Santa Barbara County Oak Restoration Program

Yearly Progress Report for the Period July 2003 - June 2004

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This progress report summarizes the activities of the Santa Barbara County Oak Restoration Program for the period July 2003 through June 2004. 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 conducted final monitoring 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 2004, 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 May 2004, we re-censused all planting locations (3242 total) to determine survivorship and growth of all seedlings/saplings. The heights of all seedlings/saplings were measured and recorded. These data were entered, and analyzed in combination with all previously collected data. Complete results will be detailed in our 2005 Final Program Report.

2004 Survivorship and Growth of Seedlings

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 2003 census resprouted in 2004. Including all treatments and both species, 7% of the acorns planted in 2000-2001, are now established seedlings. There are currently 126

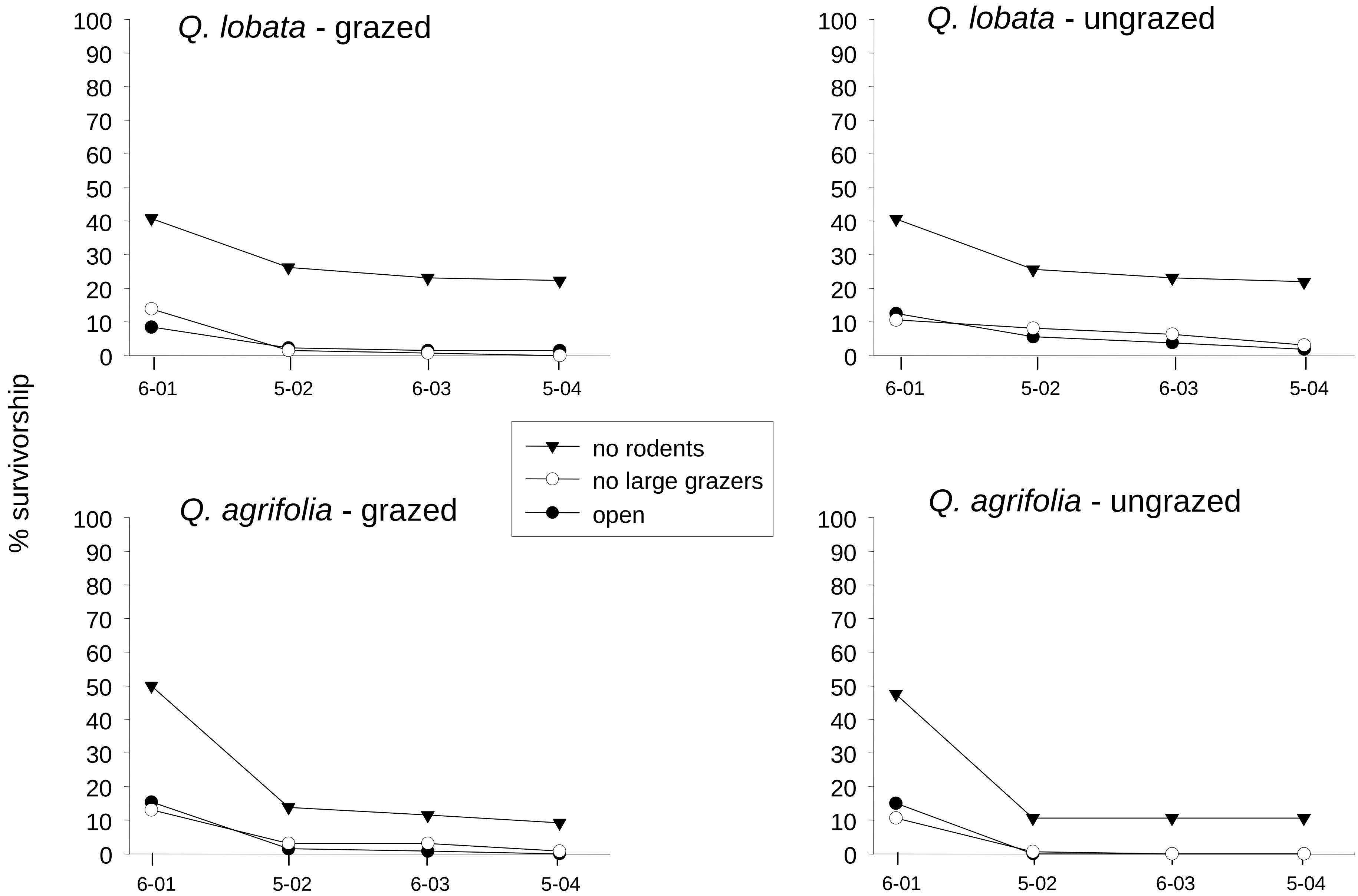

Figure 1. Percent survivorship of 3-yr old seedlings (planted in 2000-2001) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals [100 * (#seedlings/#acorns planted)] for three experimental treatments for four sampling dates.

