HISTORICAL DENSITY AND STAND STRUCTURE OF AN OLD-GROWTH FOREST IN THE BOISE BASIN OF CENTRAL IDAHO

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ABSTRACT

After 100 years without fire, the forest of the Bannock Creek Research Natural Area (BCRNA) has changed. The BCRNA of the Boise Basin is an old-growth ponderosa pine (*Pinus ponderosa*) forest. I established 11 plots there to study stand history in five habitat types of the warm, dry Douglas-fir (*Pseudotsuga menziesii*) climax series of central Idaho. Formerly open stands of old- growth ponderosa pine are now dense stands of ponderosa pine and Douglas-fir. The forest of the 1800's typically supported from 6 to 60 trees per acre (15 to 150 per hectare). Regeneration from the early 1900's, due to livestock grazing and lack of fires, has increased the densities of these stands to as many as 900 trees per acre (2223 per hectare); most are in the 250 to 600 trees per acre (620 to 1500 per hectare) range. Densities were more closely related to the number of old-growth trees and open space on the plot than to habitat type. Stand basal areas were generally below 100 square feet per acre (23 square meters per hectare) in the 1800's, but in the last decade they peaked well above 200 square feet per acre (46 square meters per hectare) before mortality caused them to level off or decline.

Although Douglas-fir did not mature in the stands of the 1800's, it is an important component of the stands today. Fuel accumulation makes the likelihood of a stand-replacing fire, as well as insect and disease epidemics, much greater than it was 100 years ago and before.

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INTRODUCTION

Boise Basin is located about 25 miles (40 kilometers) northeast of Boise, Idaho. In the central portion of the basin, rolling hills support second-growth conifer forests and shrub fields. Ponderosa pine (*Pinus ponderosa*), in various sizes, grows with a lesser amount of Douglas-fir (*Pseudotsuga menziesii*). In some stands, the two species form dense thickets. High ridges and peaks border the basin on three sides. At upper elevations Douglas-fir becomes more prevalent than ponderosa pine. Beginning in the 1860's, the Boise Basin experienced intensive gold mining, and for a short time, human population expanded greatly (Smith 1983).

In much of the western United States early explorers, trappers, miners, and settlers found old-growth ponderosa pine stands in an open parklike condition (Agee 1990, Boise National Forest 1993, Cooper 1960, Covington and Moore 1992, Habeck 1988). The Boise Basin supported an excellent example of an open ponderosa pine forest (Smith 1983). Here, frequent low-intensity ground fires favored large, widely spaced trees, mostly ponderosa pine with a small amount of Douglas-fir. Ponderosa pine is well adapted to a regime of frequent burning (Weaver 1974, Cooper 1960, Arno 1976, Steele et al. 1986, Steele 1988, Weaver 1967, Agee 1990, Barrett 1988, West 1969, Kilgore 1981).

Today, the forests of the Boise Basin are much different than they were historically. Clear-cutting and selective logging, mining, broadcast burning, and livestock grazing have caused great changes in forest structure and composition. Not only are the forests more dense now than they were historically, many stands have understory vegetation dominated with late successional, shade-tolerant conifers. These conditions make the trees more vulnerable to attacks by insects, disease, and drought (Steele et al. 1996). Increased fuel accumulation and fuel ladders make large stand-replacing fires more likely. Since 1986, wildfires on the Boise National Forest have been increasingly large and severe. Nearly 500,000 acres (200,000 hectares) have burned during the last ten years, much of it with uncharacteristic severity (USDA Forest Service 1996).

In order to better understand the present day condition of ponderosa pine forests, we must understand the historic conditions of these forests. We need proactive management of the forest rather than reaction to widespread disease and insect outbreaks and large fires such as we have seen in the last ten years. Such an approach will help us understand how silviculture and management can be used for stewardship of future forests.

STUDY AREA

I chose the Bannock Creek Research Natural Area (BCRNA) to study the history of the Boise Basin. This area has never been logged, and it has not burned since the late 1800's. BCRNA is located 8 miles (13 kilo-

Table 1. Estimated number of trees per acre on 11 plots in Bannock Creek Research Natural Area through time. The Douglas-fir habitat types are arranged from driest to moistest. Syor = mountain snowberry, Cage = elk sedge, Caru = pinegrass, Spbe = white spiraea, and Phma = ninebark.

Plot	Habitat type	Year 1850	1900	1950	1990	1993
10	Syor	28	67	538	316	272
1	Cage	39	61	244	227	222
2	Cage	83	94	116	105	11
3	Cage	17	17	355	316	139
4	Cage	22	22	255	255	189
6	Cage	61	72	177	150	116
7	Caru	61	67	155	133	128
11	Caru	6	17	333	227	216
5	Spbe	39	44	277	166	133
8	Phma	28	44	433	244	194
9	Phma	11	22	932	344	305
Average		36	48	347	226	175
Std. Error		7.2	7.9	69.4	24.1	24.6
Median		28	44	277	227	189

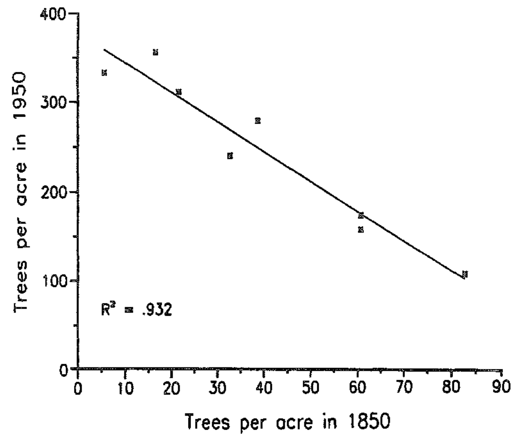


Fig. 1. Regression line shows the linear relationship between the number of trees per acre in 1850 and the number of trees per acre in 1950 on eight different plots.

meters) southeast of Idaho City in the Boise Basin Experimental Forest.

Soils in the BCRNA are gravelly, sandy loams which have been derived from underlying granite and are low in capacity to hold water. Elevation of the study plots ranges from 5,000 feet (1524 meters) to 5200 feet (1585 meters). Average annual precipitation at Idaho City is about 24 inches (0.6 meters), most of which falls as snow. Nearly all of the BCRNA is in the Douglas-fir climax zone (Steele et al. 1981). The forest structure is uneven-aged. Stands range from all ponderosa pine to mostly Douglas-fir.

