Forest Restoration at Bonesteele Ecological Park, Marion County, Oregon[1]

Karen B. Arabas, Department of Earth and Environmental Sciences, Willamette University[2]

Abstract

Marion County Parks Department has recently established Bonesteele Ecological Park with the aim of restoring the site to its pre-European settlement vegetation. Prairie restoration is already underway and this report provides results from a biogeographical study of the forest and recommendations for its restoration. Prior to European settlement the site was most likely an oak savanna maintained by periodic Native American burning. With settlement, the savanna has succeeded to a mature upland forest composed of Douglas fir, big leaf maple, hazelnut, and a variety of other native and non-native trees and plants. Three options for the forest are presented: 1) convert the forest to oak savanna, 2) do nothing, 3) remove non-natives from the forest and create savanna elsewhere on the site. I recommend the third option because it is less expensive than the first and is more in line with the restoration goals of Marion County Parks.

1.0 Introduction

Marion County Parks has undertaken a restoration initiative at its 30 acre Bonesteele Ecological Park. The primary emphasis has been directed toward restoring 20 acres of pasture to pre-European settlement upland prairie (Ridgeline Resource Planning 1999). Recent discussion among the planning committee has also revealed the need to consider the 6 acres of the site which are forested. The objective of this document is to present the results of research at Bonesteele Ecological Park designed to develop a restoration plan for the forested area. In order to develop the plan, a sound ecological understanding of the forest is needed. Characteristics including forest composition, structure, and dynamics can provide insight into the ecological processes that contribute to the form and function of the forest currently present. Field and archival research are used as a basis for the forest restoration recommendations.

---

[1] This research has been supported in part by Marion County Department of Public Works, Willamette University's Atkinson Grants, and Willamette University's Science Collaborative Research Program.

[2] I would like to thank Cindy Jones, Sara Coffey, Adrea Lovejoy, Pete Jenkins and the members of the fall 1999 Biogeography class at Willamette University for their assistance in the field and lab. This research would not have been possible without their contributions.

2.0 Site

Bonesteele Ecological Park is located in the Willamette Valley of Oregon, 8 miles southeast of Salem, Oregon at an elevation of approximately 600 feet above sea level (Figure 1). The 30 acre site is comprised of 20 acres of former agricultural field, now sown in *Festuca ovina* var. *Duriuscula* (hard fescue), an open area, and a 6 acre upland forest. The forested site is dominated by *Pseudotsuga menziesii* (Douglas fir), *Acer macrophyllum* (big leaf maple), and *Corylus cornuta* (hazelnut). Soils at the site are Nekia silty clay loam (NeC) in the Nekia-Jory association (USDA 1972). They are well-drained, weathered from basalt and tuffs, and depth to bedrock ranges between 20-40" (USDA 1972). The site slopes to the southeast at approximately 7-12%. Details on site geology can be found in Hampton (1972). Average annual precipitation measured at Salem is 39.16" measured between 1961 and 1990 (Oregon Climate Data Service no date).

[redacted]

Figure 1. Location of Marion County Park's Bonesteele Ecological Park. Asterix (*) shows location of open area where oak seedlings have sprouted (Marion County Parks no date).

3.0 Methods

I use several types of data in this report. Forest stand data (tree, seedling, sapling, herb, and shrub counts by species, and tree cores) are employed to characterize forest history, composition and structure, and to identify significant periods of disturbance or change. Second, archival data are used to link forest characteristics to natural and human impacts on the forest, such as drought, windstorms, and land use changes.

Two 100 meter N-S transects were established in the forest. A $200m^2$ circular plot was located every 20 meters along each transect for a total of 10 sampling plots. Within these plots all trees > 4 cm dbh (diameter at breast height = 1.2 m) were recorded by species, dbh, height class (suppressed, intermediate, or main canopy), and cored at 30 cm above the soil surface for age determinations. Within the 200 m^2 circular plot, live and dead saplings were tallied in a $20m^2$ circular subplot, and live and dead seedlings were counted in a $5m^2$ circular subplot. Within $1m^2$ plots established every 5 meters along the transect we recorded the density ($\#/m^2$) and percent cover of shrubs and herbs using the following cover classes: < 1%, 1-4%, 5-25%, 26-50%, 51-75%, 76-100% (Mueller-Dombois and Ellenberg 1974). Similar data from 4 additional transects (Jones 1999) were added to the initial data set, increasing the number of sampling plots to 23. These data were used to compile forest composition and structure.

All tree cores were mounted and sanded following Stokes and Smiley (1968). Ring counts were made using a stereomicroscope to determine the age of trees at coring height and to develop an age-class structure, or population diagram for the site. Tree cores were also examined for suppressions and releases. A suppression is defined as a decrease in ring width of 200% or more for 5 consecutive years; a release is an increase in ring width of 200% or more for 5 consecutive years.

4.0 Results

4.1 Forest Characteristics

We recorded 13 of the 16 tree species identified in the forest at Bonesteele (Table 1). There are several metrics for determining species dominance in a forest. One measure is basal area, or the sum of the cross-sectional areas of all the individuals of a given species per hectare. Another is density, or the number of stems of a species per hectare. Frequency, or the number of plots in which a species occurs is a third measure. Forest ecologists have found that each of these measures favors a particular characteristic of a species. For example, although the density of Douglas fir is lower than big leaf maple at Bonesteele, the basal area is higher, due to the larger diameter of the Douglas fir individuals recorded (Table 2). The big leaf maple basal area is low because the individual stems were small, but because there were many more stems recorded the big leaf maple density is higher. Accordingly, ecologists have developed a metric called Importance Value (IV) that combines basal area, density, and frequency (Cottam and Curtis 1956). The IVs show that Douglas fir and big leaf maple dominate the forest, comprising the main and intermediate canopy positions (Table 2). Hazelnut, *Abies grandis* (grand fir), *Quercus garryana* (Oregon white oak), and a handful of understory hardwoods make up the rest of the forest occurring primarily as suppressed understory trees, with the exception of Oregon white oak which occupies the main canopy.

Table 1. List of tree species found at Bonesteele Ecological Park. The bolded species were recorded as part of this study (Marion County Parks 2000).

