Long-Term Performance of Minimum-Input Oak Restoration Plantings[1]

Elizabeth Bernhardt[2] and Tedmund J. Swiecki[2]

Abstract

Starting in 1989, we used minimum-input methods to restore native oaks to parts of their former ranges in Vacaville, California. Each restoration site was analyzed, and only those inputs deemed necessary to overcome expected limiting factors for oak establishment were used. We avoided unnecessary inputs that added to cost and could have unintended negative consequences. All projects were direct-seeded by volunteers using locally collected acorns of valley oak (*Quercus lobata*) and other native oaks. Other inputs included mulch and protection from herbivores (cattle, voles) or mowing crews. Plantings received sporadic maintenance after planting. None of the plantings were irrigated or fertilized. Growth rates and survival show spatial variation at all locations. Multiple project locations now have stands of oaks that have been established at very low cost, validating the minimum input approach. Some very low input plantings had high mortality due to unanticipated impacts from fire and vole outbreaks that greatly exceeded levels previously observed. Lessons learned from the long-term performance of these plantings can be applied in an adaptive management system to accomplish low cost, ecologically sound oak restoration projects in other locations.

K*ey words*: acorns, direct seeding, herbivore protection, interior live oak, *Quercus lobata*, *Quercus wislizeni*, valley oak

Introduction

Valley oak (*Quercus lobata*) was removed from much of its former range to make way for agricultural and urban development, especially in the late 19th and early to mid 20th centuries. Regulatory protections now in place usually require some form of mitigation if valley oaks or other native oaks are removed for development. Restoration plantings in degraded or non-occupied habitat are a common mitigation requirement.

Under optimal soil and water conditions, valley oak is easy to grow, but it is more difficult to establish valley oak in suboptimal sites. In 1989, we began a project to examine low-input methods for restocking valley oaks on formerly forested parcels that were being used for cattle grazing (Bernhardt and Swiecki 1991, 1997). After visiting previous plantings and reviewing the literature, we developed a model to guide the selection of low input cultural methods needed for successful planting at a given site. Demonstration projects established at that time were designed to show whether valley oaks could be established in rangeland settings from acorns without supplemental irrigation. Based on initial success of low input techniques, the model was used to select inputs for additional restoration plantings that occurred from 1993 through 2000 in Vacaville, California. In this paper, we present long-term survival and growth data and discuss the effectiveness of the minimum input techniques employed for Vacaville plantings conducted between 1989 and 2000.

---

[1] An abbreviated version of this paper was presented at the Seventh California Oak Symposium: Managing Oak Woodlands in a Dynamic World, November 3-6, 2014, Visalia, California.

[2] Phytosphere Research, 1027 Davis Street, Vacaville CA 95687. (Phytosphere@phytosphere.com).

Methods

All sites were direct seeded using valley oak acorns collected in Vacaville. Acorns were refrigerated in plastic bags between collection and planting. Planting was conducted by volunteers from late October through December after the first soaking rains. Except as noted below, planting sites were prepared by turning over and breaking up the soil with a shovel. Volunteers selected acorns by hand that were free of insect emergence holes, decay, or other obvious defects. At each site, four acorns were planted on their sides at a depth of about 5 cm, spaced 15 cm apart in a square pattern. Planting sites were mulched with wood chips (about 0.8 to 1 m circle) obtained from local arborists, except as noted below. Planting sites were premarked to avoid potentially poor microsites for the 1989, 1993, 1999 and 2000 plantings.

On grazed parcels, planting sites were protected from by cattle browsing with protective Vaca cages (Bernhardt and Swiecki 1991). The cages were 122 cm tall, about 45 cm in diameter, and made of galvanized 12-gauge wire mesh (5 by 10 cm) fencing fabric. Each cage was secured on one side to a T-post and on the opposite side by a 86 cm length of 9.5 to 12.7 mm diameter steel reinforcing bar (rebar) driven into the soil at least 30 cm. As the oaks grew beyond the cages and showed browsing damage, in many instances cages were extended to 180 cm tall by wiring on additional fence fabric. Installation of cage extensions was sometimes delayed, so some trees were suppressed by browsing for several years. Cages were removed after trees grew well above browse height, though cage removal has been delayed beyond this point for many trees.

