Will Garry Oak Respond to Release from Overtopping Conifers?

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Abstract

Garry oak (*Quercus garryana*) woodlands provide unique habitat for many Pacific Northwest species but these habitats are rapidly disappearing as species composition shifts to conifer or land use changes to urban or agricultural. Many oak trees from former savannas or oak woodlands on Fort Lewis Military Reservation (near Tacoma, WA, USA) are currently overtopped by Douglas-fir (*Pseudotsuga menziesii*). The shade-intolerant oak has probably survived in these stands due to past thinning activities; however, as the Douglas-fir continues to increase in height, we expect most of the oaks will not survive for long. This study's primary objectives are to determine if overtopped oaks will respond to release treatments, and if so, what pre-treatment tree and stand characteristics can be used to predict response to release. The study utilizes three levels of release in each of four stands overtopped by Douglas-fir. The treatments are: *Full Release* - The removal of all conifer competitors (mean = 15) within a circular plot, centered on an oak tree and with radius equal to the height of the oak tree; *Half Release* - The removal of all conifer competitors (mean = 6) within one-half the radius of the full-release treatment; and *Control* - The background operational thinning designed to reduce competition between Douglas-fir overstory trees; on average, two conifers were cut around each study oak. The treatments were applied prior to the 2001 growing season. Baseline data were collected for trees and understory vegetation. First-year results are available for acorn production, epicormic branching, and microclimate variables. Based the fact that we did not observe any tree mortality or appearance of stressed foliage the first year and results from thinning in eastern oak forests indicate oak trees respond to increased growing space, we suspect most Garry oak trees will respond positively to release but an increase in growth rate may not be measurable for several years.

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Introduction

Garry oak (*Quercus garryana*), also known as Oregon white oak, is somewhat of an anomaly in Pacific Northwest forests. It differs from the other native hardwood species in the region in that it is shade-intolerant, but the shade it provides is usually not sufficiently dense to prevent regeneration and growth of other shade intolerant tree species such as Douglas-fir (*Pseudotsuga menziesii*) and ponderosa pine (*Pinus ponderosa*). In addition, while Garry oak can grow on a wide range of soil and site conditions, on all but the driest sites other species become established in the oak understory and eventually overtop the oaks. Garry oak woodlands and the oak savannas associated with prairies were much more common 200 years ago than they are today. The decline in acreage is due to natural invasion of conifer, deliberate stand conversion to conifers for timber production, or conversion to urban or agricultural use. Historically, plant succession was halted when fires from natural ignition sources or those set by Native Americans burned the understory. Many of the Native American tribes in the range of Garry oak burned regularly to keep the prairies and associated oak areas open (Agee 1996a, 1996b). Garry oak has been maintained on the landscape primarily by fire, and on most sites it will disappear without either repeated fire or management intervention (Agee 1990).

The loss of oak and associated prairie habitat is of great concern to many biologists and resource managers. These ecosystems have unique flora and fauna associated with them and declines both in the extent and the quality of these habitats are of great concern (Erickson 2000). For example, the western gray squirrel is currently listed as a state-threatened species in Washington, and loss of oak habitat is one of the primary reasons for declining squirrel populations (Ryan & Carey 1995). Invasion by exotic species, especially the very aggressive understory shrub Scots broom (*Cytisus scoparius*) and non-native sod-forming grasses, has resulted in historic plant communities with very different species composition and biomass than the original communities.

We began a research program on Garry oak in 1999. The first step was to determine what was known, so we compiled a bibliography for the species (Harrington & Kallas, in press). We determined that most of the information available described oak communities or their historical locations, or documented some aspect of oak biology, wildlife associated with oaks, or use and management by Native Americans. Although the need for restoration or active management of oak stands was mentioned in many papers, very little was available which documented the results from research trials on these topics. Some research results are available on management of eastern white oak (*Q. alba*), a species that is very closely related to Garry oak (Daubenmire 1978). The information available for the eastern species is of interest; however, it may not be completely relevant because eastern white oak grows under a different climate regime and is primarily found in hardwood-dominated stands.