Genus and species	**Common Name**
Abies grandis	**Grand fir**
Acer macrophyllum	**Big leaf maple**
Corylus cornuta	**Hazelnut**
Crataegus douglasii	**Black hawthorne**
Ilex spp.	**Holly**
Fraxinus latifolia	**Oregon ash**
Oemleria cerasiformis	**Indian plum**
Prunus spp.	**Cherry**
Psuedotsuga menziesii	**Douglas fir**
Pyrus fusca	Wild crabapple
Quercus garryana	**Oregon white oak**
Rhamnus purshiana	**Cascara**
Sambucus cerulea	Blue elderberry
Sambucus racemosa	**Red elderberry**
Taxus brevifolia	Pacific yew
Thuja plicata	**Western redcedar**

Table 2. Site and Stand Characteristics for Bonesteele Ecological Park. BA = Basal area. Importance value (IV) is = (relative density + relative dominance + relative frequency)/300. Asterix (*) denotes circumstances where there were too few data points to generate a statistic.

Forest Structure and Composition

	Pseudotsuga menziesii	*Acer macrophyllum*	*Corylus cornuta*	*Abies grandis*	*Quercus garryana*	*Prunus spp*	*Crataegus douglassi*	*Sambucus racemosa*	*Amelanchier anlifolia*
BA (m^2/ha)	25.0	5.8	0.2	4.0	5.1	0.3	0.1	0.2	0.1
Density (#/ha)									
Main Canopy	80	20	0	13	13	0	0	2	0
Intermediate	2	87	2	4	7	33	0	2	4
Suppressed	0	24	76	37	2	13	15	4	4
Total	83	130	78	54	22	46	15	9	9
Importance Value	34	22	13	10	8	5	2	2	2
Average age (yrs)	98	29	20	61	117	29	26	*	42
Age range (yrs)	28-150	18-44	12-27	24-85	19-304	15-38	18-32	*	26-74

4.2 Age Class Distribution

Another important characteristic is the form of the age distribution of the trees (Figure 2). By counting tree rings, we determined the age of the tree at the height it was cored. The ages are then graphed by species to produce an age class distribution. The distribution reflects the uneven age of the forest (Table 2, Figure 2). Douglas fir and Oregon white oak are the oldest species represented, and they dominate the 81-160 year age classes. The middle age classes (41-80 years) are comprised of a mix of species, dominated by grand fir and Douglas fir including big leaf maple, Oregon white oak, and some understory hardwoods. The youngest trees (age classes 11-40 years) are composed primarily of big leaf maple and a mix of hardwoods. Oregon white oak and Douglas fir are rare in the younger age classes. Seedling and sapling data show no regeneration of Douglas fir, Oregon white oak, or grand fir (Figure 2). Typical regeneration patterns of big leaf maple, *Prunus spp.* (cherry), and the understory hardwoods were observed, with high numbers of seedlings, and subsequent mortality resulting in lower numbers of saplings.

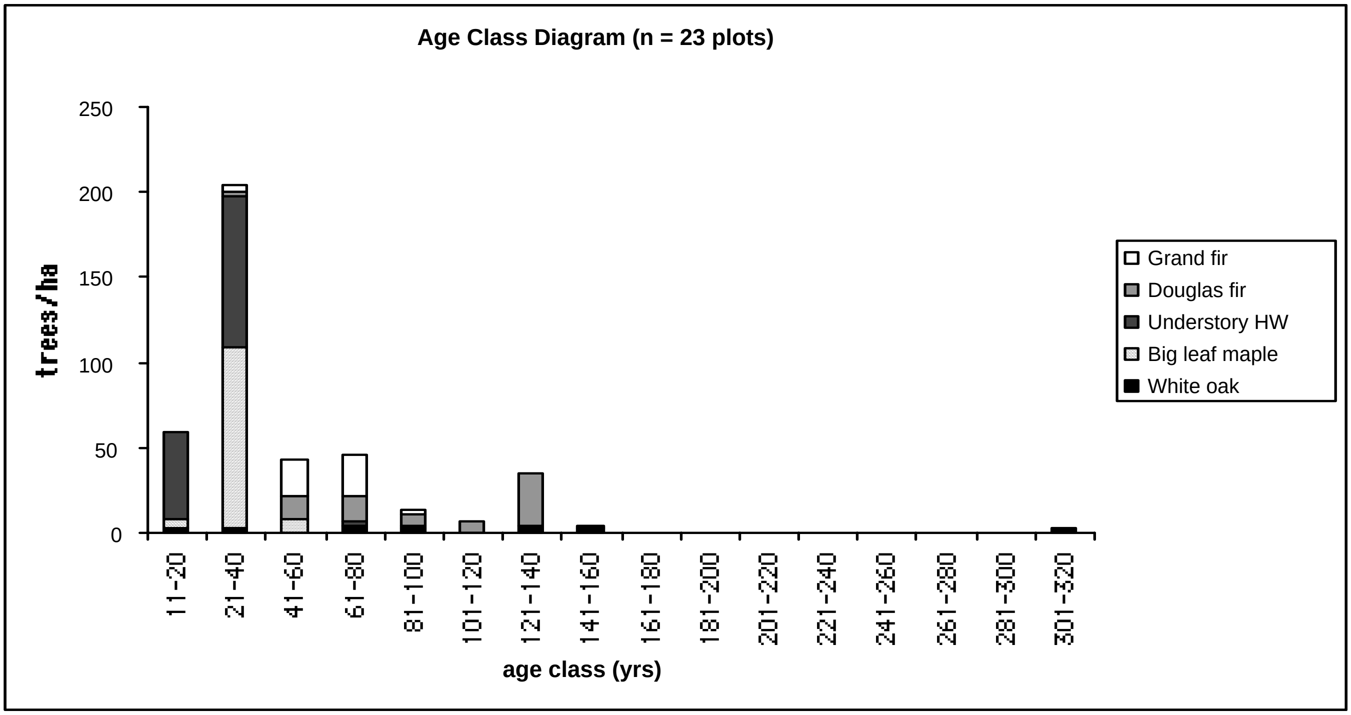

Figure 2. Age class diagram of tree species in the forest at Bonesteele Ecological Park. Understory HW (hardwoods) include: hazelnut (*Corylus* spp.), serviceberry (*Amelanchier alnifolia*), cherry (*Prunus* spp.), hawthorne (*Crataegus* spp.), and red elderberry (*Sambucus racemosa*).

