Santa Barbara County Oak Restoration Program

Yearly Progress Report for the Period July 2002 - June 2003

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Submitted to:
County of Santa Barbara Department of Planning and Development, Energy Division

June 30, 2003
Acknowledgements

We thank Michael Williams, manager of Sedgwick Reserve, for his continued support of this project. We appreciate the work of John Solem from Wise Acres Ranch in managing the cattle-grazing program at Sedgwick Reserve. We are grateful for the help of assistants and volunteers including: Dennis Odion, Cara Peace, Peter Slaughter, Shelly Cole, Rick Skillin, and the staff and docents at Sedgwick Reserve. We thank our key contact from the Santa Barbara County Energy Division, Michelle Pasini. We also thank the staff at UCSB’s Institute for Computational Earth System Science, especially Kathy Scheidemen, John Sanchez, Imelda Moseby, and Dolores Cardenas for their administrative support.
This progress report summarizes the activities of the Santa Barbara County Oak Restoration Program for the period July 2002 through June 2003. Completed activities for the year can be grouped into four main areas: 1) research on methods for restoration of oaks, 2) research to determine factors limiting natural regeneration of oaks, 3) maintenance of cattle and study site infrastructure, and 4) dissemination of information.

I) Research on methods for restoration of oaks and establishment of seedlings and saplings

Large-scale planting experiments – cohorts planted 1996 - 2001

We continue to monitor both survivorship and growth of the seedlings that resulted from four previous years’ plantings. The design and treatments for these experiments have been described in detail in previous progress reports. In spring 2003, all caged plants were checked to ensure that they are growing unrestricted; if an oak seedling reached the top of its cage, the wire-mesh top was removed. In July 2003, we will re-census all planting locations (3242 total) to determine survivorship and growth of all seedlings/saplings. The heights of all seedlings/saplings will be measured and recorded. These data will be entered, and analyzed in combination with all previously collected data on rates of seedling emergence, survivorship, and growth. Final results will be included in our 2004 Final Report.

New experiments 2002 – 2003

Preliminary findings from our large-scale planting experiments indicated that two factors are associated with high rates of oak seedling recruitment: 1) above-average rainfall, and 2) protection from seed predation and herbivory by small mammals. As shown in Figure 1, percent emergence of all treatments combined significantly increased with rainfall accumulated after planting. In this figure, data points on the far left are from 1996-97 when essentially no rain fell from early January until the following November;
Figure 1. Relationship between oak seedling emergence and rainfall in the first winter – spring after planting. Data points are emergence rates of all treatments combined for 4 planting years.

1998  *Q. lobata* - grazed

Figure 2. Percent survivorship of 4-yr old valley oak seedlings (planted in 1997-98) in large plots grazed by cattle. Data are totals [100 * (#seedlings/#acorns planted)] for three experimental treatments for six sampling dates.
on the far right are totals from 1997-98, the El Niño year. In addition, we have found that in all years, highest emergence and establishment rates are found in treatments that protect acorns and then seedlings from small mammals (e.g., Figure 2.) Two new studies were planned for 2002-2003 to determine if there are low-cost management practices that could be employed to 1) improve seedling establishment rates by increasing water to new seedlings, and 2) decrease acorn and seedling mortality due to small mammals.

**a) Acorn collection.** In the early fall, we surveyed trees throughout the study area, and identified those that were producing many acorns. We collected acorns in October 2002 with assistance from students and other volunteers from the community. With each collection group, we conducted a short tour of Sedgwick Reserve, discussed the goals of the Oak Restoration Program, and taught volunteers to identify the three species of oaks (*Quercus agrifolia*, *Q. douglasii*, and *Q. lobata*) that occur on the Reserve. All volunteers received a handout on acorn collection and storage (Appendix 1). We collected over 2500 *Q. lobata*, valley oak, and 600 *Quercus agrifolia*, coast live, oak acorns. We mapped the location of each tree from which acorns were collected, and labeled bags with the identity of each parent tree. In the laboratory damaged or insect infested acorns were discarded, and the remaining acorns were placed in a bucket filled with water and bleach (1/2 cup bleach to 1 gallon water). Floating acorns were discarded. Intact (“good”) acorns were air dried, counted, placed in plastic bags with vermiculite, and stored in refrigerated coolers (temperature = 5° C) prior to planting. In order to examine the relationship between acorn size and emergence and growth rates of the resultant seeding, we recorded acorn weights for a subsample of acorns from each collection tree.

