

## **DISTURBANCE HISTORY OF A MIXED CONIFER STAND IN CENTRAL IDAHO**

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### **INTRODUCTION**

Dendroecological methods are widely used to establish the long-term disturbance history of forests, which can help determine successional patterns, the nature, intensity, and frequency of disturbance events, and the effects of European settlement on ecosystem processes. One of the most basic dendroecological procedures for quantifying forest disturbance histories is the identification of release and suppression events in time series of radial growth increments (Lorimer and Frelich 1989, Lafon and Speer 2002, Black and Abrams 2003). Suppression and release events are quantified by decreased and increased growth, respectively, beyond a given threshold for a specified duration of time. In general, release events correspond to the magnitude of a canopy disturbance; however, there are many interrelated and confounding influences. Black and Abrams (2003) quantified relationships among tree age, size, canopy attributes, and growth rates in eastern hemlock (*Tsuga canadensis* L.) and found that radial growth rate was the best predictor of release response. Young, small, suppressed trees were much more responsive to release from suppression than older, larger, dominant trees. Release criteria have been widely established for eastern forest species (Hough and Forbs 1943, Lorimer and Frelich 1989, Payette *et al.* 1990, Nowacki and Abrams 1997), though few studies have attempted to establish release criteria for western species.

In this study, we establish release criteria for two western species, ponderosa pine (*Pinus ponderosa*) and Douglas-fir (*Pseudotsuga menziesii*). We then use these criteria to establish a nearly 400-year long disturbance history for a mesic ponderosa pine – Douglas-fir stand at Ponderosa State Park, central Idaho. Furthermore, we assess the growth responses of overstory ponderosa pine and Douglas-fir to an understory thinning followed by surface burning (restoration treatments). Responses of both species are quantified and compared. Thus in this study we 1) compare the release responses of ponderosa pine and Douglas-fir, and use that information to establish release criteria for both species, 2) establish a long-term disturbance history for the site, and 3) evaluate the effects of a thinning and burning treatment on dominant ponderosa pine and Douglas-fir trees that represent the pre-European settlement structural characteristics of the forest.

### **BACKGROUND/ DESCRIPTION OF STUDY AREA**

Study sites were located in the Meadow Marsh compartment (~6.5 ha) of Ponderosa State Park in west-central Idaho. Ponderosa State Park is located on the north end of a peninsula intruding Big Payette Lake and near the University of Idaho McCall Field Campus. Study sites were located in UTM Zone 11 0572534 Northing 4975755 Easting and at elevation ~1535m.

The effects of climate, topography, fire and human use have shaped vegetation composition and structure of Ponderosa State Park and the Intermountain West (Crane and

Fischer 1986). The local bedrock consists of granitic, Cretaceous Idaho batholith, with some Columbia River basalts around the margin of Big Payette Lake. The moraine-dammed lake and other glacial features evidence the region's glacial history. Soils are well-drained, relatively infertile, poorly developed inceptisols. Forests are found on the moraines surrounding Big Payette Lake, typically within six meters of the lake's high water level. The climate is largely continental with hot and dry summers, although winter climate is influenced by moist Pacific air masses (IDPR 1994). The town of McCall receives ~65% of its annual precipitation (70 cm) between October and March, and annual snow accumulation can be heavy (>400 cm). The climate has a direct affect on the vegetation as evidenced by the presence of species adapted to fire, drought, and snowfall. Trees here include ponderosa pine (*Pinus ponderosa*), lodgepole pine (*Pinus contorta*), quaking aspen (*Populus tremuloides*), Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), grand fir (*Abies grandis*), and Engelmann spruce (*Picea engelmannii*). A diversity of shrub (e.g. *Vaccinium* spp., *Symphoricarpos mollis*, *Amelanchier alnifolia*) and herbaceous species (e.g. *Thermopsis montana*, *Valeriana occidentalis*, *Carex* spp., Poaceae) comprise the understory.

Early records document the presence of Nez Perce Indians in this area. The Nez Perce used ponderosa pine as a food source as evidenced by peeled-bark trees. Lewis and Clark passed through the area ~60 miles north of McCall in the early 1800's, noting the hospitality of the tribes. Fur trapping was extensive from 1810 to 1845, until beaver were almost locally eradicated. Gold was discovered in the 1860's and brought many miners to the area. Farming of grain and hay began in the 1880's and in 1894 the first threshing machine powered by horses was introduced. Most of this area was grazed beginning ~1870 and was logged as early as 1889 with targeted harvest of western larch and ponderosa pine. Logging continued until ~1930 with processing at the local Hoff-Brown mill in McCall. The Oregon Shortline Railroad reached McCall in 1914 and transported logs to the mill in Cascade. Since the 1920's with the settlement of McCall, wildfire has been effectively suppressed. The Civil Conservation Corp built roads in the area in the 1930's, providing access for many more people. Settlement of the area significantly changed the natural environment from its predominantly natural condition to one of development and use.