These sites fall within Crane and Fisher's (1986) fire group three: "warm, moist ponderosa pine habitat types and warm, dry Douglas-fir habitat types usually dominated by ponderosa pine." Some of the stands have a shrub-dominated undergrowth including mountain snowberry (*Symphoricarpos oreophilus*), white spiraea (*Spiraea betulifolia*), rose (*Rosa sp.*), chokecherry (*Prunus virginiana*), ninebark (*Physocarpus malvaceus*), antelope bitterbrush (*Purshia tridentata*), oregon grape (*Berberis repens*), serviceberry (*Amelanchier alnifolia*), and Scouler willow (*Salix scouleriana*). Elk sedge (*Carex geyeri*) and pinegrass (*Calamagrostis rubescens*) dominate undergrowth in the remaining stands. Forbs are less common: arrowleaf balsamroot (*Balsamorhiza sagittata*), sticky geranium (*Geranium richardsonii*), silvery lupine (*Lupinis argenteus*) and others.

During the early 1900's, large herds of domestic sheep and cattle grazed the Boise Basin, including the BCRNA. The USDA Forest Service was officially created in 1905 and during the next 2 decades tried to control wildfires. During 1933, the Boise Basin Experimental Forest was created. This resulted in livestock exclusion from the site that would later become the BCRNA. The BCRNA was established in 1970 to preserve a 430-acre (175-hectare) example of old-growth ponderosa pine and Douglas-fir.

During late July of 1994, a year after this study was conducted, a lightning strike in the BCRNA produced the Bannock Creek fire that burned 2000 acres (810 hectares) before it was stopped. Roughly 75% of the BCRNA burned in that wildfire. The severe nature of the fire killed most of the overstory trees.

METHODS

Plot Establishment

I selected 11 plot locations to cover a range in habitat types and aspects. Each of the 11 plots were established where slope, aspect, and habitat types were uniform. The plot locations represented the whole stand in terms of structure and site heterogeneity.

Plots were 100 feet (30 meters) in diameter, or 0.18 acres (0.07 hectares). I recorded habitat type and cover estimates for shrubs, forbs, grass, slash, litter, and bare ground; all species present; and aspect and slope. Careful searches were made for fire scars, scarification, and other signs of past disturbance.

Within each plot, I measured tree diameter at breast height (dbh) on all standing trees and estimated dbh on all fallen trees. I mapped the location of all trees using distance from the plot center and a bearing from a starting point, 0 degrees. I recorded species, crown condition, and apparent vigor.

For dead trees, I estimated year of death. Most of the mortality had taken place within the last 10 years. Therefore, estimated year of death was based on the condition of the bark and if needles were still present. For trees dead 10 to 40 years, I used the degree of wood decomposition. For trees dead 40 years, I used release dates of trees around the dead tree and sometimes the age of younger trees growing along the downed log. Charcoal on logs also provided evidence that a tree died before the last fire.

As time has led to increased decomposition in older downed logs, the estimates of size and year of death became less accurate. Small trees may have established, died, and decomposed enough to escape detection. However, decomposition rates are so slow in this dry climate that any trees on the plot since the last fire

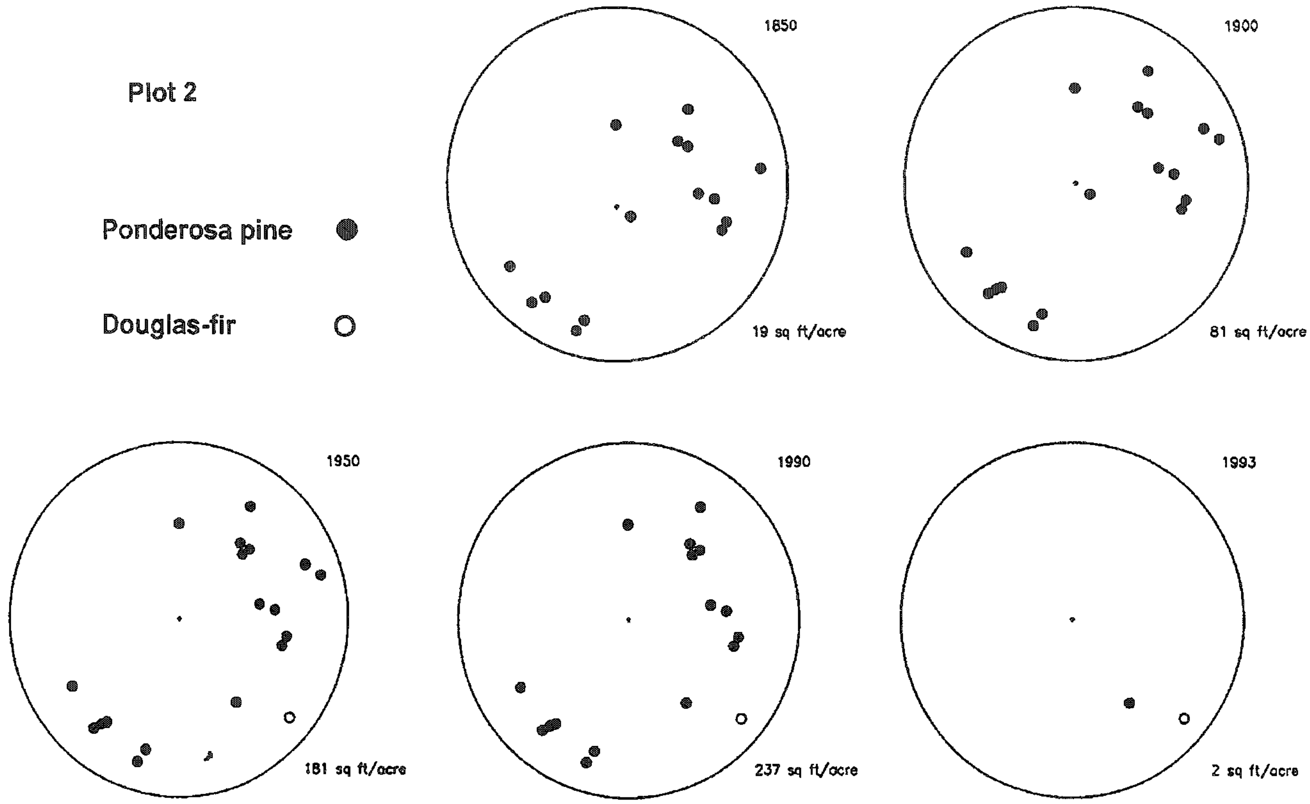


Fig. 2. Diagrams of a Douglas-fir-elk sedge plot (plot 2) showing the location of all living trees in five different years between 1850 and 1993. Estimated stand basal area appears to the lower right of each diagram. The diameter of the circle (plot) is 100 feet.

large enough to have significant basal area were still identifiable at the time of the study.