**b) Watering experiment.** As discussed above, past results indicate that emergence and survivorship are greatest in years with above-average rainfall. What remains to be understood is how much extra water in a given year is required to significantly improve establishment rates? Another question that has not been previously investigated is what is the optimal timing and mode of delivery of supplemental watering?
To address these questions we designed and established a pilot study to investigate the effects of supplemental water on valley oak and coast live oak seedling establishment. Within one large 40 x 45 m plot, in a portion of Figueroa Valley that is ungrazed, we employed a stratified random design to designate positions for planting (Fig. 3).

For each species, *Quercus lobata* and *Q. agrifolia*, we had 10 replicates of 3 treatments: 1) control, which received no supplemental water; 2) watered via disc with each rainfall event; and 3) watered once in early summer. The disc was a modified “snow saucer”, attached to irrigation hose (see photos in Appendix 2); when installed, the device captured rainfall and directed the additional water to the oak seedling. The area of the disc was 3077 cm², so with a rainfall of 22mm (1 inch) the disc would deliver ~ 7.7 liters (2 gallons) of water to the seedling. The last treatment (“watered once”) was a “one-time” watering applied in the early summer, using the total amount of supplemental water received in the disc treatment.
All plantings were protected with cages to exclude small mammals. Cages were cylinders constructed of 3’ high hardware cloth (mesh size = 0.5”); they were open at the bottom and sealed at the top with aviary wire (mesh size = 2.5”). We treated all cages with an acid wash to remove the galvanization on the lower 6”; this treatment will allow the portion of the cage that is underground to rust and disintegrate more quickly. Cages were set 12” into the ground. Two viable acorns were planted 1-2” below the soil surface, at each planting location. Prior to planting, acorns were placed into buckets of water. Acorns that floated were discarded; we planted only acorns that sank and appeared viable. Planting was completed February 6, 2003. A rain gauge placed ~100m from the plot recorded total rainfall for the season, September 5, 2002 to May 4, 2003 as 472mm (18.4”), and cumulative precipitation from planting (February 6 to May 4) as 206mm (8.1”). We estimated that the total amount of supplemental water received in the disc treatment was 60 liters (16 gallons). Thus, this was the volume of water applied on July 2nd and 3rd, 2003, to the “one-time” watering treatment; seedlings in this treatment were hand watered at a rate slow enough to avoid runoff.

We monitored all planting locations on May 1, and July 3, 2003. Seedling emergence rates are high - 85% for both species and all treatments combined. Planting sites will be monitored again in late-summer and mid-fall 2003, to determine the effects of the experimental treatments on first year survivorship and growth rates.

c) Use of raptor perches to reduce rodent activity. As described above, our previous findings indicate that small mammals significantly reduce seedling recruitment of oaks. We have initiated research to determine if there are low-cost management practices that would decrease this source of mortality, without the large-scale ecological effects of rodenticides.

One potential means of reducing small mammal populations is to attract their natural predators. Ravens, such as hawks and owls, which prey upon gophers and ground squirrels, may increase their use of an area if appropriate perches are available. In a
natural setting, perches might include dead tree branches or stumps. We conducted a pilot study to investigate whether the addition of artificial perches (large wood poles) leads to a reduction in small mammal activity and thus to a decrease in valley oak seedling mortality.

In Lisque Canyon we identified 5 pairs of circular plots (diameter = 20m) that were at least 70m from a potential raptor perch, including natural perches such as trees or snags, and artificial perches such as phone poles. Plots were also at least 70m away from each other. For each pair of plots, one was randomly selected to receive an artificial perch/raptor post. In the center of these plots we erected a large wood pole (~5m high), with a 17cm x 17 cm wooden platform nailed on the top, to serve as additional raptor perches. The other plot within each pair served as a control (i.e., ambient raptor use.)