The Park was officially established in 1965 with management guided by the IDPR Development Plan. Management in Ponderosa State Park has largely balanced public demands for recreational access, social desire for maintenance of historical character, and agency resource objectives. Historical forest condition was described as uneven-aged, "open and park-like", and with clumps of large trees and grassy understories. Historically these dry mixed conifer forests burned at low intensity and relatively frequent intervals (5-30 years) (Neuenschwander, unpublished). It is likely that these ponderosa pine forests are found on some of the more mesic sites in the area and historical fires regimes may have included more severe components, and thus, more accurately described as mixed-severity fire regimes (Morgan, pers. comm.). Wildfire has been effectively suppressed in the area (that later became Ponderosa State Park) since 1920 (Coyle, pers. comm.). Fire suppression has changed the structure, density, composition, and function of forests and contributed to the loss of grasslands. Forest surveys conducted in 1994 indicate that average tree densities at that time were four times greater than historical conditions and that ponderosa pine regeneration was not occurring. Fire exclusion has favored growth of shade tolerant species, particularly grand fir, in forests historically dominated by ponderosa pine and western larch. It is likely that the extensive period of fire suppression, compounded with

disease, drought, and insect outbreak have contributed to several large, severe fires in the region during recent decades.

Contemporary studies describe these dry forests as highly susceptible to stand-replacing fire and in danger of losing their old-growth character (IDPR 1994). Managers have used fire and restorative thinning treatments in an attempt to mimic natural disturbance, reduce fire hazard, and increase visitor safety. To address restoration objectives, stands were mechanically thinned during the winter of 1994. Thinning removed grand fir <45 cm DBH and left 35-50 ponderosa pine or Douglas-fir trees per hectare. In the spring of 1996, these stands were “treated” with a low intensity broadcast or back burn to reduce understory competition. Large trees were “pre-treated” in early spring by removing high duff accumulations around tree bases, which reduced tree mortality at the time of burning. The objectives of thinning and fire reintroduction were to restore historical ecological conditions to “the maximum extent possible” given appropriate recreational use (IDPR 1994).

## **METHODS**

### ***Field Methods***

The two objectives were to 1) establish a long-term disturbance history using ponderosa pine and Douglas-fir and 2) evaluate the effects of the understory thinning and burning treatment on both species. To address both these goals, we sampled dominant trees of both species in two adjacent stands that were topographically and edaphically similar. Both stands presumably shared a common history until 1994, when the thinning treatment was undertaken in the treated stand.

We sampled ten dominant trees of both Douglas-fir and ponderosa pine in each stand for a total of forty sampled trees. Selected trees met the following criteria:

- Dominant or codominant crown class
- At least one crown width radius from the edge of the stand
- No external evidence of decay or sever damage

For each sample tree, we collected two increment cores, assessed crown attributes, and quantified competition from nearby trees. The increment cores were taken at 30 cm from the ground on opposite sides of the tree, or as far apart from one another as possible. Cores were placed into paper or plastic straws and labeled. The live crown ratio was estimated and the crown class (dominant, co-dominant, intermediate, or suppressed) recorded.

Circular plots were installed around each tree (thus a total of 20 plots in each stand) for the purpose of identifying and assessing vegetation in direct competition with the sample trees. At each tree, plots were established by visually estimating the crown drip line and doubling that distance. Within each plot, all trees and cut stumps greater than 4 cm at stump height (~30cm) were recorded by species and diameter. Diameter was taken at stump height for both stumps and living trees, which ensured consistency in our estimates of basal area between treated and untreated stands. Crown class was recorded for each live tree. Proportion of basal area, minus that of the dominant tree, was calculated as an index of competition. Percent cover of shrubs and herbaceous vegetation (grasses and forbs) within the circular plot was estimated and summarized by Daubenmire cover classes. Local site features were recorded, such as slope position,

proximity to an edge, and evidence of rocky outcrops. Wounds, fire scars, or other unusual features on sample trees were also noted.

To determine dates of past fires, we sampled four fire-scarred stumps in the treated stand. A chain saw was used to remove a cross section from the stump top. In the event of sample separation, sections were carefully pieced together in the field, and then labeled for reconstruction in the lab.

### ***Sample Preparation***

Cores were glued into core mounts following procedures of Stokes and Smiley (1996). Once dried, cores were sanded using successively finer grits of sanding paper (120, 220, 320, 400, and 2000). Stump sections were mounted onto linoleum boards and surfaced with a belt sander and hand sanded to 2000 grit (30  $\mu$ m) sandpaper. Skeleton plots were drawn for individual cores and a master chronology was compiled for each species. All samples were crossdated against the master chronology to ensure precise dating of each growth increment. Once visual crossdating was complete, growth increments were measured using a VELMEX tree ring measurement system (Velmex, Bloomfield, NY) with precision 0.001 mm. The International Tree-Ring Data Bank program COFECHA was used to verify crossdating and measurement precision (Grissino-Mayer 2001). Any measurement time series with potential crossdating errors identified by COFECHA were visually checked and remeasured if necessary.