For areas maintained by mowing, we used 3 m lengths of 16 mm diameter steel reinforcing bar (rebar) bent into U-shaped pins. The straight ends of the rebar were driven into the ground to straddle the planting site, with the top of the pin standing about 1 m above ground level. The pins marked the sites and were intended to deter accidental mowing of the trees and were difficult to vandalize.

Height and survival data were collected in August and September 2014. Height data were collected with the aid of a telescoping measuring pole. Trunk diameter 1.37 m above grade (DBH) was measured with a caliper. Canopy diameter was measured along two perpendicular axes, using either a measuring tape or laser rangefinder. The canopy area was calculated using the formula for an ellipse. Data were analyzed using, JMP® 9.0.3 statistical software (SAS Inc., Cary NC). Tukey-Kramer HSD was used to separate means following a significant analysis of variance.

1989 planting

The planted area (east and west) was on two generally south facing hillsides divided by a residential street in north Vacaville. The hillsides were commonly grazed for several weeks or longer between December and June. Grazing duration and intensity has varied widely from year to year, and did not occur in some years. At the start of the project, we anticipated browsing by cattle, moisture stress due to weed competition, soil depth and compaction, and vandalism would be the most likely factors to limit restocking success. As part of a study, we tested five treatments, described in detail in Bernhardt and Swiecki 1991. The lowest input treatment had no protection from cattle grazing. The 2014 assessments did not include relocating the planting sites for this treatment; almost all of these were vacant after the first few years. The other four treatments were protected by Vaca cages. These treatments included augering with a 10-cm diameter bit to a depth of 45 to 60 cm and mulching with landscape fabric covered with woodchips; landscape fabric and wood chip mulch without augering; and preselection of planting sites based on penetrability by a steel probe (30 cm vs. 45 to 60 cm depth) with only dry grass mulch. We planted 30 sites per treatment per hillside. The planted area was about 1.4 ha on the east side and 1.2 ha on the west side.

1993 planting

The planted area was 2.1 ha on hill slopes and wide drainages along a watershed in a cattle-grazed area in Lagoon Valley. Soils were relatively deep and loamy, with some areas of slippage near the main drainage. Grazing typically began in late December and continued into late April or May. We anticipated that browsing by cattle and rodent chewing would be limiting factors at this location. In addition to valley oak, interior live oak (*Quercus wislizeni*) and California buckeye (*Aesculus californica*) were direct-seeded at this location. We planted 113 sites, all of which were protected with Vaca cages and mulched with wood chips. We used 61 cm tall, 15 cm diameter aluminum window screen cylinders buried to a depth of 15 cm for 82 of the planting sites to protect against rodent herbivory. Screens were folded closed at the top and open below ground. Screens were opened as soon as the plant inside reached the top of the cylinder, and were eventually removed. Empty planting sites were replanted through 1996.

1999 planting

This planting consisted of 94 planting sites over 1.2 ha in a nearly level valley floor area. Sites were along the west side of a 0.9 km long section of abandoned railroad right of way, bordered by residential and commercial development. We anticipated vandalism and accidental mowing of seedlings would be limiting factors. Sites were mulched with wood chips and rebar U-pins were installed after planting, but before seedling emergence.

2000 planting

This planting consisted of 98 planting sites over 1.2 ha along the east side of the same right of way described above for the 1999 planting. We anticipated vandalism, accidental mowing, and soil compaction would be limiting factors. A paved biking trail was constructed on the railroad bed after the 1999 planting but before the 2000 planting. Soil on the east side appeared to be more compacted than on the west side. To mitigate surface compaction, prior to planting, each premarked planting site was excavated to a depth of about 60 cm and refilled using a backhoe. Rebar U-pins were installed prior to planting. Otherwise, sites were planted and maintained as described for the 1999 planting.