4.3 Radial Growth Patterns

Analysis of tree ring width (radial growth patterns) provides more information about the population dynamics of the forest at Bonesteele. A tree ring represents the annual growth of a tree. The width of each ring reflects the particular growing conditions. For example, an individual tree that has plenty of light, nutrients and water will put on relatively wide rings compared to an individual that does not receive adequate amounts of these essential elements. Stressful conditions will be recorded as a series of narrow rings, or a suppression. Likewise, a change in the environment bringing about an increase in light or water (formation of a canopy gap, or cessation of drought), will be recorded as a series of wide rings, or a release. Generally, large scale events such as droughts will be recorded in the tree ring record of most individuals in the forest. Smaller scale events, such as openings in the forest canopy may only be recorded among the few individuals affected. By analyzing suppressions and releases one can uncover information about the disturbance history and population dynamics of the Bonesteele forest.

Releases and suppressions were noted in 98 of the 195 trees in which rings were counted (Figure 3). For the most part, the majority of the suppressions and releases are confined to one or two trees. The exceptions are:

1) releases from 1962-1964 (recorded by 9% of the trees cored)
2) a release in 1969 (recorded by 5% of the trees cored)
3) suppressions in 1959 (recorded by 7% of the trees cored)
4) suppressions in 1918, 1919, 1923, 1985, 1986 and 1994 (recorded by 5% of the trees cored)

Because these percentages do not represent a large portion of the trees and given that species can respond differentially to disturbances, species specific ring widths were investigated. Among the 36 Douglas fir sampled 20% were suppressed in 1959 (Figure 4). Additionally, 14% suppressed in 1918 and 1919, and 11% in 1923. There were no notable releases in Douglas fir. One major release in grand fir occurred over the period 1959-1963, peaking in 1962 when 21% of the trees sampled released (Figure 5). There were no noteworthy suppressions among the grand fir sampled. The other releases and suppressions noted (1969, 1985, 1986 and 1994) were distributed among all species, but at low frequencies.

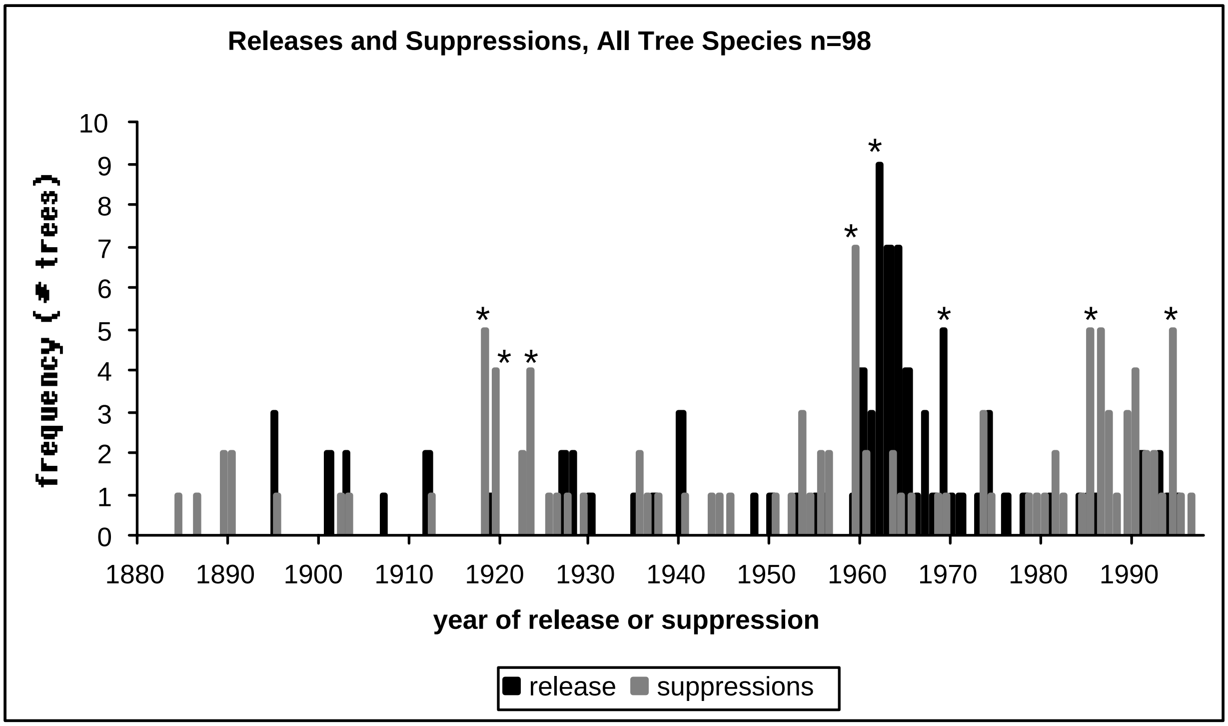

Figure 3. Bar graph showing releases and suppressions noted in all tree species. Data from tree cores. suppression is defined as a decrease in ring width of 200% or more for 5 consecutive years; a release is an increase in ring width of 200% or more for 5 consecutive years. Asterix (*) denote probable disturbance events affecting forest.