Stand Dating

I used a power increment borer (Scott and Arno 1992) to take cores from all of the trees older than 90 years and a broad sample of trees younger than 90 years. I bored the trees as close to the ground level as possible. Boring was slightly higher than ground level where bark mounds have built up over the years at the base of old-growth ponderosa pines. Repeated borings were often necessary to obtain a core which passed through or near the pith. I bored many of the dead trees at dbh because the trees were not sound enough at the ground to extract a useable core. Where the increment cores were not taken at ground level or where they did not hit the pith, the estimate of tree age was adjusted appropriately. I mounted all cores onto core boards using white water-soluble glue and evaluated them in the lab.

A magnifying glass and a binocular microscope were useful in counting the rings. To estimate past basal area, I counted backward on the cores to the year of interest, then measured that same interval to estimate the diameter at breast height in that year. To do this, I used the proportion:

$$dbh = (A \times DBH)/B$$

a) Where dbh is the diameter at breast height of a tree in the year of interest.
b) A is the length of the core from the year of interest to the pith.
c) DBH is the current diameter at breast height.
d) B is the length of the core from the outer most ring to the pith.

Fire History

Steele (et al. 1986) sampled the Bannock Creek drainage where the BCRNA is located and determined that the pre-1900 fire interval averaged 16 years for the years 1600 to 1900. Newspaper accounts (Appendix A) describe a severe drought and numerous fires burning in southern Idaho during August of 1889. This corresponds with the last fire in Steele's Bannock Creek fire chronology. I also used some of the fire scars on the old-growth ponderosa pines (Arno and Sneck 1977) to confirm the other fire dates in the BCRNA and to confirm the lack of fire since 1889.

RESULTS AND DISCUSSION

The BCRNA has changed tremendously since the 1800's. The frequent low-intensity fires that burned approximately every 16 years before 1900 maintained an open parklike forest. Tree age data show that ponderosa pine was the only tree species present in the overstory of all 11 plots before 1900.

Today, the old-growth pines can easily be distinguished from younger trees by their thick, plated, reddish and yellowish-brown bark. The ages of these

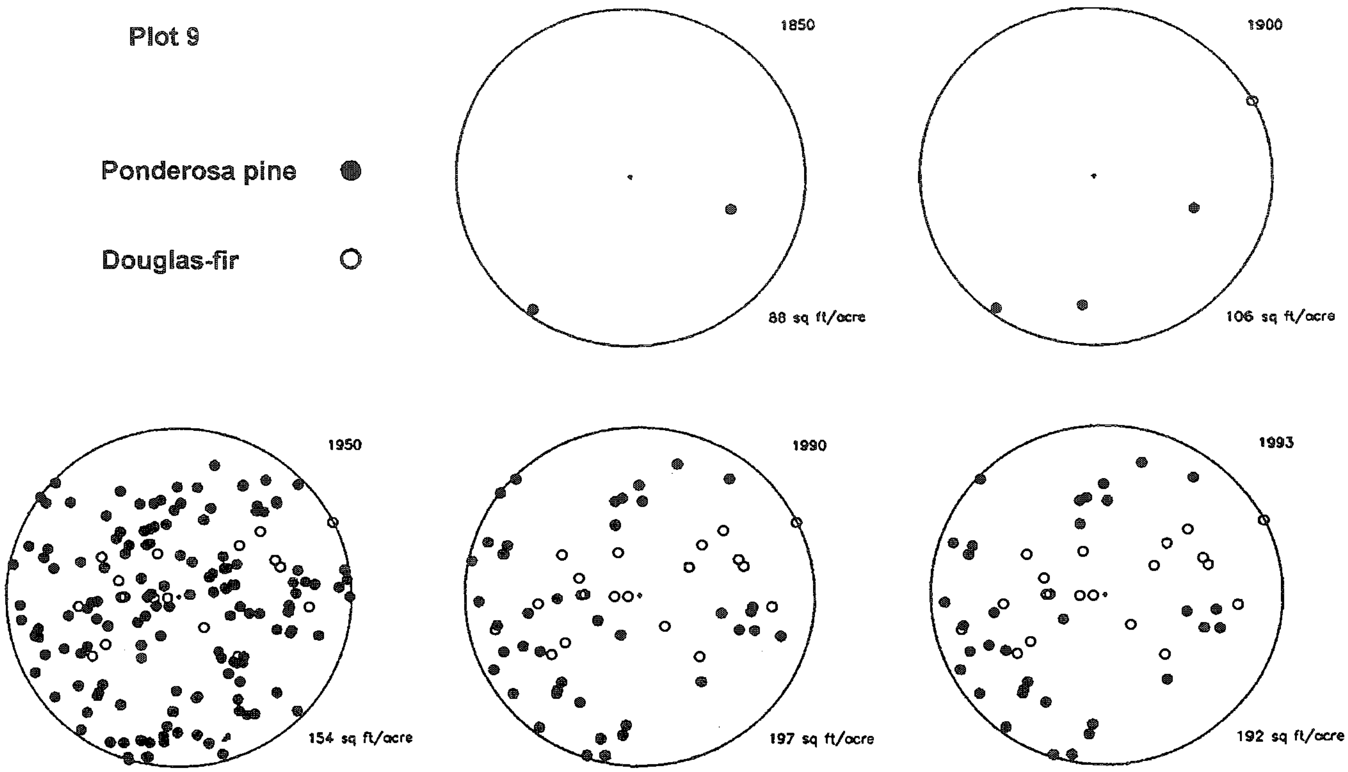


Fig. 3. Diagrams of the second Douglas-fir-ninebark plot (plot 9) showing the location of all living trees in five different years between 1850 and 1993. Estimated stand basal area appears to the lower right of each diagram. The diameter of the circle (plot) is 100 feet.