established three-year-old seedlings (90 *Q. lobata*, and 36 *Q. agrifolia*). Ninety-one percent of these seedlings are in the treatments protected from rodents (i.e., "no rodent" and "alternative cage" treatments) (Table 1).

Quercus lobata	treatment	# in cattle grazed plots	# in ungrazed plots
	no rodents	29	35
	no large grazers	0	5
	open	2	3
	alternative cage	6	10
	total	*37*	*53*

Quercus agrifolia	treatment	# in cattle grazed plots	# in ungrazed plots
	no rodents	12	17
	no large grazers	1	0
	open	0	0
	alternative cage	4	2
	total	*17*	*19*

Table 1. Number of established three-year-old oak seedlings (planted in 2000-2001) in experimental treatments (all areas combined). "Alternative cage" refers to cages that exclude rodents, but without bottom wire. Data from May 2004.

Surviving three-year old *Q. lobata* seedlings range in height from 6 to 44 cm (2 to 17") with a mean of 24 cm (9"). Heights of surviving three-year old *Q. agrifolia* seedlings range from 10 to 44 cm (4 to 17") with a mean of 22 cm (9").

Comparing survivorship of seedlings in full cages vs. "alternative" cages with no bottoms, we found no significant differences between these two treatments for either species (logit regression: $p > .59$). From planting in 2001 through May 2004, *Q. lobata* seedling survivorship was 24% in full cages vs 28% in cages with no bottoms. *Q. agrifolia* seedling survivorship in full cages was 9%, vs 10% in cages with no bottoms. We conclude that cages do not require bottoms to effectively exclude small mammals and reduce initial mortality from underground herbivores.

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 126 established four-year-old seedlings (105 *Q. lobata*, and 21 *Q. agrifolia*). Seventy percent of these seedlings are in the treatments protected from rodents (Table 2).

Quercus lobata	treatment	# in cattle grazed plots	# in ungrazed plots
	no rodents	33	42
	no large grazers	6	10
	open	1	4
	alternative cage	2	7
	total	*42*	*63*

Quercus agrifolia	treatment	# in cattle grazed plots	# in ungrazed plots
	no rodents	6	7
	no large grazers	2	0
	open	0	0
	alternative cage	1	5
	total	*9*	*12*

Table 2. Number of established four-year-old oak seedlings (planted in 1999-2000) in experimental treatments (all areas combined). "Alternative cage" refers to cages that exclude rodents, but without bottom wire. Data from May 2004.

Surviving four-year old *Q. lobata* seedlings range in height from 3 to 72 cm (1 to 28") with a mean of 24 cm (9"). Heights of surviving four-year old *Q. agrifolia* seedlings range from 10 to 63 cm (4 – 25") with a mean of 35 cm (14").

Survivorship of seedlings in full cages vs. "alternative" cages with no bottoms was not significantly different between these two treatments for either species (logit regression: p >.15). From planting in 2000 through May 2004, *Q. lobata* seedling survivorship in full

