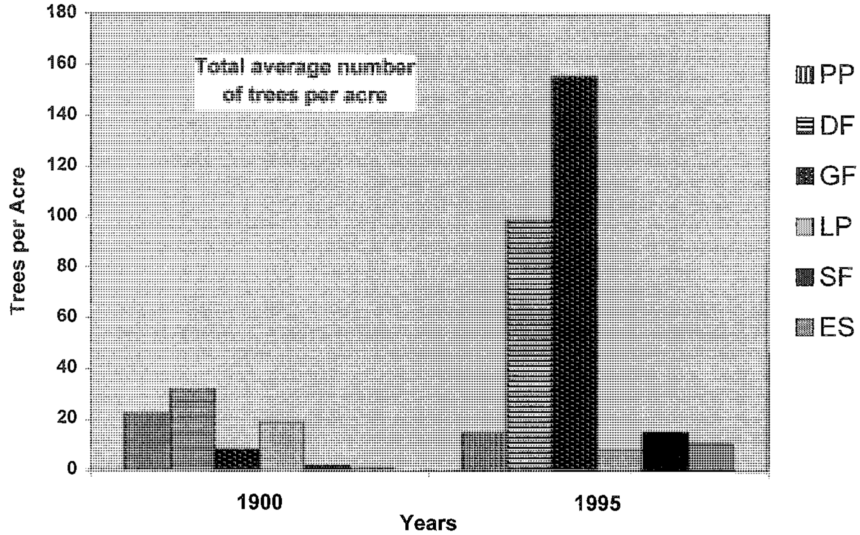

Fig. 5. Average number of trees per acre in 1995 compared to the number of trees in 1900. This figure includes all trees one inch dbh and larger.

replacing wildfire. As the overstory becomes more dense, the understory vegetation will probably be reduced due to lack of light. We see a trend toward more grand fir regeneration in the moister habitat types (Figure 7).

If managers wish to perpetuate ponderosa pine on this site, action is needed soon. If fire returns to the stand under dry conditions, it will probably not have the same effects as fire in the 1800's. Ninety-six years of fuel accumulation may result in a stand-replacement fire. Shade-tolerant tree species such as grand fir and Douglas-fir provide ladders for the fire to reach the overstory layer. Sustained heat will be generated when the deep mounds of bark are burned around the bases of the large ponderosa pines. Few of these trees, some 300 to 400 years old, can be expected to survive. Damage to the watershed and other resources is possible.

If, however, many of the shade-tolerant trees can be killed or removed and if fire can be carefully implemented during moist and cool conditions, then the early seral species might be perpetuated.

CONCLUSION

Before 1900, fire burned an average of every 19 years in this grand fir climax stand of the Silver Creek drainage in central Idaho. The last fire burned in 1899. The fires were mostly light underburns but occasionally they flared up into patchy stand-replacing fires. Lack of fire in the last 96 years has brought great change to the forest. Historically, fire maintained much of the stand in an open forest dominated by ponderosa pine and a lesser amount of Douglas-fir. Parts of the site supported pockets of dense lodgepole pine and a small area of brush field. The overstory structure consisted of a combination of mature and immature trees.

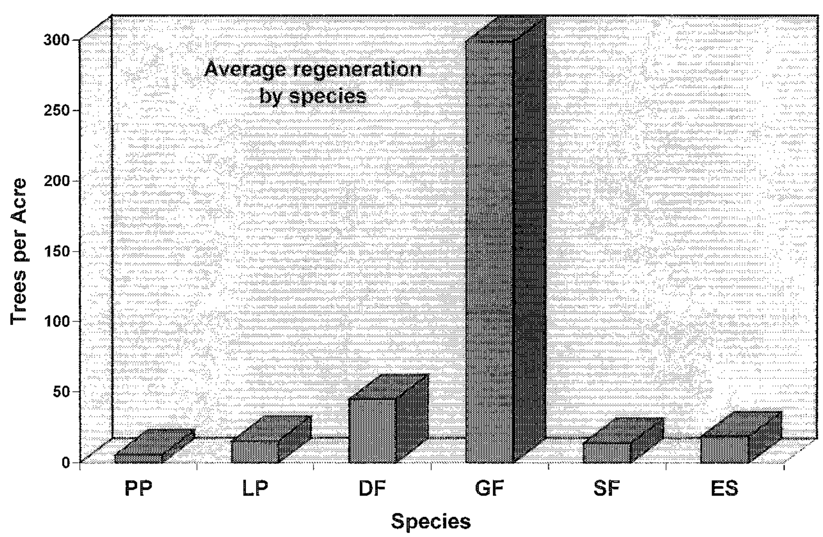

Fig. 6. Regeneration of tree seedlings per acre by species, averaged for all the plots combined. Species codes: PP-ponderosa pine; DF-Douglas-fir; LP-lodgepole pine; GF-grand fir; SF-subalpine fir; ES-Engleman spruce.

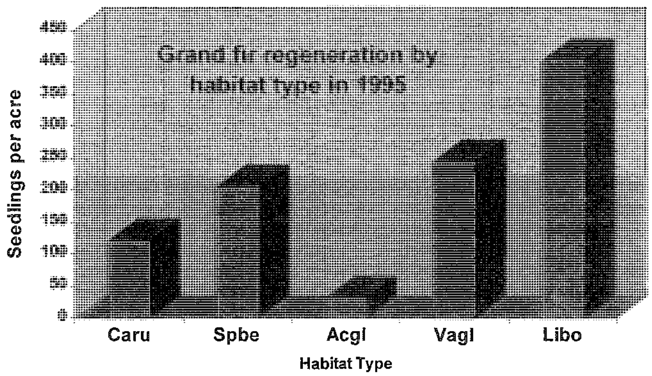

Fig. 7. Grand fir regeneration by habitat type in 1995. The habitat types are arranged from driest to moistest. Codes of habitat types follow Fig. 1.

Today, the forest is dominated by ponderosa pine, Douglas-fir, and grand fir in various combinations. Some of it is close to a climax condition, all of it is more successionally advanced than it was in 1900. The ponderosa pine component is aging; most of it is overmature and apparently weakened by competitive stress. Two-thirds of the ponderosa pine trees alive in 1900 have survived. The abundance of Douglas-fir has increased 300% and the abundance of grand fir has increased by a factor of twenty. Diversity of the forest has increased because of more tree species entered into the mix and a more complex stand structure. The stand density is three and a half times higher now than at the turn of the century. One-half of the live trees today are grand fir and one-third are Douglas-fir. Only 5% are ponderosa pine.

Ponderosa pine does not appear to have regenerated on this site during this century, and without intervention, it will probably disappear from the stand. In the absence of a major disturbance, the stand will soon be dominated by grand fir with a lesser component of Douglas-fir. Diversity will decrease and the risk of insect and disease epidemics, as well as the risk of stand-replacing fire, will increase.

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