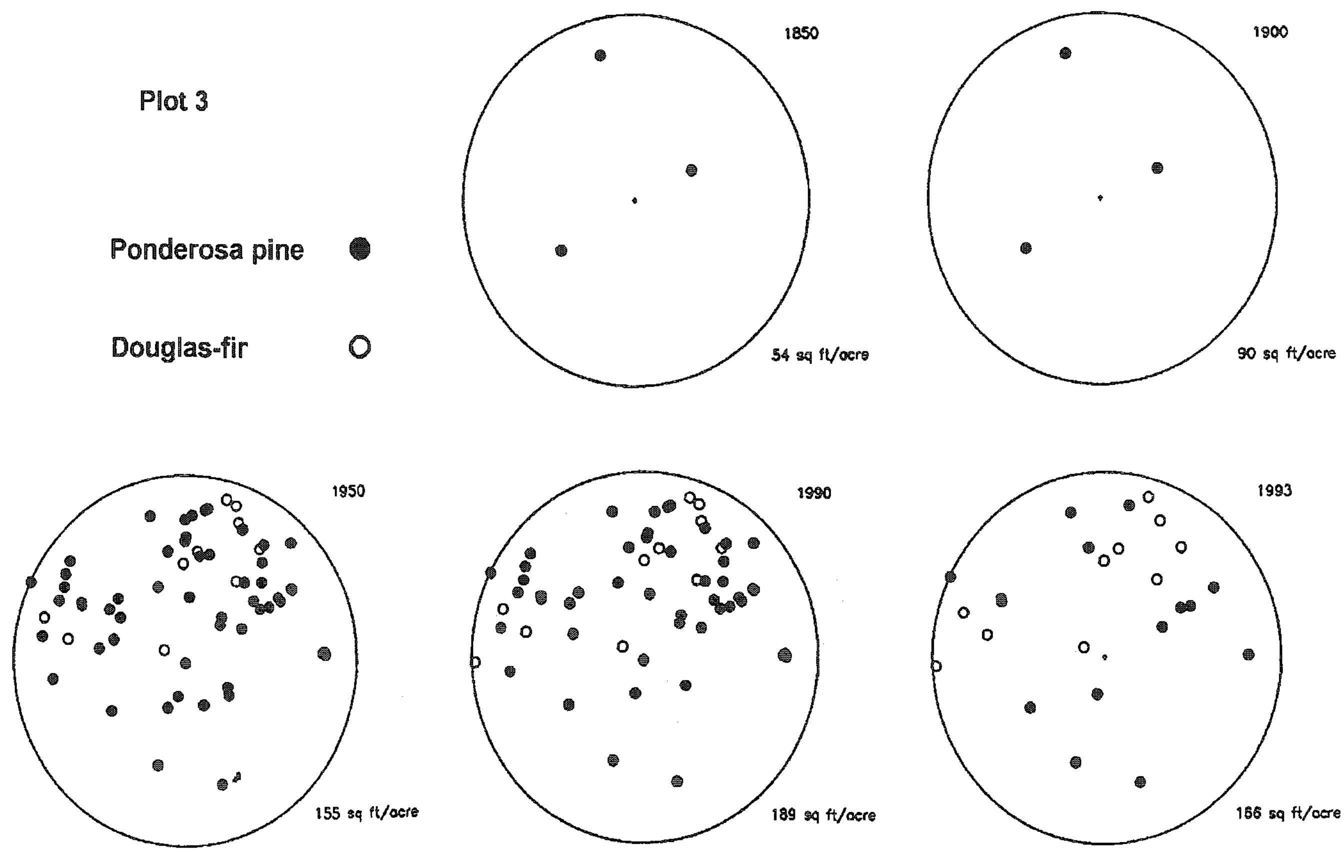


Fig. 4. Diagrams of a Douglas-fir-elk sedge plot (plot 3) showing the location of all living trees in five different years between 1850 and 1993. Estimated stand basal area appears to the lower right of each diagram. The diameter of the circle (plot) is 100 feet.

Table 2. Estimated basal area (square feet per acre) on 11 plots in Bannock Creek Research Natural Area through time. The habitat types are arranged from driest to moistest. Full names of habitat types provided in Table 1.

Plot	Habitat type	Year 1850	1900	1950	1990	1993
10	Syor	132	97	149	191	189
1	Cage	143	188	261	227	227
2	Cage	19	81	181	237	2
3	Cage	54	90	155	189	166
4	Cage	92	118	148	183	173
6	Cage	15	97	184	213	120
7	Caru	51	122	205	221	215
11	Caru	61	88	152	218	216
5	Spbe	70	94	146	123	108
8	Phma	172	62	116	188	183
9	Phma	88	106	154	197	192
Average		82	104	168	199	163
Std. Error		15.1	9.8	11.7	9.3	19.6
Median		70	97	154	197	183

overstory pines range from 140 years to 450 years. Many of these pine exhibit open-grown form: i.e., wide crowns with large diameter branches. The limbs often come within 10 feet (3 meters) of the ground. Other old-growth pines are well pruned because they grew in clusters but they are usually not as large or old as trees which had more growing space. Around the base of the old-growth pines it is common to find mounds of sloughed bark 1 to 2 feet (0.6 meters) deep. The presence of low branches indicates that past fires were of low intensity and had short flame lengths. The bark mounds and deep litter layers are another indication that fire has been absent for over a century.

The tree ages show that in the early 1900's regeneration of both ponderosa pine and Douglas-fir was abundant. Regeneration continued for 40 years and has been almost nonexistent since about 1940. This has resulted in large increases in stand density (Table 1). Stand basal area steadily increased from 1900 until the late 1980's when basal areas peaked. Since then, drought stress has led to western pine beetle (*Dendroctonus brevicomis*) outbreaks which have killed ponderosa pine of all sizes and age classes.

I compared stand density and composition for the years 1850, 1900, 1950, 1990, and 1993 to represent the different stages in stand change. The period before Euro-Americans influenced the Boise Basin fire regime is represented by 1850. In 1900, BCRNA was still under the influence of the historic fire regime. However, no fires occurred in BCRNA after 1900. This represents the beginning of fire exclusion and the beginning of the modern regeneration phase. By 1950, the regeneration had ended and the dense forest was vigorous. This is interpreted from low mortality rates. In 1990 many trees in BCRNA experienced widespread mortality.

Changes in Stand Density

In 1850, the tree densities were low and did not seem to be influenced by habitat type (Table 1). There is not a noticeable difference between the density of the drier habitat types (Douglas-fir-snowberry, Douglas-fir-elk sedge, and Douglas-fir-pine grass) and the moister habitat types (Douglas-fir-*Spiraea,* and Douglas-fir-ninebark). There is, however, a wide diversity in historic densities displayed by the 11 plots, ranging from 6 trees per acre up to 83 (15 to 205 per hectare).

After the last fire, stand densities began to increase. The dense regeneration began after the turn of the century (Table 1). This dramatic increase in stand density took place because of a combination of changes in the forest. The grazing livestock probably disturbed the ground, leaving mineral soil exposed and providing a good seedbed. Grazing by livestock reduced competition for water between tree seedlings and the dense elk sedge and pinegrass. The lack of fire in the BCRNA from 1889 until 1993 allowed the seedlings and saplings to survive.