The Fort Lewis Military Reservation, located southeast of Tacoma, Washington, U.S.A., has some of the largest oak stands remaining in western Washington. Many of the oaks in those stands are not in strong competitive positions though, as conifers have invaded and now overtop the oak. Oak in midstory and understory positions in conifer stands will not persist indefinitely due to its shade intolerance and inability to grow into position in the upper canopy. Its survival to this point is probably due in part to the long-term commercial thinning program used in conifer stands at Fort Lewis. The Forestry Program at Fort Lewis is interested in managing their oak resource and asked researchers with the Pacific Northwest Research Station to develop basic information on oak biology and ecology, and on techniques effective for restoring or managing oak woodlands and savannas.

As part of our research we designed a study to determine the response of Garry oak to release from overtopping conifers. The primary objectives of the study are to determine if overtopped oaks will respond to release treatments, and if so, what stand and tree characteristics can be used to predict response. The study was not designed to test stand-level operational treatments but rather to create a range in conditions that will allow us to identify the major factors that will predict oak tree response to release. Secondary study objectives include quantifying the effects of release treatments on growth of understory and midstory trees, cover and composition of other vegetation, microclimate variables, and acorn production. The study was implemented in spring, 2001. Since the release treatments have only been in place for one year and treatment effects on oak tree size may take years to develop, we describe initial stand conditions before and after treatment, discuss treatment implementation, and present first growing season results for microclimate at the ground, epicormic branching, and acorn production -- variables we expected to reflect immediate or short-term effects of the release treatments. Future reports will report longer-term responses to the treatments by the oak trees and other components of the ecosystem.

Methods

Study Sites

We selected four sites (Cherry Hill, Goodacre, Lake Joseph, and Sneesby) across Fort Lewis to represent a range in tree and stand conditions. All sites are on deep droughty soils derived from glacial outwash materials, are generally flat, and are at low elevation. Mean annual precipitation is 940 mm. The stands are primarily composed of Douglas-fir in the overstory and Garry oak in the midstory. Other tree species present on the sites include: bigleaf maple (*Acer macrophyllum*), red alder (*Alnus rubra*), Pacific madrone (*Arbutus menziesii*), Oregon ash (*Fraxinus latifolia*), black cottonwood (*Populus balsamifera*), cascara buckthorn (*Rhamnus pushiana*), Pacific dogwood (*Cornus nuttallii*), bitter cherry (*Prunus emarginata*), ponderosa pine (*Pinus ponderosa*), and western redcedar (*Thuja plicata*). The trees in our study plots averaged 120 years old for the oaks and 80 years old for the Douglas-fir. Each of the study stands had been commercially thinned (removing Douglas-fir) once or twice between 1980 and 2000. For ease in treatment implementation, the oak release treatments (described below) were completed as part of a larger thinning program designed to increase conifer growth.

Study Design

The study is a complete, randomized-block design with four blocks (sites), three treatments, and six replications (that is, each treatment was sub-sampled six times at each site). Thus, 18 plots were installed at each site (72 plots in total). Each circular plot was centered on an oak tree > 20 cm dbh (diameter at breast height – which is 1.3 m above the ground); plot radius was equal to the height of the center tree. The center trees were selected to represent a range in oak size and local stand conditions; the resulting plots were non-overlapping and each contained a minimum of two Douglas-fir competitors (maximum number of competitors was 47). More than one oak tree was present on almost all plots and many of the oaks were multiple stemmed.

The Full Release treatment was the removal of all conifer competitors (competitors defined as trees ≥ 10 cm dbh) on the plot (i.e., within one oak-height radius of the center oak); on average, this treatment removed 15 conifers around the study oak (Fig. 1). The Half Release treatment was the removal of all conifer competitors within one-half oak-height radius; on average, six conifers were removed in this treatment. The Control treatment had no release treatment, but some trees were removed as part of the commercial thinnings conducted in these areas between summer 2000 and spring 2001. On average, two merchantable (≥ 20 cm dbh) conifers were removed in each Control plot. Release treatments were implemented between April 15 and June 1, 2001. We cut or pulled the Scots broom from all the plots immediately following treatment implementation (May to July 2001); removing the broom helped to equalize conditions among sites and trees and was consistent with our long-term goal of restoring the native plant community.