### ***Chronology development***

As a means to initially assess stand-wide growth patterns and disturbance history, we generated a master chronology for each species. Measurement time series were detrended with either a negative exponential or negative linear regression function. Exceptions were made for any measurement time series in which the best fit function was characterized by a positive slope. Positive slopes do not reflect age-related trend, and in our samples, occurred in trees that were suppressed from establishment until a major release event later in life. To better standardize and capture this disturbance-induced effect, series with best-fit functions that had positive slopes were detrended using the mean value of the series (a horizontal line). We chose to apply rigid functions (negative exponential or linear functions) to all time series in order to retain the maximum amount of information in both high- and low-frequency domains. All detrended time series were averaged into a master chronology, which should reflect the combined effects of climate and disturbance on a stand-wide level. All aspects of chronology development were performed in the International Tree-Ring Data Bank Program Library ARSTAN.

### ***Release criteria***

We applied the Nowacki and Abrams (1997) running-mean approach as release criteria, in which a release was defined as a pulse in percent growth-change that exceeded the threshold of 25 percent. The year of maximum percent growth-change value was identified as the year of the release event. After experimenting with a variety of running-mean lengths (10 yrs, 5 yrs, etc.) and thresholds (10%, 25%, 50%, etc.), we found that the Nowacki and Abrams criteria identified what appeared to be release events in both ponderosa pine and Douglas-fir. In this stand, we also found sudden, severe suppression events that appeared to be induced by fire events. Since these events are critical to detect for establishing a disturbance history of the site, we developed a technique to identify these sudden growth declines. Such sudden depressions in growth were similar in nature to those we would expect to have occurred following an insect

outbreak (though we believe these suppressions were induced by fire damage). Thus we used the ITRDB program Outbreak to screen for the suppression growth patterns. Our criteria were that the suppression had to more than 1.8 standard deviations below the mean and that it be sustained for a minimum of eight years. Furthermore, we stipulated that there could not be a true release event as detected by the Nowacki and Abrams technique for at least fifteen years after the suppression. Such a growth increase likely reflected the tree's recovery and not an additional disturbance event. All release events were tallied using the measurement time series. Suppression events were tallied using the detrended time series, as specified by Outbreak. As an additional index of disturbance, we recorded the years of Douglas-fir growth increments showing traumatic resin ducts. Counts of resinous growth rings over time are compared to the master tree-ring chronologies from the site.

### *Climate analysis*

For climate analysis, we detrended each measurement time series with a 50% frequency cutoff 50-year splines, which are intended to reduce competitive signals and enhance the common climate signals in closed-canopy forests (Cook and Peters 1981). A master chronology was developed for each species by averaging detrended time series. Monthly climate data for Idaho NCDC Climate Division 4 were obtained from the NOAA CLIMVIS website. Climate data included average monthly temperature, total precipitation, and the average Palmer Drought Severity Index (PDSI) for each month between 1895 and 2004. The master chronology of each species was correlated with monthly data using an 18-month dendroclimatic year that included six months from the prior calendar year.

## **RESULTS**

We crossdated and measured 41 Douglas-fir and 35 ponderosa pine tree cores. The total length of the Douglas-fir master series was 327 years with 7233 rings in the chronology. Inter-series correlation was 0.594 and mean sensitivity was 0.208. The total length of the ponderosa pine master series was 403 years with 7984 rings in the chronology. Inter-series correlation was 0.528 and mean sensitivity was 0.249. Our oldest tree was a ponderosa pine that dated to 1602 (missed pith). During crossdating we discovered locally absent rings in samples from both species, with a maximum number of eight consecutive missing rings. In all cases, locally absent rings were associated with sudden, severe suppressions in growth that were likely induced by a damaging event such as fire.

Master chronologies of both species show close synchrony in growth patterns for the duration of the chronologies (Fig. 1). This is particularly true for low-frequency variability. High variance early in the chronology, especially prior to 1750, is due to low sample depth. Releases and suppression events occur at some level over the past three hundred and fifty years (Fig. 2). However, a high frequency of release and suppression events occurred between approximately 1840 and 1940 (Fig. 2). Release and suppression events were not necessarily balanced over time, suggesting various intensities or types of disturbance that favored either suppressions or releases. For example, the decade of the 1920s is characterized by a very high frequency of suppression events while the decade of the 1900s is characterized by a predominance of release events (Fig. 2). A high frequency of traumatic resin rings in Douglas-fir coincides with the period of increased release/suppression frequency (Fig. 3). The period of highest resin rings largely occurs from 1840 to 1880. Thus the onset of resin ring formation

begins at approximately the same time as an increase in release and suppression events. However, elevated levels of release and suppression events persist much longer (Fig. 2,3). Fire scars appear to be the most frequent between approximately 1820 and 1920, with a large number occurring between 1840 and 1880. Fire scars occur continuously from the beginning of the chronology, ending abruptly in 1920 (Fig. 3).