Within all pairs of plots, we designated positions for planting (Fig. 3) with 10 replicates

![Figure 4. Design for the designation of planting positions within raptor experiment plot. Planting locations are 3 m apart, distributed along 2 circles: one at 8 m from center and the second 2 m further out. Planting locations labeled “cages” have 2 holes each: both are enclosed by a large cage to exclude large mammals, but one is also planting within a small cage that excludes small mammals. Locations labeled “open” have one hole each and are open to all herbivores. Each plot contains 10 replicates per treatment.]
of three treatments: 1) protection from small mammals such as gophers and ground squirrels, 2) protection from large animals such as cattle, deer, and pigs, and 3) no protection from mammalian grazers (Fig. 5). Large and small cages were of similar construction to those established in our previous large scale planting experiments.

Large cages/fences were constructed of 4' high, 2" x 4" mesh galvanized wire (12 gauge); they were round (diameter = 18") and supported at one side with a 5' t-post, and at the other side with a 4' rebar. Smaller cages to exclude small mammals were cylinders constructed of 3' high hardware cloth (mesh size = 0.5"); they were open at the bottom and sealed at the top with aviary wire. We also treated these cages with an acid wash to remove the galvanization on the lower 6"; this treatment will allow the portion of the cage that is underground to rust and disintegrate more quickly. In positions with cages (small mammal exclusion), the cages were set 12" into the ground. Two viable valley oak
acorns were planted 1-2” below the soil surface, at each planting location. Prior to planting, acorns were placed into buckets of water. Acorns that floated were discarded; we planted only acorns that sank and appeared viable. Treatments were replicated 10 times per plot. All 10 plots are within rangeland grazed by cattle. Planting was completed February 28, 2003. Photographs of the plots are shown in Appendix 3.

We monitored all planting locations on May 8, 2003. We observed that many of the planting locations that were open to small mammals (both B and C in Fig. 5) were disturbed; the acorns had been excavated and eaten, with the acorn shell deposited at the soil surface (see photos in Appendix 4). Given the lack of obvious gopher mounds, or tailings, adjacent to the disturbances, the extent and depth of the soil disturbances (generally > 4” deep, and > 4” diameter), and the clear runways to nearby squirrel dens, we hypothesize that ground squirrels were primarily responsible for most acorn removal. Initial seedling emergence rates do not vary between the two plot types, raptor post and control, and is highest in the treatments excluding small mammals (46%). Plots will be monitored again in mid-summer and early fall 2003, to determine final emergence, first year survivorship, and growth rates.

II) Research to determine factors limiting natural regeneration of oaks

a) Understory vegetation monitoring. In May 2003, we monitored all permanent understory vegetation quadrats in our ungrazed plots. Claudia Tyler and Dennis Odion conducted the surveys. These permanent sampling quadrats were established in May 1996 within our large experimental plots to characterize the understory vegetation, and to examine effects of cattle grazing on the herbaceous vegetation of oak savannas and woodlands. Within each plot, using a stratified random design, we located 10 rectangular quadrats (100 cm x 50 cm), the corners of which were marked with metal spikes to facilitate resampling over the 10-year study period. For each quadrat, we record all plant species present, their percent cover, and the location of the quadrat relative to oak tree
canopy. Ten quadrats for each of 29 savanna and woodland ungrazed plots were sampled, for a total of 290 quadrats. The data for this year will be entered in summer 2003, and analysis of these and previous year’s results completed for our final report in 2004.

b) Physiological studies. In July, August, and November 2003, we measured several physiological characteristics of some of our oak seedlings, planted in 1997-98. We conducted all-day measurements of photosynthetic capacity and fluorescence; we also measured water relations with pre-dawn xylem pressure potentials. One finding of interest was that there was a positive relationship between seedling size/height and water availability (Fig. 6). Larger seedlings tended to have more water available to them than did small seedlings. This observation does not indicate a causative relationship; we don’t know whether larger seedlings are large because they have more water available to them, or if they have more water available to them because they are large. However, our results indicate that within a given age-class, larger seedlings are less water-stressed, suggesting that there may be a size at which mortality rates due to desiccation begin to decrease.