Initial Tree and Stand Conditions

To describe the initial stand conditions in each plot, data were collected on the overstory and midstory trees during winter 2000-2001. Diameter, height, and crown width were measured on the center oak trees. A subset of the oak trees was bored to determine age. In each plot, tree diameter, species, and distance to the center oak were recorded for all overstory and midstory trees, and heights of the two tallest competitors were measured. The main study concentrates on the treatment responses of the center oak tree and the other overstory and midstory trees (≥ 10 cm dbh). On a subset of the plots, additional measurements were taken to monitor composition and growth of the understory trees (<10 cm dbh and ≥ 0.5 m height) during early summer 2001.

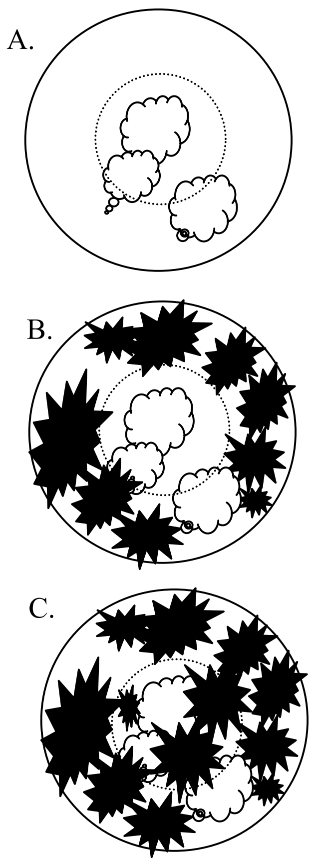

Figure 1. Examples of the release treatments. A. Full. B. Half. C. Control.
Fir = Oak =

Understory Vegetation

Understory vegetation was surveyed in early summer 2001 in a subset of the study plots; three plots in the Control and three in the Full Release treatments were sampled at all four sites. A transect was installed across the plot with the center point 1 m south of the center tree. Daubenmire plots (20 x 50 cm) were located every 2 m along the transects and percent cover by species of understory plant and percent cover of the overstory trees were recorded.

Microclimate

To monitor microclimate changes, relative humidity and temperature data loggers (HOBO model H08-032-08, Onset Computer Corp.) were installed in three Control and three Full Release plots at three sites (Cherry Hill, Goodacre and Sneesby). The data loggers were mounted 25 cm above the ground, 1 m south of each center oak. Data were recorded at 2-hr intervals beginning July 25, 2001.

Epicormic Branches

The oak trees at the center of each plot were surveyed for epicormic branches in early summer 2001. The presence of epicormic branches was noted and photographed, and their height on the bole recorded. The trees were visited again in fall-winter 2001 and examined for development of additional epicormic branches.

Acorn Production

In September 2001, we surveyed 38 of the 72 center oak trees for acorn production. These data were added to a larger, multi-year acorn survey on *Quercus garryana* that is completed each year by volunteers and employees of the Pacific Northwest Research Station (details of the methods are available at http://www.fs.fed.us/pnw/Olympia/silv/oaksurvey/acorn_survey_instructions.htm). Trees were coded using a 1 to 4 code with 1 = no acorns and 4 = heavy acorn production (Graves 1979).

Results

Initial Stand Conditions

Mean tree size for both the center oaks and the overstory Douglas-fir was similar across the four sites (Table 1). Mean height for both species was slightly greater at Lake Joseph and mean diameter was slightly greater at Cherry Hill. The tallest Douglas-fir were considerably taller and larger in diameter than the tallest oaks (Fig. 2). This resulted in a mean height ratio (center oak height: tallest competitor height) of 0.32 to 0.43. Both species were present in a range of tree sizes; however, the Douglas-fir were clearly much taller and larger in diameter than the oak at these sites (Fig. 2).