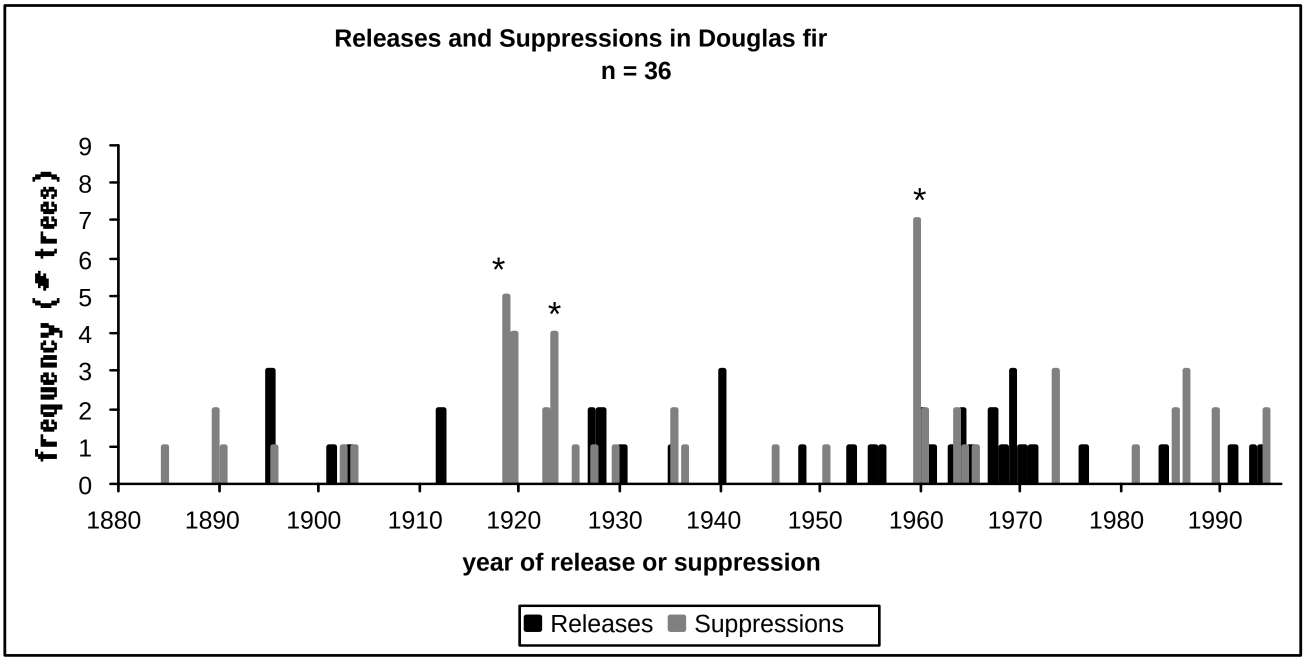

Figure 4. Bar graph showing releases and suppressions noted in Douglas fir. A suppression is defined as a decrease in ring width of 200% or more for 5 consecutive years; a release is an increase in ring width of 200% or more for 5 consecutive years. Asterix (*) at 1918 and 1923 show suppression associated with period of drought. Asterix at 1959 shows suppression related to storm damage from high winds.

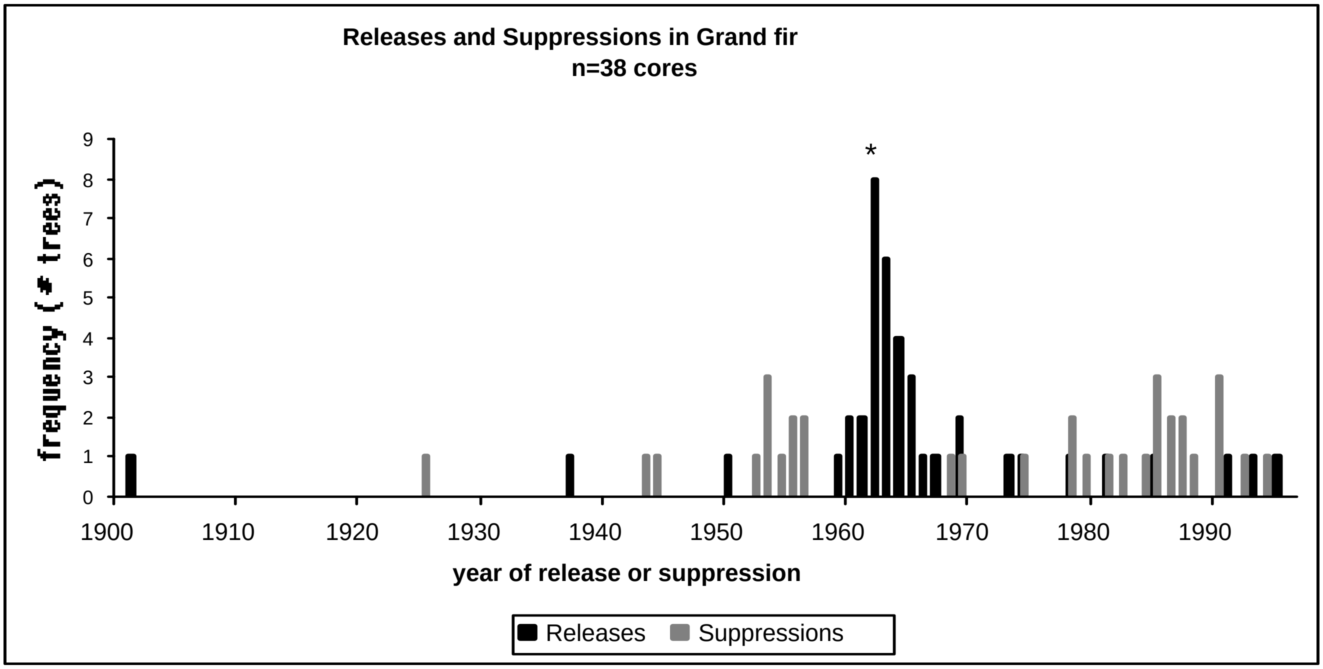

Figure 5. Bar graph showing releases and suppressions noted in grand fir. A suppression is defined as a decrease in ring width of 200% or more for 5 consecutive years; a release is an increase in ring width of 200% or more for 5 consecutive years. Note major release in 21% of trees in the late 1950s/early 1960s is probably related to gaps created by storm damage to main canopy Douglas fir.

4.4 Understory

Of the 50 species of understory herbs and shrubs noted at Bonesteele (Marion County Parks 2000) approximately half were found in the understory plots, though only 5 in any abundance. Density (number of plants/m^2) and percent cover were calculated for each species tallied. An IV (relative density + relative cover + relative frequency) was calculated to account for the different emphases of the two measures of plant dominance (Table 3). Unknown grasses had the highest IV followed by 5 native woodland species and one invasive *Rubus discolor* (Himalayan blackberry). Because the survey was completed during June and July, and because it focused on the interior of the forest, it is not surprising that only a small percentage of known plants were surveyed. There is most likely a temporal aspect to presence of understory plants and shrubs. Indeed, observations made during the fall 1999 data collection efforts confirmed that both *Montia sibirica* (Candy flower) and *Osmorhiza chilensis* (sweet cicely)were present in much lower quantities than during the summer.