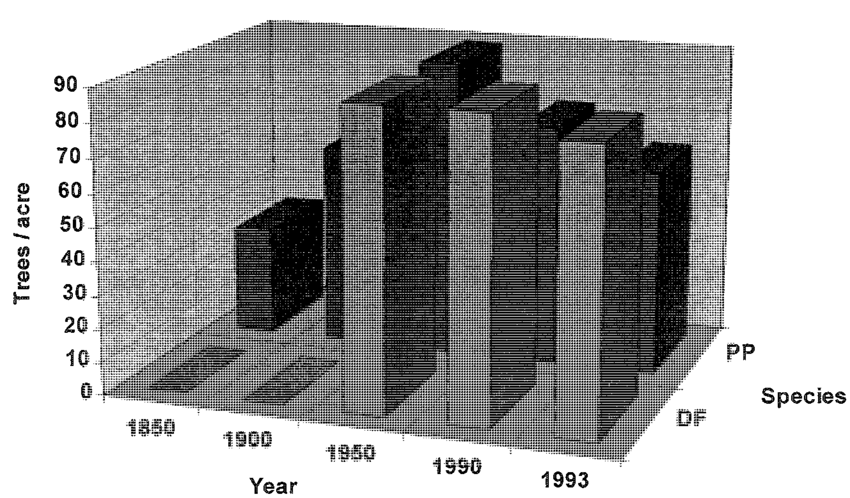


Fig. 5. Density (in trees per acre) on plot 6 for five different years. The first row of bars represents the number of Douglas-fir trees and the second represents ponderosa pine. Plot 6 is an example of a Douglas-fir-elk sedge habitat type.

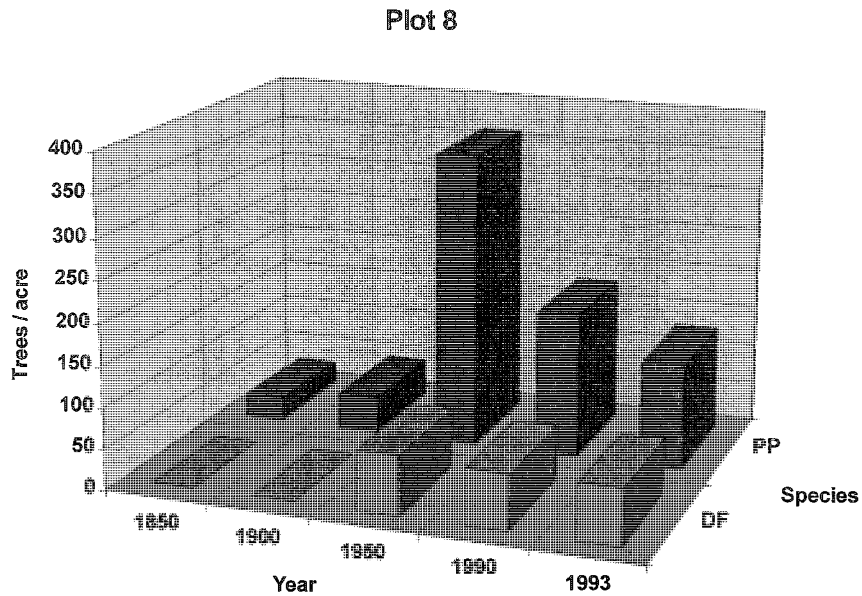


Fig. 6. Density (in trees per acre) on plot 8 for five different years. The first row of bars represents the number of Douglas-fir trees and the second represents ponderosa pine. Plot 8 is an example of a Douglas-fir-ninebark habitat type.

After livestock were removed from the BCRNA, tree regeneration ceased. By this time, stand density had increased substantially (Table 1). Between 1950 and 1990, mortality increased. The mortality continued until 1993. Much of the mortality was attributed to bark beetles; however, the underlying cause was high stress due to competition for water and nutrients.

I found no relationship between the habitat type and the stand density. There was, however, a relationship between the number of trees on the plot and the amount of regeneration. The plots with the fewest overstory trees in 1850 were the same ones that supported the most trees in 1950. This inverse relationship is a strong one with an r-squared value of -0.93 (Figure 1). It means that the most important factor influencing regeneration after the turn of the century was not how many trees were on the site to produce seed, but rather how much open space was present on each plot.

Open space would have been more conducive to regeneration because competition from established trees is intense on xeric sites. It would have been difficult for seedlings to become established near a mature tree, especially within the drip line where the highest concentration of overstory tree roots reside. It was also difficult for germinants to compete with the dense grass in the open spaces until after 1900 when livestock grazing probably reduced competition.

An example of a plot with a relatively large num-

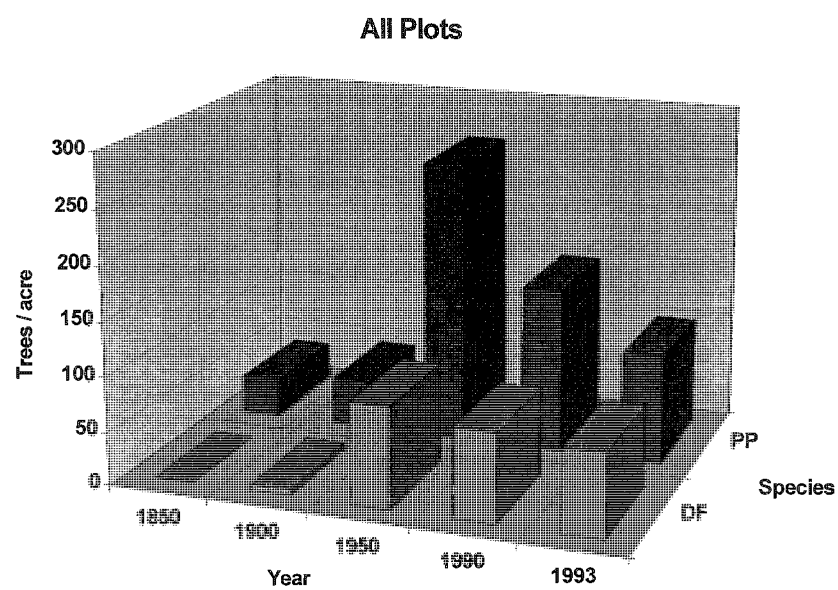
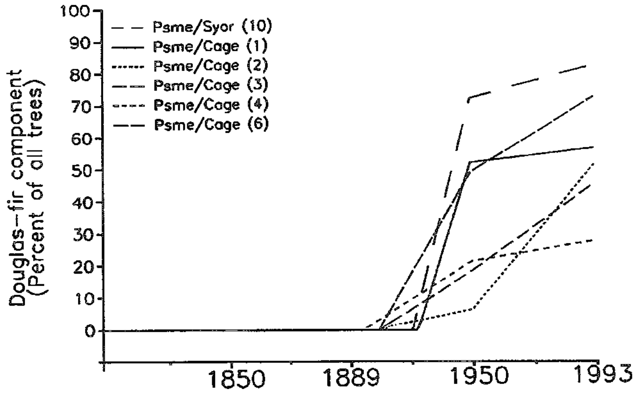


Fig. 7. Density (in trees per acre) on all plots combined for five different years. The first row of bars represents the number of Douglas-fir trees and the second represents ponderosa pine. Mature Douglas-fir trees were not present on any of the plots in 1850 but made up 43 percent of all live trees in 1993.