Figure 6. Relationship between seedling height and water availability. Data are pre-dawn xylem pressure potentials of four-year-old coast live oak and valley oak seedlings measured in July 2002.
III) Maintenance of cattle and site infrastructure

Because our research involves the use of cattle, we were required by the Institutional Animal Care and Use Committee (IACUC) at UCSB to submit a research protocol and to complete several training sessions. In addition to on-line training sessions, we conducted an all-day class, overseen by UCSB’s veterinarian and IACUC representative, on handling and care of cattle at Sedgwick Reserve in February 2003.

This year we worked with the Sedgwick Reserve, the UCSB Business Services Office, and John Solem of Wise Acres Ranch to negotiate a new lease for cattle grazing at the Reserve. The contract was approved in early April 2003. Cattle (79 cow/calf pairs) were owned and managed by John Solem.

With many hours of assistance from Sedgwick Reserve staff and other volunteers, we repaired and maintained existing fences, exclosures, tanks, troughs, and water pipe. Sedgwick Reserve purchased and installed a new, high voltage energizer (cost ~ $1900) to charge the electric fence. In addition, we received on-site consultation and training on fence layout, installation, and from regional Gallagher Power Fence Co. representative, Randy Baily. However, in spite of considerable time and effort, we were unable to maintain intact, operable electric fencing in all experimental areas before the end of the grazing season.

Due to these difficulties, as well as the short grazing season that resulted from delays in acquiring a new lease, only a portion of our experimental pastures (i.e., those in Lisque Valley) were grazed in late June this year. Although we intended to complete a full grazing cycle of all areas in 2003, it is consistent with standard rotational grazing techniques, such as those currently employed at Sedgwick Reserve, to allow paddocks to “rest” for a season. Under a rest-rotation grazing system, each pasture in
the rotation is periodically rested the entire year (Howery et al., 2000). The rest
period results in relatively high amounts of residual dry matter (RDM) at the season’s
end, which in turn leads to lower soil bulk density (soil compaction) and higher forage
productivity in the following year (Bartolome et al., 1980.)

IV) Dissemination of information

a) Tours of project site. The field experiments and oak plantings of the Santa Barbara
County Oak Restoration Program were seen by hundreds of individuals this year. We led
tours for Antioch College students, UC researchers, and members of the community.

Sedgwick Reserve’s education and outreach programs introduces many people to the oak
project each year. In 2002-2003, the Kids in Nature program at Sedgwick brought 1175
schoolchildren in grades 4 – 6, and 200 accompanying parents and teachers to the
Reserve. These students, many of whom are English learners from low performing
schools, were involved in a year-long native plant botany, habitat restoration project.
They needed to learn how to differentiate the three oaks before planting their acorns in
their habitat restoration/research plots. The volunteers teaching them used techniques
learned from Frank Davis in their volunteer training (see below), and shared information
about the oak project with the students.

Introductory Field Trip students in elementary and secondary schools (522 students plus
65 parents and teachers) were taught about the ongoing oak research as they participated
in docent-led tours at the Reserve. In addition, numerous collegiate level and adult
workshops and field trips were held at the Reserve. These visitors were also introduced
to the oak research project, visited our experimental plots, and told about the goals and
present findings of this project.
b) Sedgwick Docent Training Workshop. As described above Sedgwick docents routinely include the oak restoration experiment in their tours for K-12 and adult groups. On February 28, 2002 Frank Davis held a 1-day training workshop for Sedgwick docents to better familiarize them with the goals and findings of the project, and to learn about oak ecology and restoration. The workshop, which was attended by 18 docents-in-training, included classroom training and a tour of the project. The slides used for the classroom portion of the training can be viewed online, using Internet Explorer, at http://www.biogeog.ucsb.edu/projects/oak/talks/oakintro_files/frame.htm.

c) Public workshop. On February 1, 2003 Claudia Tyler led a workshop and fieldtrip at Sedgwick Reserve on growing oaks from acorns. This event was open to all community members, and co-sponsored by the Santa Ynez Natural History Society, WE Watch, Sedgwick Reserve, and the Santa Barbara County Oak Restoration Program (Appendix 5).

