ENDANGERED PLANT PROGRAM

DEMOGRAPHY OF *CAULANTHUS CALIFORNICUS*, *LEMBERTIA CONGDONII*, AND *ERIASTRUM HOOVERI*, AND VEGETATION CHARACTERISTICS OF ENDANGERED SPECIES POPULATIONS IN THE SOUTHERN SAN JOAQUIN VALLEY AND THE CARRIZO PLAIN NATURAL AREA IN 1993

FINAL REPORT

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ABSTRACT

Populations of two endangered and one threatened plant species were studied on the Carrizo Plain Natural Area (CPNA) and in the San Joaquin Valley of California in order to provide baseline data for continuing research on their ecology and responses to drought and site management. Results will be incorporated into a multi-species recovery plan as well as restoration and management plans for the CPNA and other preserves.

In terms of plant size and reproduction, the most successful populations of *Caulanthus californicus* were those on the CPNA, whereas *Lembertia congdonii* was equally successful on the CPNA and in the Kettleman Hills. Of the four *Eriastrum hooveri* sites studied, plants on the CPNA were smallest with poorest reproduction.

Grazing effects were compared in three populations of *L. congdonii*, each of which was divided into grazed and ungrazed portions. Reproduction of *L. congdonii* was greater in grazed than in ungrazed areas of the Carrizo Plain and Kettleman Hills, whereas the reverse was found on the Elkhorn Plain.

Distribution and morphological characters of *C. californicus* and *L. congdonii* were evaluated relative to giant kangaroo rat (*Dipodomys ingens*) precincts on the Carrizo and Elkhorn Plains. Although *C. californicus* occurred more frequently on precincts than did random points, plants growing on precincts did not differ significantly in size or reproduction from those growing between precincts. Conversely, *L. congdonii* occurred randomly with respect to precincts. The two *L. congdonii* populations studied differed in plant response to giant kangaroo rat precincts in terms of plant size and flower head production, but not in survival and achene production.

Habitat characteristics of the listed plant and animal species were assessed on 19 vegetation transects on the CPNA and 43 in the San Joaquin Valley. Exotic plants dominated in cover at most sites, yet exotics accounted for less than one-third of species composition, on average. Plant diversity was high on the CPNA compared to other areas sampled, and species richness was greater in ungrazed than in grazed areas. Native plants, including the listed species, apparently persisted in the seed bank during the recent drought.

Reintroduction of *Caulanthus californicus, Lembertia congdonii,* and *Eriastrum hooveri* is not necessary on the CPNA at this time. Exotic plants are not likely to be eradicated from the area, but active management (*e.g.*, planting, seeding, burning) could increase the proportion and distribution of native plants, particularly shrubs and perennial grasses. Controlled grazing studies are a prerequisite to management decisions. Additional research is necessary to determine the extent of the existing seed bank and the appropriate management techniques for enhancement of rare plant populations and rehabilitation of plant communities affected by drought and historic agricultural practices.

ACKNOWLEDGMENTS

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INTRODUCTION AND PROJECT OBJECTIVES

Although *Caulanthus californicus* (S. Watson) Payson and *Lembertia congdonii* (Gray) E. Greene are federally listed as endangered species, and *Eriastrum hooveri* (Jepson) H. Mason is federally listed as threatened (U.S. Department of the Interior, Fish and Wildlife Service 1990), little is known about the biology, demography, and management needs of these plant species. Field studies in the San Joaquin Valley of California and adjacent areas were conducted in Spring 1993 in order to (1) monitor the survival, growth, and reproduction of these species in various parts of their ranges and under different grazing conditions, (2) determine baseline population size so population trends can be correlated with future weather cycles and grazing regimes, (3) evaluate the association of endangered plants with the endangered giant kangaroo rat (*Dipodomys ingens*), and (4) describe the habitat of listed plant and animal species. Information on the relative performance of each species under the observed grazing regimes, the role of giant kangaroo rats in rare plant growth and reproduction, and the effect of plant community composition on species occurrence will be incorporated into a comprehensive recovery plan. Additionally, data from the Carrizo Plain Natural Area (CPNA) in San Luis Obispo County, California, will be valuable for determining strategies for restoring native vegetation in that area, which has been degraded due to farming and ranching operations over many decades, and more recently, due to drought.

METHODS

Demography

Demographic studies were conducted at 6 sites on the CPNA and 8 sites throughout the San Joaquin Valley (Figure 1, Appendix A). Populations of the listed plants were chosen for monitoring from among known localities based on (1) avoiding conflict with other research programs, (2) opportunity for comparison of different site conditions (*e.g.*, cattle grazing, occurrence of giant kangaroo rats), (3) distribution throughout the known range of each species, and (4) site accessibility.

Individual plants for study were selected randomly in one of two ways, depending on overall population size. In populations totalling 250 individuals or fewer (*Caulanthus californicus* at Sites 10 and 11, *Lembertia congdonii* at Sites 9 and 14), all plants were numbered individually, then 50 were chosen with the aid of a random number table. At the remaining sites, plants were located by pacing random distances along transects spaced 10 m apart within the population, then the closest individual of the target species to the random point was located. Circular 0.25 m^2 sampling plots were established that included the closest individual and any others within a 0.28 m radius. In plots containing more than three individuals, three were selected randomly and marked for intensive monitoring.

Few individuals of *C. californicus* were found off-precinct at Site 1 by the random process described above. Therefore, a modified method was used to select plants for

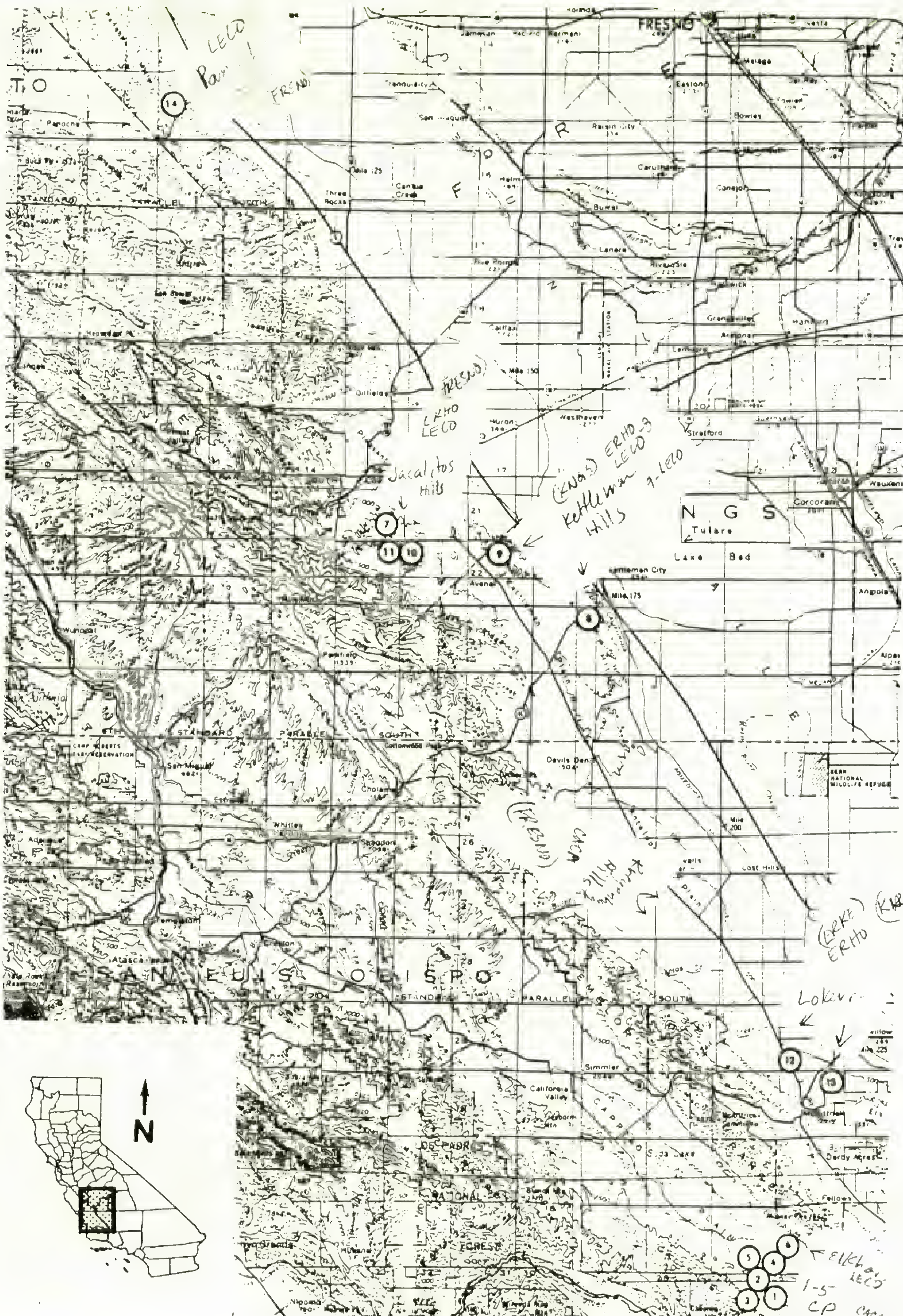

Figure 1. Approximate locations of study sites in the San Joaquin Valley, California, and adjacent areas that were used for demographic monitoring of four listed plant species in Spring 1993.

monitoring at Site 2. From each random point, the nearest *C. californicus* individual on a precinct was located and searching continued until the nearest plant off-precinct also was located. Time constraints did not permit re-marking of plants at Site 1 by the modified method.

Data collected biweekly on each marked individual included rosette diameter (in *Caulanthus californicus*), maximum stem height/length; number of stems, buds, flowers, and fruits; fruit length (*C. californicus*); and number of seeds/carpels per mature fruit (*C. californicus* and *E. hooveri*) or number of mature achenes per head (*L. congdonii*). Causes of mortality and/or damage to plant parts also were noted at each visit. Damage was attributed to cattle, insects, and/or kangaroo rats if signs indicated their presence (e.g., cattle hoof prints or droppings, small holes chewed by insects, kangaroo rat scats or burrows); otherwise, damage was recorded as due to unknown causes. Although all of the intensively-studied species were annuals and were therefore expected to die by the end of the growing season, marked individuals were considered to have survived if they persisted long enough to set seed.

Population Trends

Long-term monitoring will allow population sizes to be correlated with annual environmental variation and habitat management. Total counts were obtained in populations of *C. californicus* used for demographic studies. However, populations of *E. hooveri* and *L. congdonii* were too large for complete censuses, so density was estimated instead. Density was estimated by counting individuals of the target species in a 50 x 1 m belt centered on the vegetation transect (see "Habitat Characterization"). In extremely dense populations, one subsample was obtained per square meter in randomly-placed plots measuring 0.5 m x 0.2 m. Statistical analyses were not conducted on densities.

Grazing Effects

Time constraints prohibited controlled grazing studies in Spring 1993. Instead, demographic monitoring was carried out in several populations that were divided into grazed and ungrazed portions by fences; plant size and demographic variables then were compared within populations with respect to grazing. Two sites on the CPNA (#4 and #6) that were subject to cattle grazing from February through April 1993 met this criterion, and both supported *L. congdonii*. A third such site in the Kettleman Hills (#8) included both *E. hooveri* and *L. congdonii*. Known populations of *C. californicus* were not grazed during the flowering season in 1993.

Endangered Plant-Giant Kangaroo Rat Associations

Associations between *Caulanthus californicus* or *Lembertia congdonii* and giant kangaroo rats were investigated at Sites 1, 2, and 4 on the Carrizo Plain, where the animals occur in dense colonies. Giant kangaroo rats modify their habitat extensively by burrowing in the soil, clipping vegetation, and collecting seed (Williams and Kilburn 1991). Their burrows are concentrated into roughly circular areas known as precincts (Grinnell 1932), whereas the areas between precincts are known as interspaces or "off-precinct." For the purposes of this study, the outer margin of a precinct was delimited by the openings of converging horizontal burrows and their associated ramps. The delimited area was conclusively determined to be a precinct if the surface exhibited mounding, openings of vertical burrows, and/or accumulations of seed. Interspaces were defined as undisturbed areas between burrows that led in opposite directions. Areas in the vicinity of isolated burrows that exhibited no characteristic signs of giant kangaroo rat activity were classified as unknown.

Frequency of occurrence of rare plant individuals on precincts was compared to that of random points to determine whether or not the plants occurred disproportionately on precincts. All individuals of *C. californicus* in the two monitored populations were inspected to determine if they were growing on precincts. Occurrence of *L. congdonii* on precincts was determined during the process of evaluating random points. Placement of random points was determined by selecting a number of paces from a random-number table, then pacing along transects that were spaced 10 m apart within the limits of the population. The number of random points was not determined in advance, but instead depended on the size of the random numbers relative to the extent of each population. Each random point was classified as occurring on a precinct or in an interspace. At Site 4, after a random point was identified, the nearest individual of *L. congdonii* was located and evaluated in terms of occurrence on a precinct.