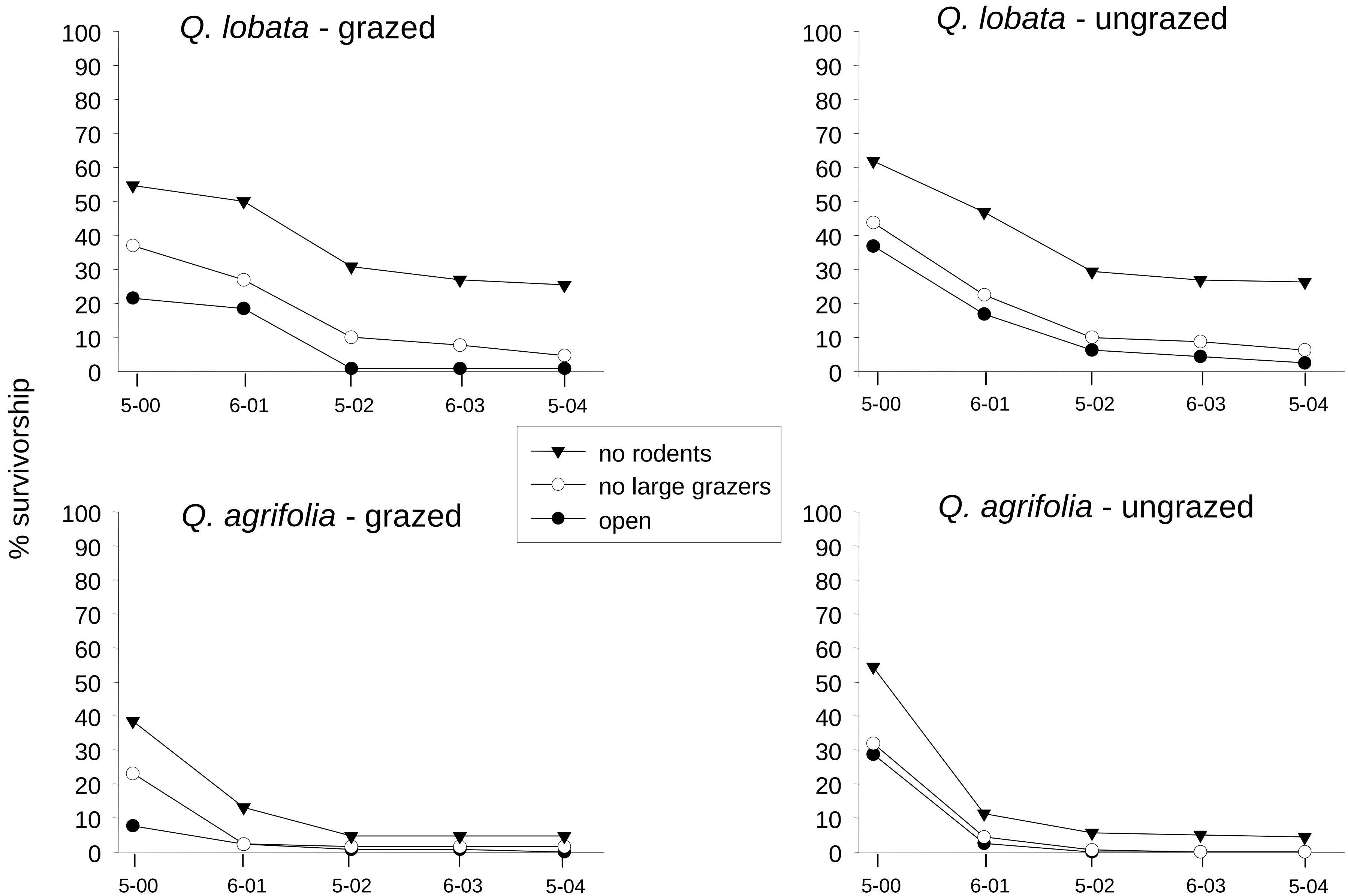

Figure 2. Percent survivorship of 4-yr old seedlings (planted in 1999-2000) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals [100 * (#seedlings/#acorns planted) for three experimental treatments for five sampling dates.

cages was 22% vs 16% in cages with no bottoms. *Q. agrifolia* seedling survivorship in full cages was 5% vs 10% in cages with no bottoms.

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). The relatively high mortality observed in 2001 - 2003, even within the rodent exclusions, has leveled off, and there were few seedlings lost this past year.

This cohort, established in an El Niño year, is the largest of all four planting efforts. Including all treatments and both species, 11% of the acorns planted in 1997-98, are now established seedlings/saplings. There are currently 295 established six-year-old seedlings (175 *Q. lobata*, and 120 *Q. agrifolia*). Seventy-three percent of these seedlings are in the treatment protected from rodents (Table 3).

Quercus lobata	treatment	# in cattle grazed plots	# in ungrazed plots
	no rodents	57	59
	no large grazers	22	8
	open	12	12
	cage controls	2	3
	total	*93*	*82*

Quercus agrifolia	treatment	# in cattle grazed plots	# in ungrazed plots
	no rodents	58	40
	no large grazers	14	1
	open	1	1
	cage controls	5	0
	total	*78*	*42*

Table 3. Number of established six-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 May 2004.