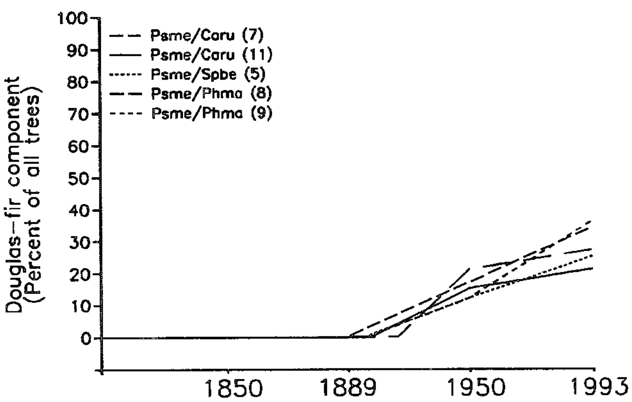


Fig. 8. Percent of live trees that are Douglas-fir in eleven different plots through time. The top graph shows the drier habitat types. The bottom graph shows the moister habitat types. The plot numbers are in parentheses following the habitat types. Habitat type abbreviations are defined in Table 1.

ber of trees in 1850 and relatively few trees in 1950 is plot 2 (Figure 2). This Douglas-fir-elk sedge habitat type, unlike the other plots, underwent little change in stand density from 1850 until after 1990 when most of the trees were killed.

Plot 9 (Figure 3) is an example of the other extreme. This Douglas-fir-ninebark habitat type went from 11 trees per acre (27 per hectare) in 1850, to >900 trees per acre (2200 per hectare) in 1950. More than 900 trees per acre creates a dense stand which is often referred to as a dog-haired thicket, typical of some of the second-growth forests in the Boise Basin.

Plot 3, another Douglas-fir-elk sedge habitat type, is more typical of most other plots (Figure 4). It supported a low but consistent density in the 1800's, and little regeneration between 1889 and 1900. By 1950 stand densities increased dramatically, and by 1993 less than 50% of the trees were still alive. In the absence of fire, insects and disease reduce tree densities when the site capability is exceeded. This, in turn, will put the stand at even higher risk of experiencing an uncharacteristically severe fire.

Changes in Stand Basal Area

Unlike tree density, which declined after 1950, stand basal area continued to increase until 1990. Three years later basal area had also declined. The estimated stand basal areas in 1850 ranged from 19 to 172 square feet per acre (4 to 40 square meters per hectare) and averaged 82 square feet per acre (19 square meters per hectare) for the 11 plots (Table 2). Steele (et al. 1996) found that ponderosa pine is at risk of mortality from western pine beetle and mountain pine beetle (*Dendroctonus ponderosae*) when total stand basal areas reach 90 square feet per acre (20 square meters per hectare) or above. Two of the three plots with basal areas above 90 square feet per acre in 1850 incurred mortality before 1900.

Most of the plots reached basal areas near or above 200 square feet per acre (46 square meters per hectare) before the basal areas began to decline. Many of the old-growth pines have died although not from the bark beetles. The beetles also killed a large proportion of trees in the mature, pole, and sampling size classes.

Changes in Species Composition

There were no signs of old-growth Douglas-fir trees in any of the plots. I observed a few large Douglas-fir down the slope near Bannock Creek and across the creek on the north and easterly aspects. Before 1900, the mature Douglas-fir trees were restricted to stream bottoms, drainages, northern aspects, and higher elevations. These trees were close enough to the plots to provide seed, however. After 1889 the lack of fire allowed Douglas-fir back into the midslope stands.

On some plots, Douglas-fir regeneration developed as strongly as ponderosa pine after the turn of the century (Figure 5). Although the Douglas-fir was not as plentiful on some other plots (Figure 6), the high mortality in ponderosa pine left the forest with a high proportion of Douglas-fir today (Figure 7). Figure 8 shows that the proportion of Douglas-fir has increased substantially in the plots over time. Overall, from 1889 to 1993, Douglas-fir has gone from not being present to >43% of the number of trees present. In the absence of disturbance, the vegetation will progress toward a condition where the Douglas-fir component will increase.

It is unknown why Douglas-fir presently makes up a greater proportion of trees in the drier habitat types (Figure 8).

The implications of more Douglas-fir trees in the stand are several. First, the stands are moving along a successional pathway. Compared to the forest of 100 years ago, adding Douglas-fir makes for a more diverse overstory. This diversity at the stand level may come at a cost, however. Historically, the diversity was probably provided on a landscape scale. In the 1800's there was probably a mix of ponderosa pine and Douglas-fir in the draws, stream bottoms, and northern slopes. More open stands of ponderosa pine occupied the midslopes and ridges. Today we find a mix of ponderosa pine and Douglas-fir where they existed historically as well as on the midslopes.

With a substantial number of Douglas-fir trees in the stand, there is now risk for dwarf mistletoe (*Arceuthobium douglasii*), western spruce budworm