d) Oral presentation at national scientific conference. In August 2002, Claudia Tyler presented a talk on findings of the Santa Barbara County Oak Restoration Program at the joint meeting of the Ecological Society of America and the Society for Ecological Restoration held in Tucson, Arizona. The theme of this annual professional meeting was “Understanding and Restoring Ecosystems”. Our presentation abstract is attached (Appendix 6), and PowerPoint presentation available on request.

e) Meeting with Santa Barbara area specialists in oak restoration. In collaboration with County staff - Michelle Pasini from the Energy Division, and Abe Leider from Planning and Development - we coordinated a meeting with consultants and other specialists involved with oak restoration projects in Santa Barbara County. The goal of this roundtable discussion was to share information about problems and successes in oak restoration projects in the county, to determine if there is practical information still lacking, and to discuss the current and proposed performance/planting standards for mitigation of oak loss. Although the types of projects discussed varied (e.g., whether
watering was a viable option at the sites, what species of oaks were used, use of nursery-grown seedlings/saplings vs. acorns) there was general consensus that desiccation, and herbivory/grazing by mammals were substantial obstacles to restoration efforts. Most projects have not accumulated data over more than a few years and thus conclusions about long-term successes of various methods are still not yet available.

**f) Oral report presented at Oak Woodland Conservation Workgroup.** We presented an oral activity report on the SB County Oak Restoration Program at the annual meeting of the University of California Oak Woodland Conservation Workgroup, held on April 1-2, 2003 in Morro Bay. This meeting was designed to bring together academic and Cooperative Extension personnel of UC’s Department of Agriculture and Natural Resources, along with other research and outreach partners, to share information, identify research and education needs, and address issues surrounding the state’s oak woodlands. The Oak Woodland Conservation Workgroup provides a forum for collaborative approaches to the varied and often conflicting challenges that oak woodlands face.

**g) Maintenance of project web-site.** We have a web-site to make information about the project goals and results available to those with access to the internet. We continue to maintain this site, at http://www.biogeog.ucsb.edu/projects/oak/oak.html.

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**Literature cited**

http://cals.arizona.edu/pubs/natresources/az1184.pdf

Appendices

1. Acorn collection procedures
2. Photographs of watering experiment
3. Photographs of raptor perch study
4. Photographs of raptor perch study – acorn removal
5. Announcement of public workshop
6. Abstract of paper presented at 2002 meeting of the Ecological Society of America
Methods of acorn collection and storage

Santa Barbara County Oak Restoration Program at Sedgwick Reserve

Collection. Acorns are collected in the fall. Acorns are ripe when they release easily from the caps, or are on the ground. We collect *Quercus agrifolia* (coast live oak) acorns from the trees, when the acorns are golden brown. We collect most *Q. lobata* (valley oak) acorns from the ground, because the canopies are almost all out of reach! It is best to choose acorns that appear intact, that have few holes, and that don’t rattle. For all acorns collected it is important that we record the tree and location where they came from. We do this for several reasons: 1) this allows us to determine if acorns from some trees are more likely to successfully produce seedlings, 2) in each plot we plant acorns that were collected as close as possible to that location, and 3) since we are planting in a reserve it is our responsibility to identify the source of acorns for all established seedlings/saplings at the conclusion of our study. Therefore, be sure to label bags with the identity of each parent tree. We also identify the tree on an accompanying air photo. Once collected, keep the acorns cool and out of the direct sun.

Sorting and storage. Damaged or insect infested acorns can be discarded, and the remaining acorns placed in a bucket filled with water and bleach (1/2 cup bleach to 1 gallon water). Floating acorns are discarded. Intact (“good”) acorns are air dried on newspaper, counted, placed in plastic bags with vermiculite, and stored in refrigerated coolers (temperature ~ 5°C) prior to planting.
Appendix 2.

Watering experiment established winter 2003, in lower Figueroa Valley, UC Sedgwick Reserve.

Watering addition treatment – disc collects and redirects additional water to oak seedlings with each rainfall event.
Appendix 3.

