Rehabilitation of a Blue Oak Restoration Project[1]

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Abstract: *Two remediations were tested for improving height growth and survival on a 2-year-old, failing, blue oak (*Quercus douglasii*) restoration project. Replanting acorns and seedlings with plastic treeshelters resulted in 75 and 88 percent survival, respectively, in areas previously showing almost total mortality. After 3 years, average height of replants (141 cm) exceeded the original planting (19 cm). In a second remediation, treeshelters retrofitted onto original planting survivors showed highly significant differences in height (*$P < 0.0001$*) and survival (*$P = 0.0001$*) between protected and unprotected pairs. Protected survivors were almost five times taller than unprotected, and averaged nearly an eight-fold height increase (130 cm), while average height of unprotected plants had not quite doubled (28 cm). Treeshelters inhibited vole, but not grasshopper predation. Results indicate treeshelters release stunted seedlings and could rehabilitate poorly performing projects.*

Natural regeneration of two endemic California oaks, blue oak (*Quercus douglasii*) and valley oak (*Q. lobata*), has been widely recognized to be a problem statewide on many sites (Bolsinger 1988, Griffin 1971, Muick and Bartolome 1987, Swiecki and Bernhardt 1993). Lack of recruitment to the sapling stage has been identified as a widespread occurrence. This has created great interest in developing techniques for artificial regeneration of these species (see Adams, and Plumb and DeLasaux in these proceedings for general reviews). At the Sierra Foothill Research and Extension Center (SFREC), located 27 km northeast of Marysville, California, we have been able to grow blue oaks to sapling size within 5 years on small (approximately 0.25-ha) plots inside cattle exclosures. This has been accomplished using weed control and with little or no irrigation, with and without screen protection of seedlings (McCreary 1991). When attempting to expand these successful attempts on a larger scale, however, we encountered setbacks. In a 1.6-ha plot intended as a demonstration for oak woodland landowners, we found that we could not duplicate the rapid height growth we had experienced previously, and that herbivory by insects and mammals was greater than anticipated. Since a large number of restoration and mitigation oak plantings have been established in the past decade throughout the state in response to perceived oak regeneration problems, we believed it likely that some of these efforts might be similarly frustrated in meeting their goals. We therefore attempted to rehabilitate our original planting, in order to evaluate readily available measures applicable to improving oak restoration efforts.

Methods

Two remedial measures were tested, both utilizing rigid plastic treeshelters (Supertubes). Both were conducted on the original planting which we deemed to be performing below expectations. This original planting was on 1.6 ha at the SFREC, on a northeast aspect at 300-m elevation. The site had been cleared with herbicides and burning in the mid-1960's. Before that time it had been oak woodland with a dense shrub component. It had been grazed by cattle continuously since 1967. The original demonstration planting, completed in 1990-91, consisted of 1440 blue oaks. Three stock types and five types of weed control

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[1] An abbreviated version of this paper was presented at the Symposium on Oak Woodlands: Ecology, Management, and Urban Interface Issues, March 19-22, 1996, San Luis Obispo, Calif.

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were evaluated, and the plot was fenced to exclude cattle. Planting spots were spaced 3 m apart in 36 rows, comprising six replications. End-of-season height and survival were taken in 1991 and 1992 and tested using a split-block ANOVA, with weed control treatments as main plots and stock types as subunits. Where significant differences were found ($P \leq 0.05$), a Fisher's Least Significant Difference test was conducted ($P \leq 0.05$). *Tables 1, 2* are given here as an illustration of the status of the plot when remediation was first employed. Our decision to employ remediation was subjectively arrived at, considering repeated die-back and mortalities caused by mid-summer grasshopper (*Melanoplus devastator*) herbivory in both years. Vole-caused (*Microtus californicus*) mortalities were also extensive and seemed to be rising because of increasingly dense vegetative cover in non-herbicide treated areas and our exclusion of cattle grazing.

Table 1—Percent survival of original restoration planting after 2 years, before remediation treatments[1]

	Survival	
	1991	1992
Stock type	*pct*	
Acorns	$^{a}67$	$^{a}49$
Bareroot	$^{b}45$	$^{b}26$
3-month seedlings	$^{c}19$	$^{c}14$
Weed control		
None	$^{a}23$	$^{a}9$
Plastic mat	$^{ab}36$	$^{b}23$
Scalping	$^{c}54$	$^{bc}32$
Glyphosate once	$^{c}56$	$^{d}45$
Glyphosate twice	$^{bc}50$	$^{cd}42$
Plot pct survival	44	30

[1] Different superscript letters in Stock Type and Weed Control categories within columns indicate significant differences ($P \leq .05$) by a Fisher's Protected Least Significant Difference test.

Table 2—Average heights of the original restoration planting after 2 years, before remediation treatments[1]

	Mean height, 1992
Stock types	*cm*
Acorns	14
Bareroot	16
3-month Seedlings	18
Weed treatment	
None	$^{a}16$
Plastic mat	$^{b}21$
Scalping	$^{a}13$
Glyphosate once	$^{a}15$
Glyphosate twice	$^{a}16$

[1] Different superscript letters in Stock Type and Weed Control categories indicate significant differences ($P \leq .05$) by a Fisher's Protected Least Significant Difference test.