Individual plants of both species were monitored on giant kangaroo rat precincts and in interspaces in conjunction with demographic studies to compare survival, size, and reproduction with respect to giant kangaroo rat activity.

Habitat Characterization

Plant communities supporting listed plant and animal species were characterized using the vegetation sampling procedure established by the California Native Plant Society (1993). Consistent with this method, point-intercepts spaced at 50-cm intervals along a 50-m transect were used to determine percent cover for each vascular plant species in each stratum. In addition, all plant species occurring within a 2.5-m belt along each side of the transect were recorded; site information such as elevation, slope and aspect were noted; and photographs were taken from each end of the transect. More than one transect was established in certain populations that varied in grazing treatment or topography. At the CPNA, vegetation was sampled in populations of the three listed plants already mentioned, as well as in populations of *Dipodomys ingens* and *Gambelia sila*. Transects also were placed in populations of other federally-listed plant and animal species in the San Joaquin Valley and adjacent foothills (Figure 2, Appendix B).

Plant community type was determined for each transect based on dominant species and site location (Holland 1986). Species identifications were determined using the Jepson Manual (Hickman 1993) and local floras (Twisselmann 1956, Hoover 1970).

Data Analyses

Nonparametric statistics were used to compare quantitative data because the variables were not normally distributed and neither variances nor sample sizes were equal. Single-factor comparisons employed the Mann-Whitney test for paired samples and the Kruskal-Wallis test for three or more samples; the resulting statistics were then converted to an approximate Chi-square value. For simultaneous analyses of two or more factors, raw data were ranked and then standard analysis of variance techniques were performed on the ranks (Zar 1984). Linear regression was not attempted because the data did not meet the necessary assumptions, even after transformation.

Contingency table analysis employing a Chi-square statistic was used to compare frequency data such as survival or occurrence on precincts; 2 x 2 contingency table analysis included Yates correction for continuity. Correlations between variables were calculated using Spearman's rank correlation coefficient, a nonparametric technique. Maximum values of diameter, height, and number of stems for each individual were used in statistical analyses. Total flower production was estimated by summing the number of buds, flowers, and fruits on each plant at each visit; the maximum value per plant was used for statistical analyses.

The Shannon Diversity Index was calculated for each vegetation transect using natural logarithms (Brower and Zar 1984, Zar 1984). Because this index incorporates both species richness and abundance, only those species that were intercepted on the transect were included in the calculations. Data were pooled over all strata for each transect. Cover values were relativized for analyses by transect, but raw (absolute) cover values were used for comparisons by plant species.

Coordination with Dr. Paula Schiffman

In order to ensure consistency, standardized vegetation sampling techniques were agreed upon and practiced jointly prior to data collection. Moreover, to maximize data collection and avoid overlap, the two research groups focused on different locations within the CPNA. Employees of the San Joaquin Valley Endangered Species Recovery

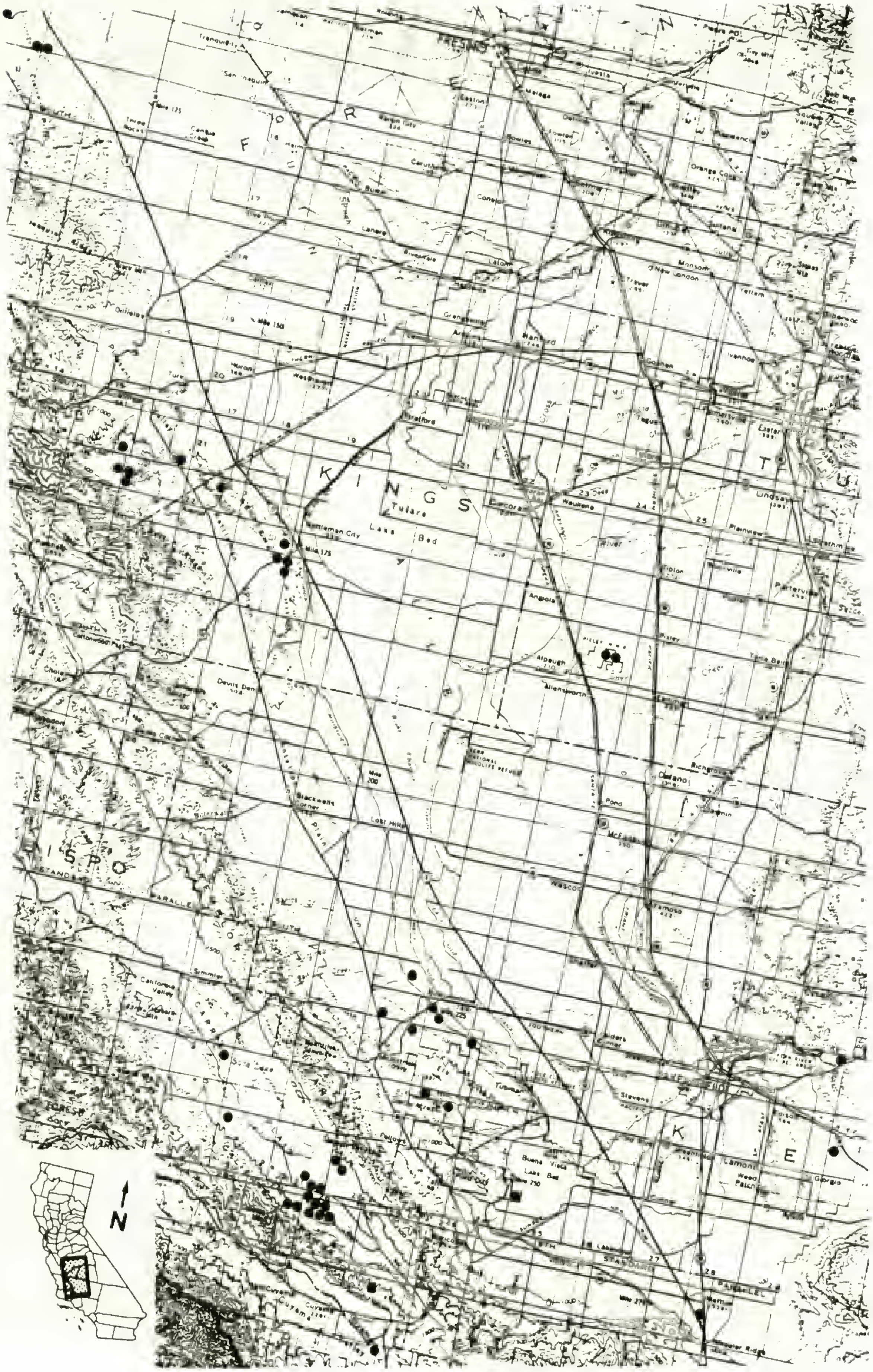

Figure 2. Approximate locations of vegetation transects sampled in Spring 1993 in the San Joaquin Valley and adjacent areas, California.

Planning Program concentrated on sampling in known populations of listed plant and animal species, whereas Dr. Schiffman directed her sampling to common vegetation associations. However endangered animals, particularly *Dipodomys ingens*, may have been present in the latter areas. Finally, copies of all transect data sheets and maps, as well as a computer file on diskette, were provided to Dr. Schiffman after the field season had ended.

RESULTS

Data collection began on 15 February 1993, when the *C. californicus* and *L. congdonii* populations on the Carrizo and Elkhorn Plains were in the seedling and/or rosette stages, and *E. hooveri* seeds had not yet germinated. Monitoring continued through senescence of all marked individuals. The last day of data collection was for monitoring of *E. hooveri* on 8 June 1993. Data on rare plant occurrence on giant kangaroo rat precincts were collected from 8 April through 10 May 1993.

Factors responsible for mortality were not readily apparent in most monitored populations. Typically, plants were alive at one visit and dead or missing on subsequent visits. Primary causes of damage to marked plants were noted when known, but these agents may or may not have contributed to plant mortality. A combination of age, heat, and water stress most likely was responsible for the death of many plants.

Caulanthus californicus

Plants from the two Carrizo Plains populations were significantly greater in most measurements of size and fecundity than those from the Kreyenhagen Hills (Table 1). When all four populations were compared, the two from the Carrizo Plain differed significantly from each other in rosette diameter, number of stems, and total flower production. The two Kreyenhagen Hills populations differed from each other in plant height and flower production. Competition from other herbs may not have been related to successful growth and reproduction of *C. californicus* because the herbaceous cover was similar on three sites that encompassed the range of plant size and fruit production.

Plants on the CPNA were subject to burial under loose soil and/or stem clipping by giant kangaroo rats, but damaged *C. californicus* individuals typically produced new shoots from the rosette. Plants in the Kreyenhagen Hills also showed damage to the stems and leaves, but the source could not be determined. Flowering and fruiting in the Kreyenhagen Hills occurred several weeks earlier than on the Carrizo Plain, which is approximately 300 m higher in elevation.

Table 1. Comparison of attributes among four *Caulanthus californicus* populations (see Appendix A for exact locations). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

POPULATION		CARRIZO PLAIN		KREYENHAGEN HILLS	
		#1 (n = 66)	#2 (n = 56)	#10 (n = 50)	#11 (n = 52)
Number surviving to fruiting		42/66[a] (63.6%)	37/56[a] (66.1%)	N/A[1]	N/A
Number damaged by	giant kangaroo rats	25/66[a] (37.9%)	27/56[a] (48.2%)	0/50[b] (0%)	0/50[b] (0%)
	insects	3/66[a] (4.5%)	6/56[a] (10.7%)	0/50[a] (0%)	2/52[a] (3.8%)
	unknown sources	0/66[a] (0%)	0/56[a] (0%)	7/50[b] (14.0%)	5/52[b] (9.6%)
Rosette diameter (cm)		8.15[a] ± 0.76	5.55[b] ± 0.49	1.22[c] ± 0.35	0.35[c] ± 0.16
Height (cm)		24.99[a] ± 1.96	18.65[a,b] ± 1.81	10.09[c] ± 0.80	15.16[b] ± 0.75
Number of stems		3.46[a] ± 0.35	1.98[b] ± 0.25	1.48[b] ± 0.15	1.15[b] ± 0.10
Total flower production		73.30[a] ± 19.21	36.25[b] ± 9.72	8.16[c] ± 1.76	10.39[b] ± 1.35
Fruit length (cm)		3.71[a] ± 0.18 (n = 129)	3.14[a] ± 0.14 (n = 34)	1.61[b] ± 0.23 (n = 10)	2.05[b] ± 0.12 (n = 38)
Number of seeds per fruit		40.33[a] ± 2.28 (n = 129)	27.53[a] ± 2.34 (n = 34)	8.80[b] ± 3.60 (n = 10)	12.66[b] ± 1.72 (n = 38)
Date flowers first observed in 1993		18 March	18 March	(9 March)[2]	(9 March)[2]
Date mature fruits first observed in 1993		7 April	7 April	(9 March)[2]	(9 March)[2]
Population size		494	1490	225	197
Herbaceous cover (%)		94	85	96	95-97

[a] Means followed by the same letter are not significantly different at $P = 0.05$.
[1] Not calculated due to missing data.
[2] Flowering and/or fruiting well advanced at date of first visit.

Caulanthus californicus individuals were significantly associated with giant kangaroo rat precincts on the Carrizo Plain (Tables 2 and 3). A number of plants at Site 2 were omitted from the analysis because their occurrence on or off precincts could not be determined with certainty. Giant kangaroo rats were not present at the Kreyenhagen Hills sites. Few attributes differed significantly on versus off precincts in either Carrizo Plain population (Tables 2 and 3). Rosette diameter at Site 2 was significantly greater off precinct, and at $\alpha = 0.10$, survival of *C. californicus* individuals at Site 1 was significantly higher on precincts than off. However, clipping of plant parts by giant kangaroo rats did not differ significantly with respect to precincts. Variability between sites accounted for the majority of differences between the two populations (Table 4). When differences due to occurrence on precincts were factored out, fruit length and number of seeds per fruit differed significantly between Sites 1 and 2 (Table 4), which had not been evident when all four populations were compared without respect to precincts (Table 1). Site-by-precinct interactions were not significant, with the possible exception of rosette diameter (Table 4).