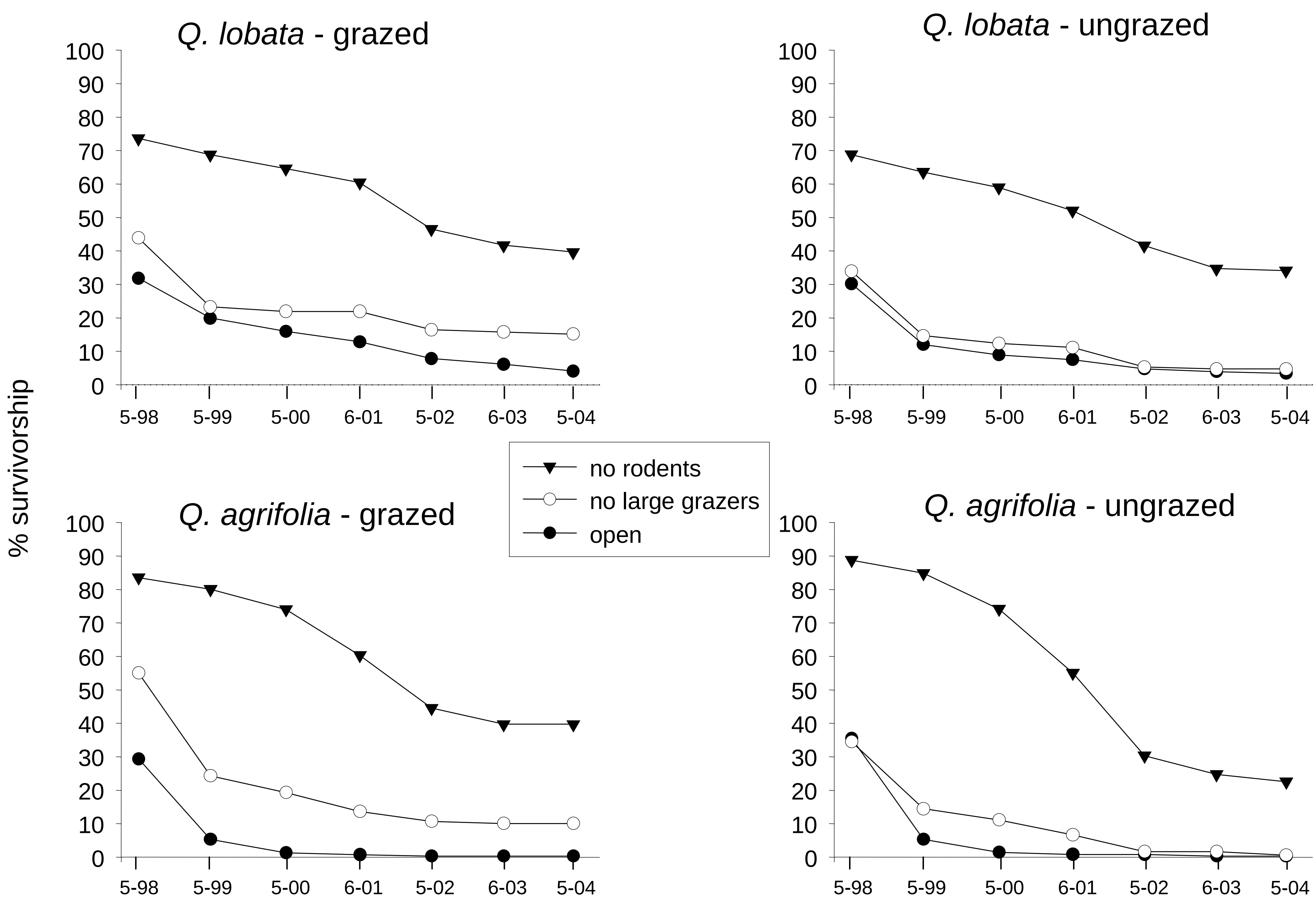

Figure 3. Percent survivorship of 6-yr old seedlings (planted in 1997-98) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals [100 * (#seedlings/#acorns planted) for three experimental treatments for seven sampling dates.

Surviving six-year old *Q. lobata* seedlings range greatly in height, from 4 to 192 cm (2 to 76") with a mean of 45 cm (18"). Heights of surviving six-year old *Q. agrifolia* seedlings also range greatly, from 7 to 214 cm (3 – 84") with a mean of 72 cm (28"). The tallest seedlings present in our experiments are those planted in this cohort.