Table 3. Density, percent cover, and Importance Value (IV) for understory shrubs and herbs recorded at Bonesteele Ecological Park in June/July 1999. IV = (relative density + relative frequency + relative cover).

Genus and species	**Common Name**	**Density/m^2**	**% cover/m^2**	**IV**
Unknown Grasses		111.10	6.54	25.1
Montia sibirica	Candy Flower	30.00	20.61	21.3
Osmorhiza chilensis	Sweet Cicely	13.96	10.50	13.3
Symphoricarpos albus	Snowberry, Common	4.00	11.31	9.9
Mycelis muralis	Wall Lettuce	16.14	6.27	7.6
Rubus discolor	Himalyan Blackberry	1.60	6.81	6.8
Circaea alpina	Enchanter's-Nightshade	4.92	3.10	4.7
Galium boreale	Bedstraw, Northern	0.52	1.00	2.0
Tellima grandiflora	Fringe Cup	0.40	0.74	1.7
Unknown Composites	Unknown Composites	0.54	0.68	1.4
Polystichum munitum	Sword Fern	0.08	2.06	1.3
Pteridium aquilinum	Bracken Fern	0.12	1.36	1.1
Rumex spp.	Dock	0.48	0.61	0.8
Rubus ursinus	Trailing Blackberry	0.26	0.33	0.7
Rubus laciniatus	Evergreen Blackberry	0.12	0.03	0.5
Adenocaulon bicolor	Trail plant/Pathfinder	0.06	0.35	0.5
Miscellaneous unknowns		0.18	0.05	0.4
Geranium erianthum	Northern Geranium	0.12	0.06	0.4
Hedera helix	English ivy	0.02	0.05	0.2
Lapsana apogonoides	Nipplewort	0.04	0.01	0.2
Daucus carota	Queen Anne's Lace	0.02	0.01	0.2

5.0 Discussion

5.1 Forest Structure

These data enable one to reconstruct the forest history that resulted in the current forest composition and structure at Bonesteele Ecological Park. The age class diagram suggests that prior to European settlement (mid-1800s) the site was dominated by Oregon white oak (Figure 2). No longer a dominant species, Oregon white oak is the oldest at the site (average age = 117 years, Table 2), and 60% of the individuals are in the main canopy. Though Oregon white oak can occur in pure, closed canopy stands, the low density of oaks at Bonesteele, and their open grown structure at this site (large trunk with lateral branches forming a large, rounded crown) suggest they established under open conditions, rather than as individuals in forest gaps (USDA 1990). The age class structure also shows oaks present in almost all age classes. At first, this might imply that oak will continue to be a presence in the forest, however this is unlikely for several reasons. First, the lack of Oregon white oak seedlings or saplings is evidence that oaks are not regenerating (Figure 2). Second, Oregon white oak is not shade tolerant and the few younger individuals won't survive competition with Douglas fir and big leaf maple (USDA 1990).

Historically oak savanna in the Willamette Valley is a relict from a warmer and drier climatic period which existed 9000 years ago, and ended between 7000-4000 years ago (Whitlock 1992). Historical evidence suggests these oak communities were maintained by Native American burning practices (Boyd 1986). Since European settlement of the area, land use has shifted from hunting and gathering to large scale agricultural processes, resulting in extensive land clearing and cessation of burning. The decline in fire in particular has been shown to initiate succession from oak savanna to closed hardwood forest in other geographic areas (Abrams 1982, Abrams and Downs 1990). The successional sequence (change in vegetation) at Bonesteele may be described as follows:

oak savanna → oak, douglas fir, bigleaf maple, grand fir → big leaf maple and mixed hardwoods

Oak savanna was maintained by frequent, low-intensity fire which killed competing vegetation and kept the canopy open thus providing adequate light for seedling establishment and growth. Upon cessation of burning practices in the mid 1800s Douglas fir, big leaf maple, and grand fir were able to establish among the open grown oaks, and for a period of time all species regenerated. Approximately 60 to 80 years ago increasing tree density resulted in a more closed forest canopy, altering growing conditions to favor establishment of shade tolerant hardwood species such as big leaf maple and cherry. Over the past 40 years regeneration and recruitment (movement of seedlings and sapling from the understory to older age classes) of Oregon white oak, Douglas fir, and grand fir has essentially ceased while big leaf maple and the understory hardwoods have continued to regenerate.

Big leaf maple has attained its dominant position in the Bonesteele forest by its ability to persist in shaded understory conditions. It may eventually attain main canopy position through vigorous growth in canopy gaps formed from natural thinning or logging of Oregon white oak or Douglas fir (USDA 1990). In fact, the large numbers of big leaf maple which established and survived between the late 1950s and 1980 may be a cohort responding to such gap formation. Visual inspection of annual growth rings confirms that big leaf maple grows more quickly than the other species.

Aerial photographs taken of the site between 1936 and 1986 also provide evidence of changes in forest cover at Bonesteele. Duncan (1999) analyzed these aerial photographs to show that forest cover increased by 15% during that time period. Caution must be taken in interpreting the photographs because this is a qualitative analysis, dependent on the researcher's ability to interpret vegetation from photographs. In addition, the photographs vary in quality by season, scale, and time of day, all of which can affect apparent forest cover. Despite these problems, it is clear from casual observations of the photos that the site was more open in 1936 than it is currently.

This successional sequence has been noted elsewhere in the Willamette Valley. Habeck (1962) demonstrated conversion of oak savanna to oak forest and projected future succession to Douglas fir and big leaf maple in Monmouth OR. Vegetation maps prepared by the Oregon Biodiversity Project also show a decrease in oak savanna and woodland (Oregon Biodiversity Project 1988).

5.2 Disturbance History

Forest succession is driven not only by soil, climate, and life history characteristics of vegetation, but also by disturbance events. There are several types of natural and human disturbance affecting the forest at Bonesteele. Two major natural disturbances in particular are most likely recorded in the dendroecological record at Bonesteele: windstorms and drought.