Climate strongly affects growth in Douglas-fir and ponderosa pine in Ponderosa State Park. Among monthly temperature, precipitation, and PDSI, PDSI showed the strongest correlations with the master chronologies of both species. Moisture is strongly limiting to these species, especially in the summer months. Correlations are positive and highly significant for most of the year, excluding the spring for Douglas-fir and the winter and spring for Ponderosa pine (Fig. 4). Overall, these correlations are stronger for Douglas-fir than ponderosa pine. The effects of long-term (multidecadal) oscillations in PDSI are clearly apparent in both the Douglas-fir and ponderosa pine chronologies throughout the twentieth century (Fig. 5).

The thinning and burning treatment in the treated stand reduced basal area by almost fifty percent. Prior to treatment, basal area was  $\sim 48.2 \text{ m}^2/\text{ha}$ , which is comparable to the current basal area of  $29.2 \text{ m}^2/\text{ha}$  in the untreated stand. After treatment, basal area of live competing trees in treated stands was  $\sim 19.01 \text{ m}^2/\text{ha}$ . Prior to treatment, long-term growth patterns were very similar in both stands (data not shown). Following the treatment, Douglas-fir shows a slight increase in ring width index in comparison to growth in the untreated stand (Fig. 6). Though the treated ponderosa pine exhibit higher growth after the treatment, though growth in this group was elevated in comparison to the untreated group prior to the treatment date (Fig. 7).

## DISCUSSION

Our analysis of disturbance history is unique in that we included suppressions as well as release events. Calculation of release events is by far the predominate means by which to reconstruct disturbance histories (Rubino and McCarthy 2004), though others have found the combination of release and suppression events useful for identifying disturbance events (Lafon and Speer 2002). We found that in western conifers on this site, that suppression contributed to elucidating the disturbance history of the site. These sudden and severe characteristics of these suppression events are most similar to the effects of insect outbreaks, which led us to use the program Outbreak to quantify these suppression events. We do not believe that insects caused these suppression events since there were no substantial differences in growth patterns between Douglas-fir and ponderosa pine over the past 300 years. Insects would likely be specific to either one of these species, and we could expect substantial depressions in growth of the affected species in comparison to the other. Instead, we believe these suppression events were most likely caused by severe damage from fire and logging. Although climate, particularly drought, strongly influences growth in these forests, our release criteria should remove the high and low frequency oscillations induced by climate cycles. Disturbance events appear to have caused more sudden, sustained, and profound changes in growth trajectory that could be isolated using our criteria.

Indeed, the disturbance history of this stand reflects the land-use history and settlement patterns for the region. Between 1820 and 1840, all indices including release/suppression analysis, frequency of resinous rings, and fire scars suggest an increase in disturbance, which lasted through the early twentieth century. The most severe and frequent disturbance appears to have occurred between 1840 and 1880. Settlement or at least transient use by hunters and

trappers is believed to have begun in the 1820s, with more permanent settlement in the 1850s and 1860s. Land-use from grazing, logging, and the increased fire frequency typically associated with initial settlement may explain the observed increase in disturbance in the stand. Evidence of frequent disturbance persists through the early 20<sup>th</sup> century, which is consistent with reports of logging in this area through the 1940s. Effective fire exclusion after this time is evident given the low frequency of releases, suppressions, and resinous growth increments. Most important is a complete lack of fire scars in our samples after 1920, despite a consistent fire frequency apparent through the beginning of the chronology.

Fire exclusion appears to have allowed the establishment of a dense understory dominated by grand fir. This is consistent with other studies in the region that have documented increases in understory density and fire-sensitive, shade-tolerant trees in conjunction with fire exclusion (Steele *et al.* 1986, Sloan 1998). Of particular interest were the effects of restoration on the remaining overstory trees. The thinning and burning that reduced basal area by over half did not have strong effects of dominant tree growth in terms of ring width index. A slight increase in growth was noted in the treated trees, but the differences between treated and untreated stands were minimal. Understory and mid-story competition does not appear to have a major effect on releasing dominant trees, at least in terms of ring width. Crown competition with understory and midstory trees was probably minimal given the height and low live crown ratios of the dominant trees. Foliage of these trees was likely well above the competing understory and midstory trees that were removed. Given the density of the stand, we believed that the release from below-ground competition would have at least some effect, but this was not the case according to our master chronologies. This agrees with the findings that understory trees show much more vigorous releases than their overstory counterparts following disturbance (Lorimer and Frelich 1989, Black and Abrams 2003).