There were no significant differences between cage controls and fenced "open" locations on seedling establishment for either species (logit regression: $p > .70$). This corroborates our previous findings that our cages that exclude rodents do not have unknown secondary effects or "caging artifacts".

d) Cohort planted in 1996-1997

Out of 2100 acorns planted in 1996-1997, a total of 17 seven-year-old established seedlings have survived. One recorded as dead last year, resprouted this year. There are presently 11 seven-year old *Q. lobata* and 6 seven-year old *Q. agrifolia* seedlings. The treatment that was most successful was that which excluded small and large mammals (Fig. 4). There is one *Q. lobata* seedling surviving from the 1996 - 1997 planting that is in the open. There are more seedlings present in areas that are grazed by cattle than in ungrazed areas (11 vs. 6).

Seven-year old *Q. lobata* seedlings range in height from 10 to 116 cm (4 to 46"), with a mean of 55 cm (22"). Seven-year old *Q. agrifolia* seedlings range from 14 to 110 cm (5 to 43") with a mean of 73 cm (29").

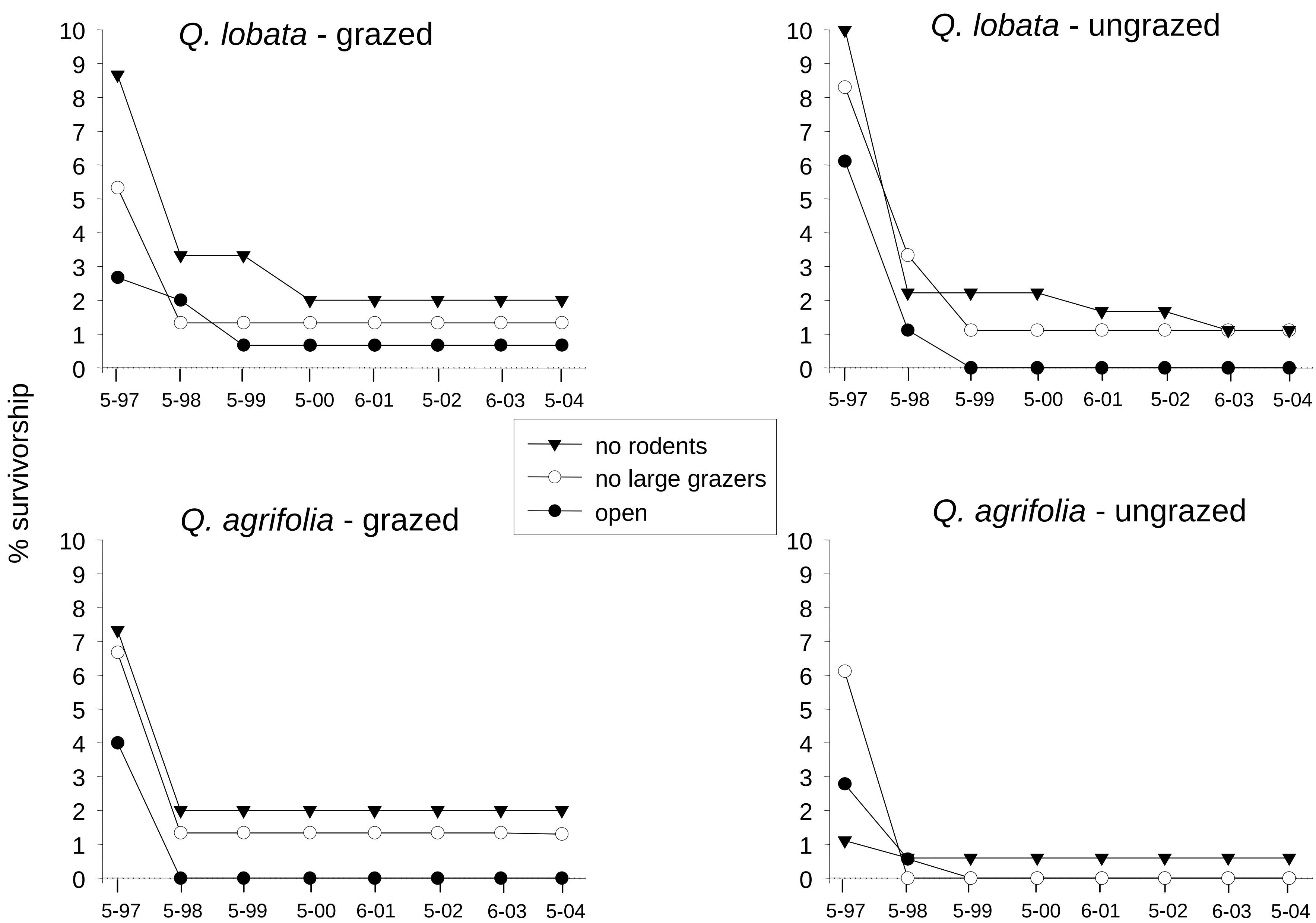

Figure 4. Percent survivorship of 7-yr old seedlings (planted in 1996-97) in large plots grazed by cattle, vs. those fenced to exclude cattle. Data are totals [100 * (# seedlings/#acorns planted)] for three experimental treatments for eight sampling dates. Note scale of y-axis: maximum value = 10.

e) Summary

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

	planting year					
	1996 - 1997	1997 - 1998	1998 - 1999	1999 - 2000	2000 - 2001	Sum
Quercus lobata	11	175	-	105	90	381
Quercus agrifolia	6	120	-	21	36	183
sum	1617	306		126	126	564
# planted per sp	1050	1360		928	928	4266

Table 4. Total number of seedlings of each species in each age class surviving to May 2004. 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 6.6% (8.9% for *Q. lobata*, 4.3% for *Q. agrifolia*), plantings that were protected from small mammals is currently as high as 40% ('97-'98 *Q. lobata* and *Q. agrifolia*). Third, herbivory by insects such as grasshoppers may reduce seedling survivorship across all treatments in some years, as observed in 2000 - 2001.

Pilot Studies 2002 – 2003

Preliminary findings from our large-scale planting experiments, described above, 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. We established two new experiments in 2002-2003, to study potential means of influencing these factors in the field. We monitored these experiments in the spring 2004.