Garry oak and Douglas-fir were the primary tree species in both the overstory/midstory and the understory. Smaller amounts of bigleaf maple, Oregon ash, bitter cherry, cascara buckthorn, and Pacific madrone were also found in the understory. Understory oak trees (trees <10 cm in diameter) averaged between 2 and 3 cm at Cherry Hill, Goodacre, and Lake Joseph, but less than 1 cm at Sneesby (data not shown).

Table 1. Mean diameter at breast height and height for Garry oak and Douglas-fir at each site prior to treatment.

	Garry oak		*Douglas-fir*	
Site	*DBH (cm)*	*Ht (m)*	*DBH (cm)*	*Ht (m)*
Cherry Hill	31.8	15.5	57.2	39.4
Goodacre	29.8	16.1	46.6	40.0
Lake Joseph	29.8	16.4	52.2	43.2
Sneesby	31.3	16.1	43.1	39.0

Over 100 vascular plant species were identified across all four sites and approximately 75% of the species were native. Although 25% of all identified species were non-native, they accounted for no more than 10% of total cover on any site. Cover of non-native species (mostly grasses) at Cherry Hill was twice as great as at the other three sites (data not shown).

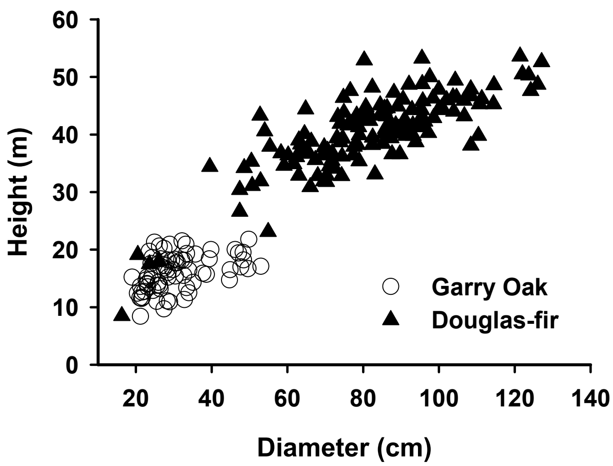

Figure 2. Height versus diameter for Garry oak and Douglas-fir at four sites on Fort Lewis, Washington.

At the beginning of the project, Scots broom was found at all sites and in over half the plots at each site. If broom was present on a plot, its density ranged from 273 to 1341 stems ha^{-1}. Broom plants averaged about 2 m tall.

Treatment Implementation

The release treatments were implemented under the Fort Lewis timber sale program. Trees to be cut were selected by the researchers and painted to indicate they should be cut. Language included in the sale contracts directed that oak trees were to be preserved, if at all possible, and the timber sale administrator and the loggers were informed of the study's purpose prior to the beginning of logging.

All trees to be removed were hand felled. Overall, the loggers did an excellent job in removing the Douglas-fir trees without damaging the oaks. Only two trees were 'skinned' (bark removed on one side of the bole) and breakage of branches was minimal. The lack of damage was especially noteworthy given the large size (many trees >100 cm in diameter) and long crowns (generally > 60% crown length) on the Douglas-fir trees that were removed. We suspect that having skilled fallers and good communication among the various parties involved (researchers, forest management staff, person who prepared the timber sale contract, the timber sale administrator, and the loggers) were essential in meeting our objectives of releasing oak trees with minimal damage to the residual trees.

Basal area prior to treatment averaged 40 m^2 ha^{-1} and was dominated by Douglas-fir at all sites (Table 2). There was substantial variation in total basal area and species composition from plot to plot, but overall, Lake Joseph had the highest basal area of Douglas-fir, and Sneesby had the highest basal area of oak. Mean basal area of Douglas-fir averaged about 33 m ha^{-1} prior to treatment; all the basal area of Douglas-fir was removed in the Full Release treatment and an average of 11 m^2 ha^{-1} was removed in the Half Release treatment.