The goals of the 1994 and 1996 treatments were to restore the stand to a pre-European settlement condition, which appears to have been achieved. Though the treatment did not release overstory trees, the trees do not appear to be damaged and continue to grow vigorously. This thinning has opened the understory and facilitated the regeneration of ponderosa pine, at least in places, as well as Douglas-fir. Grand fir also occurs in large numbers in the understory of the treated stand. To continue to facilitate the success of ponderosa pine, we believe that additional treatments will be necessary. Disturbance is associated with the dominance of ponderosa pine and Douglas-fir on this site, and the trees remaining on the site have developed with a history of frequent fires and thinning. Indeed, managers are planning future restoration treatments based on what they have learned from previous treatments. In future treatments, goals will be to minimize skid trails, activity fuels, and negative visual impacts. Managers need more information about appropriate scheduling (how long they need to wait to burn again) of thinning and burning treatments to achieve desirable regeneration densities while simultaneously minimizing ground and ladder fuels. Yet our study provides clear information on the long-term disturbance history of this forest and the conditions that led to its development.

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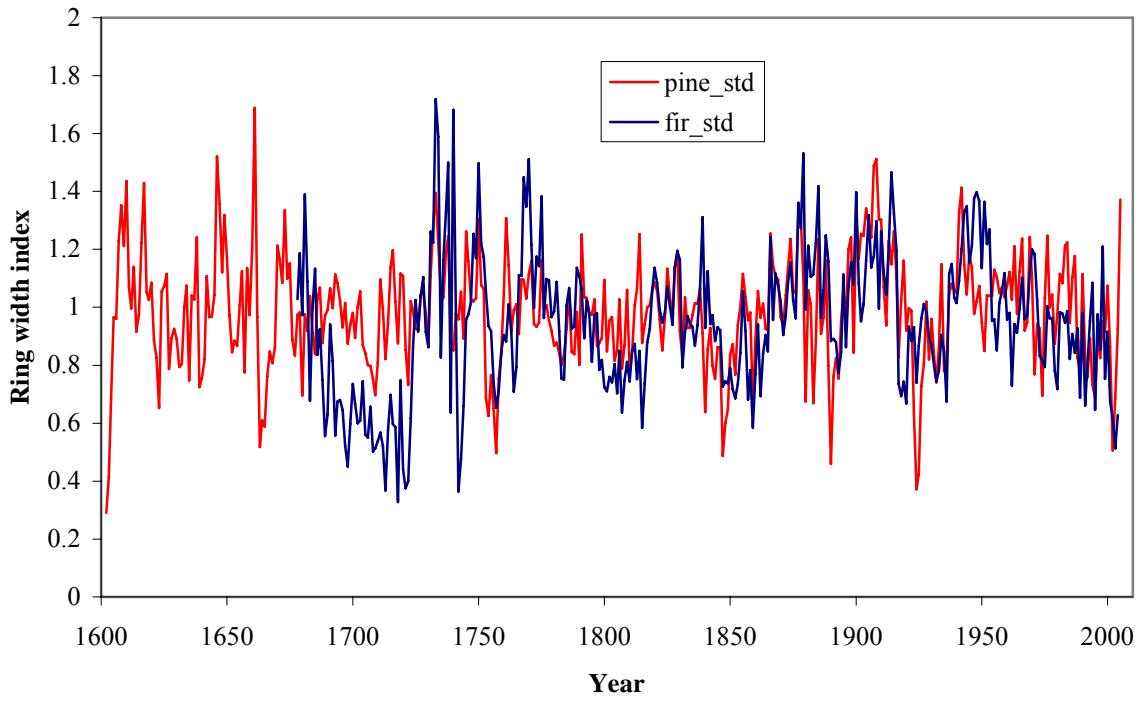


Figure 1. Master chronologies for Douglas-fir and ponderosa pine.

