The Effects of Caging *Quercus agrifolia* and *Quercus lobata* seedlings in Arastradero Preserve, Palo Alto, California

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Abstract

Oak woodlands, which are known to have the richest wildlife species abundance of any habitat in California, have been disappearing lately. Therefore, restoration of oak woodlands has been of concern. However, restoration of oak woodlands has been difficult because of numerous factors affecting the survival and growth of oak tree seedlings, including deer browsing. Researchers have tried to prevent young oak seedlings from being browsed by deer by using protection. This project examined two methods of protection, tubing and caging. Coast live oak trees and valleys oak trees from the Arastradero Preserve in Palo Alto, California were studied. The two goals of this experiment is to see if coast live oak trees and valley oak trees grow faster when protection is placed over them and if they have a higher survival rate when protection is used. The trees were studied in seven different sites: the Corte Madera Site, the Lake Arastradero site, the barn site, the house site, the west cottage site, the east cottage site, and the acorn trail site. Some of the trees were caged or tubed and some were not. Measurements were taken of each tree for height and diameter. Single way ANOVA was be used to find the correlation between growth and several categories, including species, site, competition, shade, protection, and types of protection. A difference in growth and survival rates between protected trees and unprotected trees was found. A correlation between method of protection and growth was not found.

Introduction

In the past, oak woodlands have been used primarily for livestock production. They have gained importance recently because of the awareness that they have the richest wildlife species abundance of any habitat in California (Verner 1980). Oak woodlands are especially vital to maintenance of the diversity of bird species in California (Verner 1983). However, oak regeneration in recent years since grazing pressures have been reduced on oak woodlands has been of concern. Numerous species have shown particularly low survival rates and slow growth rates during the seedling stage. A growing body of evidence suggests that many of the areas dominated today by non-native annual grasses may formerly have been dominated by different vegetation types such as oak woodland, chaparral or coastal scrub (Hamilton 1997).

The two species of oak trees examined in this project were coast live oak trees and valley oak trees. Coast live oak trees are the most common oak in the South California coast. The live oak trees survive better in dry weather than other oak trees and are evergreen trees (www.treeguide.com). Specimens crowded by other trees have more slender branches and less spreading crowns (Everett 1977). They contain pointy leaves. Decay, site grade changes, and low wind speeds are more frequently associated with coast live oak failures than other trees (Edberg and Berry 1999). Valley oak trees are among the oldest and largest of oak trees. They contain leaves with lobes and are deciduous trees (Little 1980). Both coast live oak trees and valley oak trees have short trunks that can attain 4 feet in diameter, have wide-spreading branches and can reach a height of 100 feet. Leaves do not last more than one year and fall in the spring, about the same time new leaves are developing.

Deer usually prefer areas which have woodlands to hide and open land to graze in (www.mich.com/~serenget/facts.htm). They especially like young forests because they provide more food. Old forests provide less food because the bigger oak trees, which are hard for deer to browse, prevent younger oak trees from surviving. Deer are more likely to browse in the summer than in the winter. In the winter, they rely on fat reserves.

The survival and growth of oak tree seedlings is inhibited by numerous factors. Deer browsing was found to have a large, negative influence on the survival and growth of oak tree seedlings (Stange and Shea 1998). Coast live oak trees seem to have a better chance than valley oak trees to reach the sapling stage even though they are both browsed by deer

(Griffin 1983). Different species of grasses were also found to have negative effects on oak tree restoration (Gordon and Rice 1993). Other possible effects on oak tree restoration included rodent herbivory, fire, and insects (Mcdougald, Standiford, Frost and Phillips 1997). Gophers are especially deadly to oak seedlings in that they can kill the roots and kill the seedlings (Griffin 1983). Oak trees also need adequate amounts of light to survive (Mcgee 1979). Soil composition is also a determinant of how successful oak tree restoration is (Carmean 1979). Coast live oak trees were found to fail more often because of decay, site grade changes, low wind speeds, and saturated soil conditions than other hardwoods, conifers, or eucalyptus (Edberg and Berry 1999). Young oak trees are also less likely to survive in areas which do not have natural disturbances such as fires (Mcgee 1979). Researchers have tried to find out different ways to protect oak trees from these negative effects.