Microclimate

Since the application of the Full Release treatment removed much of the overstory tree canopy, it had an immediate effect on air temperature and relative humidity. Maximum daily air temperature was almost always higher in the Full Release than in the Control plots, with a maximum difference of 9°C recorded in August 2001 (Fig. 3a). Minimum daily relative humidity was lower in the Full Release compared to the Control, with a maximum difference of 19%, also recorded during August (Fig. 3b). Treatment differences in microclimate were much greater during the growing season than during the rainy winter months (data not shown).

Epicormic Branches and Crown Width

Prior to treatment, epicormic branches were present on 16% of the trees but the presence of epicormic branches varied substantially by site (from 0% of the trees at Goodacre to 61% at Sneesby). Mean crown widths were

Table 2. Post-treatment basal area in trees > 10 cm dbh by site and treatment. Basal area in cut trees is in parentheses.

Site	*Species Type*	*Full Release*	*Half Release*	*Control*
Cherry Hill	Douglas-fir	0.0 (28.3)	19.0 (7.8)	39.8
	Garry oak	4.0	4.7	5.6
	Other species	1.2	0.3	7.3
Goodacre	Douglas-fir	0.0 (26.3)	20.5 (11.8)	29.0
	Garry oak	1.5	2.3	2.2
	Other species	0.0	0.7	0.1
Lake Joseph	Douglas-fir	0.0 (39.4)	39.7 (19.4)	41.1
	Garry oak	4.4	5.5	2.2
	Other species	1.6	0.6	0.6
Sneesby	Douglas-fir	0.0 (36.2)	21.5 (7.8)	23.7
	Garry oak	4.9	5.5	13.0
	Other species	0.9	0.1	0.1

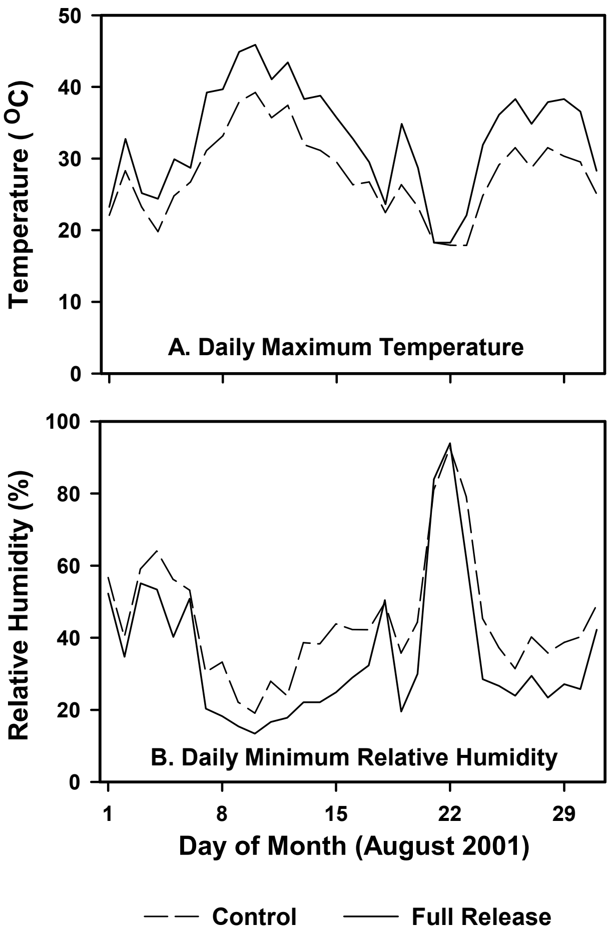

Figure 3. Daily microclimate extremes during August 2001 for Control and Full Release treatments at 3 sites.

fairly similar across the sites (6.2 to 8.3 m) but crowns widths of individual trees varied substantially (3.2 to 14.9 m). There was no apparent relationship between crown size and presence of epicormic branches; that is, trees with smaller crowns did not on average have more or fewer epicormic branches than trees with larger crowns. The epicormic branches existing on the study trees were fairly long (>20 cm) and apparently had been initiated many years ago. There was no increase in epicormic branches on the Control or released oaks during the first growing season after treatment.