Eriastrum hooveri

Survival, height, and flower production in *E. hooveri* were significantly lower on the Carrizo Plain than at all of the other sites (Table 5). Virtually all of the plants at all sites had a single stem, although some individuals did branch. Therefore, data for number of stems are not presented. *Eriastrum hooveri* plants did not resprout following stem breakage due to trampling or herbivory by cattle, rodents, or insects. However, physical damage and competition from species other than *Eriastrum* probably were not responsible for the high mortality rate at the Carrizo Plain site because both were comparatively low. Instead, mortality at Site 3 may have been primarily density-dependent. Fresno, Kern, and Kings County populations flowered and produced fruit well in advance of the population in San Luis Obispo County. The elevation at Site 3 is 400-600 m higher than at the other *E. hooveri* study sites.

Several problems were encountered at Site 3, which contained a mixture of three *Eriastrum* species. The final sample size was small because fewer than half of the marked individuals proved to be *E. hooveri*. In addition, the density estimate was invalid because it was obtained prior to flowering and may have included stems of other species. Similarly, Site 13 included both *E. hooveri* and *E. pluriflorum*. However, data collection was not compromised because no individuals of the latter species had been marked, and density was estimated while the plants were in flower.

At Kettleman Hills Site 8, where *E. hooveri* was monitored in both grazed and ungrazed areas, no significant differences in survival, size, or reproduction were found at the 0.05 level (Table 6). However, the data suggest that (1) survival was higher in the grazed area, (2) plants were taller in the ungrazed area, and (3) fecundity did not differ due to grazing. Sources of damage differed significantly between the grazed and

Table 2. Comparison of *Caulanthus californicus* attributes on vs. off giant kangaroo rat precincts at Site 1 on the Carrizo Plain, San Luis Obispo County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

LOCATION RELATIVE TO PRECINCT		ON (n = 44)	OFF (n = 15)	X^2	P
Number surviving to fruiting		31/44 (70.5%)	6/15 (40.0%)	3.23	0.072
Number damaged by	giant kangaroo rats	15/44 (34.1%)	7/15 (46.7%)	0.31	0.575
	insects	1/44 (2.3%)	1/15 (6.7%)	0.00	0.989
Rosette diameter (cm)		7.84 ± 0.90	8.35 ± 1.72	0.07	0.787
Height (cm)		25.24 ± 2.23	20.31 ± 3.96	2.24	0.134
Number of stems		3.48 ± 0.47	3.53 ± 0.64	0.17	0.678
Total flower production		81.57 ± 27.46	51.47 ± 22.90	0.80	0.370
Fruit length (cm)		3.57 ± 0.18 (n = 60)	3.70 ± 0.19 (n = 32)	0.91	0.339
Number of seeds per fruit		40.87 ± 4.02 (n = 60)	46.03 ± 3.66 (n = 32)	2.31	0.128
Number of occurrences	*C. californicus*	288/494 (58.3%)	206/494 (41.7%)	5.64	0.018
	Random points	16/42 (38.1%)	26/42 (61.9%)		

Table 3. Comparison of *Caulanthus californicus* attributes on vs. off giant kangaroo rat precincts at Site 2 on the Carrizo Plain, San Luis Obispo County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

LOCATION RELATIVE TO PRECINCT		ON (n = 26)	OFF (n = 27)	X^2	P
Number surviving to fruiting		16/26 (61.5%)	19/27 (70.4%)	0.15	0.698
Number damaged by	giant kangaroo rats	16/26 (61.5%)	11/27 (40.7%)	1.54	0.215
	insects	3/26 (11.5%)	3/27 (7.4%)	0.15	0.701
Rosette diameter (cm)		4.45 ± 0.55	6.70 ± 0.81	4.79	0.029
Height (cm)		17.82 ± 2.30	19.73 ± 2.88	0.06	0.803
Number of stems		1.81 ± 0.32	2.22 ± 0.40	0.65	0.420
Total flower production		26.27 ± 10.42	45.82 ± 17.25	0.48	0.483
Fruit length (cm)		3.00 ± 0.19 (n = 14)	3.08 ± 0.17 (n = 18)	0.58	0.446
Number of seeds per fruit		27.86 ± 3.10 (n = 14)	24.83 ± 3.06 (n = 18)	0.52	0.470
Number of occurrences	*C. californicus*	766/1340 (57.2%)	574/1340 (42.8%)	9.28	0.002
	Random points	7/27 (25.9%)	20/27 (74.1%)		

Table 4. Results of nonparametric analysis of variance for *Caulanthus californicus* at Carrizo Plain Sites 1 and 2, on and off giant kangaroo rat precincts. See Appendix A for exact site locations.

FACTOR	df	SITE		PRECINCT		SITE x PRECINCT INTERACTION	
		F	*P*	*F*	*P*	*F*	*P*
Rosette diameter	1,108	3.46	0.066	1.75	0.189	3.05	0.084
Height	1,108	1.48	0.226	0.76	0.385	1.85	0.177
Number of stems	1,108	10.21	0.002	0.77	0.383	0.01	0.907
Total flower production	1,108	5.03	0.027	0.01	0.946	1.57	0.212
Fruit length	1,120	6.73	0.011	1.14	0.288	0.10	0.751
Number of seeds per fruit	1,120	10.15	0.002	0.34	0.561	2.09	0.151

Table 5. Comparison of attributes among four *Eriastrum hooveri* populations (see Appendix A for exact locations). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

POPULATION		CARRIZO PLAIN #3 (n = 27)	JACALITOS HILLS #7 (n = 55)	KETTLEMAN HILLS #8 (n = 65)	LOKERN #13 (n = 130)
Number surviving to fruiting		7/27^{a} (25.9%)	41/55^{b} (74.5%)	41/65^{b,c} (63.1%)	75/130^{c} (57.7%)
Number damaged by	cattle trampling	0/27^{a,c} (0%)	6/55^{a} (10.9%)	18/65^{b} (27.7%)	0/130^{c} (0%)
Number damaged by	rodents	0/27^{a} (0%)	0/55^{a} (0%)	13/65^{b} (20.0%)	29/130^{b} (22.3%)
Number damaged by	unknown sources	2/27^{a} (7.4%)	5/55^{a} (9.1%)	6/65^{a} (9.2%)	4/130^{a} (3.1%)
Height (cm)		2.52^{a} ± 0.23	6.30^{b} ± 0.37	5.15^{b} ± 0.30	5.86^{b} ± 0.30
Total flower production		2.81^{a} ± 0.60	8.46^{b} ± 1.06	8.20^{b} ± 0.96	11.18^{b} ± 1.37
Number of seeds per fruit		N/A	8.05^{a} ± 0.46 (n = 37)	6.34^{a} ± 0.26 (n = 64)	7.85^{a} ± 0.49 (n = 124)
Date flowers first observed in 1993		23 April	31 March	24 March	5 April
Date fruits first observed in 1993		20 May	15 April	13 April	19 April
Population size		ca. 10,500[2]	< 10,000	ca. 10,000[2]	< 10,000
E. hooveri density (plants/m^2)		(69.4)[3]	9.20	1.70[4] 2.82 26.40	8.40
Herbaceous cover (%)		66-89	96	89-98	88-96

[a] Means followed by the same letter are not significantly different at P = 0.05.
[1] Not calculated due to missing data.
[2] Estimate from Lewis (1992).
[3] Density estimate may include stems of *E. pluriflorum* and *E. diffusum*.
[4] Three belts sampled within population.

Table 6. Comparison of *Eriastrum hooveri* attributes in grazed vs. ungrazed areas at Site 8 in the Kettleman Hills, Kings County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

SITE GRAZING REGIME IN 1993		GRAZED (n = 32)	UNGRAZED (n = 33)	X^2	P
Number surviving to fruiting		24/32 (75.0%)	17/33 (51.5%)	2.91	0.088
Number damaged by	cattle trampling	18/32 (56.3%)	0/33 (0%)	22.94	0.000
	rodents	0/32 (0%)	13/33 (39.4%)	13.39	0.000
	unknown sources	0/32 (0%)	6/33 (18.2%)	4.42	0.035
Height (cm)		4.53 ± 0.31	5.74 ± 0.49	3.65	0.056
Total flower production		8.38 ± 1.37	8.03 ± 1.36	0.08	0.772
Number of seeds per fruit		6.42 ± 0.33 (n = 38)	6.23 ± 0.43 (n = 26)	0.23	0.630
E. hooveri density in belt transect (plants/m^2)		2.82	1.70[1] 26.40	*	*
Herbaceous cover (%)		89	96-98	*	*

[1] Two belts sampled within ungrazed population.

* Not tested.

ungrazed areas, with the primary factors being cattle trampling and rodent clipping, respectively. Damage rates were higher than mortality rates because plants that were damaged after setting seed were considered to have survived to reproduction. The reduced vegetation cover in the grazed area may have contributed to the greater survival rates and shorter plants. Conversely, competition from the tall, dense herbaceous cover in the ungrazed area may have led to greater mortality of *E. hooveri* but taller growth of the surviving individuals. Density estimates were not instructive due to their extreme variability, even with respect to a given grazing treatment.

<u>*Lembertia congdonii*</u>

Lembertia congdonii stems grew both upright and prostrate; therefore, maximum stem length rather than height was used as an index of size. Significant damage to marked *L. congdonii* plants was caused by kangaroo rats (*Dipodomys* spp.), cattle, and unknown herbivores (Table 7). However, the plants typically produced additional stems to replace those lost to herbivory and/or trampling, and thus damage was not directly related to mortality. Of the five general areas where *L. congdonii* was studied, the Carrizo Plain, Elkhorn Plain, and Kettleman Hills all exhibited exceptional plant size and flower head production compared to the Jacalitos and Panoche Hills (Table 7). However, achene production at Site 8 in the Kettleman Hills significantly exceeded all other sites. Flowering and fruiting of plants in the northern populations preceded those in the southern populations because the former are several hundred meters lower in elevation. The number of individuals varied greatly among populations, with the fewest at Sites 7, 9, and 14. On the Carrizo and Elkhorn Plains, *Lembertia congdonii* was essentially continuous, with the combined populations representing millions of plants (Lewis 1993). Most *L. congdonii* populations senesced before density estimates could be obtained. Herbaceous cover was fairly consistent over all of the study sites. Heavy grazing may have reduced herbaceous cover as well as *L. congdonii* size and reproduction at Site 14 in the Panoche Hills.

Grazing did not affect performance of *L. congdonii* predictably in the divided populations studied (Tables 8-10). Survival did not differ significantly between grazed and ungrazed areas at Sites 4 and 6. Plants at Site 8 were marked too late in the season to evaluate survival. Maximum stem length, number of stems, and flower head production in grazed areas were equal to or greater than in the corresponding ungrazed areas at each of the three sites. The number of achenes per head was not significantly affected by grazing at Site 4, negatively affected at Site 6, and positively affected at Site 8. Trampling by cattle was a significant cause of damage only at Site 4 on the CPNA. Percent cover of herbaceous vegetation was similar over all sites and between grazed and ungrazed portions. Considering both statistical significance and observed trends, grazing seems to have been beneficial to *L. congdonii* reproduction on the Carrizo Plain and in the Kettleman Hills, but was neutral or detrimental on the Elkhorn Plain.

Table 7. Comparison of attributes among seven *Lembertia congdonii* populations in Spring 1993 (see Appendix A for exact locations). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

POPULATION		CARRIZO PLAIN		ELKHORN PLAIN	JACALITOS HILLS	KETTLEMAN HILLS		PANOCHE HILLS
		#4 (n = 155)	#5 (n = 18)	#6 (n = 191)	#7 (n = 30)	#8 (n = 51)	#9 (n = 71)	#14 (n = 74)
Number surviving to fruiting		116/155^{a} (74.8%)	N/A[1]	149/191^{a} (78.0%)	N/A	N/A	N/A	N/A
Number damaged by	cattle trampling	16/155^{a} (10.3%)	4/18^{a} (22.2%)	4/191^{b} (2.1%)	0/30^{b} (0%)	1/51^{b} (2.0%)	0/71^{b} (0%)	11/74^{a} (14.9%)
	insects	0/155^{a} (0%)	0/18^{a} (0%)	3/191^{a} (1.6%)	0/30^{a} (0%)	0/51^{a} (0%)	1/71^{a} (1.4%)	1/74^{a} (1.4%)
	rodents	41/155^{a} (26.5%)	0/18^{b,c} (0%)	49/191^{a} (25.7%)	3/30^{b} (10%)	0/51^{b,c} (0%)	33/71^{d} (46.5%)	0/74^{c} (0%)
	unknown sources	13/155^{a,b} (8.4%)	3/18^{a,c} (16.7%)	6/191^{b,d} (3.1%)	1/30^{a,b,d} (3.3%)	2/51^{a,b,d} (3.9%)	0/71^{d} (0%)	17/74^{c} (23.0%)
Maximum stem length (cm)		17.86^{a} ± 0.91	23.23^{a,b} ± 3.01	15.61^{a} ± 0.72	7.04^{c} ± 0.75	26.56^{b} ± 1.34	23.60^{a,b} ± 1.55	9.04^{c} ± 0.52
Number of stems		4.59^{a,b} ± 0.53	3.83^{a,b,c} ± 0.54	5.30^{a} ± 0.24	2.30^{c,d} ± 0.26	4.28^{a,b} ± 0.33	3.18^{b,d,e} ± 0.24	2.73^{c,e} ± 0.18
Total flower head production		49.87^{a,b} ± 5.93	31.78$^{a\text{-}d}$ ± 10.95	60.86^{a} ± 5.61	5.90^{c,d} ± 0.98	40.77^{a,b} ± 5.70	32.17^{b,e} ± 6.12	11.47^{d,e} ± 1.33
Number of achenes per head		14.01^{a} ± 0.20 (n = 276)	14.07^{a} ± 0.86 (n = 27)	14.94^{a} ± 0.18 (n = 482)	13.43^{a} ± 3.01 (n = 7)	20.11^{b} ± 0.99 (n = 38)	13.98^{a} ± 0.46 (n = 89)	8.61^{c} ± 0.63 (n = 36)
Date flowers first observed		19 March	(29 March)[2]	12 March	(31 March)[2]	(26 March)[2]	(22 March)[2]	(7 April)[2]
Date fruits first observed		15 April	12 April	13 April	(31 March)[2]	(26 March)[2]	(22 March)[2]	(7 April)[2]
Population size		ca. 26,000[3]	ca. 2 million[3]	ca. 2,000[3]	72	ca. 10,000[3]	155	350
Herbaceous cover (%)		93-97	93	94-99	96	96-99	92	83-92

Footnotes to Table 7.

