Influence of Winter-Spring Livestock Grazing on Survival and Growth of *Quercus lobata* and *Q. agrifolia* Seedlings[1]

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Abstract

The relative importance of livestock grazing in limiting or enhancing oak recruitment remains unclear because results from previous studies have been contradictory. In Santa Barbara County, we have replicated large-scale planting experiments from 1997 to 2001 to determine the effects of cattle and other factors on seedling establishment of valley oak (*Quercus lobata*) and coast live oak (*Q. agrifolia*). We manipulated cattle grazing (ungrazed vs. winter-spring rotational grazing) and protection from small and large mammals. Rainfall and seed predation and herbivory by small mammals—most likely gophers and ground squirrels—significantly impacted rates of seedling recruitment. Exclusion of cattle alone has not significantly increased establishment of either valley or coast live oak. However, protected seedlings in pastures with cattle have higher survival and growth rates than protected seedlings in plots excluding cattle. Our results suggest that winter-spring livestock grazing can have indirect positive effects on oak establishment, by reducing herbaceous biomass and associated small mammals adjacent to protected seedlings. Contrary to expectations based on the relative abundance of natural oak seedling recruits, establishment and survival of coast live oak planted in our experiments has been significantly and consistently lower than that of valley oak.

Keywords: Cattle, coast live oak, mortality, oak recruitment, regeneration, sapling, valley oak.

Introduction

In a number of oak woodlands and savannas throughout the world, stands are composed of large, old adults with few individuals in the smaller, younger classes, raising concerns that natural recruitment of the oaks may be insufficient to balance adult mortality (Shaw 1968, Saxena and Singh 1984, Holzman 1993, Swiecki and others 1993, Loftis and McGee 1993, Russell and Fowler 1999). In California, these observations have stimulated many studies, which have demonstrated that oak seedling recruitment may be extremely limited in space and time as a result of many natural and anthropogenic factors operating independently or together (reviewed by Tyler and others 2006).

The role of cattle in affecting oak recruitment remains controversial. Cattle grazing has been implicated as being one of the main factors responsible for poor oak recruitment in rangelands. However, the relative importance of browsing by livestock vs. native herbivores such as deer in limiting natural oak recruitment remains unclear

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and may be site- or region-specific (Muick and Bartolome 1987, Hall and others 1992, Standiford and others 1997, Swiecki and others 1997). This debate is complicated by the observation that the removal of livestock has rarely led to increased levels of oak recruitment, even after many decades (e.g., blue oaks, White 1966; valley oaks, Callaway 1992).

The Santa Barbara County Oak Restoration Program was funded as a long-term ecological study that would improve our understanding of the role of cattle and other factors in limiting or promoting establishment of oaks in large-scale, rangeland environments. Our previous findings (reported in Tyler and others 2002) indicate that rainfall, and seed predation and herbivory by small mammals—most likely gophers and ground squirrels—significantly impacted rates of seedling recruitment. This long-term program provides the opportunity to follow cohorts of seedlings as they transition to the sapling stage. Here, we describe survival and growth rates of *Quercus lobata* (valley oak) and *Q. agrifolia* (coast live oak) seedlings planted from 1997 to 2001, specifically evaluating the impacts of livestock grazing.

We chose to plant valley and coast live oak for several reasons. Valley oak was selected because it is the oak species of greatest concern in California, in large part because its reported recruitment is the lowest among all eight oak tree species in the state (Muick and Bartolome 1987, Bolsinger 1988, Barrett and Waddell this volume). This species has also been heavily impacted through various forms of development as its distribution coincides with areas of intense land use and land development, contributing to its perceived critical status. Coast live oak provides an excellent comparison to valley oak because it commonly occupies the same type of savanna and open woodland habitat, and it is reported to have much higher levels of natural seedling establishment. Of the three oak species dominant in Santa Barbara County, coast live oak has been the least studied.