The first remedial measure was a partial replanting of the least successful original treatment. Our objective was to raise our stocking level, while comparing treeshelter protected acorn and seedling replants in our predator-rich plot. Sixty pre-germinated blue oak acorns and 60 3-month-old seedlings from the same source were planted in January and March of 1993 into the same spots where there had been no initial weed control and almost complete seedling mortality. Ten acorns and 10 seedlings were planted into each of the six replications that had been controls in our previously designed restoration study. All plantings were protected with a 1.2-m (4-ft) plastic treeshelter sunk 8-10 cm into the soil. Glyphosate (1.5 percent) was sprayed in a 1-m radius around each treeshelter. Spraying was repeated in spring of 1994 and 1995. We assessed height and survival annually. Differences in survival and height between stock types were tested with a one-way analysis of variance (rejection level, $P \leq 0.05$).

The second remediation tested whether better performance of surviving seedlings from the original planting could be stimulated by the addition of treeshelter protection. Eighty-three pairs of survivors were matched by replication, treatment group, proximity to one another within the replication, and height. In spring 1993, one of each of the 83 pairs was randomly selected and fitted with a treeshelter; the other was left unprotected. Average height of the two groups was nearly the same at this time (protected group 17 cm, unprotected 16 cm). Each pair continued to receive the weed treatment it originally had been assigned. Treatments were maintained for 3 years, and height and survival were assessed annually. Heights of stems were found to be normally distributed using the Wilk-Shapiro statistic and were then tested with a paired t-test (rejection level, $P \leq 0.05$). A chi-square test for independence was used to evaluate the differences in numbers of survivors from the protected and unprotected groups in each of the 3 years.

Each year, heights were measured to the maximum height reached that season. For seedlings greatly damaged by voles or grasshoppers, mainly those unprotected, this gave the most optimistic estimate of their potential for future growth, since many of these plants were so badly damaged that they would resprout only from the root crown in succeeding years. Similarly, survival was assessed in the most optimistic manner. Survival for 1995 could only be truly determined by resprouting in spring 1996 (which is yet to come), so survival was assumed for all plants whose status was questionable at this time.

Results

After 3 years, average height of replanted acorns and seedlings had exceeded the original planting (*table 3*), though the latter group had 2 more years of field

Table 3–Average height and survival of acorn and seedling replants after 3 years, compared to unremediated original planting[1]

	Mean height			Survival		
	1993	1994	1995	1993	1994	1995
	cm			*pct*		
Original plot	17	20	19	16	16	16
Acorn replants	91	133	141	$^{a}78$	$^{a}80$	75
Seedling replants	91	140	141	$^{b}95$	$^{b}93$	88
P-values, ANOVA	0.96	0.27	0.99	0.01	0.03	0.06

[1] Different superscript letters indicate significant differences ($P < .05$) for acorn and seedling replants by a one-way ANOVA performed on acorns and seedlings for each year. Original plot averages were not part of this test.

growth. Average height of replants (141 cm) was more than seven times greater than the original planting (19 cm). There were no significant differences between heights of acorn or seedling replants, and after 3 years they had identical average heights. While seedlings had statistically significant higher survival (88 percent) than direct seeded acorns (75 percent), both of these protected replants exceeded the original planting, which had stabilized at 16 percent survival.

The original restoration planting continued to be attacked by both voles and grasshoppers. Forty-four percent of these unprotected seedlings showed severe damage clearly attributable to voles, and this did not include those plants clipped off entirely (an ambiguous sign of vole predation), for which no sure cause of damage was evident. None of the protected replants received vole damage, but all that grew above the 1.2-m treeshelter height were annually defoliated by grasshoppers. While apparently severe, this defoliation was followed by refoliation generally within 2 months. In 1995, for example, all plants were stripped of their leaves between August 1 and August 22. During October, they refoliated and even experienced some late season growth flushes. Few of the unprotected plants of the original planting, which were attacked with equal severity, refoliated in this manner.

In our second remediation, evaluating protected versus unprotected pairs, there were clear benefits of treeshelter protection. Height and survival differences between pairs were highly significant for all 3 years ($P < 0.001$). Mean height of the unprotected group increased only slightly in the first season (average height at start = 16 cm), while their protected counterparts (average height at start = 17 cm) showed more than a three-fold increase in height (*table 4*). After 3 years, unprotected seedlings had not quite doubled in height, while protected ones had grown more than seven times taller than their initial height.

Table 4—Average height and survival after 3 years for pairs of survivors of original restoration planting with and without retrofitted treeshelter protection

	Mean height			Survival		
	1993	1994	1995	1993	1994	1995
	cm			*pct*		
Unprotected (n=83)	20	29	28	87	77	76
Protected (n=83)	60	98	130	100	99	98
P-values[1]	<0.0001	<0.0001	<0.0001	0.0006	<0.0001	0.0001

[1] P-values for height in each year resulted from paired t-tests; P-values for survival resulted from Chi-Square tests on numbers of survivors.