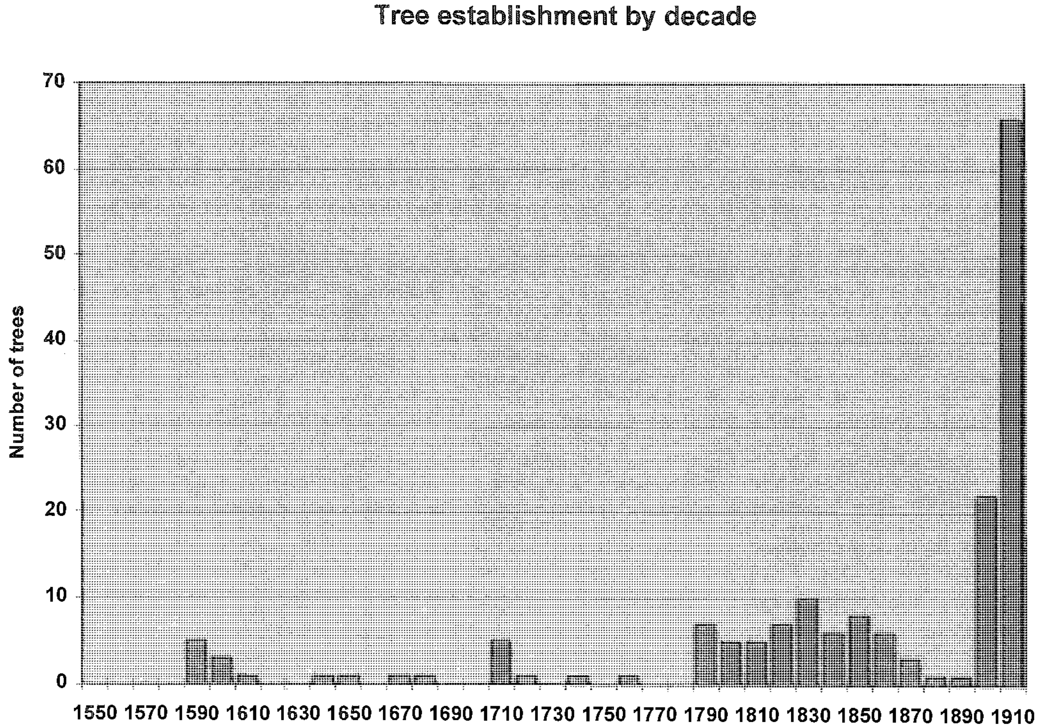


Fig. 9. Number of trees established in each decade between the years 1550 and 1900 from all plots combined (total area 1.98 acres). Data are based only on the plot trees which were sound enough to age in 1993.

(*Choristoneura occidentalis*), Douglas-fir tussock moth (*Orgyia pseudotsugata*), and Douglas-fir beetle (*Dendroctonus pseudotsugae*) (Steele et al. 1996). Also, Douglas-fir do not self prune lower branches as well as ponderosa pine and therefore provide fuel ladders for wildfire to easily reach the crown layer.

Changes in Mortality Rates

The result of competition and limited resources is physiological stress and eventual mortality. I realize that my ability to estimate the year a tree died is not accurate. However, using broad mortality classes reduces this error. In the BCRNA there was a small amount of mortality during the 1960's; about 0.9 trees per acre (2.2 per hectare) per year. During the 1970's mortality increased to 1.5 trees per acre (3.7 per hectare) per year. During the early 1980's the tree mortality rate increased to 6.1 per acre (15.1 per hectare) per year. By the late 1980's the rate increased to 9.3 trees per acre (23.0 per hectare) per year and from 1991 to 1993 16.0 (39.5 per hectare) trees per acre per year died.

Regeneration

When the establishment years for all the existing trees in the 11 plots are combined into one graph (Figure 9), patterns of tree establishment are striking. Regeneration seems to have been successful during certain periods and unsuccessful during other periods. This shows an episodic characteristic of ponderosa pine regeneration. Most seedlings were established between 1780 and 1880. Other periods of regeneration were only 10 to 30 years long.

I could not find any relationship between the seedling establishment and the corresponding fire dating for the BCRNA area (Steele et al. 1986). Seedling establishment was probably dependent on the timing and intensity of the fires, the irregular production of seed by ponderosa pine, and moist-dry cycles. How these factors interacted to produce regeneration is not certain. For instance, it may be that dry cycles promote regeneration by causing the ground fires to be slightly more intense. These fires may have produced more thorough site preparation exposing mineral soil, burned away more of the ground fuels extending the time before the site could again carry a fire, and reduced competition from grasses rather than stimulating their growth.

CONCLUSIONS

The forest of the BCRNA has changed in many ways since the 1800's. Before 1900, the forest contained open-grown old-growth ponderosa pine, probably with an understory of pinegrass and elk sedge. The density of the forest has increased substantially since the 1800's. Most of the new tree establishment occurred between 1900 and 1930. Stand basal areas were not stable in the 1800's and today they are much higher. Recent reductions in basal area are the result of stress from competition and high mortality.

The stand structure during the 1800's was mostly uneven-aged although there were some small even-aged patches of trees. The composition was entirely ponderosa pine on the midslopes where the plots were located. Douglas-fir trees grew in the moist drainages, northern slopes, and stream bottoms. During 1993 Douglas-fir comprised 43% of the live trees on the midslopes.

Plots with many old-growth trees tended to have less regeneration after 1900 than plots with few old-growth trees. Open space promoted regeneration. Tree regeneration was almost nonexistent after 1950. With both fire and livestock removed from the site, a deep litter layer has created a barrier to new seedling establishment.

Tree mortality was light until 1970. It increased in the 1970's and early 1980's and became pervasive in the late 1980's and 1990's. The most important cause of mortality was the western pine beetle which attacked a wide range of size classes in ponderosa pine.

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Appendix A

The following newspaper accounts from the *Idaho Statesman* describe the fire season of 1889 in the mountains near Boise, Idaho.

Articles	Date
Forest Fires	Aug. 2
More Fires	Aug. 2
Large Forest Fires Reported in Wood River Country	Aug. 4
Seasons of Drouth	Aug. 4
Forest Fires	Aug. 4
Local News	Aug. 6
Local News	Aug. 8
[no title]	Aug. 13
Another Blaze	Aug. 21
Forest Fires	Aug. 24
[no title]	Sept. 3
Fighting Fires: Large Force of Men Battling the Flames	Sept. 10
Weather-wise	Sept. 13
Chips	Sept. 13
[no title]	Sept. 22

A FIRE FREQUENCY AND COMPARATIVE FUEL LOAD ANALYSIS IN GAMBEL OAK OF NORTHERN UTAH

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ABSTRACT

A fire history and fuels study within the Gambel oak (*Quercus gambelii*) shrub vegetation type of northern Utah found higher fuel loads and more mature to decadent stems in areas of less frequent documented wildfires. In areas of recent burns, dead fuel loads were reduced, and there was an increased cohort of younger oak stems. The clones whose stems are in a more mature to decadent state have reduced mast production, limit wildlife access and movement (Kufeld 1983), and increase the chance of having a more severe wildfire when fire does occur. The accumulations of fine fuels and larger, dead woody materials that now exist contribute to making wildfires more intense and severe when they do occur.

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INTRODUCTION

A fire history and fuels study was conducted within the Gambel oak (*Quercus gambelii*) shrub vegetation type of northern Utah to compare fuel loading between areas of varying fire frequency and recently burned and unburned sites. The urban-wildland interface nature of the study area, with its immediate proximity to a large population center, Ogden, Utah, provides ready ignition sources for person-caused wildfires. The majority of ignitions appear to be concentrated near the population centers and do not extend to the limit of the oak brush type. One objective of this study was to determine fuel loading among areas of varying fire occurrence and use the information to identify areas for natural hazardous fuels treatments while concurrently benefitting wildlife access and utilization. An additional objective was to establish a fire history to compare Native American and natural ignitions in presettlement times with present fire frequency. Comparing presettlement fire occurrences with fire frequency post-European settlement would highlight changes in fire frequency that may be attributable to shifts in cultural uses.