Site Description

Research is being conducted on the Sedgwick Reserve, a 5,860-acre (2,372-ha) ranch managed by the University of California Natural Reserve System, and located at the base of Figueroa Mountain in the Santa Ynez Valley in central Santa Barbara County. The climate is Mediterranean, with hot dry summers and cool wet winters. Mean annual rainfall (calculated for a 55-year period) is 400 mm (15.8 inches). Total precipitation (as recorded at the nearest National Weather Service recording station) for the rain-years including 1996 to 2001, when acorn planting was conducted, ranged from 300 mm in 1996 to 1997 to 830 mm in 1997 to 1998.

Cattle grazing was managed by California Polytechnic State University, San Luis Obispo, from 1995 to 2002, and by Wise Acres Ranch from 2002 to 2006. Within our experimental areas (~525 acres), grazing paddocks range from 1 to 52 acres, with an average size of 23 acres. The timing and duration of grazing has varied from year to year, dependent on grass availability, but has been conducted each year in winter/spring between the period December and June. Herd size has also varied annually based on forage availability, but has averaged 124 heifers or cow/calf pairs.

Our experimental plots were 50 x 50 m. Fifteen of these large plots were controls, open to cattle grazing, and fifteen excluded cattle with the use of electric fence. The cattle exclosures were accessible to deer and pigs, which could go over or under the electric fence. In savanna areas, we centered each plot on an adult oak tree, the canopy of which covered an average of 10 percent of the total plot area. Eight plots were located in a treeless area that was clearcut in ~1950 (the “Airstrip”). Plots were paired, with one plot randomly selected to be fenced to exclude cattle. These plots were established in 1995.

Large-Scale Planting Experiments

We replicated large-scale planting experiments in four different years to determine the effects of cattle and other ecological factors on oak seedling establishment in oak savannas and woodlands (detailed methods described in Tyler and others 2002). In our large experimental plots, described above, we planted acorns collected from valley oak and coast live oak on the site. Within the plots, experimental treatments included: 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. The characteristics, or conditions, of these treatments varied depending on whether they were within large plots grazed by cattle or plots fenced to exclude cattle. Most notably, within grazed plots grass and herbaceous cover was reduced on average for all treatments, while ungrazed plots generally had abundant cover and biomass of grasses and other vegetation.

Large cages that protected from deer, pigs, and cattle within the plots were vertical cylinders 18" in diameter and constructed of 4' high, 2" x 4" mesh galvanized wire (12 gauge). Cages were supported at one side with a 5' t-post, and at the other side with a 4' rebar. This design was based on the “Vaca cage” described in Swiecki and Bernhardt (1991). Smaller cages to exclude both small and large mammals were vertical cylinders constructed of 3'-high hardware cloth (mesh size = 0.5"), sealed at both ends with aviary wire, and set 12" into the ground. Each treatment was replicated five times within each plot for each species, each planting year.

In winters of 1997, 1998, 2000, and 2001, we planted approximately 1,000 acorns of each species, two acorns per planting location. Number of locations planted per individual treatment (n) ranged from 65 to 180. Acorns and seedlings did not receive supplemental water.

Results and Discussion

Survival Rates

Seedling emergence and survivorship were both very low for acorns planted in 1997. Rainfall in 1996-1997 was well below average, with the last rainfall of the season occurring in mid-January 1997. Only 12 planting locations (1.2 percent of total planted) have 9-year-old seedlings (eight valley oak and four coast live oak locations). The treatment that was most successful was that which excluded small and large mammals. Only one open-planted valley oak seedling survived from the 1996-1997 cohort. There are more planting locations with seedlings present in areas that are grazed by cattle than in ungrazed areas (*table 1*).

Establishment was much higher in the subsequent planting years (1998, 2000, and 2001). Survival rates are above 50 percent overall for 8-year-old seedlings planted in 1998 and protected from small mammals (*table 1*). Planting success has varied greatly among years (most likely a function of rainfall), and the highest survival rates are for seedlings protected from small mammals. These two factors play the major role in affecting early seedling establishment (Tyler and others 2002), and therefore significantly impact long-term survival rates across treatments. Effects of livestock grazing appear to be more subtle.