[a] Means followed by the same letter are not significantly different at $P = 0.05$.
[1] Not calculated due to missing data.
[2] Flowering and/or fruiting well advanced at date of first visit.
[3] Estimate from Lewis (1993).

Table 8. Comparison of *Lembertia congdonii* attributes in grazed vs. ungrazed areas at Site 4 on the Carrizo Plain, San Luis Obispo County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

SITE GRAZING REGIME IN 1993		GRAZED (n = 78)	UNGRAZED (n = 77)	X^2	P
Number surviving to fruiting		59/78 (75.6%)	57/77 (74.0%)	0.002	0.963
Number damaged by	cattle trampling	16/78 (20.5%)	0/77 (0%)	15.47	0.001
	kangaroo rats	23/78 (29.5%)	18/77 (23.4%)	0.46	0.496
	unknown sources	3/78 (3.8%)	10/77 (13.0%)	3.11	0.078
Maximum stem length (cm)		17.46 ± 1.19	18.26 ± 1.38	0.08	0.777
Number of stems		5.26 ± 0.41	3.91 ± 0.33	5.00	0.025
Total flower head production		66.58 ± 10.17	32.94 ± 5.46	8.71	0.003
Number of achenes per head		14.16 ± 0.25 (n = 167)	13.79 ± 0.32 (n = 109)	2.05	0.152
L. congdonii density in belt transect (plants/m^2)		3.88	2.62	*	*
Herbaceous cover (%)		93	97	*	*

* Not tested.

Table 9. Comparison of *Lembertia congdonii* attributes in grazed vs. ungrazed areas at Site 6 on the Elkhorn Plain San Luis Obispo County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses. F values are from within-site precinct-by-grazing nonparametric analysis of variance.

SITE GRAZING REGIME IN 1993		GRAZED (n = 104)	UNGRAZED (n = 87)	X^2	P
Number surviving to fruiting		81/104 (77.9%)	68/87 (78.2%)	0.02	0.897
Number damaged by	cattle trampling	4/104 (3.8%)	0/87 (0%)	1.80	0.180
	insects	2/104 (1.9%)	1/87 (1.1%)	0.02	0.876
	kangaroo rats	21/104 (20.2%)	28/87 (32.2%)	2.97	0.085
	unknown sources	2/104 (1.9%)	4/87 (4.6%)	0.41	0.523
Maximum stem length (cm)		16.09 ± 0.97	15.05 ± 1.07	0.55	0.458
Number of stems		5.66 ± 0.32	4.87 ± 0.36	3.00	0.083
Total flower head production		64.38 ± 7.63	56.66 ± 8.31	3.05	0.081
Number of achenes per head		14.09 ± 0.22 (n = 283)	16.10 ± 0.27 (n = 200)	30.59	0.000
Herbaceous cover (%)		99	94	*	*

* Not tested.

Table 10. Comparison of *Lembertia congdonii* attributes in grazed vs. ungrazed areas at Site 8 in the Kettleman Hills, Kings County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

SITE GRAZING REGIME IN 1993		GRAZED (n = 23)	UNGRAZED (n = 28)	X^2	P
Number damaged by	cattle trampling	1/23 (4.3%)	0/28 (0%)	*	*
	unknown sources	1/23 (4.3%)	1/28 (3.6%)	*	*
Maximum stem length (cm)		29.16 ± 2.14	24.42 ± 1.60	3.55	0.060
Number of stems		4.09 ± 0.46	4.43 ± 0.48	0.18	0.670
Total flower head production		49.04 ± 10.31	33.96 ± 5.90	0.56	0.454
Number of achenes per head		23.05 ± 1.05 (n = 21)	16.47 ± 1.37 (n = 17)	9.69	0.002
Herbaceous cover (%)		99	96-99	*	*

* Number of occurrences or sample sizes too small to perform test.

Survival, size, and reproduction of *L. congdonii* were investigated on giant kangaroo rat precincts and in interspaces at Sites 4 and 6 on the Carrizo and Elkhorn Plains, respectively. Plants growing on precincts were subject to significantly more damage from giant kangaroo rat activity (e.g., clipping, burial under loose dirt) than those in interspaces (Tables 11 and 12). However, survival was not affected by clipping because damaged plants generally persisted long enough to set seed. Plant success relative to occurrence on precincts differed between the two sites (site-by-precinct interaction; Table 13). Precincts did not significantly affect size of *L. congdonii* at the Carrizo Plain site (Table 11), but on the Elkhorn Plain individuals growing on precincts were larger, had more stems, and produced more heads than those between precincts (Table 12). Frequency of occurrence of *L. congdonii* on precincts was determined only at Site 4, where individuals were randomly distributed with respect to precincts (Table 11). Observations suggested that a similar distribution pattern occurred at Site 6 on the Elkhorn Plain.

The three-way interaction between sites, grazing, and precincts on the CPNA was significant for several *L. congdonii* variables (Table 11). Means for each cell are not presented, but inspection indicated that the highest mean values over all attributes were at the Elkhorn Plain, on precincts, in the grazed area. Low means were found under two combinations of conditions: (1) on the Elkhorn Plain, off precincts, in the ungrazed area, and (2) on the Carrizo Plain, on precincts, in the ungrazed area.

Habitat Characterization

Vegetation sampling was conducted on 19 transects on the CPNA and on 43 transects in other areas (Appendices B and C). Overall, vascular plant cover was high in 1993, and non-vegetated areas of bare soil or plant litter often were associated with kangaroo rat (*Dipodomys* spp.) activity. Cryptogams (*e.g.,* moss, lichen, algae) were not often recorded on the transects. However, the low cover percentage of cryptogamic crust was to some extent an artifact of the sampling procedure, in which non-vascular plants were recorded only if the pointer did not hit living vascular plants or plant litter. On the sampled transects, the proportion of exotic plant species ranged from 16.2% in the Kreyenhagen Hills to 51.9% in the Panoche Hills and was 28.1% on the CPNA.

Cover and composition values were averaged over all transects that supported each listed species (Table 14). Transects in *C. californicus* populations had the greatest species richness and contained the lowest proportion of exotic plants. *Opuntia basilaris* var. *treleasei* occupied the most sparsely-vegetated sites. Listed species often were found in vegetation associations dominated by a particular plant species. Of the 14 transects in *C. californicus* populations, 8 were dominated by *Vulpia myuros* and 3 by *V. microstachys*. *Eriastrum hooveri, Lembertia congdonii*, and *Gambelia sila* often occurred together, and the majority of sites were dominated by *V. myuros, Schismus* spp., and/or *Bromus madritensis* ssp. *rubens*. Transects in *Eremalche parryi* ssp. *kernensis* and *Opuntia basilaris*

Table 11. Comparison of *Lembertia congdonii* attributes on vs. off giant kangaroo rat precincts at Site 4 on the Carrizo Plain, San Luis Obispo County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

LOCATION RELATIVE TO PRECINCT		ON (n = 72)	OFF (n = 50)	X^2	P
Number surviving to fruiting		54/72 (75.0%)	38/50 (76.0%)	0.01	0.930
Number damaged by	cattle trampling	5/72 (6.9%)	7/50 (14.0%)	0.96	0.328
	kangaroo rats	26/72 (36.1%)	7/50 (14.0%)	6.23	0.013
	unknown sources	3/72 (4.2%)	7/50 (14.0%)	2.60	0.107
Maximum stem length (cm)		17.55 ± 1.24	17.62 ± 1.72	0.00	0.963
Number of stems		4.83 ± 0.41	4.24 ± 0.40	0.48	0.489
Total flower head production		38.78 ± 6.18	54.92 ± 11.12	0.38	0.535
Number of achenes per head		14.05 ± 0.31 (n = 114)	14.31 ± 0.31 (n = 101)	0.31	0.577
Number of occurrences	*L. congdonii*	71/140 (50.7%)	69/140 (49.3%)	0.22	0.639
	Random points	68/144 (47.2%)	76/144 (52.8%)		

Table 12. Comparison of *Lembertia congdonii* attributes on vs. off giant kangaroo rat precincts at Site 6 on the Elkhorn Plain, San Luis Obispo County, California (see Appendix A for exact location). Means are shown ± standard error. Sample size is as indicated at the top of each column unless given in parentheses.

LOCATION RELATIVE TO PRECINCT		ON (n = 55)	OFF (n = 73)	X^2	P
Number surviving to fruiting		47/55 (85.5%)	54/73 (74.0%)	1.84	0.175
Number damaged by	cattle trampling	3/55 (5.5%)	1/73 (1.4%)	0.64	0.423
	insects	2/55 (3.6%)	1/73 (1.4%)	0.06	0.803
	kangaroo rats	27/55 (49.1%)	22/73 (30.1%)	4.00	0.045
	unknown sources	4/55 (7.3%)	1/73 (1.4%)	1.55	0.213
Maximum stem length (cm)		22.15 ± 1.33	11.18 ± 0.89	35.83	0.000
Number of stems		6.72 ± 0.47	4.26 ± 0.32	16.84	0.000
Total flower head production		98.35 ± 14.02	33.45 ± 4.87	23.25	0.000
Number of achenes per head		14.88 ± 0.21 (n = 301)	15.60 ± 0.40 (n = 126)	1.94	0.164

Table 13. Results of nonparametric analysis of variance for *Lembertia congdonii* at Sites 4 and 6 on the Carrizo and Elkhorn Plains, on and off giant kangaroo rat precincts, in grazed and ungrazed areas. See Appendix A for exact site locations.

FACTOR	df	SITE		PRECINCT		GRAZING		INTERACTIONS							
								SITE x PRECINCT		SITE x GRAZING		PRECINCT x GRAZING		SITE x PRECINCT x GRAZING	
		F	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Maximum stem length	1,242	0.25	0.615	20.85	0.000	0.00	0.993	18.50	0.000	0.09	0.766	0.54	0.463	5.86	0.016
Number of stems	1,240	2.65	0.105	12.53	0.000	9.22	0.003	6.14	0.014	0.02	0.896	1.55	0.215	5.60	0.019
Total flower head production	1,242	4.69	0.031	8.23	0.004	8.81	0.003	15.20	0.000	0.73	0.393	1.14	0.288	3.05	0.082
Number of achenes per head	1,634	6.63	0.010	0.90	0.343	11.85	0.001	0.00	0.998	24.76	0.000	6.85	0.009	8.54	0.004

Table 14. Mean cover and species composition of native versus exotic plant species on vegetation transects in habitats of listed plant or animal species in the southern San Joaquin Valley and adjacent areas, Spring 1993. Means are shown ± standard error. See Appendix B for transect locations and Appendix C for results from individual transects.

