A California Black Oak Restoration Project in Yosemite Valley, Yosemite National Park, California[1]

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Abstract: *In 1985, California black oak (*Quercus kelloggii*) stands in Yosemite Valley, Yosemite National Park, California, were identified as a sensitive plant community requiring protection and restoration. Changes in natural fire processes, encroachment by conifer trees, browsing by large populations of deer (*Odocoileus *spp.) and rodents, and impacts from construction projects and uncontrolled visitor use had caused a significant decline of black oak density and stand structure. Restoration work began in 1987, and after 8 years, the results have been positive. Low-profile fences have virtually eliminated problems of human trampling, and 172 of 500 transplanted oak seedlings have become established. The seedlings received a variety of treatments that potentially enhanced seedling survival, growth, and vigor. Seedling growth or survival were not affected by fertilizer, but there was a significant difference in oak seedling survival, growth, and vigor between tree shelters of open plastic mesh or solid double-layer plastic. This project has provided the park with valuable information about restoring native species and effectively managing visitors in a heavily used area.*

In 1985, the open, mature stands of California black oaks (*Quercus kelloggii*) in Yosemite Valley were identified as a sensitive plant community requiring protection and restoration (USDI 1985). In Yosemite Valley, this species forms pure open stands of large stately trees with an herbaceous understory, unlike other areas of California where it typically grows in mixed conifer stands or more open stands intermixed with shrubs and other tree species. This difference is primarily attributed to frequent low-intensity natural and Native American-caused fires.

The Southern Sierra Miwok Indians frequently lit surface fires in Yosemite Valley oak stands to maintain oak habitat, which would otherwise have been encroached by more shade-tolerant species. This frequent disturbance was also thought to enhance acorn production by reducing potential plant competition to mature oaks and recycling nutrients in the soil. Today, the black oak stands provide food, shelter, and habitat for at least 45 wildlife species and produce many products which were used by Native American groups in the area (Anderson 1993).

Pure California black oak stands currently cover about 60 ha of Yosemite Valley, a 90-percent reduction from the original 500-600 hectares that existed when the valley was first discovered by Euro-Americans in 1851 (Gibbens and Heady 1964). Furthermore, the remaining black oak stands have few trees less than 130 years old. This decline is visible in photographic comparisons and is most likely due to the suppression of frequent fires that have allowed invasion by conifer trees, primarily incense-cedar (*Calocedrus decurrens*) and California white fir (*Abies concolor* var. *lowiana*).

Oak establishment subsequently decreased because black oak saplings and trees are intolerant of dense shade. Increased browsing by rodents and deer (Odocoileus spp.), caused by a decrease in human and wildlife predators parkwide, also probably reduced the success of seedlings that did manage to become established after the 1850's. These factors, in conjunction with the effects of trampling and destruction of understory and seedling vegetation by visitors,

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subsequent soil compaction, and construction projects, served to further endanger the sustainability of the remaining oaks in Yosemite Valley (Angress 1985). The potential loss of this plant community led to a restoration project proposal in 1987.

In October 1988, a pilot restoration project began at the "schoolyard oak woodland" (so named because of its location adjacent to the Yosemite Valley elementary school) with an initial donation of $50,000 from The Yosemite Fund. In 1990 an additional $200,000 was received through The Yosemite Fund to continue oak restoration in other areas of Yosemite Valley. This paper focuses on the restoration methods used and results obtained at the schoolyard site.

The general goal of this restoration project was to re-establish the open California black oak community. The plan consisted of revegetating the understory with native herbaceous species, and improving soil characteristics to promote natural oak seedling establishment over time. In addition, before natural oak seedling establishment, nursery-grown oak seedlings were planted to create an early age class under the mature oaks.

Methods

Site Description and Original Condition

The schoolyard oak stand grows at an elevation of 1,200 m at the end of colluvial and alluvial fans with gravelly to sandy soils. This stand, with about 50 mature black oak trees forming an open overstory with no other overstory species, serves as an ecotone between the low-lying montane meadows adjacent to the Merced River and the higher, drier mixed-conifer and live oak forests growing on the alluvial fans and talus slopes (Acree 1994). The site is 0.5 km west of the Yosemite Valley Visitor Center, between the village mall and Yosemite Lodge.