Other plantings

Other plantings took place in 1994, 1996, 1997, and 1998 on hillside open-space in Lagoon Valley that was formerly grazed. Planting sites were not premarked or protected in any way and no followup maintenance was conducted. We anticipated that rodents and weed competition for soil moisture would be limiting factors. Sites were mulched with wood chips.

Calculation of canopy cover

For each location, the canopy area of trees with DBH >0 was summed and divided by the total area of the planting. Canopy spread was not recorded for some trees; for those, canopy area was calculated from DBH using the formula based on a regression (fig. 2). Canopy spread of existing mature trees was measured from digital images using Google Earth®.

Results

Survival

Emergence and survival for valley oaks was initially high (> 95 percent of planting sites) for all planting years. Surviving tree densities for locations shown in table 1 vary from 37 to 77 trees per ha. In the oldest (1989) plantings, survival of planting sites protected by Vaca cages (70 percent west, 74 percent east) did not change between the 2014 and 1995 censuses (Bernhardt and Swiecki 1997). No significant differences in survival were seen between the four planting treatments in Vaca cages. We did not attempt to relocate the unprotected planting treatment, but 13 unprotected oaks, all less than 1 m tall, were observed. Most of these were originally planted in Vaca cages that were subsequently lost due to vandalism; no more than two or three may be survivors from the unprotected treatment.

Table 1—Survival of valley oaks, and percent single, double, or multi-trunked at five planting locations

Planting	Age in 2014, years	Percent				
		survival	DBH>0	one trunk	two trunks	multiple trunks
1989-east[a]	25	74	72	60	31	9
1989-west[a]	25	70	58	20	10	70
1993	21	84	69	64	28	8
1999	15	91	83	40	44	16
2000	14	94	84	30	43	27

[a]Sites in Vaca cages only.

In May 2007, a grass fire burned most of the 1989 west planting, affecting 77 percent of the planting sites. Trees in the burned area were either topkilled and have since resprouted from ground level (65 percent of all surviving trees) or were at the edge of the burned area and scorched but not topkilled (7 percent of all surviving trees). The remainder appear unaffected by the fire. Due to prolific sprouting of topkilled trees, fire did not decrease survival compared with 1995 census data.

Survival of the 1993 planting (table 1) was affected by both cattle and voles (presumably *Microtus californicus*). Within the first year of planting, four sites had to be abandoned because cattle had pushed over and mangled the Vaca cages. Because of the heavier cattle use at this location, we reinforced cages by wiring them to the T-posts and adding additional T-posts and rebar to the most impacted sites. Wire screens afforded very short-lived protection; within a year or two, we had to open the screen cylinders because oaks and buckeyes had reached the closed tops. This planting was affected by a surge in the local vole population in 1999. Vole populations and associated damage attained levels we had not previously seen locally. Scattered vole damage have been observed sporadically in the planting after

1999. To date, 16 valley oaks with DBH values ranging up to 12 cm have been girdled and topkilled by voles, and other trees have been partially girdled. Survival of the 15 sites planted with California buckeyes is 100 percent. Eight of 18 sites planted with interior live oak acorns contain surviving trees.

Survival was highest overall at the two youngest plantings (table 1). The 1999 and 2000 plantings are mowed once or twice annually by city crews in May and late summer. In early May 2000, 46 sites in the 1999 planting were mowed by inmate crews using string trimmers while the city coordinator for the site was on vacation. Plants were mowed to heights as low as 5 cm. The mowed seedlings resprouted, and although they were significantly shorter than the unmowed seedlings by August 1999 (8.5 cm vs 15.7 cm), survival on a planting site basis (at least one seedling per site) did not differ. Accidental mowing of marked sites with rebar pins has been an ongoing problem for trees that are shorter than 1 m. Some rebar pins have been rolled over and destroyed by mowing equipment and some sites than have not had the pins replaced (six in 1999 planting, seven in 2000 planting) have been mowed down annually.