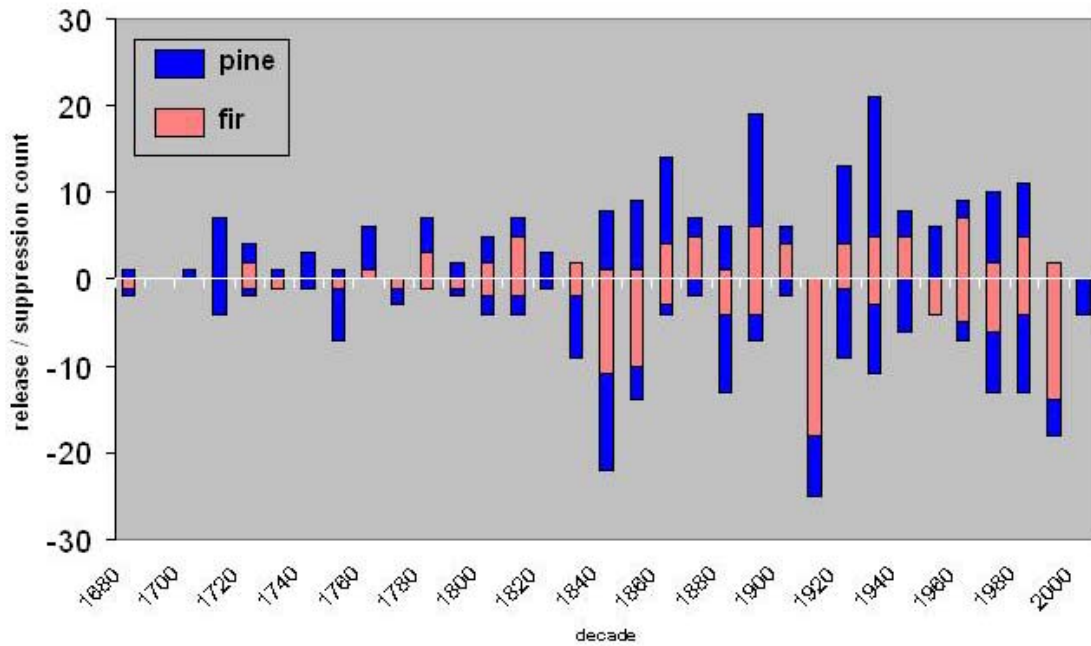


Figure 2. Release (positive counts) and suppression (negative counts) events for Ponderosa State Park.

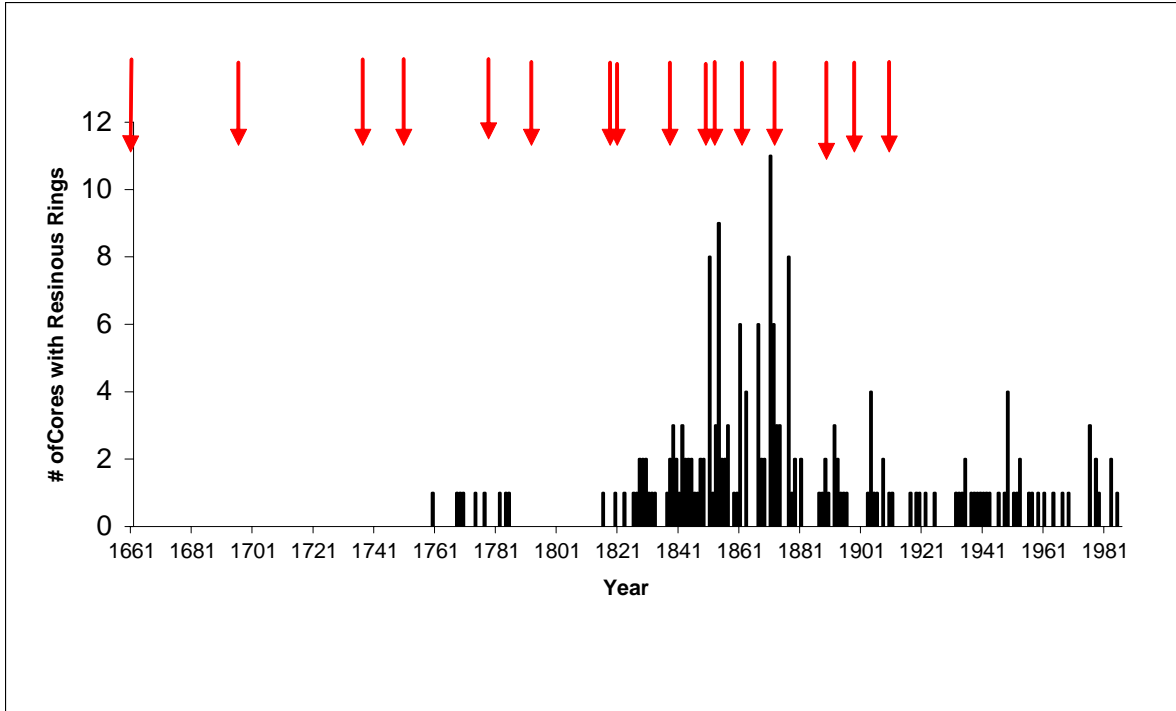


Figure 3. Count of traumatic resin ducts in Douglas-fir. Approximate fire dates as estimated from fire scars are also shown (red arrows).