Various methods to improve survival of oak saplings have been tried including using cages, plastic mesh, polypropylene sleeves, tubes, and fabric mats. The mats were found to be ineffective, because even though they decreased plant competition, they made the young oak trees more visible to deer, and consequently more heavily browsed (Stange and Shea 1998). In addition, in the same study, tubes were found to be effective. Propypropylene sleeves and plastic mesh were also found to be less effective than tubes (Ward 1996). Caging was found to increase growth rates and survival rates of coast live oak seedlings in the first year (Parikh and Gale 1998). However, in the second year, caging retarded growth but still increased survival rates of the seedlings. After two years, no effects on seedling survival or growth by caging were found. In this case caging and tubing were used. The positive aspect of caging is that sunlight is able to get through without much inhibition. The negative aspect of caging is that small animals are still able to nibble off the young oak trees with ease. Conversely, the positive aspect of tubing is that small animals are not able to get to the trees with ease. The negative aspect of tubing is that sunlight has a harder time getting to the trees and the growth of the diameter of the young oak trees may be reduced (West 1999). Both methods of protection do interfere with the tree's growth once the trees become large enough, and should be removed to prevent restriction in tree survival.

In the summer of 1998 in the Arastradero Preserve in Palo Alto, an environmental group called Bay Area Action conducted a survey of the Preserve's oaks (Arastradero

Preserve 1998, elect. comm.). The mature oaks consisted of coast live oaks trees *(Quercus agrifolia* Nee), valley oak trees (*Quercus lobata* Nee), and black oak trees. The volunteers examined the grasses and weeds beneath the oaks looking for seedlings, saplings, and young oaks in a stand near a former barn site. The Bay Area action volunteers found that woodlands and hilltops have many trees which are fifty years or older and many small seedlings but hardly any trees in between these two age groups. Many seedlings had been nibbled on by deer. Italian thistle and non-native grasses deprived the young oaks of space and water.

The Arastradero Preserve consists of seven sites, the Corte Madera Site, the acorn trail site, the west cottage site, the east cottage site, the barn site, the house site, and the Lake Arastradero site. The Corte Madera site is on the eastern side of the Arastradero Preserve. It is mostly open, is located on the edge of a forest, and contains native thistles, which would compete with the saplings. The Lake Arastradero site is a bank on the eastern side of Lake Arastradero. The saplings that were experimented on there were older and had more shade than the other sites in general. The competition tended to be other big trees. The east cottage site and the west cottage site had native thistles as competition, and the saplings were located at the edge of the forest. The acorn trail site had saplings in the open and under the edges of a forest. It had non-native thistle and native thistle as competition. In the barn site, all of the oak trees are in the open, and there would be only intraspecific competition. In the house site, most of the oak trees are in the open and are not interfered with by other plants. Through December and November of 1997, Bay Area Action volunteers planted 30 coast live oak trees and 10 valley oak trees in the house site and planted 30 coast live Oak and 10 valley oak trees in the barn site. In October 1998, some of the seedlings were caged and had chicken wire placed around their root systems to protect them from underground herbivory. Some of the seedlings were also tubed. In the Corte Madera site, the acorn trail site, the west cottage site, and the east cottage site, some oak trees were also caged. This study is designed to see the effects of caging and tubing on the growth of the oak trees.

The first goal of this experiment is to find out if coast live oak and valley oak trees grow faster when protection designed to prevent herbivory, such as cages and tubes, is placed over them. The second goal of this experiment is to find out if more coast live oak seedlings and valley oak seedlings survive when protection is placed over them. Specifically, the

efficacy of caging and tubing is being researched. If the native oaks do grow faster, specific reasons of why the native oaks grew faster will be discussed. Such reasons could include decreased deer herbivory, decreased gopher herbivory, and/or decreased insect herbivory as a result of the caging or tubing.

Methods

Research for this experiment was done at the Arastradero Preserve in the hills of Palo Alto. The surface area of the preserve is 609 square acres. In the winter, the weather is cloudy with rain. In the spring and fall, the weather is sunny with low humidity. The preserve has a small lake in the northeastern region. Trails for pedestrians and bicyclists run throughout the preserve but do not affect the oak trees. The preserve has three different kinds of habitat: oak woodland, grassland savannah, and riparian. The grassland is 95% non-native European annual grasses and yellow star thistle. The rest is California native perennial grasses. Eucalyptus trees and grasses, native and non-native, grow in the preserve besides oak trees. Deer and gophers browse the young oak trees in the area. It seems that the deer are more likely to browse at the edges of small forests rather than in the middle of forests possibly because of better visibility of the seedlings. The young oak trees seem to be clustered in different sites. The sample trees were be measured in seven specific sites, the Barn site, the House site, the Acorn trail site, the Arastradero Lake Dam site, the Corte Madera Site, Caretaker's Cottage East site and Caretaker's Cottage West site. The barn site and most of the house site is open and has tanbark placed on the ground to prevent plants other than oak trees from growing. When grass, thistles, and shrubs are not growing, more oak trees are able to grow (Piroznikow 1998). The other sites mostly have thistle growing, which does interfere with the growth of the oak trees.