Plantings surrounding raptor post – experiment on the use of raptor perches to reduce rodent activity.

Plantings in control plot – experiment on the use of raptor perches to reduce rodent activity.
Acorns excavated and eaten in fenced treatment, which excludes large mammals

Acorns excavated and eaten in open treatment
Santa Ynez Valley Natural History Society  
P.O. Box 794  
Los Olivos, California 93441

Press Release / Calendar Item

Contact: John Evarts, 688-0413

**Growing Oaks from Acorns:**
A Hands-On Workshop and Field Trip

**Saturday, February 1, 2:00 to 4:00 p.m.**

**UC Sedgwick Reserve**

The Santa Ynez Valley Natural History Society invites the public to join research biologist Claudia Tyler for a workshop to learn techniques for growing oak trees from acorns. Participants will plant acorns at a restoration site at UC Sedgwick Reserve using several different methods. They will also tour the long-term oak regeneration study plots at the 5900-acre Reserve.

Dr. Tyler has been manager of the Santa Barbara County Oak Restoration Program since 1996, and she is conducting research on factors limiting recruitment of valley and coast live oaks. She has recently completed a review of studies on the demography and ecology of California oaks.

This workshop is co-sponsored by WE Watch, Sedgwick Ranch, and the Santa Barbara County Oak Restoration Program. It is free to members of the Santa Ynez Valley Natural History Society and the co-sponsoring organizations. Others will be asked for a $15 donation.

To reach Sedgwick Reserve, take Highway 154 to Roblar Road (east); turn left on Brinkerhoff Road. The entrance to the Reserve is at the end of Brinkerhoff. For more detailed directions, call the Reserve at 686-1941.

# # # #
Factors Limiting Recruitment in Valley and Coast Live Oak

Claudia M. Tyler, Bruce E. Mahall, and Frank W. Davis, University of California, Santa Barbara, CA 93106; 805-455-5711; tyler@lifesci.ucsb.edu

Oak woodland and savanna habitats, among the most diverse communities in North America, have suffered significant losses in the past century. In addition, natural regeneration of the oaks in these systems, appears to be insufficient to maintain current populations. The relative importances of factors that may be responsible for this lack of regeneration are not clearly understood. We have replicated large-scale planting experiments in four different years, to determine the effects of cattle and other ecological factors on seedling establishment of valley oak (*Quercus lobata*) and coast live oak (*Q. agrifolia*). In 33 large experimental plots (50 x 50 m) we planted acorns from *Q. lobata* and *Q. agrifolia*. Fifteen of these large plots are controls, open to grazing, fifteen exclude cattle with the use of electric fence, and three are ungrazed in large ungrazed pastures. Within the plots, experimental treatments included: 1) protection from small mammals, 2) protection from large animals, and 3) no protection from mammalian grazers. In winters 1997, 1998, 2000, and 2001, we planted approximately 1000 acorns of each species. Results confirm that seed predation and herbivory by small mammals are a significant “bottleneck” to oak seedling recruitment on the landscape scale. Comparing results among years indicates that lack of late winter rainfall can significantly reduce oak emergence and establishment. Survivorship of protected acorns and seedlings is comparable in grazed and ungrazed areas.

ORAL SESSION

Plant Population Ecology

Key words: *Quercus*, grazing, seedling recruitment
Santa Barbara County Oak Restoration Program

Addendum to

Yearly Progress Report for the Period July 2002 - June 2003

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University of California at Santa Barbara

Submitted to:

County of Santa Barbara Department of Planning and Development, Energy Division

September 25, 2003
Addendum to 2002-2003 Yearly Progress Report

2003 Survivorship of Seedlings in Planting Experiments: Summary

a) Cohort planted in 2000-2001

The highest survivorship for both species has been for seedlings that are protected from small mammals (Fig. 1). Although there was mortality of some seedlings, overall numbers are higher than last year because some individuals that were recorded as “dead” in the 2002 census resprouted in 2003. Including all treatments and both species, 7% of the acorns planted in 2000-2001, are now established seedlings. There are currently 129 established two-year-old seedlings (89 Q. lobata, and 40 Q. agrifolia). Eighty-five percent of these seedlings are in the treatments protected from rodents (Table 1).