Before 1988, the site received heavy foot traffic and was criss-crossed with 14 social trails ranging from 0.5 to 3 m in width. In summer 1988, a 2- to 4-m wide trench was dug by heavy equipment through the middle of the stand to install new underground electrical cables. This resulted in a 15-m wide swath of bare ground. The entire area was trampled to varying degrees. The most highly impacted sites consisted of highly compacted (cement-like) bare ground with less than 10 percent vegetation cover of mostly exotic plant species resistant to trampling such as puncture vine (*Tribulus terrestris*), pigweed (*Chenopodium album*), and Jerusalem-oak (*C. botrys*). Moderately disturbed sites had less deeply compacted soils dominated by early-successional native species including sierra lessingia (*Lessingia leptoclada*), diffuse gayophytum (*Gayophytum diffusum*), horseweed (*Conyza canadensis*), and kelloggia (*Kelloggia galioides*). Undisturbed or minimally trampled sites consisted of a dense mixed herbaceous layer of bracken fern (*Pteridium aquilinum* ssp. *pubescens*), dragon sagewort (*Artemesia dracunculus*), occasional showy milkweed (*Asclepias speciosa*), and several native and exotic grasses.

Restoration Work

Vegetation Documentation

In 1987, before restoration work, the condition of the site's understory vegetation was documented by the establishment of permanent photo points. These were set up to illustrate changes in understory species composition and cover following each major step in the restoration process, and to show planted and natural oak seedling development. The photo points were re-taken at the same phenological period each year from established locations around the site. Although they did not provide a quantitative means of assessing understory changes, they did allow park staff to subjectively evaluate the general goal of re-establishing the open California black oak community.

Site Preparation

In 1988, the area was blocked off to foot traffic with a low (0.6-meter) post-and-rope fence. Invasive exotic plant species were removed by hand to promote the establishment of a native species understory over time. No attempt was made to remove naturalized exotic grasses, however, since these species are found throughout Yosemite Valley and would simply recolonize the site or allow colonization by other more undesirable exotic species if they were removed.

Soils were scarified to a depth of 25 cm in bare areas by a small tractor equipped with digging tines. In vegetated or sensitive areas, hand-held digging forks and spade shovels were used to loosen soils to a depth of 10 cm. All bare areas were watered heavily before soils were loosened. Locally gathered native seeds of dragon sagewort, showy milkweed, deer grass (*Muhlenbergia rigens*), and California goldenrod (*Solidago californica*) were then scattered over the site. Direct transplanting of adjacent native species was also done, following natural vegetation patterns (Alexander 1988). During the spring and summer of 1989, invasive exotic plants, including bull thistle (*Cirsium vulgare*) and woolly mullein (*Verbascum thapsus*), were weeded by hand in the project area, and additional native seeds were scattered.

Oak Seedlings Planted

In fall 1989, 500 2-year-old black oak seedlings were planted that had been grown at a local nursery from acorns collected from the site in fall 1987. The acorns had been planted in tubes and were later transplanted into D-pots (10- by 10- by 30-centimeters) to promote the development of deep root systems. Seedlings were distributed in groups of three to five trees, randomly spaced throughout the site where wooden stakes thrown into the air had landed.

Once seedling locations had been marked, planting holes were drilled to a depth of 0.6 m using a power auger and posthole digger. The auger was critical for efficiently digging holes, and the posthole digger was used when the soil became too rocky or compacted for the auger. The holes were lined with unstapled bottomless cylinders of 0.6-cm galvanized steel mesh to prevent root damage by numerous area rodents. The holes were then watered thoroughly and backfilled with 30 cm of loosened soil to enable rapid root growth from the bottom of the root ball.

Each seedling was removed from its container with soil intact around the roots and placed into a hole. A time-release fertilizer tablet was dropped into the holes for 250 randomly chosen seedlings. The holes were filled in to ground level, and the soil around each seedling was tamped in using the handle-end of a shovel. The seedlings were then watered, surrounded in a 1-m diameter by locally gathered oak leaf mulch to a depth of 5-10 cm, and protected from browsing by a tree shelter of either solid double-layer plastic or open plastic mesh. Oak leaf mulch was then applied to the entire site to an overall depth of 10-15 cm to add organic matter to soils made barren by years of trampling and construction work. Finally, informational and “area closed” signs were installed along the fenceline.

Altogether, the seedlings received four different treatments: solid double-layer plastic tree shelter with fertilizer (n = 53), solid double-layer plastic tree shelter without fertilizer (n = 55), open plastic mesh tree shelter with fertilizer (n = 197), and open plastic mesh tree shelter without fertilizer (n = 195). Treatments were distributed randomly throughout the site to account for variations in moisture availability, shading, soil compaction, and other local variables.