Unprotected and unmaintained planting sites on nongrazed grassy upland sites showed good initial emergence but had low long-term survival. For example, the 1994 hillside planting had 95 percent initial survival of valley oak sites the August after planting. By 3 years after planting, survival of valley oak planting sites was 57 percent. In 1999, 5 years after planting, high vole populations in the Lagoon Valley area caused severe damage to this and other unprotected plantings (1996, 1997, 1998), as well as established natural regeneration in nongrazed areas. Some established natural oak saplings with basal diameters greater than 7 cm were killed by girdling of the stem above and below the soil line. Less intense vole population outbreaks have occurred at several times since 1999, mainly in grassy, nongrazed sites. In addition to vole herbivory, large portions of the 1996, 1997, and 1998 plantings were burned in several successive years. Consequently, only a few surviving valley oaks remain from these plantings. Most of the survivors are in mid- to lower-slope positions where oaks unaffected by voles have grown well. The maximum DBH among these survivors is 35 cm. Although deer frequent the area, we have not observed height growth being suppressed by deer browsing at these sites.

Growth

Tree size parameters showed relatively wide distributions for all plantings (table 2, fig. 1). The largest trees were in the oldest plantings (fig. 1) but all sites contained small trees that were less than 1.4 m tall and had no DBH. At each location, trees of similar sizes tended to be spatially clustered, indicating the strong role of underlying soil conditions, such as depth and available moisture, as primary determinants of tree size. Tree DBH, height, and canopy spread in the different plantings overlapped substantially (figs. 1, 2) despite the difference in ages for the plantings. Across all plantings, DBH was highly correlated with height and canopy spread (fig. 2).

Table 2—Comparison of size attributes (mean ± standard deviation), and calculated canopy cover of valley oaks at 5 planting locations. Means followed by the same letters are not statistically different from one another according to Tukey-Kramer HSD

Planting	DBH, cm	Height, m	Canopy spread, m^2	Canopy cover, pct
1989-east[a]	13.2a ± 8.6	5.0a ± 3.2	12.1b ± 13.9	10.0
1989-west[a]	11.9ab ± 6.b[2]	4.5a ± 2.1[b]	13.5b ± 9.0[b]	3.6
1993	14.3a ± 10.8	5.3a ± 3.1	31.2a ± 25	10.5[c]
1999	11.0ab ± 6.7	5.4a ± 2.6	15.6b ± 12.6	9.6
2000	8.7b ± 6.0	4.8a ± 2.6	11.4b ± 9.9	7.0

[a]Sites in Vaca cages only.
[b]Unburned trees only.
[c]Includes canopy contributions of interior live oaks and protected natural trees.

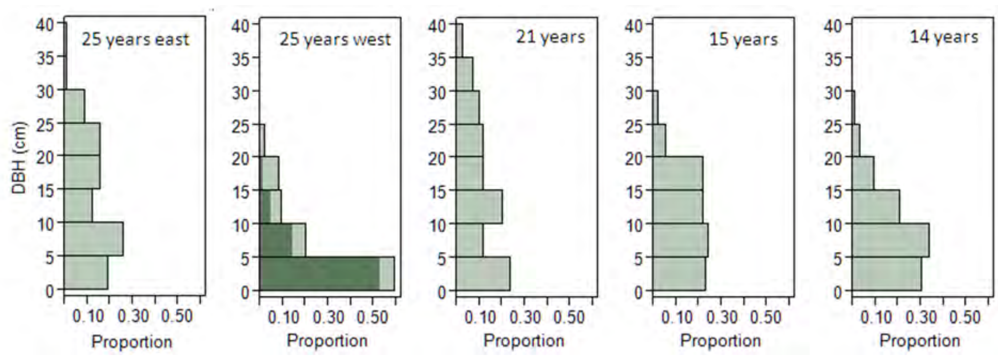

Figure 1—Distribution of DBH values for plantings shown in tables 1 and 2. Dark shading for second chart from left represents topkilled trees in the burned section of the planting.