a) Watering experiment. As described in our previous report, 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 planted *Quercus lobata* and *Q. agrifolia* acorns in winter 2003. For each species, 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 previous progress report, 2002-2003); when installed, the device captured rainfall and directed the additional water to the oak seedling. The area of the disc was 3077 cm^2, 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 that 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 in 2003 and in May 2004. Seedling emergence rates were very high - 90% for both species and all treatments combined. Survival rates have also been high, ranging from 60 – 100% (Table 5). We have not detected any significant

			treatment	
		control	watered once	disk – water each rainfall
Quercus lobata	# locations	10	9	10
	total # seedlings	17	18	20
	mean ht., cm	16.0	16.7	16.3
	(s.e.)	(1.3)	(1.0)	(0.8)
Quercus agrifolia	# locations	7	7	9
	total # seedlings	12	13	15
	mean ht. (cm)	5.9	11.9	11.2
		(1.1)	(1.2)	(1.5)

Table 5. One-year old seedlings established in watering experiment. Given for each treatment and each species are: number of locations (out of 10) with at least one seedling, total number of seedlings (out of 20 acorns planted), and mean height of seedlings in cm (with one standard error). Data from May 2004. Acorns planted in February 2003.

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differences in establishment rates among treatments, though for *Q. agrifolia*, establishment has been highest in the disk-watered treatment (Table 5). Establishment is slightly higher for *Q. lobata* than for *Q. agrifolia*. This difference between species was statistically significant (logit regression, species: $p = .048$). *Q. lobata* seedlings have established in nearly all 30 locations planted.

Seedling heights vary between the two species and among treatments (Fig. 5). *Q. lobata* seedlings are significantly taller than *Q. agrifolia* seedlings, and for *Q. agrifolia* we found significant effects of treatment on seedling height; seedlings that received water, either via one-time watering or disk, were significantly taller than controls (2-way ANOVA: species: $p < .001$; treatment: $p = .02$; species*treatment: $p = .06$).