Acorns of Coast Live Oak trees (*Quercus agrifolia* Nee) and Valley Oak trees were planted in the barn site in December 13, 1997 and in the house site on November 20, 1997. Two hundred planted and naturally regenerating oak seedlings at all the sites were identified and tagged in October and November 1998. One hundred oak trees throughout the six sites were caged or tubed. Cages were cylindrical, two feet in diameter, and five feet tall for each tree. The wire formed two by two inch squares. The cage had no top. Tube were made of white polyvinylchloride and let sunlight in. The tubes were about four feet tall each. Wire

was placed on the top of the tubes. Chicken wiring was placed around the roots to deter gophers from biting at the roots of the oak trees. Researchers took height and diameter measurements when seedlings were caged or tubed.

At the time of the study, most saplings were four feet or below in height. The oak trees were measured in two sessions. One session was in the months of October and November, and the second session was in March. The two hundred trees that had been previously tagged were measured. The species and site of each oak tree were noted; whether the tree was caged, tubed, or unprotected was also noted; the diameter of the base of the stems of each sample tree was measured; the height of the trees was also measured; and discoloration of the leaves and branches of the trees were noted to see if they were dying or healthy. Percentage canopy cover was measured with a densiometer. Some trees had their percentage shade assumed because of the difficulty of using a densiometer in those areas. Also, if the tree was in an open field with no large trees, zero percent shade was assumed. Competition within a one foot radius was observed and recorded as a percentage. In the second session, trees were noted to see whether they had fallen down or were missing. Those trees were assumed not to have survived.

Other factors were taken into account. Evidence of the presence of deer, such as deer trails and deer feces, were reported. Also, evidence of the presence of gophers was noted. Any unusual events, such as fire, were noted. Trees were examined to see if deer had nibbled on them.

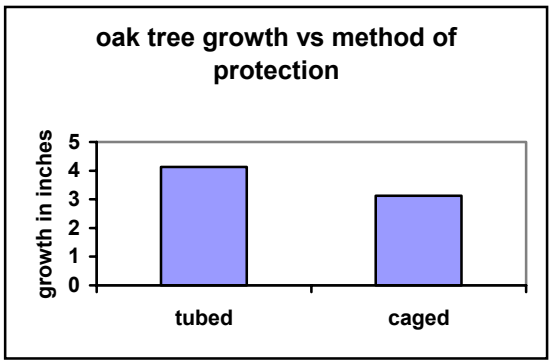
Soil composition was be analyzed. Three samples soil from each of the seven sites were analyzed. Each sample weighed about 0.3 pounds and were taken from the surface of the ground. Different layers of soil were measured by mass percentage. Sieves were used to separate the soil into different layers. The pH of the soil was measured with litmus paper. Average rainfall of the site was recorded.

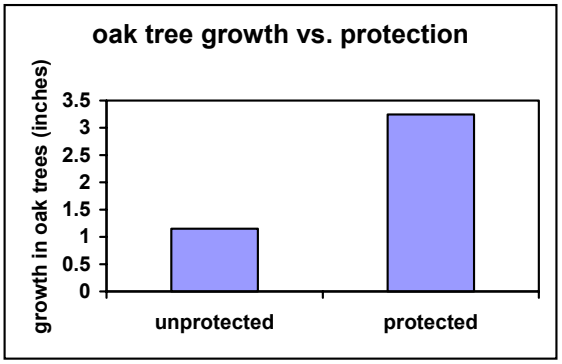
After the data is taken down, multi-factor ANOVA testing was determined if there is a relationship between protection and growth by using the patterns of growth between the caged trees between the fall and spring. ANOVA testing was used to determine if there is a difference in growth between caged trees and tubed trees. Also, ANOVA testing was used to see if there is a difference in growth between oak trees with varying competition, canopy cover, species, and sites. If there was a significant correlation between caging and growth,

observations were taken into account to explain the correlation. Spatial analysis may be used to differentiate between trees in different sites. ANOVA testing was used to determine different rates of growth between trees in different sites. Another variable that will be looked into is survival rate. Missing trees and trees that have fallen down were assumed not to have survived. ANOVA testing was be used to determine survival rates of oak trees in different categories, such as protection, site, competition, shade, and species.

Results

Data of one hundred and fifty-seven oak trees were taken in the first session in October and November. The Lake Arastradero trees were taken out of statistical analysis because they were older than the other trees. Comparing the first set of data and the data taken before this study, there seemed to be a correlation between rates of growth and protection with an R-value of 0.20. There also seemed to be no difference between the rates of growth between caged trees and tubed trees. Oak trees with more plant competition grew slower than oak trees with less competition with an R-value of –0.49. Oak trees with more shade seemed to grow slower than oak trees with less shade with an R-value of –0.3176. Between sites there seemed to be differences in rates of growth of the oak trees. The oak trees in the barn and house sites grew faster than the oak trees in the other sites. The Lake Arastradero Dam site oak trees seemed to be older and had more shade than the other oak trees. The acorn trail and cottage oak trees were found to have the most competition from the other plants. Coast live oak trees seemed to grow faster than valley oak trees with an R-value of 0.34. Some of the oak trees were observed to have brown leaves and seemed to be dying. Other oak trees were observed to have leaves with spots, a sign of disease. In seven cages, no remnants of the oak trees could be found indicating that the oak trees had died.