In the 1989-east planting, the largest trees were located at the bottom of the slope along an alluvial fan. Vaca cages have been removed from these large trees, so initial treatment assignments, which were marked on the T-posts, were not available. However, all initial treatments were represented among these uniformly large trees. About one third of the remaining trees in the 1989-east had treatment codes still visible. For these trees, the original treatment did not significantly affect DBH, height, or canopy spread.

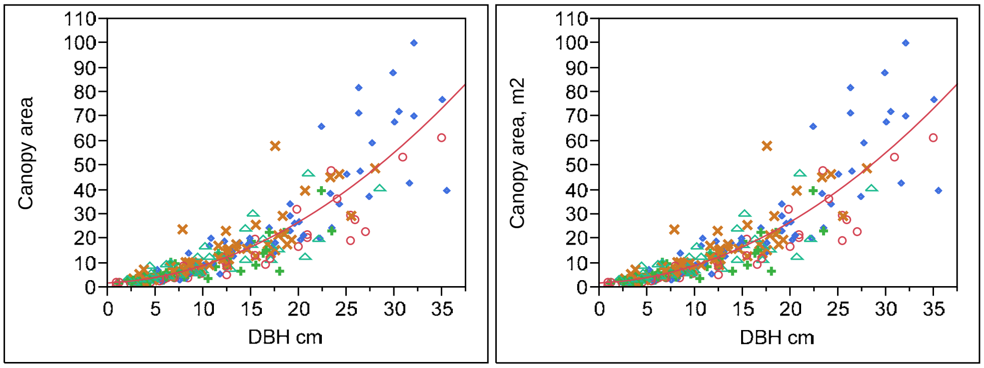

Figure 2—Relationships between DBH and tree height (left) and DBH and canopy area (right) across all plantings. Planting year symbols: 1989-east = o, 1989-west = +, 1993 = ◇, 1999 = X, 2000 = Δ. Regression equations: Left, Height, m = 1.96 + 0.287 x DBH cm, R^2 = 0.795, F ratio P <0.0001. Right: Canopy area, m^2 = -6.174 + 1.502 x DBH cm + 0.0529*(DBH cm-12.32)^2, R^2 =0.772, F ratio P <0.0001.

Unlike the 1989-east planting, the largest trees in the 1989-west planting were along the hill crest and on a southeast-facing slope. In the 1993 planting, the largest trees were mostly on a north-facing slope and in broad drainages, and were more common in the lower elevations of the planting, which spanned about 85 m of elevation change. Spatial clustering of tree sizes was also evident on the level planting sites used for the 1999 and 2000 plantings, with poorer growth occurring in the more compacted and poorly-drained soils near the center portion of the linear area.

All 55 trees topkilled by the 2007 fire in the 1989-west planting resprouted prolifically. Nine of these had not yet attained a DBH. For the remaining resprouts, the mean DBH of the largest live stem was 3.9 cm (range 0.6 to 10.1 cm, n = 46), significantly smaller (t test P <0.0001) than the DBH of trees outside the burned area shown in Table 2. We were able to measure DBH of the fire-killed trunk at 42 of the burned sites, these averaged 4.2 cm (range 1 to 10.8 cm). The original planting treatments did not significantly affect DBH, canopy area, or height of either nonburned or resprouted topkilled trees in the 1989-west planting. The non-burned trees in the 1989-west planting did not differ significantly from trees in the 1989-east planting with respect to DBH, height, or canopy area (table 2).

As part of the 1993 planting, we installed Vaca cages around browse-suppressed (less than 1 m tall) natural regeneration that was near a mature valley oak in the lower portion of the planting area. We protected six valley oaks that were well beyond the canopy of the existing oak, leaving some adjacent and nearby oaks unprotected. These oaks grew rapidly when protected from winter-spring cattle browsing and most required extended cages within a few years. In 2014, DBH of these trees ranged from 17 to 49 cm. Unprotected regeneration in the same area has remained less than 1 m tall.

Among the interior live oaks in the 1993 planting, seven trees had DBH values ranging from 4.2 to 47 cm, heights from 2.6 to 9 m, and canopy spreads from 3 to 98 m^2. One interior live oak tree had been topkilled by voles and had resprouted prolifically. Its largest sprout was 1.5 m tall with a DBH of 3 mm.