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</tr>
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<tr>
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<td>4</td>
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<td></td>
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<td>total</td>
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<td>18</td>
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Table 1. Number of established two-year-old oak seedlings (planted in 2000-2001) in experimental treatments (all areas combined). “Alternative cage” refers to cages, which exclude rodents, but without bottom wire. Data from June 2003.
Figure 1. Percent survivorship of 2-yr old seedlings (planted in 2000-2001) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals \([100 \times (#\text{seedlings}/#\text{acorns planted})]\) for three experimental treatments for three sampling dates.
Surviving two-year old *Q. lobata* seedlings range in height from 4 to 33 cm (2 to 13”) with a mean of 17 cm (7”). Heights of surviving two-year old *Q. agrifolia* seedlings range from 4 to 59 cm (2 to 23”) with a mean of 15 cm (6”).

*b) Cohort planted in 1999-2000*

As above, the highest survivorship for both species has been for seedlings that are protected from small mammals (Fig. 2). Including all treatments and both species, 7% of the acorns planted in 1999-2000, are now established seedlings. There are currently 131 established three-year-old seedlings (106 *Q. lobata*, and 25 *Q. agrifolia*). Sixty-three percent of these seedlings are in the treatments protected from rodents (Table 2).

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</tr>
<tr>
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</tr>
<tr>
<td>alternative</td>
<td>1</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td><strong>cage total</strong></td>
<td><strong>10</strong></td>
<td><strong>15</strong></td>
<td></td>
</tr>
</tbody>
</table>

Table 2. Number of established three-year-old oak seedlings (planted in 1999-2000) in experimental treatments (all areas combined). “Alternative cage” refers to cages, which exclude rodent, but without bottom wire (see Fig. 2D). Data from June 2003.
Figure 2. Percent survivorship of 3-yr old seedlings (planted in 1999-2000) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals \[100 \times (\text{#seedlings}/\text{#acorns planted})\] for three experimental treatments for four sampling dates.
Surviving three-year old *Q. lobata* seedlings range in height from 3 to 64 cm (1 to 25”) with a mean of 19 cm (7”). Heights of surviving three-year old *Q. agrifolia* seedlings range from 7 to 53 cm (3 – 21”) with a mean of 24 cm (9”).

c) *Cohort planted in 1997-1998*

The differences in seedling survival among the treatments have been maintained from last year. The highest seedling/sapling establishment rates are for those protected from small mammals (Fig. 3). In all treatments that are not protected from small mammals, the highest mortality thus far appears to have occurred in the first season after emergence. However, there has been relatively high mortality within the past three years in the rodent exclusions as well, particularly for *Q. agrifolia* in ungrazed plots. As described in our previous reports, it is possible that the thick grass cover has attracted higher densities of herbivorous insects, or competed with seedlings for water.

Including all treatments and both species, 11% of the acorns planted in 1997-98, are now established seedlings/saplings. There are currently 306 established five-year-old seedlings (183 *Q. lobata*, and 123 *Q. agrifolia*). Seventy one percent of these seedlings are in the treatment protected from rodents (Table 3).

Surviving five-year old *Q. lobata* seedlings range greatly in height, from 5 to 178 cm (2 to 70”) with a mean of 39 cm (15”). Heights of surviving five-year old *Q. agrifolia* seedlings also range greatly, from 5 to 217 cm (2 – 85”) with a mean of 65 cm (26”). The tallest seedlings present in our experiments are those planted in this cohort.
Figure 3. Percent survivorship of 5-yr old seedlings (planted in 1997-98) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals $\left(\frac{\#\text{seedlings}}{\#\text{acorns planted}}\right)$ for three experimental treatments for six sampling dates.

A 7
Table 3. Number of established five-year-old oak seedlings (planted in 1997-1998) in experimental treatments (all areas combined). "Cage control" refers to half cages, which provide shade and other secondary caging effects but allow access to rodents. Data from June 2003.