Since 1989, work at the schoolyard site consisted of measuring oak seedling growth and mortality, re-photographing the site to document herbaceous understory re-establishment, weeding out exotic plant species, and eliminating all herbaceous plants within 0.5 m of each oak seedling. The rope in the fence was replaced with more durable, visible, and vandal-resistant plastic-coated cable. About 100 western raspberry (*Rubus leucodermis*) and 50 dragon sagewort plants were also planted in a few locations where visitors persisted in crossing the fence. The thorny western raspberry plants were especially effective in deterring visitors from walking through the restoration site, and the sagewort rapidly covered bare areas.

In 1995, new 1- to 2-m tall solid double-layer plastic tree shelters were installed over 166 of the remaining 172 oak seedlings planted in 1989 and secured to 2.5-m tall metal snow stakes. Six seedlings over 1 meter tall were enclosed in 0.5- by 2-m wire mesh cylinders, to allow the seedlings to sway and develop stronger trunks. More than 100 naturally established oak seedlings were also documented and measured. Their approximate ages were estimated on the basis of height and branching form, and the healthiest in appearance were protected from browsing by the installation of solid double-layer plastic tree shelters.

Experimental Design and Sampling

The California black oak seedlings planted in 1989 were monitored to assess the effect of the two types of tree shelters and the fertilizer treatment. The seedlings were marked with aluminum tags attached to the outside of each tree shelter which included the tree identification number, type of shelter, and whether or not they had received fertilizer. Unfortunately, the tags were highly visible and many tags were either vandalized or were chewed off by deer or other animals. As a result, only 109 seedlings comprised the sample in 1995, although 172 seedlings had survived.

Seedling heights were first measured immediately following planting in 1989. Surveys of seedling survival and growth were then conducted in 1991, 1992, 1993, and 1995 after leaf-out (May to June, depending on the year). Measurements were taken from ground level to the top of the woody stem. Some seedlings had double- or triple-shoots, and only the tallest shoot height was recorded. Seedlings in poor health (insect damage, fungus, late leaf-out) were noted on the data sheet. Dead individuals were also noted, and the tree shelters and tags were removed from the site.

Statistical Analysis

Descriptive statistics were calculated for each surviving seedling for each year surveyed, separated into the four treatments (*table 1*). A Levene statistic determined that the variances of seedlings within the two tree shelter types were significantly different. Therefore, a Kruskal-Wallis (nonparametric) one-way ANOVA was used to compare overall height differences of 1995 seedlings for the two tree shelter types.

Results

Understory Vegetation

Native plant understory establishment was evaluated subjectively on the basis of photographs. The appearance of the site showed an increase in overall plant cover. Exotic plant species had declined in both number and distribution over the site, based on notes taken during weeding.[3] There was a much greater cover of bracken

[3]Fritzke, Susan L. 1995. Journal records, on file at Resources Management Office, Yosemite National Park.

fern and California goldenrod in wetter areas, and drier sites were dominated by dragon sagewort, showy milkweed, kelloggia, and other native plants.

Planted Oak Seedlings

Seedling mortality was greatest between 1989 and 1991, probably from a combination of drought conditions prevalent at that time, planting shock, and loss of tree shelters due to wildlife, weather (wind and snow), and people. Forty seedlings died in 1991, eleven in 1992, five in 1993, and seven between 1994 and 1995. The remaining losses were from unknown causes.

In 1995, 109 marked and 63 unmarked planted seedlings remained in the restoration site, or 34 percent overall survival. Thirty-nine percent of the seedlings in solid double-layer plastic tree shelters survived the first 6 years, as opposed to only 17 percent of those seedlings in open plastic mesh shelters (*fig. 1*).

The seedlings within solid double-layer plastic exhibited the greatest range of variability in 1995 height (from 0.08 to 1.59 m) and the greatest average height (0.69 m). The seedlings in solid double-layer plastic shelters were significantly taller ($P = 0.0097$) than those in open plastic mesh shelters, with single-stemmed growth and minimal lateral branching. This should enable these seedlings to grow above browse height (estimated at 2 m) more quickly.