At most planting spots more than one of the four planted acorns emerged, but we did not thin multiple seedlings. By 2014, the number of planting spots with multiple oaks varied from location to location (table 1). We excluded the burned, topkilled plants from further analysis. There was no correlation between the DBH of the largest stem at each planting spot and the number of stems at each spot. One seedling usually became dominant and the additional seedlings were suppressed. Among multiple-tree sites where at least one tree had attained a DBH, 54 percent had a second tree that was at least 1.37 m tall. The average DBH of the largest stem was significantly greater than the average of the second stem that was at least 1.37 m tall. Codominant stems were most common in the 1999 and 2000 plantings. The trunks of these trees appear to fuse at the base where they come in contact, though it is not clear whether the appressed trunks actually become grafted together or remain separated by included bark.

The larger oaks at all planting sites have been producing acorns for a number of years. Some small seedlings arising from these were observed in the 1989 and 1993 plantings, although they have been suppressed by grazing.

Removing protective hardware

Removal of protective Vaca cages from large trees was generally delayed beyond the optimum timing and has only been completed to the degree needed for the 1989-east and 1993 plantings in the past 4 years. In a number of instances, especially where the height of the Vaca cage had been extended, branches had grown through the wire mesh. Branches and trunks generally grow around the wire, which can become completely embedded in the tree and can only be cut away at the bark surface. In some cases, straight sections of wire could be cut off and pulled out of the stems, but removal of the Vaca cage at this late stage was time consuming and sometimes difficult. Rebar used to anchor the cages also became embedded at the base of the largest tree trunks and had to be cut off in some instances. Similarly, tops of T-posts were cut off at or below grade with a portable reciprocating saw in instances where roots had grown over the anchor plates and the posts could not be pulled. Rebar U-pins have not yet been removed from most of the 1999 and 2000 plantings. Removal of the pins is overdue for many trees that have begun to grow around rebar that is against the trunk.

Discussion

Results from these plantings show that restoration of valley oaks from direct seeded acorns without irrigation can be successful, even in rangeland settings. These observations confirm earlier results showing that cattle strongly inhibit natural or artificial valley oak regeneration by browsing seedlings and saplings (Bernhardt and Swiecki 1997). No more than a few of the 60 original unprotected sites from the 1989 plantings have survived, and these and other nonprotected seedlings at this lightly grazed site are less than 1 m tall. Natural browse-suppressed oak regeneration that was protected from grazing in the 1993 planting grew as well as the planted acorns, whereas short unprotected oaks also failed to grow above 1 m. In contrast, the few surviving oaks in the unprotected plantings in nongrazed areas nearby have grown into small trees, even though deer are common in this area. Protecting browse-suppressed natural regeneration in cattle-grazed areas can be used to recruit valley oak (Bernhardt and Swiecki 1997) and blue oak (McCreary and others 2011), but opportunities are limited where mature trees are very sparse or absent.

By controlling the growth of herbaceous vegetation, grazing can indirectly promote growth and survival of protected oak seedlings by making the habitat less favorable for voles (Bernhardt and Swiecki 1997, McCreary 2001, McCreary and others 2011). Valley oak seedlings planted in nongrazed grassy areas suffered much more attrition from vole herbivory than seedlings in the nearby grazed parcel, although relatively large saplings were damage even in the grazed parcel. Although voles have been reported to seriously limit oak survival and growth at other sites (Tecklin and McCreary 1993), vole herbivory was not a problem at all Vacaville locations. Significant damage from voles or other rodents has not been observed in the 1989 plantings, which appear to have habitat suitable for voles, or in the 1999 and 2000 urban plantings where habitat is not suitable for voles. Because vole damage can occur when trees are well beyond the size that shelters or screens are useful, habitat modification and other population control measures may be worthwhile inputs.