Quercus lobata

<table>
<thead>
<tr>
<th>Treatment</th>
<th># in cattle grazed plots</th>
<th># in ungrazed plots</th>
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</thead>
<tbody>
<tr>
<td>no rodents</td>
<td>59</td>
<td>58</td>
</tr>
<tr>
<td>no large grazers</td>
<td>23</td>
<td>8</td>
</tr>
<tr>
<td>open</td>
<td>15</td>
<td>13</td>
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<td>2</td>
<td>5</td>
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<tr>
<td>total</td>
<td>99</td>
<td>84</td>
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</tbody>
</table>

Quercus agrifolia

<table>
<thead>
<tr>
<th>Treatment</th>
<th># in cattle grazed plots</th>
<th># in ungrazed plots</th>
</tr>
</thead>
<tbody>
<tr>
<td>no rodents</td>
<td>57</td>
<td>43</td>
</tr>
<tr>
<td>no large grazers</td>
<td>13</td>
<td>3</td>
</tr>
<tr>
<td>open</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>cage controls</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>total</td>
<td>76</td>
<td>47</td>
</tr>
</tbody>
</table>

d) Cohort planted in 1996-1997

Out of 2112 acorns planted in 1996-1997, a total of 16 six-year-old established seedlings have survived. One died in the past year. There are presently 5 six-year old Q. agrifolia seedlings, and 11 six-year old Q. lobata. The treatment that was most successful was that which excluded small and large mammals (Fig. 4). There are no seedlings surviving from the 1996 - 1997 planting that were in the open. In addition, there are more seedlings present in areas that are grazed by cattle than in ungrazed areas (10 vs. 6).

Six-year old Q. lobata seedlings range in height from 11 to 114 cm (4 to 45”), with a mean of 48 cm (19”). Six-year old Q. agrifolia seedlings range from 60 to 108 cm (24 to 43”) with a mean of 76 cm (30”).
Figure 4. Percent survivorship of 6-yr old seedlings (planted in 1996-97) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals \[100 \times \left( \frac{\#\text{seedlings}}{\#\text{acorns planted}} \right)\] for three experimental treatments for seven sampling dates. Note scale of y-axis: maximum value = 10.
e) Summary

There are currently valley and coast live oaks of four age classes, as a result of our planting experiments (Table 4).

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Quercus lobata</td>
<td>11</td>
<td>183</td>
<td>-</td>
<td>106</td>
<td>89</td>
<td>389</td>
</tr>
<tr>
<td>Quercus agrifolia</td>
<td>5</td>
<td>123</td>
<td>-</td>
<td>25</td>
<td>40</td>
<td>193</td>
</tr>
<tr>
<td>sum</td>
<td>16</td>
<td>306</td>
<td>131</td>
<td>129</td>
<td>582</td>
<td></td>
</tr>
<tr>
<td># planted per sp</td>
<td>1056</td>
<td>1363</td>
<td>928</td>
<td>928</td>
<td>4275</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Total number of seedlings of each species in each age class surviving to June 2003. No acorns were planted in 1998 – 1999 because acorns were unavailable.

Results from our four large-scale planting experiments (1996 - 1997, 1997 – 1998, 1999 – 2000, and 2000 - 2001) indicate that several factors play a role in limiting or promoting seedling recruitment of oaks. First, abundant rainfall in late winter, as seen in the El Niño year 1998, can significantly enhance emergence and survivorship; the cohort established in that year remains the largest. In addition, very low rainfall results in low seedling emergence, as seen in the 1996 – 1997 cohort, and in increased seedling mortality as observed in 2002. Second, as observed in all four planting years, at all planting sites, and in both grazed and ungrazed plots, seed predation and herbivory by small mammals (most likely gophers and ground squirrels) significantly reduces oak seedling recruitment. While overall establishment rate of acorns planted at this time is 6.8% (9.1% for Quercus lobata, 4.5% for Quercus agrifolia), plantings that were protected from small mammals is currently as high as 40% (’97-’98 Q. lobata). Third, herbivory by insects such as grasshoppers may reduce seedling survivorship across all treatments in some years, as observed in 2000 - 2001.