Species	Sample size	Total herb cover (%)	Relative exotic herb cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent of exotic species
Caulanthus californicus	14	94.57 ± 1.08	44.86 ± 6.16	2.07 ± 0.97	0.07 ± 0.07	19.57 ± 0.96	19.35 ± 1.41
Eremalche parryi ssp. *kernensis*	7	85.71 ± 3.91	62.18 ± 6.92	14.29 ± 5.74	0.14 ± 0.14	12.86 ± 2.69	33.74 ± 4.29
Eriastrum hooveri	17	85.65 ± 2.63	71.51 ± 3.27	6.41 ± 1.75	0.18 ± 0.13	14.06 ± 0.96	36.31 ± 2.66
Lembertia congdonii	14	93.50 ± 1.52	68.27 ± 4.21	1.07 ± 0.87	0.07 ± 0.07	16.21 ± 0.80	36.03 ± 2.78
Opuntia basilaris var. *treleasei*	5	82.80 ± 5.49	63.80 ±12.66	8.40 ± 3.11	0	15.20 ± 0.97	34.61 ± 3.94
Dipodomys ingens	21	94.33 ± 0.91	64.78 ± 3.01	1.52 ± 0.65	0.05 ± 0.05	16.14 ± 0.92	31.38 ± 2.47
Gambelia sila	19	90.68 ± 3.04	68.35 ± 2.70	1.16 ± 0.61	0	13.90 ± 0.97	33.52 ± 2.16

var. *treleasei* populations also were dominated by *B. madritensis* ssp. *rubens*. The exception to this pattern was *Dipodomys ingens*, which was found in habitats dominated by a variety of plant species.

Transects at the CPNA were located in two plant communities (Holland 1986), with the majority in Upper Sonoran Subshrub Scrub (Table 15). Significantly more exotic plant species were present in Non-native grassland than in Upper Sonoran Subshrub Scrub. Transects on the Carrizo and Elkhorn Plains did not differ significantly in cover, but the former had a larger number of plant species present, including more exotic species, than did the latter. Grazed and ungrazed areas had similar vegetation cover, but species richness was lower and exotics were more prominent in grazed areas. Over all transects, cover of exotic plants accounted for the majority of total vascular plant cover and more than one-quarter of plant species diversity.

The exotic grasses *Schismus arabicus, Vulpia myuros,* and *Bromus madritensis* ssp. *rubens* and the exotic forb *Erodium cicutarium* were the plant species most frequently encountered and dominated (or co-dominated) on many transects on the CPNA (Table 16). Although many native plant species occurred on transects, only *Lasthenia californica* and *Vulpia microstachys* achieved dominance in any of the CPNA samples. The native, perennial bunchgrasses *Poa secunda* ssp. *secunda (= P. scabrella)* and *Nassella (= Stipa) cernua* were present only on transects from the western margin of the CPNA, and only the former constituted measurable cover (averaging 0.5%).

DISCUSSION

Historic agricultural practices on the Carrizo Plain included dry-land farming and livestock grazing (Russ Lewis and Roy van de Hoek, personal communications). Habitat modification resulting from these practices presumably led to the extirpation of individual colonies of plant species now listed as endangered. *Caulanthus californicus* was thought to have been extirpated from the Carrizo Plain after 1958 (Twisselmann 1956, Hoover 1970, Taylor and Davilla 1986), but the species was rediscovered by Mike Foster in 1988 (Roy van de Hoek, personal communication). Additional populations have been located on the CPNA every year since 1988 (Russ Lewis, personal communication). Hoover (1970) reported the occurrence of *L. congdonii* on the Carrizo Plain during the period of intensive use, but only a few small populations were observed during the 1980s (Taylor 1989). Colonies of both species may have remained unnoticed in uncultivated areas.

Caulanthus californicus now occurs primarily in areas of the CPNA that were grazed but not farmed, whereas extensive colonies of *L. congdonii* were noted in 1993 in both grazed and previously cultivated areas of the CPNA (Lewis 1993). *Lembertia congdonii* also has been found in previously cultivated areas of Lost Hills (Taylor and Buck 1993). For populations to appear in sites that were farmed, either seeds must have

Table 15. Mean cover and species composition of native versus exotic plant species on vegetation transects from various plant communities and treatments sampled on the Carrizo Plain Natural Area, San Luis Obispo County, California, in Spring 1993. Means are shown ± standard error.

Plant community or treatment	Sample size	Total herb cover (%)	Relative exotic cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent of exotic species
Non-native Grassland	5	94.20 ± 1.74	58.53 ± 4.39	1.40 ± 1.40	0	16.80 ± 1.46	38.55* ± 5.59
Upper Sonoran Subshrub Scrub	14	91.29 ± 2.27	63.74 ± 3.68	3.71 ± 1.46	0.21 ± 0.16	17.29 ± 1.14	24.32* ± 1.26
Carrizo Plain (west side)	14	91.07 ± 1.20	59.93 ± 3.45	3.93 ± 1.49	0.21 ± 0.16	18.36* ± 0.99	28.64 ± 2.93
Elkhorn Plain	5	94.80 ± 2.11	69.19 ± 4.84	0.80 ± 0.58	0	13.80* ± 1.11	26.44 ± 2.04
All ungrazed transects	11*	94.18 ± 1.28	59.47 ± 4.07	2.27 ± 1.05	0.09 ± 0.09	18.73* ± 1.07	24.71 ± 1.60
All grazed transects	6	89.13 ± 3.61	66.35 ± 4.03	4.25 ± 2.35	0.25 ± 0.25	15.00* ± 1.25	32.67 ± 4.40
Over all transects	19	92.05 ± 1.73	62.37 ± 2.94	3.11 ± 1.14	0.16 ± 0.12	17.16 ± 0.90	28.06 ± 2.20

1 Two transects were omitted because grazing status for 1993 was unknown.
* Pair (within column) significantly different (P less than 0.05).

Table 16. Plant species most commonly encountered on 19 transects in endangered species populations on the Carrizo Plain Natural Area, San Luis Obispo County, California, in Spring 1993.

Species[1]	Origin[2]	Average absolute cover (%)[3]	Presence[4]	Constancy[5]	Dominance[6]
Schismus arabicus	E	43.26 ± 1.55	18	18	11
Erodium cicutarium	E	27.47 ± 4.37	19	18	5
Vulpia myuros var. *hirsuta*	E	26.16 ± 6.20	18	18	8
Bromus madritensis ssp. *rubens*	E	17.58 ± 3.88	19	17	5
Lasthenia californica	N	9.37 ± 3.69	15	10	1
Vulpia microstachys var. *pauciflora*	N	8.21 ± 2.31	16	13	1
Tropidocarpum gracile	N	4.89 ± 2.00	9	7	0
Pectocarya penicillata	N	4.42 ± 1.19	14	12	0
Lepidium nitidum	N	4.11 ± 1.40	15	10	0
Lotus wrangelianus	N	3.89 ± 1.25	12	10	0
Amsinckia tessellata	N	3.78 ± 1.56	14	7	0
Trifolium gracilentum var. *gracilentum*	N	3.68 ± 1.20	14	12	0
Hordeum murinum	E	3.53 ± 2.48	10	6	1
Calandrinia ciliata	N	3.42 ± 0.42	11	9	0
Linanthus liniflorus	N	1.74 ± 0.84	13	6	0
Eriogonum gracillimum	N	1.63 ± 0.88	12	6	0

[1] Nomenclature follows Hickman (1993).
[2] E = exotic, N = native.
[3] Number of interceptions per species per 100 transect points.
[4] Number of belt transects on which the species occurred.
[5] Number of transects on which the species was intercepted.
[6] Number of transects on which the species was dominant or co-dominant.

persisted in the seed bank or recently dispersed to the site. Annuals of arid environments have evolved a strategy of drought escape by spending the dry season as seeds (Jones et al. 1981). Even during periods of optimal germination conditions, not all seeds of such species germinate, and this strategy protects the population against unfavorable conditions during the growing season following the germination period (Philippi 1993). Seed coats of both *C. californicus* and *L. congdonii* require prolonged weathering before seed dormancy can be broken (Mazer and Hendrickson 1993a,b). Moreover, *Lembertia congdonii* has dimorphic seeds that may differ in germination requirements (Taylor 1989), thus preventing all seeds from germinating in a given year. Seed bank studies would reveal whether buried seed is present in historic locations that do not currently support these listed species.

The observed variability in morphology, fecundity, and phenology among monitored populations may be due to habitat differences, local variations in weather conditions, and/or genetic diversity (Davy and Jefferies 1981). Plant communities, elevation, aspect, soils, and historic land uses vary among the areas (Ellen Cypher, unpublished data). Furthermore, precipitation in the San Joaquin Valley decreases along both north-south and west-east gradients (Major 1988). The causes of variation among populations and their implications for species conservation can be determined only through long-term demographic and morphological studies, intensive sampling of site conditions, and analysis of genetic diversity (Massey and Whitson 1980, Falk and Holsinger 1991, Owen and Rosentreter 1992).

Population responses to drought and management also can be evaluated by continued monitoring. Density and population estimates from 1993 are presented as baseline values for comparisons with other years. Unfortunately, timing affects the counts due to death of individuals through the growing season. Moreover, densities can vary greatly even within a single population due to the clumped distribution of plants. Density estimates may provide a useful index of abundance between years if they are compared for the same belt transect and at the same phenological stage.

Only gross estimates of rare plant population size on the CPNA are available from years preceding the recent drought. In general, populations of both *C. californicus* and *L. congdonii* have been increasing in size in recent years (Russ Lewis, personal communication), although few seeds of the latter species germinate in years of below-average rainfall (Twisselmann 1967, Taylor 1989). The few populations of *L. congdonii* observed on the Carrizo Plain in 1986 included at most "several hundred" individuals each (Taylor 1989), whereas in 1993 many populations included thousands of plants (Lewis 1993).

Despite the loss of some individual populations, the Carrizo Plain Natural Area is an important site for the long-term conservation of both *Caulanthus californicus* and *Lembertia congdonii*. It is one of the three remaining centers of concentration known for *C. californicus*, along with Santa Barbara Canyon in Santa Barbara County and the

Kreyenhagen Hills in Fresno County (Russ Lewis and Bruce Delgado, personal communications; California Department of Fish and Game 1991). In addition to the Carrizo Plain, primary areas for *Lembertia congdonii* are (1) the Panoche Hills of Fresno and San Benito Counties, (2) the Kettleman Hills of Fresno and Kings Counties, and (3) the Lost Hills area of Kern County (Russ Lewis, personal communication; Taylor 1989). The few populations of *Eriastrum hooveri* on the CPNA do not represent a significant portion of extant colonies. Major concentrations of this species occur in (1) the Cuyama Valley of Santa Barbara and San Luis Obispo Counties, (2) the Elk Hills-Buena Vista Hills-Lokern area of Kern County, (3) Lost Hills, and (4) the Kettleman Hills (Taylor and Davilla 1986, Lewis 1992).

The observed differences in rare plant performance between grazed and ungrazed areas on the CPNA may not be representative of grazing conditions in other years or at other sites. Studies of grazing effects on rare plants during 1993 were observational, not experimental, and did not control for intensity of use or possible differences in soil or microtopography between grazed and ungrazed portions of the sites. Grazing intensity varied even within portions of sites that were subject to cattle use, depending on forage availability and on the placement of livestock attractants such as water troughs and salt blocks (Ellen Cypher, personal observation). Therefore, these preliminary data should not be used as a basis for management decisions, but rather as indicators of the need for additional studies.

Giant kangaroo rats may promote growth of rare plants by creating favorable microhabitats or by dispersing seeds. Soils on precincts of another species of kangaroo rat, *Dipodomys spectabilis*, were higher in available nitrogen and lower in bulk density than soils of interspaces (Moorhead et al. 1988, Mun and Whitford 1990). Similar factors may have been responsible for the greater size and reproduction of *L. congdonii* on precincts on the Elkhorn Plain. However, if nitrogen is not the limiting factor at a particular site, occurrence on precincts may not affect plant size or reproduction. When moisture was limiting, plant cover did not differ between *D. spectabilis* precincts and interspaces (Moorhead et al. 1988). Perhaps limiting nutrients other than nitrogen regulated the size and reproduction of plants in Carrizo Plain populations of *C. californicus* and *L. congdonii*, which did not differ between precincts and interspaces.

Precinct age also may have affected plant response. Nitrogen accumulations in soils of recently-established precincts are likely to be appreciably lower than those in precincts used by generations of animals. Presence of giant kangaroo rats was verified at Sites 1, 2, and 6 prior to 1987, but Site 4 apparently was not inhabited at that time (Williams 1992). Although the relative ages of precincts at Sites 1 and 2 are unknown, precincts at the former typically were well-defined due to mounding, whereas those at the latter site were less distinct. Thus, degree of giant kangaroo rat activity may have influenced the growth response of *C. californicus*.

The disproportionate occurrence of *C. californicus* on precincts in both Carrizo Plain populations suggests that giant kangaroo rats may cache seeds or fruits of this species. Selective harvesting of seeds by giant kangaroo rats can lead to dominance of preferred plant species on precincts (Schiffman 1994). Giant kangaroo rats apparently seek out *C. californicus*, because stems of this species were clipped with equal frequency both on precincts and in interspaces. Conversely, clipping of *L. congdonii* was limited primarily to plants occurring on precincts.