Table 1*—Summary of current survival rates for valley oak and coast live oak seedlings planted 1997 to 2001 in plots grazed by cattle vs. those fenced to exclude cattle. Data are the percent of planting locations with a seedling (one or two) present in 2006. Asterisks indicate a significant difference between grazed and ungrazed plots for a given treatment (logit regression, P < .05).*

				GRAZED	UNGRAZED
	yr planted	sdling age	treatment	% survivorship	
Valley oak	1997	9 yr-old	open	1.3	0.0
			no lrg anim	2.7	2.2
			no sm or lg mammals	2.7	1.1
	1998	8 yr-old	open	4.7	5.6
			no lrg anim	16.4	7.0
			no sm or lg mammals	55.6	42.5
	2000	6 yr-old	open	1.5	3.8
			no lrg anim	4.6	8.8
			no sm or lg mammals	29.2	35.0
	2001	5 yr-old	open	1.5	2.5
			no lrg anim	0.0	2.5
			no sm or lg mammals	32.3	31.3
Coast live oak	1997	9 yr-old	open	0.0	0.0
			no lrg anim	1.3	0.0
			no sm or lg mammals	2.7	1.1
	1998	8 yr-old	open	0.0	0.0
			no lrg anim	**11.0***	***1.1**
			no sm or lg mammals	**53.4***	***25.8**
	2000	6 yr-old	open	0.0	0.0
			no lrg anim	1.5	0.0
			no sm or lg mammals	6.2	6.3
	2001	5 yr-old	open	0.0	0.0
			no lrg anim	0.0	0.0
			no sm or lg mammals	12.3	15.0

Comparing seedling survival in similar treatments planted in grazed plots to those in plots excluding cattle, allows one to examine both direct and indirect effects of livestock grazing. First, we can ask whether exclusion of cattle alone allowed for significantly higher survival. Comparing open treatments for both species and all years, establishment rates do not vary significantly between grazed and ungrazed plots. There were no significant differences, indicating that even if acorns are planted, removal of livestock grazing alone does not enhance oak establishment. Our findings also indicate that winter-spring livestock grazing alone is not a management tool that will promote natural oak recruitment in rangelands similar to those studied.

Competition with non-native annual grasses has been hypothesized to be a cause of low-recruitment rates in oaks (Griffin 1971, Danielsen 1990, Gordon and Rice 1993, Gordon and Rice 2000). Thus, livestock grazing may indirectly enhance oak seedling establishment by reducing competition. To isolate this indirect effect of grazing, one may compare the difference between survival of seedlings that are protected from both small and large mammals in grazed vs. ungrazed plots. This difference was significant only for the 1998 cohort of coast live oak (logit regression, $P < 0.001$), where survival of protected seedlings was higher in grazed areas.

Another potential indirect effect of cattle grazing and removal of biomass is change in small-mammal activity. For example, gopher activity has been found to be greater in ungrazed areas compared to grazed areas (Stromberg and Griffin 1996). Comparing the survival of seedlings planted in 1998 (the cohort experiencing effects of grazing removal the longest) and protected from large mammals only in grazed vs. ungrazed areas, rates were higher for those in grazed areas—significantly so for coast live oak (logit regression, $P = .026$) and nearly so for valley oak (logit regression, $P = .060$). Since small mammals have access to this treatment in both locations, this difference suggests that small mammal activity is greater in the ungrazed areas, and that livestock grazing may provide an indirect positive effect by reducing deleterious impacts of small mammals on oak seedling survival.

Contrary to our expectations, survival rates have been lower for coast live oak than for valley oak nearly every year, in every treatment. This result suggests that observed patterns of high natural recruitment in coast live oak (e.g., Bolsinger 1988, Barrett and Waddell this volume), are not due to higher seedling survivorship rates in this species, but may be a result of other factors, such as differences in acorn production or seed predation rates.

Seedling Growth

Heights of surviving seedlings vary among species and cohorts (*table 2*). As expected, on average, heights are greatest for the older cohorts, though the tallest individuals are those planted in 1998, an El Niño year with plentiful rainfall. Coast live oaks are slightly taller than valley oaks at the same age and in comparable treatments.