STUDY AREA

The study area encompassed 64,000 hectares with an oak brush dominated vegetation type along the Wasatch Mountain range on the Ogden Ranger District, Wasatch-Cache National Forest in Utah. Specifically, the study area included a western exposure of the Wasatch Mountains that abuts the large population center of Ogden, Utah and an eastern side of the range that is adjacent to a more rural but growing population and consists of three small towns, Liberty, Eden, and Huntsville, Utah. Population estimates from 1997 place the Ogden, Utah area population at 169,000 and the rural portion of the study area at approximately 5,500 (Barker 1997). Elevation of the study area ranged from 1340 meters to approximately 2133 meters.

The literature classifies the shrub portion of the study area as Fire Group Two: Montane Maple-Oak Woodland and states, "In the past, the more extensive grass cover likely permitted relatively frequent fires during the dry season" (Bradley et al. 1992). The majority of the shrub acreage is dominated by Gambel oak. The study area constitutes the northernmost reaches of Gambel oak, whose present distribution then extends south through Arizona into New Mexico (Harper et al. 1985). Gambel oak usually occurs as a low growing tree, and these oak woodlands provide wildlife habitat and protection from soil erosion. Areas dominated by oak vegetation are subject to periodic fire, and due to its ability to sprout profusely from the surviving root system, it recovers well after burning (Harper et al. 1985). The fire regime of the study area has been altered due to introduction of grazing (which reduces fine fuels), elimination of Native American burning, and active fire suppression (Bradley et al. 1992). Oak stands appear to be more extensive now than they were 75 to 150 years ago, encouraged by less frequent fires. A fire regime of low-intensity, frequent fires would have inhibited establishment of oak seedlings (Bradley et al. 1992).

A photographic history of vegetation change in the Bonneville Basin, in which the western portion of the study area lies, found that oak clones have expanded considerably since settlement, but it has been only recently that new clones have appeared (Rogers 1982). Rogers (1982) attributes this to the grazing taking place at the turn of the century as well as wildfires that inhibited the establishment of new oak clones. The new clones visible this century are attributable to the reduction and termination of livestock grazing as well as fire suppression. An area within the study area that Rogers (1982) visited showed oak clones increasing in size, and the appearance of new clones since 1901.

Gambel oak, while not highly palatable, is an important mule deer (*Odocoileus hemionus*) winter forage due to its availability and abundance (Harper et al. 1985). As well as providing forage, Gambel oak also provides cover for many wildlife species. Although it can provide necessary cover, it can grow to be too dense and impenetrable and exclude big game from the area (Kufeld 1983).

Historical and Cultural Uses

The Native American populations present in the study area before European settlement were of both the hunter-gatherer and agriculturalist traditions. The bulk of human activity was concentrated between the 1520 meter to 2130 meter elevation, in areas dominated by sagebrush (*Artemisia sp.*), juniper-pinyon (*Juniperus sp.-Pinus edulis*) and mountain brush vegetation (Harper 1986). The climate made this an area of suitable habitation for longer periods of the year than the upper or lower elevations.

Native Americans purposely burned to favor seed crops or certain plants and as an aid in hunting. Once European settlers arrived in the 1800's, the area experiencing frequent burning was reduced, first through increasing numbers of domestic livestock as settlement became widespread in the 1850's, then by the removal of the Native American people themselves. Road, trail, and canal construction in the foothills contributed to a reduction in the areal extent of fires (Harper 1986).

The introduction of domestic livestock grazing contributed to alterations in vegetative structure and diversity. Sheep numbers totalled 1,000,000 in 1885 and boomed to 3,818,000 in 1900. The Wasatch-Cache area, which includes the study area, accounted for 56% of the sheep number in 1900, or over 2,000,000 sheep. Eyewitness accounts stated that the sheep would eat everything within reach as they trailed from one bed ground to another (Peterson and Speth 1980). Permits for both cattle and sheep increased significantly in the area until about World War I. Sheep numbers declined after 1918, and Forest Service officials began to recognize overgrazing was occurring (Peterson and Speth 1980).

Overgrazing by cattle and sheep tends to reduce palatable grasses and shrubs. They are then replaced by less palatable shrubs, trees, and annual grasses. In terms of fire frequency, grazing can reduce fine fuels that would support wildfires that in turn reduce shrubs and trees. In other areas, introduced annual grasses that are able to tolerate grazing and provide fine fuels actually increase fire frequency, to the detriment of perennial grasses and forbs which cannot become established under a high fire frequency regime (Rogers 1982).

Table 1. Shrub stems within 27.9 m^2 plots counted and classified into four age classes (1992 USDA Forest Service Region 4 Range Analysis Handbook). The amount in each class was then used to relate the condition of the shrubs to the last known disturbance.

	Age class	
1	sprout/sapling	plant firmly established, smooth bark, 0.25–1.3 cm dia.
2	mature	complex branching, fissured bark, evidence of flowering or acorn production
3	decadent	+50% dead wood in crown
4	dead	no live crown, root firmly attached

METHODS

Measurement of fuel loading and determination of the parameters of fire frequency and mean fire-return interval, fuels, and age measurements were conducted in areas of known recent burns and areas where the last disturbance from wildfire was undocumented.

During the summer and fall of 1994, sampling transects were established in recently burned oak sites–1990 and 1991–and then in adjacent sites that were not documented as recent burns. The burned and unburned paired sites were similar in aspect, slope, and elevation. A total of 15 areas were sampled, including three paired burned and unburned sites. All sites were chosen according to their predominance of oak cover by using a U.S. Forest Service vegetation map. Once transects were established, two of the eight unburned sites exhibited evidence of recent burns, in approximately 1975 and 1985.

An oak fuels inventory was conducted by collecting information on dead and down fuel loading, shrub fuel loading, herbaceous fuel loading, and duff and litter depth. Using Brown's planar intersect method (Brown 1974) and methods for inventorying surface fuels and biomass (Brown et al. 1982), fuels transects were located at fixed intervals (30.5 meters) on random angles along the main sampling line. The sampling line was established on a diagonal selected to intersect oak shrubs across the sample area. The number of fuels transects read per location depended on the length of sampling line that could be established in a contiguous vegetation type and slope. Photographs were taken in association with each fuels transect. Oak stems were collected to determine age and approximate year of the most recent disturbance.

In conjunction with the oak fuels inventory, line intercept transects were conducted to measure shrub composition, canopy cover, density, age-class structure, and browse utilization. Forty lines were read in the 15 study areas, two or three per area depending on the length of the sampling line. The line intercept transects were paired with alternating fuels transects, therefore they were established every 61 meters along the main sampling line in random directions. Methods followed are described in the 1992 USDA Forest Ser-