Native California grasslands have been altered from presettlement conditions due to introduction of exotic plants, livestock grazing, cultivation, and fire (McClintock 1987, Heady 1988). Drought interacts with overcultivation and overgrazing to degrade both vegetation and soils; vegetation degradation includes changes in cover, structure, and species composition (Grainger 1992). The exact effects of livestock grazing and the 1987-1992 drought on the vegetation of the CPNA are unknown because baseline vegetation data are not available for comparison. Furthermore, the vegetation data presented herein are not meant to be representative of the entire CPNA nor of the entire range of habitats of each listed species. Transect sampling was conducted as part of more extensive investigations of listed species habitat in the San Joaquin Valley and plant community characteristics on the CPNA. These data will serve as a baseline to reveal patterns of vegetation change over time and their relationship to population sizes of listed species.

Compared to the state as a whole, the sampled transects had a higher proportion of non-native plants. Exotics comprise approximately 11-16% of the plant species in California, depending on the criteria used to determine inclusion in the flora (McClintock 1987, Raven 1988). However, the grassland and shrubland habitats of the listed species under study have been impacted more heavily than forested communities by exotic plants (Mooney et al. 1986). Non-native plants likely achieved dominance long before the recent drought (Wester 1981). Most of the exotic species commonly encountered on transects became established in California during the 19th century (Heady 1988).

Active management such as planting and prescribed burning could increase the cover and distribution of native plants on the CPNA, particularly perennial grasses and shrubs. If native species persist in the seed bank, planting may not be necessary, but germination of unwanted exotics would need to be prevented (van der Valk and Pederson 1989). Regardless of the restoration techniques used, exotic plants are not likely to be eradicated (Heady 1988, Schiffman 1994).

Management for listed plants may focus on reducing competitors, predators, or pathogens, and/or promoting symbiotic species such as pollinators, seed dispersers, and mycorrhizal fungi (Davy and Jefferies 1981, Messick 1987, Maunder 1992). Optimal conditions for each species are unknown. Determination of appropriate management strategies to ensure the long-term survival of rare plants, both on the Carrizo Plain and at other sites throughout their ranges, depends on site-specific experimental research (Bratton and White 1980, Massey and Whitson 1980, Davy and Jefferies 1981, Hodgkinson 1992).

RECOMMENDATIONS

Management decisions for the CPNA and other public lands should take into consideration the needs of listed plants and animals. However, directed research is necessary to make informed decisions. Aspects of rare plant biology and ecology that could be elucidated through further research include (1) site conditions affecting plant performance, (2) population responses to potential management techniques, (3) interactions with other plant and animal species in the community, (4) reproductive biology, and (5) genetic diversity within and between populations. For practical purposes, however, research topics and target species must be prioritized according to recovery needs.

Of the species included in this report, *Caulanthus californicus* should receive highest priority for continued research because it has the most restricted distribution and the fewest individuals. The causes of differing plant success among *C. californicus* sites should be investigated. Preliminary research may indicate whether site factors are limiting plant fecundity in the Kreyenhagen Hills or whether other factors should be considered, such as lack of pollinators or low genetic diversity. Data collection could be streamlined by focusing on reproductive plant characters, particularly survival to maturity, fruit production, and seed set. Research could be conducted either in the laboratory or in the field to evaluate the importance of site variables such as precipitation patterns, soil nutrient levels, and competition.

A secondary research need is to determine the impact of current livestock grazing practices on listed plants, particularly *C. californicus* and *L. congdonii*. Many of the known populations occur in present or former pastures, but resource personnel do not know whether or not to allow grazing to continue because empirical studies have not been conducted. Grazing studies should be conducted first in areas where tall, dense herbaceous vegetation may be outcompeting rare plants. The *L. congdonii* populations at Sites 5 and 8 met this criterion in 1993. At minimum, survival and fecundity of the listed plants should be compared between grazed and ungrazed treatments. Effective research requires a commitment from the administering agencies to manage grazing in specific study areas in order to meet rigorous statistical and experimental design criteria, which will require controlling livestock density, access to pastures, and seasons of use.

Finally, monitoring of rare plant populations should be continued through a full range of precipitation conditions, including years of drought, and normal and above-average rainfall. For each listed plant species, the number of individuals should be counted annually at designated sites to determine whether known populations of listed plants are declining, increasing, or remaining stable. More intensive monitoring, including tracking survival and fecundity, will be necessary during and after any trials of burning, planting, or other management techniques in habitats occupied by endangered or threatened species.

Reintroduction of *Caulanthus californicus*, *Lembertia congdonii*, and *Eriastrum hooveri* on the CPNA is not recommended at this time because populations already are present. However, populations on the CPNA could provide seed sources for future reintroductions elsewhere if determined to be necessary for recovery. Any seed collections should be made according to guidelines established by the Center for Plant Conservation (1991) and only if appropriate permits have been issued by the U.S. Fish and Wildlife Service and the California Department of Fish and Game.

LITERATURE CITED

Bratton, S. P., and P. S. White. 1980. Rare plant management--after preservation what? Rhodora 82:49-75.

Brower, J. E., and J. H. Zar. 1984. Field and laboratory methods for general ecology. Second edition. William C. Brown Publishers, Dubuque, IA. 226pp.

Brown, J. H., and E. J. Heske. 1990. Control of a desert-grassland transition by a keystone rodent guild. Science 250:1705-1707.

California Department of Fish and Game. 1991. Annual report on the status of California state listed threatened and endangered animals and plants. California Department of Fish and Game, Sacramento, CA. 192pp.

California Native Plant Society. 1993. Field sampling protocol. Unpublished report. California Native Plant Society, Sacramento, CA. 5pp.

Center for Plant Conservation. 1991. Appendix: genetic sampling guidelines for conservation collections of endangered plants. Pages 225-238 in D. A. Falk and K. E. Holsinger, editors. Genetics and conservation of rare plants. Oxford University Press, New York, NY.

Davy, A. J., and R. L. Jefferies. 1981. Approaches to the monitoring of rare plant populations. Pages 219-232 in H. Synge, editor. The biological aspects of rare plant conservation. John Wiley and Sons, New York, NY.

Falk, D. A., and K. E. Holsinger, editors. 1991. Genetics and conservation of rare plants. Oxford University Press, New York, NY. 283pp.

Grainger, A. 1992. Characterization and assessment of desertification processes. Pages 17-33 in G. P. Chapman, editor. Desertified grasslands: their biology and management. Academic Press, London, England.

Grinnell, J. 1932. Habitat relations of the giant kangaroo rat. Journal of Mammalogy 13:305-320.

Heady, H. F. 1988. Valley grassland. Pages 491-514 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. 1988 Edition. California Native Plant Society, Sacramento, CA.

Heske, E. J., J. H. Brown, and Q. Guo. 1993. Effects of kangaroo rat exclusion on vegetation structure and plant species diversity in the Chihuahuan Desert. Oecologia 95:520-524.

Hickman, J. C., editor. 1993. The Jepson manual: higher plants of California. University of California Press, Berkeley, CA. 1400pp.

Hodgkinson, K. C. 1992. Elements of grazing strategies for perennial grass management in rangelands. Pages 77-94 in G. P. Chapman, editor. Desertified grasslands: their biology and management. Academic Press, London, England.

Holland, R. F. 1986. Preliminary descriptions of the terrestrial natural communities of California. California Department of Fish and Game, Sacramento, CA. 156pp.

Hoover, R. F. 1970. The vascular plants of San Luis Obispo County, California. University of California Press, Berkeley, CA. 350pp.

Jones, M. M., N. C. Turner, and C. B. Osmond. 1981. Mechanisms of drought resistance. Pages 15-38 in L. G. Paleg and D. Aspinall, editors. Physiology and biochemistry of drought resistance in plants. Academic Press, Sydney, Australia.

Lewis, R. 1992. *Eriastrum hooveri* field inventory. Unpublished report to U.S. Bureau of Land Management, Bakersfield, CA. 116pp. + maps.

Lewis, R. 1993. *Lembertia congdonii* field inventory. Unpublished report to U.S. Bureau of Land Management, Bakersfield, CA. 80pp. + maps.

Major, J. 1988. California climate in relation to vegetation. Pages 11-74 in M.G. Barbour and J. Major, editors. Terrestrial vegetation of California. 1988 Edition. California Native Plant Society, Sacramento, CA.

Massey, J. R., and P. D. Whitson. 1980. Species biology, the key to plant preservation. Rhodora 82:97-103.

Maunder, M. 1992. Plant reintroduction: an overview. Biodiversity and Conservation 1:51-61.

Mazer, S., and B. Hendrickson. 1993a. Demography and reproductive biology of San Joaquin woolly threads (*Lembertia congdonii*: Asteraceae). Report to the California Department of Fish and Game, Sacramento, CA. 54pp.

Mazer, S. J., and B. A. Hendrickson. 1993b. Demography, ecology, and reproductive biology of California jewelflower (*Caulanthus californicus*: Brassicaceae). Report to the California Department of Fish and Game, Sacramento, CA. 113pp.

McClintock, E. 1987. The displacement of native plants by exotics. Pages 185-188 in T. S. Elias, editor. Conservation and management of rare and endangered plants. California Native Plant Society, Sacramento, CA.

Messick, T. C. 1987. Research needs for rare plant conservation in California. Pages 99-108 in T. S. Elias, editor. Conservation and management of rare and endangered plants. California Native Plant Society, Sacramento, CA.

Mooney, H. A., S. P. Hamburg, and J. A. Drake. 1986. The invasions of plants and animals into California. Pages 250-272 in H. A. Mooney and J. A. Drake, editors. Ecology of biological invasions of North America and Hawaii. Springer-Verlag, New York, NY.

Moorhead, D. L., F. M. Fisher, and W. G. Whitford. 1988. Cover of spring annuals on nitrogen-rich kangaroo rat mounds in a Chihuahuan Desert grassland. American Midland Naturalist 120:443-447.

Mun, H. T., and W. G. Whitford. 1990. Factors affecting annual plants assemblages on banner-tailed kangaroo rat mounds. Journal of Arid Environments 18:165-173.

Owen, W. R., and R. Rosentreter. 1992. Monitoring rare perennial plants: techniques for demographic studies. Natural Areas Journal 12:32-38.

Philippi, T. 1993. Bet-hedging germination of desert annuals: beyond the first year. American Naturalist 142:474-487.

Raven, P. H. 1988. The California flora. Pages 109-137 in M. G. Barbour and J. Major, editors. Terrestrial vegetation of California. 1988 Edition. California Native Plant Society, Sacramento, CA.

Schiffman, P. M. 1994. Promotion of exotic weed establishment by endangered giant kangaroo rats (*Dipodomys ingens*) in a California grassland. Biodiversity and Conservation. In press.

Taylor, D. W. 1989. Status survey of San Joaquin woolly-threads (*Lembertia congdonii*). U.S. Fish and Wildlife Service, Sacramento, CA. 27pp. + Appendices.

Taylor, D. W., and R. E. Buck. 1993. Distribution of San Joaquin woolly-threads (*Lembertia congdonii*) in the vicinity of Lost Hills, Kern County, California. Unpublished report to Lost Hills Utility District, Lost Hills, CA. 17pp.

Taylor, D. W., and W. B. Davilla. 1986. Status survey of three plants endemic to the San Joaquin Valley and adjacent areas, California. U.S. Fish and Wildlife Service, Sacramento, CA. 131pp.

Twisselmann, E. C. 1956. A flora of the Temblor Range and the neighboring part of the San Joaquin Valley. Wasmann Journal of Biology 14:161-300.

Twisselmann, E. C. 1967. A flora of Kern County, California. University of San Francisco, San Francisco, CA. 395pp.

U.S. Department of the Interior, Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of endangered or threatened status for five plants from the southern San Joaquin Valley. Federal Register 55(139):29361-29370.

van der Valk, A. G., and R. L. Pederson. 1989. Seed banks and the management and restoration of natural vegetation. Pages 329-346 in M. A. Leck, V. T. Parker, and R. L. Simpson, editors. Ecology of soil seed banks. Academic Press, San Diego, CA.

Wester, L. 1981. Composition of native grasslands in the San Joaquin Valley, California. Madrono 28:231-241.

Williams, D. F. 1992. Geographic distribution and population status of the giant kangaroo rat, *Dipodomys ingens* (Rodentia, Heteromyidae). Pages 301-328 *in* D. F. Williams, S. Byrne, and T. A. Rado, editors. Endangered and sensitive species of the San Joaquin Valley, California: their biology, management, and conservation. California Energy Commission, Sacramento, CA.

Williams, D. F., and K. S. Kilburn. 1991. *Dipodomys ingens*. Mammalian Species 377:1-7.

Zar, J. H. 1984. Biostatistical analysis. Second edition. Prentice-Hall, Inc., Englewood Cliffs, NJ. 718pp.