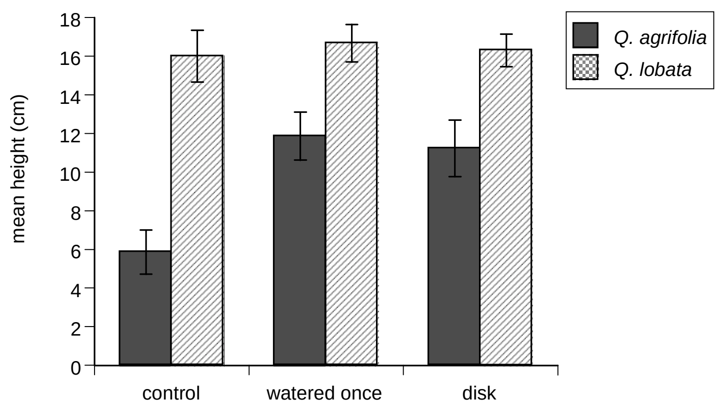

Figure 5. Effects of watering treatments on 1-year-old seedling height, May 2004. Data are means plus 1 standard error.

Conclusions. The results of any supplemental watering experiment are likely to vary depending on the amount of rainfall occurring in the year of the study. In 2003 – 2004, rainfall was above average at 472mm (18.4”). Our finding that watering treatments did not improve emergence may have been due to the fact that there was enough natural precipitation to ensure germination; even emergence in the control treatment was very high. We suggest that supplemental watering could yield very different results in a year with below-average rainfall.

One of the interesting findings from this pilot study is that the two species have responded differently. *Q. lobata*, valley oak, has not been affected by the watering treatment, but *Q. agrifolia*, coast live oak, has had higher growth rates with either method of adding supplemental water. Our previous work has shown that growth rates are often correlated with survivorship; the seedlings that die in a given year are, on average, the smallest individuals in the cohort. Thus, it is possible that we will observe higher mortality over time in the unwatered treatment for *Q. agrifolia,* even though the watered treatments will not be receiving any additional water in the future. We will continue to monitor this experiment and determine whether the “boost” provided to the watered seedlings in their first year, results in higher survivorship and growth in the long-term.

b) Use of raptor perches to reduce rodent activity. Our previous findings indicate that small mammals significantly reduce seedling recruitment of oaks. In 2003, we began a pilot study to investigate whether the addition of artificial raptor 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 established 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 with 10 replicates 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. 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 plots are within rangeland grazed by cattle. Planting was completed February 28, 2003.

We monitored all planting locations in April 2004. Seedling emergence and survival rates were significantly higher in locations protected from small mammals (Fig. 6) (logit regression: treatment, $p < .001$); we found no significant difference between open planting locations, and those protected from large mammals. As reported last year, we observed

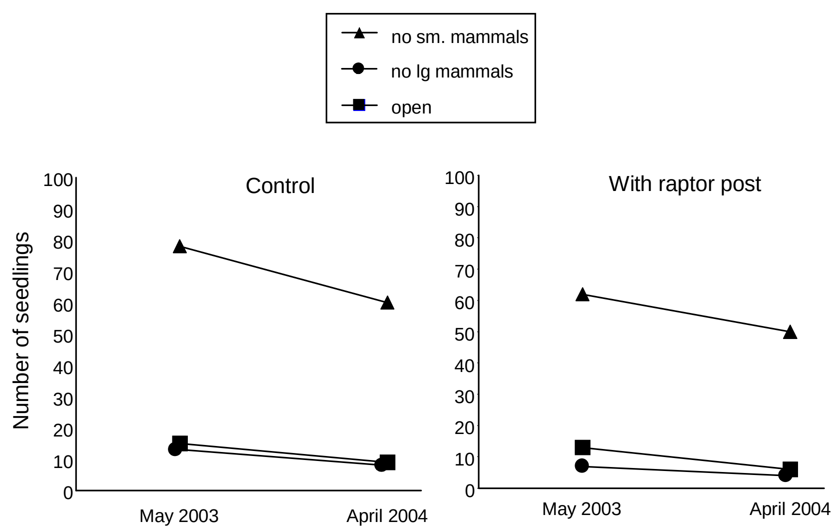

Figure 6. Effects of experimental raptor perches on establishment of valley oak seedlings planted with varying protection from seed predators and grazers. Shown are total numbers of seedlings emerged and surviving out of 100 acorns planted. Acorns planted in February 2003. Data from May 2003 (emergence) and April 2004 .

soon after planting in February 2003, that many of the locations open to small mammals were disturbed; the acorns had been excavated and eaten, with the acorn shell deposited at the soil surface. We hypothesize that ground squirrels were responsible for most acorn removal.