Survival in the unprotected group continued to decline, but not dramatically. Even so, 98 percent of protected plants survived, while 76 percent (best case) of the unprotected survived after 3 years. According to our chi-square analysis, these were highly significant differences. By the third year of this study, no protected plants showed signs of vole predation, while 23 percent of those unprotected showed definite signs of vole damage or mortality. Grasshopper defoliation and subsequent refoliation were similar to the replanting remediation above.

Discussion

Since the early 1980's, evidence has been mounting for the use of treeshelters to increase growth and survival of oaks. Windell's (1992) review of the literature and reprinting of some of the early research papers reports overall beneficial results for a number of British and eastern U.S. oak species. Our results concur with these generally positive findings, but the California experience does not present a uniform picture. Enhanced height growth and survival of blue oaks grown in treeshelters at the Sierra Foothill Research and Extension Center (McCreary and Tecklin 1993; McCreary and Tecklin, these proceedings), which inspired the use of these devices to rehabilitate our demonstration planting, have not been duplicated at the Hopland Center (Costello and others 1991, 1996). In that north coastal California setting, blue oaks grew and survived better in treeshelters only if irrigated, and valley oaks responded more favorably than blue oaks. Plumb and DeLasaux (these proceedings) in central-coastal California, moreover, found that treeshelters enhanced height growth of coast live oak (*Quercus agrifolia*), but not survival, probably due to micro-climate-induced pest problems inside the shelters. It remains to be clarified if these are regional, specific, or other differences.

In replanting our plot with treeshelter-protected acorns and seedlings, we attempted to overcome what we perceived to be a vole predation problem in the densest cover on our plot where there was almost complete initial seedling mortality. The simple technique of sinking the treeshelters 8-10 cm into the soil was meant to inhibit vole access. This technique seems to have succeeded, but the rapid height growth and improved survival that we report in this remediation could be confounded by the weed treatment they received and may not be solely attributable to a treeshelter effect. In the case of our treeshelter retrofitted pairs, however, plants tested were from all weed treatments and stock types, although a smaller sampling was from the least effective weed treatments. We are, thus, more confident in ascribing the improved height growth and survival the first year after treatment and thereafter to treeshelters. We were never able to achieve comparable height growth among unprotected plants elsewhere in the plot, even with thorough weed control treatment.

The complete absence of vole predation of our protected replants is consistent with the experience of others who have tested treeshelters as effective protection against voles (Davies and Pepper 1989). Though treeshelters did not completely protect seedlings against grasshopper defoliation, there was a difference in the severity of attack on protected and unprotected plants. Unprotected plants were vulnerable to defoliation, regardless of age or height. Young, thin stems were often girdled, at best setting growth back to root crown level. So long as protected plants were below the tops of their treeshelters, they were rarely defoliated by grasshoppers. Once they over-topped their treeshelters as older, thicker-barked plants, they may have been more resistant to severe grasshopper damage, and thus refoliated quickly, as was observed.

Retrofitting treeshelters onto surviving oaks in restoration plantings offers possibilities for improving the performance of these seedlings that have been able to overcome the often unpredictable environmental challenges of the planting site. Such seedlings are a valuable resource for successful restoration, and our results indicate it is possible to release them from a stunted condition. We are aware of only two other studies that retrofitted survivor seedlings, but these were carried out on eastern U.S. and British species. One reported a doubling of height after one year (Myers and others 1991), and the other showed a four-fold increase after 2 years (Tuley 1985). Both are consistent with our findings.

Under adverse natural conditions, blue oak seedlings often persist for many years, perhaps as advance regeneration, but exhibit little height growth and finally die (Allen-Diaz and Bartolome 1992, Swiecki and others 1991). While numerous seedlings can be found on most sites, it is common to find sites lacking sapling-sized blue oaks, or with low sapling-to-tree ratios (Bolsinger 1988, Muick and Bartolome 1987, Swiecki and Bernhardt 1993). Could natural regeneration be enhanced with treeshelters, as our study indicates is possible with planted stock? Where this has been tried with northern red oak (*Quercus rubra*), the results were not promising (Walters 1991), but we have yet to evaluate how naturally recruited blue oak seedlings in California might respond.

Conclusions

Extensive planting of oaks is recent to California: most projects are no more than 5 years old. There are published accounts of successful larger-scale establishment of oaks (Bernhardt and Swiecki 1991, Griggs, Costello and others, both in these proceedings), but assessment of the long-term success of artificial regeneration of oaks in California continues. Accounts of the eastern U.S. experience (Lorimer 1993, Pope 1993) should alert us to expect some failures in these efforts.

Should oak restoration projects fall short of their objectives, restorationists should consider retrofitting survivors or replants with treeshelters. The price of treeshelters has decreased; a 1.2-m treeshelter currently costs less than $2. They are proving to be effective protection of trees from rodents, a consideration on most sites. In addition, seedlings in shelters grow far more rapidly, and it is much easier to spray herbicides around protected seedlings for weed control. They may not be the “silver bullet” for oak restoration, but further use of these devices will give us a better idea of their utility for California conditions. Further experiments should also test their applicability in growing seedlings, both planted and of natural occurrence, to the sapling stage, a vexing problem in California.

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