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APPENDIX A. Names, numbers, and locations of study sites in the San Joaquin Valley, California, and adjacent areas that were used for demographic monitoring of listed plant species in Spring 1993.

Species monitored	Site Number	Township	Range	Section	Quarter-section	Elevation (m)	Grazing regime
CARRIZO PLAIN (SAN LUIS OBISPO COUNTY)							
Caulanthus californicus	#1	11N	26W	8	NE	716	ungrazed
	#2	12N	26W	31	SE	686	ungrazed[1]
Eriastrum hooveri	#3	11N	27W	11 12	NE NW	792	ungrazed
Lembertia congdonii	#4	32S	21E	35	SE	655	cattle grazed
		32S	21E	36	SW	655	ungrazed[1]
	#5	32S	21E	27	NW	640	cattle grazed
ELKHORN PLAIN (SAN LUIS OBISPO COUNTY)							
Lembertia congdonii	#6	32S	22E	20	W 1/2 of NE 1/4	709	ungrazed
		32S	22E	20	NW 1/4 & E 1/2 of NE 1/4	701	cattle grazed
JACALITOS HILLS (FRESNO COUNTY)							
Eriastrum hooveri, *Lembertia congdonii*	#7	21S	15E	26	NE	381	cattle grazed
KETTLEMAN HILLS (KINGS COUNTY)							
Eriastrum hooveri, *Lembertia congdonii*	#8	23S	18E	2	SE	189	cattle grazed
		23S	18E	12	NW	175-190	ungrazed
Lembertia congdonii	#9	22S	17E	10	SW	311	cattle grazed

Species monitored	Site Number	Township	Range	Section	Quarter-section	Elevation (m)	Grazing regime
KREYENHAGEN HILLS (FRESNO COUNTY)							
Caulanthus californicus	#10	22S	16E	7	NW	373	ungrazed[2]
	#11	22S	15E	12	NW	404	ungrazed[2]
LOKERN (KERN COUNTY)							
Eremalche kernensis	#12	29S	22E	32	SW	198	ungrazed[3]
Eriastrum hooveri	#13	30S	22E	2	NW	190	ungrazed
PANOCHE HILLS (FRESNO COUNTY)							
Lembertia congdonii	#14	15S	12E	20	SW	195	cattle grazed[4]

1 No livestock, but grazed occasionally by pronghorn (*Antilocapra americana*).
2 Not grazed during flowering season, but cattle-grazed during summer.
3 Supposed to be ungrazed, but sheep were present early in season.
4 Exclosure installed around most of population in March 1993.

APPENDIX B. Locations of vegetation transects sampled in Spring 1993 in the San Joaquin Valley and adjacent foothills, California.

7.5' Quadrangle (Site name)	Public land survey coordinates				Treatment	Listed species present[6]	Transect code (Site #)
	Township	Range	Section	1/4			
FRESNO COUNTY							
Kreyenhagen Hills (Jacalitos Hills)	21S	15E	26	NE	cattle grazed[1]	*Erho/Leco*	JA11 (Site 7)
	21S	15E	34	SE	ungrazed	*Erho* *Leco*	JA32 JA31
Kreyenhagen Hills	22S	15E	12	NW	ungrazed[2]	*Caca*	KRWT1 KRWT3 KRWT2 (Site 11)
	22S	16E	7	NW	ungrazed[2]	*Caca*	KRSC (Site 10)
	22S	16E	18	NW	ungrazed[2]	*Caca*	KRCC1 KRCC2
Monocline Ridge	15S	12E	36	NE SE	?	*Diin*	TU4 TU1
	15S	13E	31	NW SW	?	*Diin*	TU2 TU3
Tumey Hills (Panoche Hills)	15S	12E	20	SW	ungrazed[3] cattle grazed	*Erho/Leco* *Erho/Leco*	PAN1 PAN2 (Site 14)
KERN COUNTY							
East Elk Hills	30S	23E	2	NE	ungrazed	*Erho*	K12
Edison	30S	30E	19	NW SW	ungrazed	*Optr*	SR1 SR2 SR3
Lokern	29S	22E	10	SE	sheep grazed	*Erke*	K10
	29S	23E	19	NE	ungrazed?	*Erho*	K9
	29S	23E	29	NW	sheep grazed	*Erke*	K11
Mettler	11N	20W	23	SW	ungrazed?	*Optr*	K8
Mouth of Kern	32S	25E	18	SE	ungrazed	*Erke*	K6
Oil Center	29S	28E	1	NE	sheep grazed	*Optr*	K7

7.5' Quadrangle (Site name)	Public land survey coordinates				Treatment	Listed species present[6]	Transect code (Site #)
	Township	Range	Section	1/4			
Reward	29S	22E	32	SW	ungrazed[4]	*Erke*	K3 (Site 12)
Taft	31S	23E	10	SW	ungrazed	*Gasi*	K5
West Elk Hills (Lokern)	30S	22E	2	NW	ungrazed?	*Erho/Gasi*	K1 K2 (Site 13)
	31S	23E	5	NW	ungrazed?	*Gasi*	K4
KINGS COUNTY							
La Cima (Kettleman Hills)	22S	17E	10	SW	cattle grazed	*Leco*	KG1 (Site 9)
Los Viejos (Kettleman Hills)	22S	18E	26	SE	ungrazed?	*Erho*	KG3
	23S	18E	1	SW	cattle grazed	*Erho/Gasi*	LC6 (Site 8)
	23S	18E	2	NE SE	cattle grazed	*Erho* *Leco/Gasi*	KG2 LC2 (Site 8)
	23S	18E	12	NW	ungrazed	*Leco/Gasi* *Leco/Gasi* *Erho/Leco /Gasi* *Erho/Gasi*	LC1 LC3 LC4 LC5 (Site 8)
SAN LUIS OBISPO COUNTY							
Chimineas Ranch	31S	19E	11	NE	ungrazed	*Diin*	CP2
Cuyama	10N	25W	9	SW	ungrazed	*Erho*	SLO
Painted Rock	32S	20E	8	NW	cattle grazed	*Diin*	CP18

7.5' Quadrangle (Site name)	Public land survey coordinates				Treatment	Listed species present[6]	Transect code (Site #)
	Township	Range	Section	1/4			
Panorama Hills (Elkhorn Plain)	32S	22E	18	NW	cattle grazed	*Diin/Gasi*	CP16
	32S	22E	20	NE	ungrazed cattle grazed	*Leco/ Diin/Gasi*	CP3 CP4 CP9 CP10 (Site 6)
Wells Ranch (Carrizo Plain)	11N	26W	4	NW	ungrazed	*Caca/Diin*	CP13
	11N	26W	5	NE NW	ungrazed	*Caca/Erke /Diin* *Caca/Diin*	CP15 CP17
	11N	26W	8	NE	ungrazed	*Caca/Diin*	CP1 (Site 1)
	11N	26W	9	NW	ungrazed	*Caca/Diin*	CP19
	11N	26W	10	NE	ungrazed	*Caca/Diin*	CP14
	11N	27W	11	NE	ungrazed	*Erho*	CP12 (Site 3)
	11N	27W	12	NW	ungrazed	*Erho*	CP8 (Site 3)
	12N	26W	31	SE	ungrazed	*Caca/Erke /Diin*	CP5 (Site 2)
	32S	21E	27	NW	cattle grazed	*Leco/Diin*	CP11 (Site 5)
	32S	21E	35	SE	cattle grazed	*Leco/Diin /Gasi*	CP6 (Site 4)
	32S	21E	36	SW	ungrazed[5]	*Leco/Diin /Gasi*	CP7 (Site 4)
SANTA BARBARA COUNTY							
Fox Mountain	9N	25W	11	SE	ungrazed	*Caca*	SB
TULARE COUNTY							
Pixley	23S	24E	22	SE	grazed	*Dini/Gasi*	PIX1
	23S	24E	23	NE	grazed?	*Dini/Gasi/ Erke*	PIX2

Footnotes to Appendix B.

[1] Supposed to be ungrazed, but cattle have been present throughout season.
[2] Not grazed during flowering season at the present time.
[3] Exclosure installed in March 1993 following grazing damage.
[4] Supposed to be ungrazed, but sheep were present early in season.
[5] No livestock, but grazed by pronghorn (*Antilocapra americana*).
[6] *Caca* = *Caulanthus californicus*
Diin = *Dipodomys ingens*
Dini = *Dipodomys nitratoides nitratoides*
Erho = *Eriastrum hooveri*
Erke = *Eremalche parryi* ssp. *kernensis*
Gasi = *Gambelia sila*
Leco = *Lembertia congdonii*
Optr = *Opuntia basilaris* var. *treleasei*

APPENDIX C. Cover, species composition, and diversity on vegetation transects sampled in the San Joaquin Valley and adjacent foothills, California, Spring 1993. See Appendix B for transect locations.

Transect code (Site #)	Listed species present[1]	Sampling date	Total herb cover (%)	Relative exotic herb cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent exotic species	Shannon diversity index[2]
FRESNO COUNTY									
JA11 (Site 7)	*Erho/Leco*	15 April	96	59.84	0	0	18	33.33	2.24
JA31	*Leco*	12 May	80	36.36	0	0	16	18.75	2.45
JA32[3]	*Erho*	12 May	85	39.63	0	0	18	27.78	2.23
KRCC1	*Caca*	23 March	98	8.30	0	0	16	12.50	2.21
KRCC2	*Caca*	23 March	92	10.27	0	0	28	10.71	2.60
KRSC (Site 10)	*Caca*	28 April	96	20.82	0	0	21	19.05	2.62
KRWT1[4] (Site 11)	*Caca*	30 March	97	49.30	0	0	19	15.79	2.30
KRWT2 (Site 11)	*Caca*	28 April	95	32.41	0	0	14	21.43	2.12
KRWT3[4] (Site 11)	*Caca*	28 April	97	61.24	0	0	17	17.65	2.02
PAN1 (Site 14)	*Erho/Leco*	21 April	92	89.15	12	0	10	50.00	1.73
PAN2 (Site 14)	*Erho/Leco*	21 April	83	80.92	0	1	13	53.85	2.02
TU1	*Diin*	18 May	98	64.62	0	0	12	50.00	1.88
TU2	*Diin*	18 May	99	77.94	0	0	11	36.36	1.68

Transect code (Site #)	Listed species present[1]	Sampling date	Total herb cover (%)	Relative exotic herb cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent exotic species	Shannon diversity index[2]
TU3	*Diin*	21 May	98	80.60	0	0	13	46.15	1.76
TU4	*Diin*	21 May	91	82.27	0	0	9	44.44	1.61
KERN COUNTY									
K1 (Site 13)	*Erho/Gasi*	6 April	96	64.84	4	0	12	25.00	1.92
K2 (Site 13)	*Erho/Gasi*	6 April	88	55.71	2	0	15	40.00	2.01
K3 (Site 12)	*Erke*	6 April	90	83.33	18	0	8	37.50	1.49
K4	*Gasi*	18 May	79	66.99	1	0	6	16.67	1.06
K5	*Gasi*	18 May	44	81.13	11	0	6	50.00	1.43
K6	*Erke*	18 May	73	83.13	39	0	5	40.00	1.05
K7	*Optr*	12 April	94	88.75	4	0	15	46.67	1.92
K8	*Optr*	7 May	98	90.61	3	0	12	33.33	1.64
K9	*Erho*	14 May	71	83.52	20	0	6	50.00	1.40
K10	*Erke*	23 April	82	30.97	26	0	14	28.57	1.96
K11	*Erke*	23 April	74	68.18	17	0	10	40.00	1.64
K12	*Erho*	21 May	64	82.42	14	0	8	50.00	1.61
SR1	*Optr*	11 May	72	22.39	19	0	18	22.22	2.26
SR2	*Optr*	11 May	73	65.46	4	0	15	33.33	1.92
SR3	*Optr*	11 May	77	51.80	12	0	16	37.50	2.41

Transect code (Site #)	Listed species present[1]	Sampling date	Total herb cover (%)	Relative exotic herb cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent exotic species	Shannon diversity index[2]
KINGS COUNTY									
KG1 (Site 9)	*Leco*	5 April	92	82.78	0	0	18	38.89	1.91
KG2	*Erho*	20 April	91	67.50	9	0	15	33.33	1.98
KG3	*Erho*	19 May	76	81.74	16	0	15	26.67	2.03
LC1 (Site 8)	*Leco/Gasi*	14 April	99	82.11	0	0	19	36.84	1.73
LC2 (Site 8)	*Leco/Gasi*	20 April	99	80.18	0	0	13	30.77	1.71
LC3 (Site 8)	*Erho/Leco/Gasi*	27 April	96	61.11	0	0	18	38.89	2.43
LC4 (Site 8)	*Erho/Leco/Gasi*	3 May	96	84.57	0	0	17	41.18	2.09
LC5 (Site 8)	*Erho/Gasi*	27 April	98	80.10	0	0	15	46.67	2.05
LC6 (Site 8)	*Erho/Gasi*	3 May	89	76.25	0	0	16	31.25	1.87
SAN LUIS OBISPO COUNTY									
CP1 (Site 1)	*Caca/Diin*	6 April	94	63.27	11	0	22	18.18	2.43
CP2	*Diin*	12 April	99	52.90	0	0	18	27.78	2.49
CP3 (Site 6)	*Leco/Diin/Gasi*	14 April	97	68.05	1	0	12	25.00	1.68