However, contrary to our expectations, we found no significant effect of the raptor perches on either emergence or numbers of seedlings present in April 2004 (Fig. 6) (logit regression: post, p >.20).

Conclusions. The results of this study support our findings from the large-scale planting experiments: small mammals significantly reduce emergence and establishment. The addition of artificial perches to attract predators did not reduce small mammal activity however. We propose several possible explanations for the lack of an effect of the raptor perches. First, raptors may not have been attracted to the posts. The perches may not have been large enough, or it may require a period of time for raptors to get accustomed to and begin to use the posts. Second, the posts may have been used by raptors that do not reduce the "critical" small mammals. We made observations of small falcons, such as American Kestrels, using the perches during the day. These birds primarily eat very small prey. We collected an owl pellet from below one of the posts; owls are nocturnal predators. Although Valley Pocket Gophers may be active day or night, California Ground Squirrels, one of the abundant small mammals at Sedgwick, is active/above-ground only during the day, and therefore not likely to be affected by noctural predators.

II) Research to determine factors limiting natural regeneration of oaks

Understory vegetation monitoring. In May 2004, we monitored all permanent understory vegetation quadrats in our 33 experimental planting plots. 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 33 savanna plots were sampled, for a total of 330 quadrats. The data entry for this year has begun and will be completed by the end of summer 2004. Analysis of these and previous year's results completed for our final report in 2005.

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, complete several training sessions on animal procedures and regulations, maintain regular observation and care records at the site, and submit monthly census reports.

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 January 2004. Cattle were managed by John Solem.

We repaired and maintained existing barbed-wire and electric fences, exclosures, tanks, troughs, and water pipe. Sedgwick Reserve purchased a new, portable energizer (cost ~ $350) to charge the electric fence in some of the more remote paddocks.

We met regularly with Reserve staff and the owner of the herd to plan grazing schedules, infrastructure maintenance, and other aspects of the cattle grazing operation.

In all pastures that include our experimental plantings, a total of 44 cattle (43 young heifers and 1 steer) grazed during the grass growing season. Detailed grazing records for the cattle operation for the year 2003 – 2004 are provided in Appendix 1.

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 UC researchers, and members of the community.

Sedgwick Reserve's education and outreach programs introduces many people to the oak project each year. In 2003-2004, the Kids in Nature program at Sedgwick brought over 1000 schoolchildren in grades 4 – 6, and 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 shared information about the oak project, learned from our previous docent training workshops.

Students in elementary and secondary schools (over 500 students plus 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) Meeting with Santa Barbara area specialists in oak restoration. In collaboration with Joddi Leipner from the Energy Division, we coordinated a meeting with consultants and other specialists involved with oak restoration projects in Santa Barbara County. The goals of this roundtable discussion were to provide information about the County's Oak

Ordinance, and oak planting performance standards, and to provide a forum for discussion of problems and successes in oak restoration projects in the county. The meeting, held at the Santa Barbara Botanic Garden, was well attended and met its goals.

c) 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.

Appendices

1. Grazing records, 2004.
2. Summary from meeting with Santa Barbara County staff and restorationists.

Grazing records for experimental pastures at Sedgwick Reserve 2004. Appendix 1.

dates cattle in	# of cows	# of bulls	dates cattle out	# of cows	# of bulls
3/19/2004	43				
4/9/2004		1			
			6/8/2004	43	1
TOTALS	**43**	**1**	**TOTALS**	**43**	**1**

date in	date out	days of use	pasture name	acreage	# of head	stock head days
3/19/04 12:30	3/24/04 12:30	5.00	The Tank Pasture (#18)	11	43	215.00
3/24/04 12:30	3/31/04 12:30	7.00	Quinn Flat (#17)	10	43	301.00
3/31/04 12:30	4/9/04 12:30	9.00	The Bottleneck (#16)	32	43	387.00
4/9/04 12:30	4/20/04 12:30	11.00	The Bottleneck (#16)	32	44	484.00
4/20/04 12:30	4/29/04 12:30	9.00	Upper Lisque (#8)	20	44	396.00
4/29/04 12:30	5/12/04 12:30	13.00	Middle Lisque (#6)	25	44	572.00
5/12/04 12:30	5/25/04 12:30	13.00	Airstrip (#3)	27	44	572.00
5/25/04 12:30	6/8/04 12:30	14.00	Lower Lisque (#5)	32	44	616.00
						3543.00