5.2.1 Windstorms

Windstorms may have two different effects on the forest. Strong winds may snap off tree tops and branches, reducing the ability of individuals to photosynthesize. This would be recorded in the tree ring record as a growth suppression. When main canopy trees are wind-snapped a light gap may be created, providing additional light to the understory. Individuals in the understory may respond to the increased light with a vigorous period of growth, recorded as a release in the tree ring record. In extreme cases, when soils are saturated and the water table is high, trees may be uprooted by wind. However, there was no evidence of windthrow at the site, and given the deep and well-drained soils (USDA 1972) one would not expect to see uprooted trees on the site.

Two major windstorms that affected Marion County in 1958 and 1962 appear to be reflected in the tree ring record at Bonesteele. On November 3, 1958 a windstorm swept Western Oregon causing destruction of millions of board feet of timber and gusting up to 70 mph at the Portland airport (National Weather Service 2000). At Bonesteele, 7% of all trees recorded a suppression in 1959 (Figure 3) (because it was a late season storm, the growing season - 1959 - following the storm recorded the effects). Of the main canopy Douglas fir, 20% suppressed in 1959 (Figure 4). This is probably due to damage to the upper bole and branches of Douglas fir from the high wind, which was observed at the site.

As noted above, removal of canopy dominants creates light/space gaps of which light tolerant understory species take advantage. Of all the trees recording suppressions and releases, 9% released by 1962, another 7% by 1963 and 1964 (Figure 3). Of the younger grand fir in the understory 21% released in 1962, 16% in 1963, 11% in 1964 (Figure 5). The continued releases may also be attributed to further damage from the notorious Columbus Day storm of October 12, 1962. This storm, which moved up the Willamette Valley from the south sustained winds of 58 mph in Salem with gusts up to 90 mph and caused millions of dollars in damage (National Weather Service 2000). Another storm on March 27, 1963 brought wind gusts of 68 mph to Salem (National Weather Service 2000). Without specific data on tree damage from Bonesteele it is difficult to say which storms resulted in canopy damage. However, the patterns of suppressions and releases from 1959 to the mid-1960s suggest that some or all of the storms were responsible for tree damage and gap creation, which eventually altered the composition and structure of the forest at Bonesteele.

5.2.2 Drought

Suppressions not related to windstorms may be attributed to droughty periods in which precipitation is lower than normal. The Palmer Drought Severity Index (PDSI) is used to indicate the degree of wet or dry conditions (National Climatic Data Center 2000b). The index ranges from +6.0 to -6.0, with positive values indicating wet spells and negative values indicating dry spells(Figure 6). Drought has the effect of limiting tree growth, which is reflected by the tree as tree ring suppression. By comparing the suppression record (Figures 3, 4, and 5) with the Palmer Drought Severity Index (Figure 6), it appears that at least 2 droughts (1918 - rated “moderate”, and 1923 rated “severe”) caused suppressions in 14% and 11% respectively of all Douglas fir cored. A small portion of the trees (5%) may also have responded with suppressed growth to milder droughts of 1985 and 1994. Caution should be used in interpreting the recent suppressions as drought-related; other factors such as canopy closure can also affect ring width and cause suppressions.

5.2.3 Human Disturbance

Finally, human disturbance has also affected the forest at Bonesteele. In particular, logging and agriculture have been important. Although logging dates are unknown, evidence in the form of stumps is present in the forest. Logging can create canopy gaps and thus may have contributed to the tree ring releases discussed. Further investigation into land-use history may uncover dates of logging. Second, continued use of the surrounding open area as agricultural fields has generated human-made forest boundaries. In his aerial photograph study Duncan (1999) notes changing plow lines during that time period. Again, further research into land-use history including land ownership, logging and agricultural practices, and other disturbances is important to filling in these gaps in the overall forest history at Bonesteele.

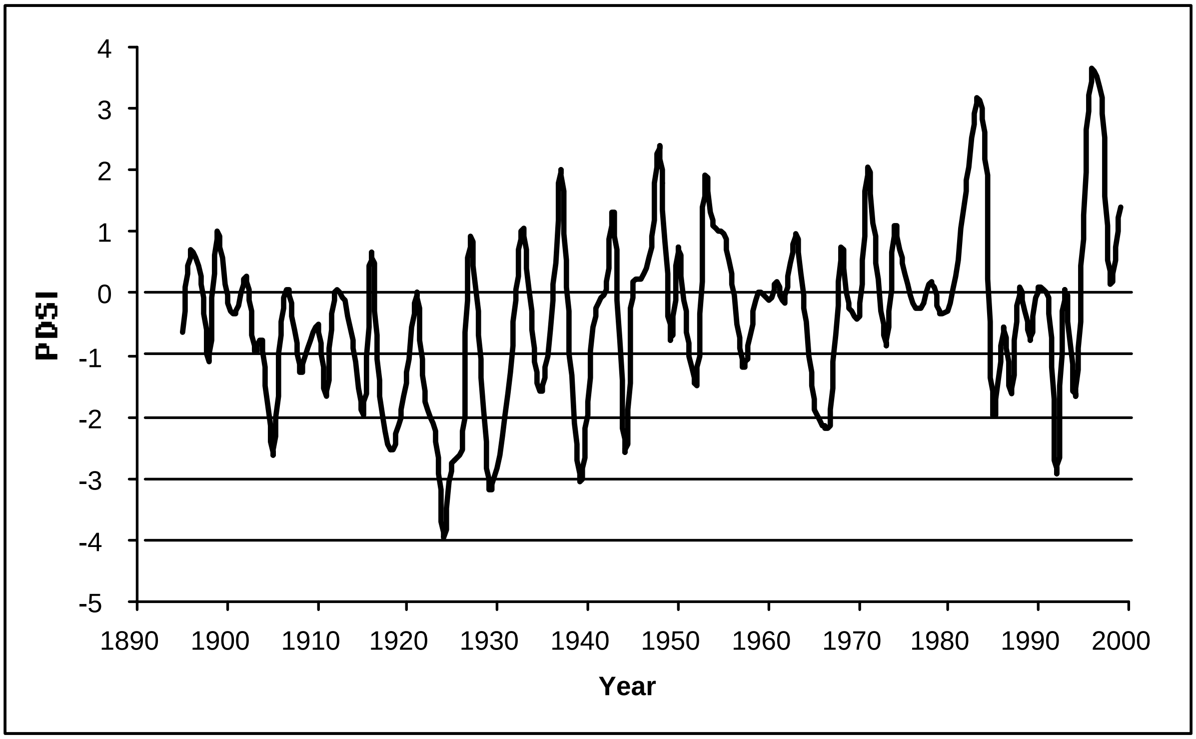

Figure 6. Palmer Drought Severity Index (PDSI) for 1895-1999 in Region 2 Oregon (Willamette Valley). PDSI is a meteorological drought index used to assess the severity of dry or wet spells of weather. The index ranges from +6.0 to -6.0, with positive values indicating wet spells and negative values dry PDSI values: normal = 0 to -0.5; incipient drought = -0.5 to -1.0; mild drought = -1.0 to -2.0; moderate drought = -2.0 to -3.0; severe drought = -3.0 to -4.0; and greater than -4.0 = extreme drought. Note the drought conditions 1918, 1923, 1992. Source: National Climatic Data Center, 2000a. and 2000b.