Transect code (Site #)	Listed species present[1]	Sampling date	Total herb cover (%)	Relative exotic herb cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent exotic species	Shannon diversity index[2]
CP4 (Site 6)	*Leco/Diün/Gasi*	14 April	94	71.18	3	0	14	28.57	1.68
CP5 (Site 2)	*Caca/Erke/Diün*	21 April	85	54.27	0	1	22	22.73	2.60
CP6 (Site 4)	*Leco/Diün/Gasi*	22 April	93	47.62	0	0	18	27.78	2.35
CP7 (Site 4)	*Leco/Diün/Gasi*	22 April	97	55.84	0	0	21	33.33	2.41
CP8 (Site 3)	*Erho*	23 April	89	77.06	18	0	21	23.81	2.27
CP9 (Site 6)	*Leco/Diün/Gasi*	28 April	97	60.81	0	0	13	23.08	1.92
CP10 (Site 6)	*Leco/Diün/Gasi*	28 April	99	60.49	0	0	18	22.22	2.14
CP11 (Site 5)	*Leco/Diün*	3 May	93	63.56	0	0	14	50.00	1.83
CP12 (Site 3)	*Erho*	6 May	66	75.90	9	2	11	27.27	1.46
CP13	*Caca/Diün*	10 May	97	66.36	1	0	19	26.32	2.08
CP14	*Caca/Diün*	11 May	89	26.06	0	0	21	19.05	2.18
CP15	*Caca/Erke/Diün*	11 May	96	60.09	0	0	23	17.39	2.34
CP16 (Site 6)	*Diün/Gasi*	12 May	87	87.08	0	0	12	33.33	1.38
CP17	*Caca/Diün*	13 May	97	81.60	6	0	16	31.25	1.94

Transect code (Site #)	Listed species present[1]	Sampling date	Total herb cover (%)	Relative exotic herb cover (%)	Shrub cover (%)	Cryptogam cover (%)	Number of plant species	Percent exotic species	Shannon diversity index[2]
CP18	*Diin*	19 May	90	72.73	7	0	13	53.85	1.82
CP19	*Caca/Diin*	14 May	91	63.10	3	0	18	22.22	2.32
SLO	*Erho*	21 May	80	55.45	5	0	11	18.18	1.71
SANTA BARBARA COUNTY									
SB	*Caca*	22 April	100	30.92	8	0	18	16.67	2.35
TULARE COUNTY									
PIX1	*Dini/Gasi*	6 May	75	59.26	0	0	11	36.36	1.65
PIX2	*Erke/Dini/Gasi*	6 May	100	55.28	0	0	8	50.00	1.32

1 SPECIES CODES:
Caca = *Caulanthus californicus*
Diin = *Dipodomys ingens*
Dini = *Dipodomys nitratoides nitratoides*
Erho = *Eriastrum hooveri*
Erke = *Eremalche parryi* ssp. *kernensis*
Gasi = *Gambelia sila*
Leco = *Lembertia congdonii*
Optr = *Opuntia basilaris* var. *treleasei*

2 Shannon Diversity Index calculated using natural logarithms.

3 Transect only 25 m long.

4 Same transect sampled twice.

APPENDIX D. Photographs of vegetation transects from the Carrizo Plain Natural Area, San Luis Obispo County, California. See Appendix B for exact transect locations.

CP1 0 m

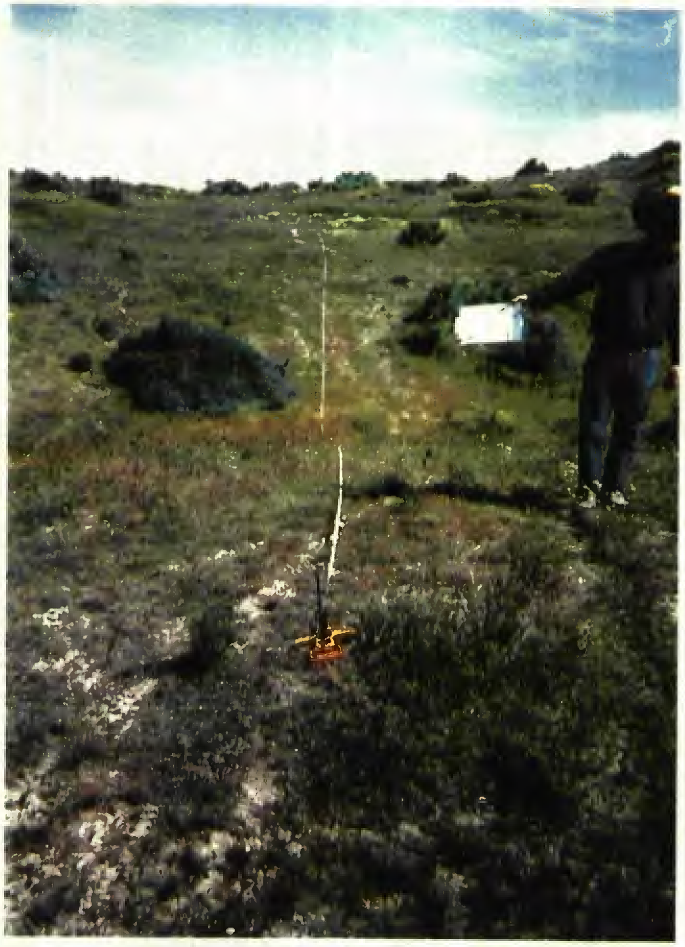
CP2 0 m

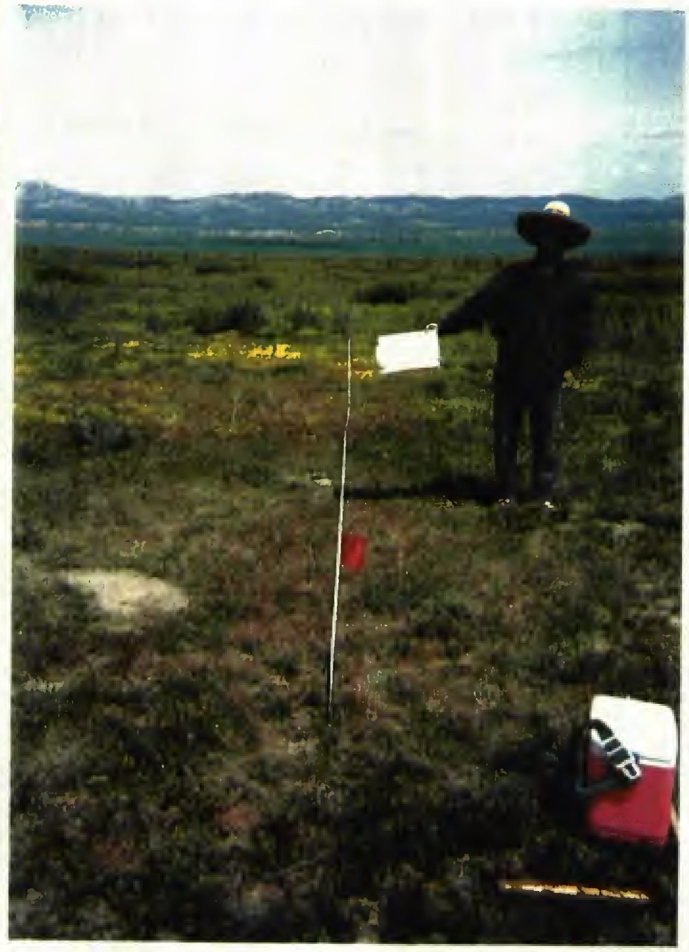
CP3 0 m

CP4 0 m

CP5 0 m

CP6 0 m



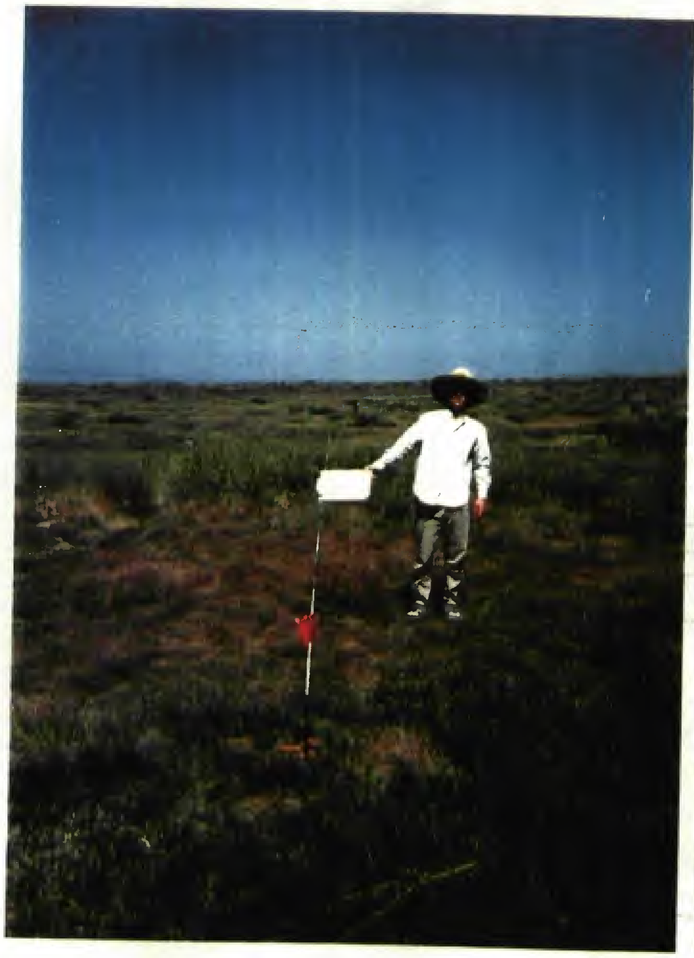


CP7 0 m

CP8 0 m

CP9 0 m

CP10 0 m

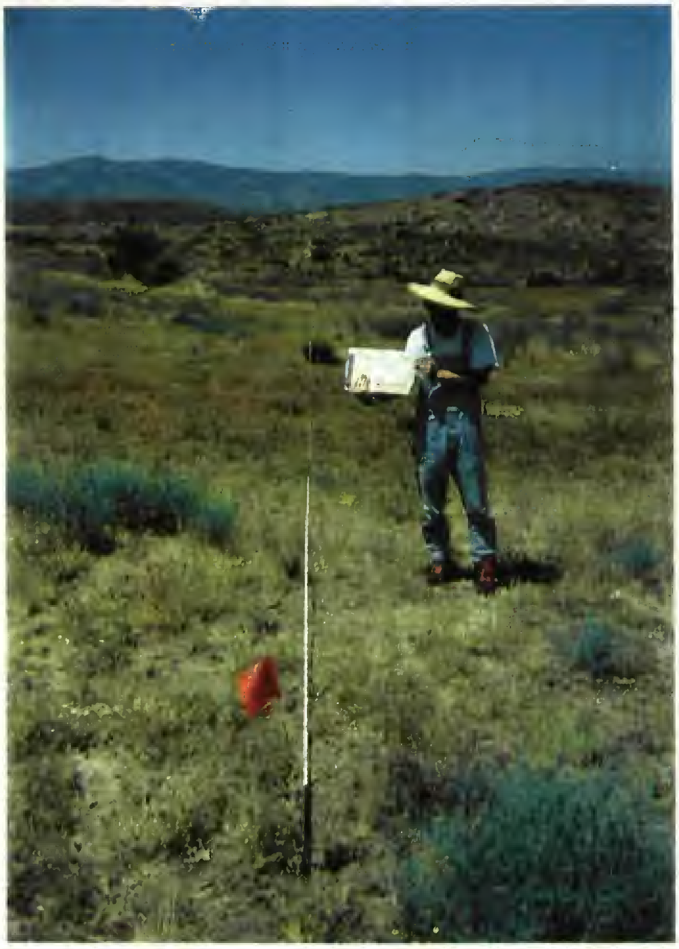


CP11 0 m

CP12 0 m

CP13 0 m

CP14 0 m



CP15 0 m

CP16 0 m

CP17 0 m

CP18 0 m

CP19 0m

CP19 50m