In the comparison between the fall set and the spring set of data, the oak trees with protection grew faster than oak trees with no protection with an F-value of 8.061 and a P-Value of 0.0057. Oak trees with more competition grew slower than oak trees with less competition with an F-value of 1.291 and a P-value of 0.2612. Trees with more shade had an equal average of growth with trees with less shade. The F-value was 0.833 and the P-value was 0.6502. There seemed to be no correlation between growth and method of protection with an R-value of –0.13523.

Lake Arastradero had the most sand as part of its soil with about 55% sand as part of its soil on average. The acorn trail site also had 50% of its soil as sand. The other sites had less sand at about 20%. Corte Madera seemed to have the least sand as part of its soil.

Gopher holes were found throughout the park, although no gopher were actually sighted. Deer trails and deer beds could not be found, and no deer were sighted. It is known that deer live in a forest east of the preserve. The absence of deer may be because they only browse the oak trees during the winter. Snakes were sighted. They are known not to have effects on oak trees but may have an effect on gopher. No bobcats were sighted.

Discussion

According to the comparisons between the group's measure of the trees and the first set of data taken in the experiment and between the first set of data and the second set of data, trees with protection grew faster than trees with no protection because animals were inhibited from eating at the trees with protection and growth. This result has been replicated by other studies (Parikh and Gale 1998),(Stange and Shea 1998). There seemed to be no difference in growth between tubes and cages also in both comparisons. Tubes and cages are similar enough such that they may not show significant differences. Trees with less plant competition grew faster than trees with more plant competition because the roots of the trees did not have to compete with other plants' roots for water and minerals. In the comparison between the baseline data and the first set of data, trees with more shade grew slower than trees with more shade because the bigger oak trees that provided the shade competed with the young oak trees for water and minerals. However, in the comparison between the first set of data and the second set of data, there seemed to be no correlation between shade and growth. In this experiment, the young oak trees seemed to have adequate shade so they did not have

to grow at a faster pace to gain shade. Trees at certain sites grew faster than trees at other sites. The house and barn site trees grew faster because they had less competition than other sites. The acorn trail site and cottage site trees grew slower because they had more competition from yellow thistles and other grasses. The Lake Arastradero trees grew faster because they had more water from the lake. The soil at the Lake Arastradero site seemed to be better in that it contained more sand and less rock, so roots could better receive minerals and water.

It seems that soil does matter in how fast oak trees grow. The Lake Arastradero Site seemed to have to best soil, because it has a nearby lake. The Acorn Trail Site seemed to have pretty good soil, because of the older oak trees that it already contains. The older oak trees add shade and moisture to the soil. The other sites had worse soil than Lake Arastradero Site and the Acorn Trail site.

Deer were not sighted because they might only appear at night to avoid being sighted by people. Also, deer do not feed as much during the winter. They eat more during the summer. However, deer pellets were found confirming that there were deer. Even though gophers were not sighted, there were many gopher holes. Gophers may also be coming out only at night.

Conclusion

This study has shown that protection should be used to help oak tree restoration in the future. Previous studies have shown that both caging is effective (Parikh and Gale 1998) and tubing is effective (Stange and Shea 1998). However, after a period of time, both methods hinder the growth of the oak trees. Whether tubing or caging should be used is uncertain due to the findings that there is no difference between the two methods. Also, in the house site and barn site, pieces of wood were placed on the ground to stop other plants from growing besides the oak tree seedlings. This seems to be effective in helping oak trees grow.

Cages may be more effective than tubing because it is less restrictive than tubing. No conclusion about chicken wiring can be made because its effects were not examined in this project. Also, the costs of both methods should be considered to help organizations decide what to methods to use in oak tree restoration.

This study should probably be prolonged to see the point at where protection loses its effectiveness. The size of protection that is most effective should also be examined. Measurements of the roots should also be examined in the future. Studies in different environments for oak trees should be done to see if different environments have an effect on the growth of oak trees. For instance, oak trees are more likely to grow near a lake than other places. Further studies should be used to find differences in methods of protection to determine what is the best method of protection.

Also, the total environmental impact of protection should be examined. For example, if deer are not allowed to browse the oak trees, then will the deer population decrease as a result? Would the reduction of deer outweigh the restoration of oak trees? A way to balance the two effects may have to be found.

Acknowledgements

I would like to thank Caryl Waggett and Karen Cotter for helping me with this project.

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