The average height of fertilized seedlings in both types of shelters was somewhat greater than unfertilized seedlings, but these differences were not significant. There was no significant difference in the survivorship of fertilized

Table 1—Summary of oak seedling surveys, 1989-1995

Year	Solid double-layer plastic with fertilizer *n* = 53	Solid double-layer plastic without fertilizer *n* = 55	Open plastic mesh with fertilizer *n* = 197	Open plastic mesh without fertilizer *n* = 195	Total *n* = 500
1989	Mean height: 0.06 m (2.4 in.) (s = 0.03 m)	Mean height: 0.07 m (2.8 in.) (s = 0.04 m)	Mean height: 0.07 m (2.8 in.) (s = 0.05 m)	Mean height: 0.07 m (2.8 in.) (s = 0.04 m)	500 (year planted)
1991	45 survive (85 pct) Mean height: 0.16 m (6.3 in.) (s = 0.08 m)	42 survive (76 pct) Mean height: 0.15 m (5.9 in.) (s = 0.06 m)	106 survive (54 pct) Mean height: 0.18 m (7.1 in.) (s = 0.11 m)	106 survive (54 pct) Mean height: 0.17 m (6.7 in.) (*s* = 0.06 m)	299 survive (60 pct of original plantings)
1992	33 survive (62 pct) Mean height: 0.29 m (11.4 in.) (*s* = 0.17 m)	32 survive (58 pct) Mean height: 0.28 m (11 in.) (*s* = 0.16 m)	53 survive (27 pct) Mean height: 0.24 m (9.4 in.) (*s* = 0.09 m)	55 survive (28 pct) Mean height: 0.23 m (9.1 in.) (*s* = 0.11 m)	173 survive (36 pct of original plantings)
1993	26 survive (48 pct) Mean height: 0.56 m (22 in.) (*s* = 0.37 m)	26 survive (47 pct) Mean height: 0.47 m (18.5 in.) (*s* = 0.34 m)	46 survive (23 pct) Mean height: 0.34 m (13.4 in.) (*s* = 0.21 m)	44 survive (23 pct) Mean height: 0.31 m (12.2 in.) (*s* = 0.17 m)	141 survive (28 pct of original plantings)
1995	21 survive (39 pct) Mean height: 0.69 m (27.1 in.) (*s* = 0.45 m)	21 survive (38 pct) Mean height: 0.45 m (17.7 in.) (*s* = 0.30 m)	34 survive (17 pct) Mean height: 0.41 m (16.1 in.) (*s* = 0.25 m)	33 survive (17 pct) Mean height: 0.33 m (13.0 in.) (*s* = 0.18 m)	109 survive (22 pct of original plantings)