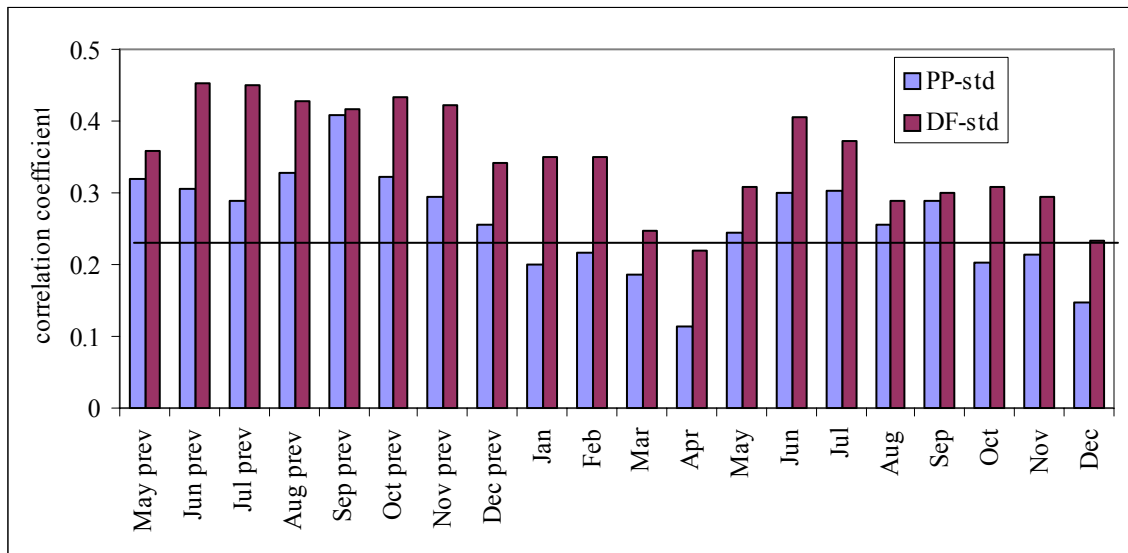


Figure 4. Correlation between master chronologies and monthly averages of Palmer Drought Severity Index. Horizontal line indicates the threshold for  $p < 0.01$ .

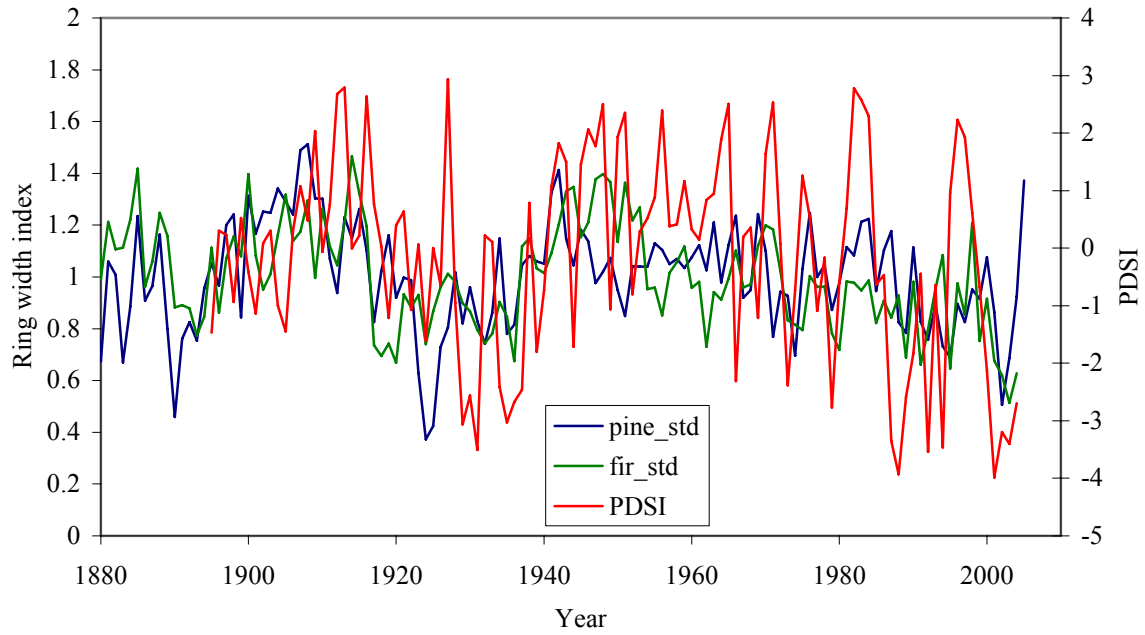


Figure 5. Palmer Drought Severity Index and master chronologies for Douglas-fir and Ponderosa pine over the twentieth century.