6.0 Recommendations and Conclusions

The current forest at Bonesteele Ecological Park is a result of successional processes common in the Willamette Valley. Several hundred years ago prior to European settlement of the valley Bonesteele was most likely oak savanna, maintained by periodic burning by indigenous people. Following European settlement large portions of oak woodland and savanna were converted to agricultural fields. Remnant savanna, in the absence of fire, slowly succeeded to the mixed hardwood/conifer forest we see today. Following the successional path observed by Habeck (1962) in Polk County we can project future conversion to upland hardwood forest at Bonesteele.

Marion County Parks has established Bonesteele Park as its flagship ecological restoration site, with the goal of returning as much of the site to its pre-European vegetation as possible. The goals of restoration at Bonesteele are stated as follows:

a) Cultivate with plants that had a high probability of being on the property pre-European settlement.
b) Create a native plant experience to fully realize the land's scientific, educational, and aesthetic potential. We intend to be disciplined in how we do this to avoid creating a park that has lost any potential for authenticity or genuineness.
c) Avoid becoming a botanical garden for every plant that may have ever existed in the Willamette Valley. It is the intent that other parks representing different soils, elevations and hydrologic conditions will be created to accommodate the biodiversity of Marion County.
d) Provide long-term scientific research and educational opportunities
e) Provide a tranquil park setting for users wanting and needing a sanctuary from the stresses of contemporary life (Marion County Parks 1999).

Considerable effort has been made in replanting the agricultural field with native prairie species. The question that remains is how to tie in the rest of the site to the prairie, specifically, what should the role of the forest be. There are several options ranging from low to high impact (both in terms of resources and ecological impact), each of which are outlined below and reviewed with the restoration goals in mind.

Option 1: Convert the forest to oak savanna

One option is to convert the 6 acre forest to oak savanna. Such efforts have been successful at other sites, particularly in the mid-West U.S. where there are large areas of restored oak savanna and a high level of organization and cooperation among restoration organization (Jones 2000). A brief description of the techniques needed to accomplish this option follow:

1) Mechanically thin the forest to remove overstory species (Douglas fir, grand fir, big leaf maple) and open the midstory. This requires removal of trees, chemically treating stumps (to prevent sprouting), and burning slash.

2) Periodic prescribed burning to prevent litter buildup and to discourage establishment of invasive species. The burning rotation used by Missouri Department of Natural Resources varies from 1-3 years, depending on fuel types and fuel accumulation (McCarty 1993).

Table 4. Pros and Cons of Option 1: Convert the Forest to Oak Savanna

PROS	**CONS**
• provides opportunity to invest in large-scale restoration project in Willamette Valley	• cost is high: In 1993 McCarty (1993) estimated the cost of these treatments at $1200/acre.

• will create a large (6 acre) piece of savanna	• potential public relations issues with logging and thinning site
• provides long-term scientific and educational opportunities (goal d)	• mechanical manipulation required by this option may be viewed as less “authentic or genuine” than intended (goal b)

Option 2: Do nothing

This option means leaving the forest in its current state and allowing natural successional forces to govern it. The county could concentrate resources on prairie restoration, leaving the forest as an example of ecological change as a result of post-European settlement land use practices.

Table 5. Pros and Cons of Option 2: Do Nothing

PROS	CONS
• lowest cost option	• abrupt transition from prairie to forest
	• investment in removal of non-native species already underway
	• does not provide much opportunity for long-term scientific research and education (goal d)

Option 3: Develop a small oak savanna elsewhere on the site and continue to remove non-native species from forest

A third alternative (and my recommendation) is to continue removing the non native species from the forest (but to otherwise leave the forest intact), and to concentrate on developing a small oak savanna to the west of the forest (Figure 1). This option takes advantage of the presence of oak seedlings already established there. Following burning to remove grass in this area in 1998, about 40 oak seedlings sprouted. Since last summer the seedlings have increased in height by approximately 50% (Table 6). Continued light prescribed fire may further encourage development of a small oak savanna. In addition, prescribed fire used to maintain the prairie can be allowed to burn into the edges of the forest to control invasive species. This may have the additional effect of encouraging oak establishment along the forest edge as well, creating a transition from the prairie to the forest. This edge is currently maintained by plowing and represents an abrupt transition from plow-line to forest edge. Coffey’s (1999) data show fairly low fuel levels along the edges of the forest, and so under appropriate burning conditions allowing the fire to move into the forest edge should not present a threat to the entire forest.

Table 6. Oak seedling heights recorded at Bonesteele Ecological Park August 1999 and June 2000. Average percent change in height is 49%.

	8/14/99	6/1/00	
Seedling #	height (cm)	height (cm)	% change
58	58	63	8.6
60	23	29	26.1
61	27	28	3.7
63	13	32	146.2
64	28	30	7.1
65	20	42	110.0

66	22	28	27.3
67	20	27	35.0
68	23	40	73.9
70	25	34	36.0
71	52	66	26.9
72	22	32	45.5
73	29	50	72.4
74	29	50	72.4
79	13	20	53.8
80	18	28	55.6

Table 7. Pros and Cons of Option 3: Develop Small Oak Savanna Elsewhere, Remove Non-Native Species from Forest.