Acorn Production

Acorn production in western Washington in 2001 was generally low, but some trees did produce heavily (D. Peter, personal communication). In our study, 68% of the trees did not produce any acorns, 18% produced a few acorns, and 13% produced a moderate amount (none produced a heavy crop). Acorn production varied among sites, with Sneesby having the highest percentage (92%) and Cherry Hill having the lowest percentage (33%) of non-producing trees (Table 3). There was no clear trend in acorn production with treatment; however, at the first area logged (Goodacre) the percentage of trees with acorns was higher in the Full Release treatment than in the Control, while at the last area logged (Sneesby) the opposite pattern was present (the percentage of trees with acorns was lower in the Full Release treatment than in the Control). The number of trees observed for acorn production was fairly low and no direct observations of flowering were made, so we can't say what was responsible for the difference in treatments across the sites. We do know that Garry oak flowers during May in our area, so it is possible that logging at Sneesby during May could have resulted in physical or environmental damage to the flowers present at that time, thus, reducing the future production of acorns.

Table 3. Percent of trees with acorns in fall 2001 by site and treatment. N=number oak trees observed.

	Acorn Production			
	Full Release		*Control*	
Site	*N*	*% with Acorns*	*N*	*% with Acorns*
Cherry Hill	3	67	3	67
Goodacre	5	60	4	25
Lake Joseph	3	33	3	33
Sneesby	4	0	5	20

Discussion

We are not aware of any documented examples that illustrate the response of Garry oak to release from overtopping conifers. Results from eastern forests generally indicate that eastern white oak (*Q. alba*) exhibits positive growth responses when it is released from competition. Released white oak in intermediate crown positions in mixed oak stands in Missouri doubled their growth rates and reached a maximum growth rate 7-9 years after release (Graney 1998). Growth was increased for released white oak in Illinois compared to controls throughout a 20-year period of measurement (Schlesinger 1978). In other studies in southern Illinois and Tennessee, response of white oaks to release was related to initial size, age, stem form, crown development, and degree of release (Schlesinger 1978; McGee 1981); white oaks in the best condition (initial size, growth rate, or crown condition) responded the most to release treatments. Graney (1998) found it took three years for 50-year-old white oaks in Missouri to respond to release. Codominant and intermediate pole-size white oak released in upland hardwoods of southern Illinois responded to release regardless of age if the oak had an adequate relative crown size (Minckler 1957). Most of our study trees had small crowns due to years of overtopping. Based on the results from these studies of *Q. alba*, and given the relatively advanced age (most > 100 years old) and small crowns of our midstory oak trees, we would expect mean response to release will be slow and relatively small in magnitude. The initial size and condition of our oaks varied substantially, however, and trees with the largest crowns will probably respond much more quickly and to a greater degree than the more suppressed trees.

Oak trees in understory positions in the study may also respond more quickly to release than the average oak in a midstory crown position as the understory oaks generally had much larger crown ratios (crown ratio = percentage of bole length with live foliage) than the larger trees. In West Virginia, oak seedling growth and form improved after single-tree canopy release (Carvell 1967). In addition, the seedlings that received increases in light of 10-20% had as much improvement in growth as seedlings that received 80-90% more light; thus, it is possible that the Half Release treatment may be as effective as the Full Release treatment in increasing growth of the understory oaks. Carvell (1967) suggested that seedlings with small root systems may not respond well to heavy release treatments because the increased radiation reaching the ground in that type of treatment would result in drier soil conditions compared to the controls. Soil moisture is likely to be limiting seedling and sapling growth in all our treatments due to the low water-holding capacity of the excessively drained soils at our study sites. Removal of the conifer overstory in our study could increase soil moisture in parts of the soil profile as conifer root systems would no longer be withdrawing soil moisture and conifer crowns would not be intercepting light summer rains. Other species in the understory, such as Douglas-fir, may also respond favorably to release; response of the conifers may not be immediate, however, as the foliage on the conifers in understory positions would be adapted to low light conditions and the trees may have to build new crown to take full advantage of the increased light and change in soil conditions.