**Douglas-fir standard chronologies: Treated vs. Untreated stands**

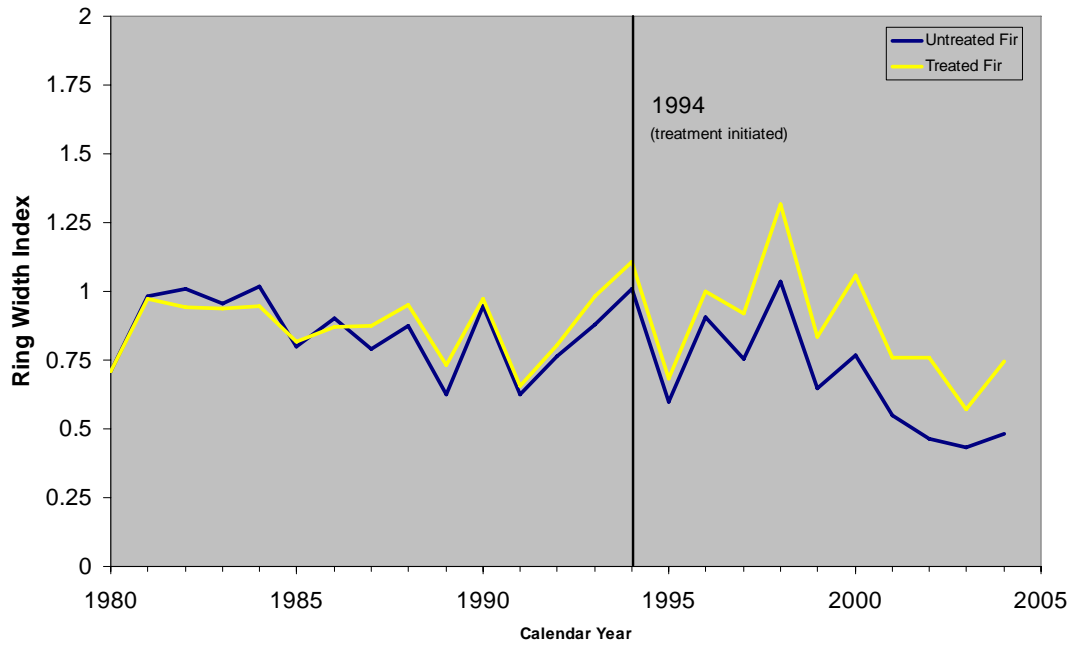


Figure 6. Master chronologies of dominant Douglas-fir in the treated (thinned and burned) stand and untreated stand.

**Ponderosa pine standard chronologies: Treated vs. Untreated stand**

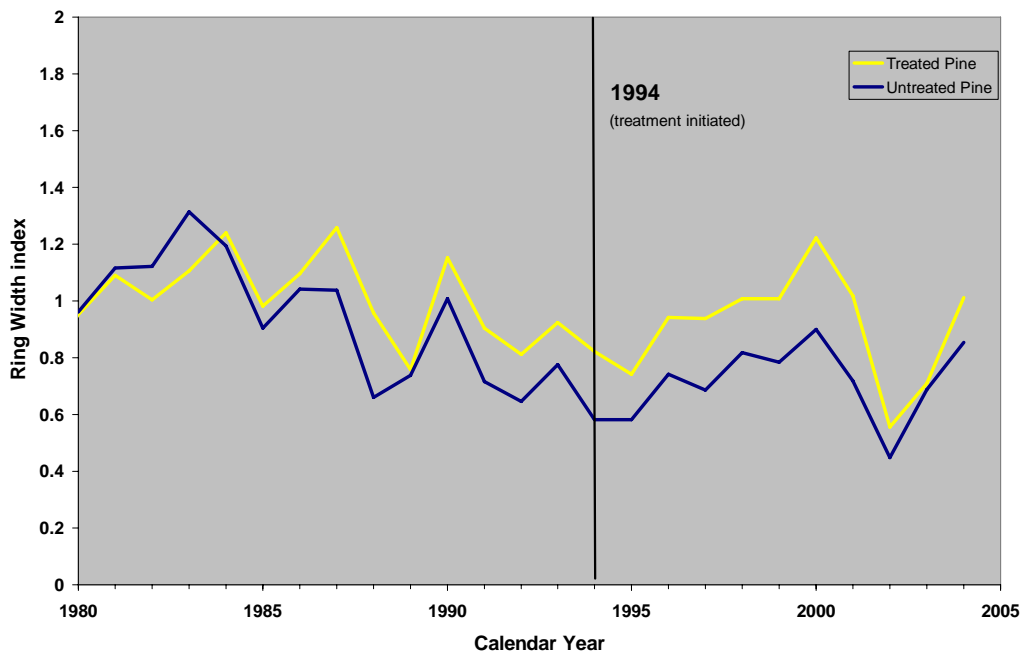


Figure 7. Master chronologies of dominant ponderosa pine in the treated (thinned and burned) stand and untreated stand. Treatment was initiated in 1994 and concluded in early 1996.