***Table 2**—Growth of valley oak and coast live oak seedlings planted 1997 to 2001 in plots grazed by cattle vs. those fenced to exclude cattle. Data are mean seedling heights (cm) plus one standard error, for four seedling cohorts measured in July 2006. Asterisks indicate a significant difference between grazed and ungrazed plots for a given treatment (t-test, P < .05).*

				GRAZED	UNGRAZED
	yr planted	sdling age	treatment	mean ht in cm (& SE)	
Valley oak	1997	9 yr-old	open	8.0 (0)	-
			no lrg anim	105.5 (13.5)	81.5 (2.5)
			no sm or lg mammals	127.0 (67.0)	74.0 (0)
	1998	8 yr-old	open	19.1 (6.8)	32.1 (2.3)
			no lrg anim	71.2 (11.3)	60.8 (8.8)
			no sm or lg mammals	88.2 (6.2)	97.5 (9.5)
	2000	6 yr-old	open	11.0 (0)	15.7 (5.4)
			no lrg anim	**61.3 (5.2) ****	**** 38.6 (6.1)**
			no sm or lg mammals	63.5 (4.1)	59.0 (5.1)
	2001	5 yr-old	open	16.0 (0)	25.5 (12.5)
			no lrg anim	-	37.5 (2.5)
			no sm or lg mammals	53.1 (4.9)	45.9 (3.3)
Coast live oak	1997	9 yr-old	open	-	-
			no lrg anim	187.0 (0)	-
			no sm or lg mammals	140.5 (38.0)	159.0 (0)
	1998	8 yr-old	open	-	-
			no lrg anim	131.3 (31.4)	67.0 (0)
			no sm or lg mammals	130.5 (8.6)	138.8 (12.5)
	2000	6 yr-old	open	-	-
			no lrg anim	84.0 (0)	-
			no sm or lg mammals	68.0 (12.2)	84.2 (15.8)
	2001	5 yr-old	open	-	-
			no lrg anim	-	-
			no sm or lg mammals	63.4 (5.6)	58.5 (4.9)

Assessing the effects of livestock grazing, as above, on seedling height, we first compared open treatments in grazed vs. ungrazed areas, and found no significant differences (t-tests, $P > .05$), indicating that removal of cattle alone does not improve oak seedling growth. Examining indirect effects of grazing, we found no significant differences in the heights of seedlings protected from both small and large mammals in grazed vs. ungrazed areas, suggesting that removal of herbaceous biomass alone did not enhance growth rates of seedlings in grazed pastures. We did find evidence of a positive indirect effect of grazing on valley oak, related to small mammal effects. In our 2000 cohort, the seedlings protected from large mammals were taller in the grazed areas compared to the ungrazed areas (t-test, $P = 0.026$). As above, since small mammals have access to this treatment in both areas, this suggests that small mammal activity may have been greater in the ungrazed plots, thus reducing oak seedling growth.

Summary and Implications for Oak Restoration in Rangelands

Our experimental results suggest that several factors, especially rainfall and seed predation and herbivory by small mammals, play a significant role in limiting or promoting seedling recruitment of oaks. Excluding cattle has not enhanced survival or growth rates of planted unprotected valley or coast live oak seedlings. At the same time, cattle grazing by itself (without additional protection of seedlings) has not led to higher levels of oak establishment, as has been suggested by some range managers. These results indicate that winter-spring livestock grazing is unlikely to be solely responsible for low oak recruitment rates in California, nor is it the management tool that by itself will solve the “oak regeneration problem.” However, we found that indirect effects of grazing (on protected seedlings) were positive or neutral for survivorship and growth. These findings are similar to those reported for valley oak by Swiecki and Berhardt (1991). This result may not hold at higher stocking densities or if grazing is continued into the summer months when seedlings are more likely to be browsed.

The results of these experiments provide some guidance for those planting oaks in similar xeric rangeland settings by indicating the range of survival and growth one might expect if acorns are planted using these treatments. Swiecki and Bernhardt (1991) provide similar and very helpful guidelines for valley oak in Northern California. As discussed previously, survival and growth rates have varied considerably among years, planting cohorts, and species. Less variability could be expected if irrigation were used, though such methods are unlikely to be cost-effective in large-scale rangeland settings.

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