The microclimate data reflected the immediate effects of the treatments on the environmental conditions near the forest floor. The observed changes in microclimate may have resulted in increased soil microbe activity and nutrient cycling rates. Increased growing season temperatures and lower relative humidity may also favor the oak- and prairie-associated species over the shade-tolerant species more commonly found in understories of conifer stands. Unfortunately, the increased light and warmer, drier conditions that should be favorable to native species associated with oak savannas are likely to also be favorable for many of the non-native species present on the sites, especially Scots broom. As discussed above, though, it is not known how the combined factors of increased radiation to the forest floor and decreased competition below ground will impact soil moisture through the profile; nor is it known how the various components of the understory plant communities will respond and, in turn, impact soil and water nutrient availability.

The presence of exotic species in these stands will need to be addressed in the future if we hope to return these stands to the plant community composition that would have existed in the past. One of the non-native, invasive species of major concern is Scots broom, an introduced shrub that is common throughout Fort Lewis (as well as most of the range of Douglas-fir). It can form thick shrubby monocultures, change the soil chemistry, and can aggressively out-compete native vegetation. Due to the high numbers of broom at the beginning of the study, and the species' ability to produce large numbers of seed that remain viable for many years in the soil seed bank, it will be very difficult to eradicate broom from the plots.

Although no epicormic branches were observed in the first year, epicormic branches may develop in later years and these branches could play an important role in acquiring light resources, especially for trees with small crowns. Released eastern white oaks in Virginia initiated more epicormic branches than unreleased trees (McGee & Bivens 1984). In a study in southern Illinois, however, epicormic branches did not appear on white oak until three years after release (Minckler 1957). Pruning branches located below the main crown reduced the growth of released oak trees in Illinois, indicating that lower branches can significantly contribute to growth (Schlesinger 1978).

With increased light to the crown, we would expect released trees to have greater acorn production than non-released trees at some point in the future. If the release treatments result in substantial production of epicormic branches, however, acorn production may not necessarily increase, as epicormic branches do not produce acorns (at least not initially). McDonald and Ritchie (1994) suggest using a series of thinnings for California black oak (*Q. kelloggii*) to allow the oak to gradually increase expansion of the main crown and reduce the amount of epicormic branches.

Future Plans and Predictions

We plan to continue to follow these plots for many years. In order to better interpret the responses in our study we have recently installed 1-m long soil water access tubes in Control and Full Release plots at three of our sites to monitor soil moisture throughout the profile. Our soil moisture monitoring will start in spring 2002. Also during 2002, we will continue to monitor air temperature and relative humidity, resurvey for acorn production and epicormic branches, measure understory trees, and bore a subsample of overstory trees to see if diameter growth responses to the treatments are beginning. In 2003, we will repeat the vegetation surveys and the soil moisture and microclimate measurements, resurvey for acorn production and epicormic branches, and remeasure the overstory trees in all treatments. Longer term, we also hope to monitor treatment effects on other ecosystem components that may be affected by changes in overstory composition and density, such as populations of soil invertebrates (baseline sampling was done for invertebrates in 2001).

As discussed above, we expect most of the oaks to respond significantly to the release treatments but the timing and degree of response will probably depend on initial tree size and age. Trees that were severely suppressed at the beginning of the trial may not respond at all or for many years if their crowns initially were very small. Other factors that may impact future growth of the oaks in the released plots are the development of the understory (especially Scots broom) and expansion of Douglas-fir crowns from trees left on the plots or present on the perimeter of the plots. Douglas-fir currently in the understory may also overtop the released oak if their future growth potential is significantly greater than that of the released oaks. Our study was designed with six plots in each treatment in anticipation that we would want the future flexibility to apply additional treatments to the overstory or understory. This study is a first step but many such trials will be needed to develop the knowledge base to allow managers to restore form and function to degraded oak ecosystems.

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