PROS	**CONS**
• no mechanical thinning required (Option 1)	• expense of burning
• oak seedlings already in place	• public relations of prescribed burning
• prairie/savanna burning may benefit forest edges	
• provides excellent opportunity for long-term scientific research and education (goal d)	
• efforts already underway	

Prescribed burning is used frequently as a restoration tool, however planning and executing a prescribed burn that achieves specific results can be quite difficult (Arabas 1997). This is because restoration ecology is experimental: there is no “How To” manual for restoration burning. Despite the frequent use of prescribed fire by land managers, information on the techniques and results of burning is often not published. In addition, techniques and effects are often site specific and transferring identical techniques to a different site may produce unanticipated results.

Most important in drawing up a prescribed burning program is to carefully establish the ecological/restoration goals of the burning ahead of time for all three areas: oak savanna, prairie and forest margins. For example, burning may topkill some plants and stimulate growth of others depending upon season of burning. In the midwest oak savannas spring burning has the following effects: it tends to topkill woody plants, stimulate warm season grasses, and can be hot. Fall burning stimulates cool season grasses, encourages fall germination by providing a seedbed, and tends to be cooler (McCarty 1993). This is because fuels and vegetation will vary with the season of burning. A detailed burning plan is beyond the scope of this report. Consultation among members of the Bonesteele Work Group and individuals experienced in ecological burning in the Willamette Valley is strongly advised.

Several sources can provide guidance for restoration burning at Bonesteele. First, a major conference series on Oak Savanna Restoration sponsored by the Environmental Protection Agency (EPA) has resulted in numerous papers on relevant topics, and the proceedings are available on the internet, giving land managers easy access to information on restoration goals, techniques, and results. In addition, several journals have been established in the past 20 years including *Restoration and Management Notes* and *Restoration Ecology*, in which results of restoration efforts are reported. Finally, a Pacific northwest oak study group has recently formed, bringing together forest practitioners, academics, and land managers to discuss oak forests in the area. Each of these sources can provide valuable help designing the next steps in restoring oak savanna to Bonesteele Ecological Park.

7.0 References

Abrams, M. D. 1982. Fire and the development of oak forests. *Bioscience*. 42: 346-353.

Abrams, M. D., and J. A. Downs. 1990. Successional replacement of old-growth white oak by mixed mesophytic hardwoods in southwestern Pennsylvania. Can. J. For. Res. 20:1864-1870.

Arabas, K.B. 1997. *Fire and Vegetation Dynamics in the Eastern Serpentine Barrens*. PhD. Thesis. The Pennsylvania State University.

Boyd, R. 1986. Strategies of Indian burning in the Willamette Valley. *Canadian Journal of Anthropology*. 5:65-86.

Coffey, S. 1999. *Fuel Load Along a Gradient at Bonesteele Park, Marion County, Oregon.* Research report from the Science Collaborative Research Program, Willamette University.

Cottam, G., and J.T. Curtis. 1956The use of distance measures in phytosociological sampling. *Ecology* 37:451-460.

Duncan, K. 1999. *Vegetation Changes in the Willamette Valley Since European Settlement: Bonesteele Park as a Case Study.* Senior Thesis in Environmental Science. Willamette University.

Habeck, J.R. 1962. Forest succession in Monmouth Township, Polk County, Oregon since 1850. *Proceedings of the Montana Academy of Sciences*. 21:7-17

Hampton, E.R., 1972. *Geology and Ground Waster of the Molalla-Salem Slope Area, Northern Willamette Valley, Oregon*. U.S. Geological Survey, Water Supply Paper #1997.

Jones, D.C. 1999. *Vegetation Dynamics of Bonesteele Park, Marion County, OR.* Research report from the Science Collaborative Research Program, Willamette University.

Jones, C.D. 2000. *Ecological Restoration of Oak Savanna Ecosystems*. Senior Thesis in Environmental Science. Willamette University.

Marion County Parks. no date. *Vicinity Map*. [online] available: http://www.open.org/~mpubwork/parks/images/bnstl.gif[6/2/00]

Marion County Parks. 1999. *Bonesteele Park Restoration Plan*. [online] available: http://www.open.org/~mpubwork/parks/bonesteele/bonesteeleplan.htm [6/2/00].

Marion County Parks. 2000. *Plants Identified at Bonesteele Park*. [online] available: http://www.open.org/~mpubwork/parks/bonesteele/plantid.htm [5/8/00]

McCarty, K. 1993. *Restoration in Missouri Savanna* [online] available: http://www.epa.gov/glnpo/oak/oak93/mccarty.html [5/28/00]

Mueller-Dombois, D. and H. Ellenberg. 1974. *Aims and Methods of Vegetation Ecology*. New York. John Wiley and Sons.

National Climatic Data Center 2000a *Palmer Drought Severity Index* [online] available: http://www.ncdc.noaa.gov/onlineprod/drought/xmgrg3.html [5/20/00]

National Climatic Data Center 2000b [online] *Time Bias Corrected Divisional Temperature-Precipitation-Drought Index* available: http://www.ncdc.noaa.gov/onlineprod/drought/droughtreadme.html [5/20/00]

National Weather Service. 2000. *Oregon's Historical Windstorms*. [online] available: http://www.wrh.noaa.gov/Portland/windstorm.html [5/26/00].

Oregon Biodiversity Project. 1998. *Oregon's Living Landscape: Strategies and Opportunities to Conserve Biodiversity*. Defenders of Wildlife. Washington, D.C.

Oregon Climate Data Service. no date. *Monthly Means and Extremes, Salem, OR.* [online] available: http://www.ocs.orst.edu/pub_ftp/climate_data/mme/mme7500.html [5/23/00]

Ridgeline Resources Planning. 1999. Bonesteele Prairie Restoration: Draft #3 Plan Outline. [online] available: http://www.open.org/~mpubwork/environment/restoration/index.htm [5/25/00]

Stokes, M. A. and T.L. Smiley. 1968. *An Introduction to Tree-Ring Dating*. Chicago. University of Chicago Press.

USDA (U.S. Department of Agriculture). 1990. *Silvics of North America: Volume 2, Hardwoods.* Agricultural Handbook No. 654. Washington, D.C. U.S. Forest Service.

USDA (United States Department of Agriculture). 1972. *Soil Survey of Marion County Area, Oregon*. Washington, D.C. GPO.

Whitlock, C.W. 1992. Vegetational and climatic history of the Pacific Northwest during the last 20,000 years: implications for understanding present-day biodiversity. *Northwest Environmental Journal*. 8: 5-28.