***n* = number, *s* = standard deviation**

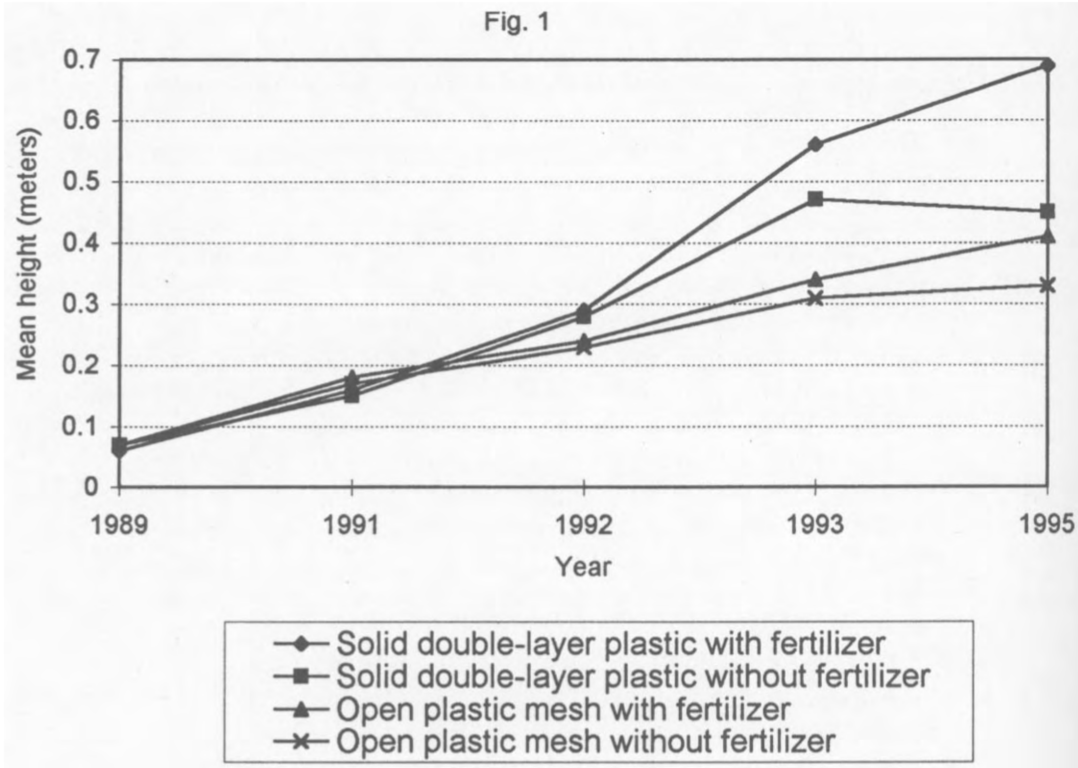

Figure 1—Average height of surviving oak seedlings, 1989-1995.

seedlings in either solid double-layer plastic or open plastic mesh shelters (*table 1*). The apparent loss in height in 1995 of non-fertilized seedlings in solid double-layer plastic tree shelters was attributed to dead or browsed shoots. The re-sprouts, measured in 1995, were considerably shorter and therefore brought down the average.

Discussion and Conclusions

Overall Condition of the Restoration Site

The condition of the schoolyard oak site has improved since restoration began in 1988. It now has a thriving native plant understory, and more than 100 naturally established 1- to 3-year-old black oak seedlings are scattered throughout the site. Six overstory oak trees within the restoration site have died since 1988, making natural oak seedling establishment even more important for maintaining the black oak community at this site.

The previously cement-like soils have been further loosened by ground squirrels (*Spermophilus beecheyi*), pocket gophers (*Thomomys bottae*), and other biotic and abiotic forces, allowing the natural establishment of black oaks and other native plants. Fencing has successfully eliminated 90-95 percent of the foot traffic that originally went through the area. These short fences are visually unobtrusive, but are surprisingly effective at confining use to delineated pathways around restoration areas.

Planted Oak Seedlings

One hundred seventy-two 10-year-old planted black oak seedlings are now growing within the restoration site. The greatest survival rates were seen in seedlings protected by double-layer solid plastic tree shelters. This can be attributed to a number of factors. First, the bamboo poles supporting the open plastic mesh rotted within a year, making it easy for humans and deer to dislodge the mesh tree shelters, as opposed to the more sturdy 3-cm^2 square wooden stakes holding the solid double-layer plastic in place. The open mesh shelters also broke down more quickly than the solid tree shelters, and seedlings in open mesh were therefore more frequently exposed to browsing. The solid double-layer plastic tree shelters not only protected the seedlings from outside forces, but probably created a more favorable microclimate which promoted greater survival (Costello and others 1996).

The 0.6-cm galvanized steel mesh screens installed in each seedling hole before planting appear to have been effective at reducing the number of seedlings lost to root predation. As the seedlings continue to grow, these unstapled screens can expand to allow normal root growth. In addition, naturally established oak seedling mortality from root browsing is expected to decrease as root browse pressure is taken off these seedlings by the establishment of more herbaceous and shrubby vegetation. Eventually, ground-screens should not be necessary at this site.

Future Management Directions

Park staff have begun evaluating the possibility of prescribed burning the site, which would add nutrients to the soil and discourage mistletoe and insect infestations on mature black oak trees. Burning could also benefit the oak seedlings by reducing competition from other plants, including a number of ponderosa pine and incense-cedar seedlings that have become established since restoration work began. However, a burn could also kill the above-ground portions of the oak seedlings, so all aspects are being weighed.

In the future, California black oak restoration efforts in Yosemite will be streamlined to eliminate unnecessary steps. Appropriate levels of site preparation, such as eliminating trampling, loosening soils, and reducing the number of exotic plants under overstory oaks will be prescribed on the basis of particular site characteristics.

For example, in areas where oak seedlings will be planted, rodent-proof screens will not be used if the soil is rocky. Fertilizer will not be used on oak seedlings, as it does not appear to either stimulate more rapid growth or assure seedling survival. The effectiveness of solid double-layer plastic tree shelters supported by snow stakes will reduce the need to plant oak seedlings in such high densities, as long as each planted seedling is monitored over a long period of time to reduce mortality from vandalism and wildlife. The snow stakes the park currently uses have a spade on the bottom and are sunk into the ground 0.5 m which makes them very difficult to pull out.

Finally, visitor education through the use of informational signs and articles will continue to play an important role in ensuring understanding and compliance to closed-off areas and fences.

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