Although Vaca cages, U-pins, and other protective devices may be necessary to recruit trees, additional labor and cost is required to remove these devices. Timely removal can minimize the work required and allow for easier reuse of materials while avoiding potential damage to trees. Monitoring and an available source of labor are needed to optimize the removal of cages and other devices. Because oaks can grow at widely different rates, hardware removal may need to extend over many years.

The spring grass fire that burned the 1989-west 18 years after the planting did not affect survival of this planting, but the topkill of trees by fire set the growth of these trees back many years. In contrast, repeated grass fires in much younger plantings (1 to several years old) along with vole activity resulted in high attrition rates in several unmaintained plantings in nongrazed areas. We previously showed strong negative effects of fire on growth and survival of natural blue oak seedlings in this same general area (Swiecki and Bernhardt 2002).

Because continued tree attrition due to fire, vole damage, or other factors can continue for many years after initial establishment, we have avoided thinning planting sites to a single tree per site. The presence of multiple seedlings per site has not shown a negative effect on tree growth up to 25 years after planting. Similar results have been seen by Tyler and Moritz (*Quercus lobata* seedlings and conspecific neighbors: Competitors or allies? these proceedings). In most sites, a single tree becomes dominant even though suppressed additional trees persist for many years. However, these suppressed trees may still be capable of being released if the dominant tree is killed or severely damaged.

Canopy cover after 14 to 25 years was still relatively low at all locations (table 2). Nevertheless, projections based on likely mature canopy spreads show current tree densities are adequate to result in moderate to high canopy cover when trees reach mature sizes. For example, the average canopy area of mature oaks near the 1993 planting site is about 250 m^2. If all of the surviving valley and interior live oaks in this planting (37 oaks/ha, lowest density of the sites) attained typical mature canopy spread, canopy cover would be about 93 percent. This argues against planting at initially dense rates to increase canopy cover in the short term and instead suggests a strategy of phased planting over time if needed to increase cover. Furthermore, because soil variations strongly influence tree growth over the long term, increasing density in areas with inherently slow growth is a poor strategy for increasing canopy cover.

Acknowledgments

We thank the many volunteers who have assisted with data collection, tree planting, or cage removal over the years, most recently Steve Edmundson, Daniel Garcia, Pam Muick, and

Rhett Richardson. We also thank the City of Vacaville for support and materials and the California Department of Forestry and Fire Protection for initial funding.

References

Bernhardt, Elizabeth A.; Swiecki, Tedmund J. 1991. **Minimum input techniques for valley oak restocking**. In: Standiford, Richard B., tech. coord. Proceedings of the symposium on oak woodlands and hardwood rangeland management. Gen. Tech. Rep. PSW-126. Berkeley, CA: 2–89.

Bernhardt, E.A.; Swiecki, T.J. 1997. **Effects of cultural inputs on survival and growth of direct seeded and naturally occurring valley oak seedlings on hardwood rangeland.** In: Pillsbury, Norman H.; Verner, Jared; Tietje, William D., tech. coords. Proceedings of the symposium on oak woodlands: ecology, management, and urban interface issues. Gen. Tech. Rep. PSW-160. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 301–311.

McCreary, D.D., 2001. **Regenerating rangeland oaks in California.** Oakland, CA: University of California Agriculture and Natural Resources Communication Services Publication 21601. 71 p.

McCreary, D.; Tietje, W.; Davy, J.; Larsen, R.; Doran, M.; Flavell, D.; Garcia, E. 2011. **Tree shelters and weed control enhance growth and survival of natural blue oak seedlings.** California Agriculture 65: 192–196.

Swiecki, T.J.; Bernhardt, E.A. 2002. **Effects of fire on naturally occurring blue oak (*Quercus douglasii*) saplings.** In: Standiford, Richard B.; McCreary, Douglas; Purcell, Kathryn L.; tech. coords. Proceedings of the fifth symposium on oak woodlands: oaks in California's changing landscape. Gen. Tech. Rep. PSW-GTR-184. Albany, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station: 251–259.

Tecklin, J.; McCreary, D.D. 1993. **Dense vegetation may encourage vole damage in young oak plantings.** Restoration and Management Notes 11: 153.