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Population Characteristics of *Eschscholzia Rhombipetala*

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POPULATION CHARACTERISTICS OF *ESCHSCHOLZIA RHOMBIPETALA* E. GREENE (PAPAVERACEAE)

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Espeland and Carlsen: *Eschscholzia rhombipetala* population

ABSTRACT

A population of *Eschscholzia rhombipetala*, a species that, until several years ago, was thought to be extinct, occurs in and around a hillside slump (small landslide) in the Corral Hollow area of the Altamont Hills of California. Here we describe the population and co-occurring vegetation from a five-year study. A second population was found fewer than three km away from this population in spring of 2002. Where possible, data from both populations are reported. Both populations occur on clay soil like the only other known population in the Carrizo Plain. Population numbers ranged from 9 to 285 plants. *Eschscholzia rhombipetala* presence was negatively affected by exotic grass and thatch cover and positively influenced by bare ground and exotic forb cover. Plant height predicted number of reproductive units (buds plus flowers plus seed capsules) per plant ($p < 0.004$) and seed capsule length was also highly correlated with plant height ($p < 0.001$). Plant performance was significantly different among microhabitats, and plants in the active slump tended to do better than those elsewhere. The population expansion upslope into grassland areas in 2002 may indicate the presence of a seed bank for this small-seeded annual, and its association with bare ground and greater performance in the slump may indicate that some disturbance is necessary for population maintenance.

Key words: *Eschscholzia rhombipetala*, rare plants, disturbance, clay soils, California grassland

INTRODUCTION

Eschscholzia rhombipetala (the diamond-petaled poppy) is an extremely rare spring-flowering annual plant included on the California Native Plant Society (CNPS) List 1B (CNPS 2001). The historic range of this species includes the inner north Coast ranges, the eastern San Francisco Bay region, and the inner South Coast Ranges. The last herbarium collections of this plant were made in 1950 in San Luis Obispo county, and the species has since been presumed extinct. In 1993, a population of *E. rhombipetala* was discovered in the northern part of the Carrizo Plain by David Keil (pers. comm.) of California Polytechnic University, San Luis Obispo, but has not been seen since 1995.

A population of *E. rhombipetala* was identified during a habitat survey in 1997 at Site 300 (Preston 2000), a high-explosive test site operated by the University of California for the Department of Energy in the Corral Hollow area, on the border between Alameda and San Joaquin counties (Figure 1). The 13-hectare site is closed to the public and has had no agricultural activities since its establishment in the 1950s. Collections of *E. rhombipetala* have been made at Corral Hollow, both in 1937 (UC765993) and in 1949 (P. Raven, pers.comm.). Like the Carrizo plain population, the first Site 300 *E. rhombipetala* population occurs in an ecotone on heavy clay soil. The ecotone at Site 300 was formed by a landslide within a minor east-west drainage to a major north-south trending canyon. The landslide formed a slump at the bottom of the slide, with sharp scarp faces on the northern and southern sides of the slump. This *E. rhombipetala* population is found on the southern side of the slump (a north-west facing aspect) near the edge of the scarp, some distance into the surrounding grassland, and in the slump itself. The slump and surrounding grasslands are composed primarily of exotic species in the genera *Avena*, *Bromus*, *Sonchus* and *Brassica*. The rare tarplant *Blepharizonia* *plumosa* (CNPS List 1B, CNPS 2001) and its more common relative *Blepharizonia laxa* (Baldwin et al. 2001) also occur in the slump.

A second population of *E. rhombipetala* was discovered in spring of 2002 in another habitat survey, less than three km from the first population (site 1). This population occurs on a steep, northwest-facing slope. While it may occur on an historic slump, the soil of the population area is not noticeably more active than its surroundings. The second population at site 2 occurs in a grassland of exotic species similar to that at site 1.

Eschscholzia rhombipetala is a small (5-30 cm tall), erect annual. It is similar in appearance to other *Eschscholzia* species, but is quite diminutive and easily overlooked. The yellow petals are 3-15 mm long on a barrel-shaped receptacle, and when in bud, may be erect or nodding, with a blunt or short point. The fruit is a capsule, generally 4-7 cm long, containing numerous round, net-ridged black seeds 1.3-1.8 mm wide (Clark 1993).

In this paper we describe the *E. rhombipetala* population and the vegetation surrounding it. Through this research, we hope to describe the population, eventually predict circumstances under which large population sizes may be found, and aid other researchers in locating additional populations of this rare plant species.

METHODS AND MATERIALS

Census

The entire *E. rhombipetala* population at site 1 was censused on 08 Apr 98. Small, numbered flags were used to mark individual plants so they could be tracked. Height, flower number, capsule number and capsule length data were collected. On 18 Apr 98, the population was revisited and marked plants were found and remeasured. The same method of measuring and marking took place on 30 Apr 99, with a follow-up visit on 21 May 99. In 2000 through 2002, the population was censused on single dates: 24

Mar 00, 30 Mar 01, and 29 Mar 02. The population at site 2 was censused on 05 Apr 02. Data collected for marked and measured plants were height, flower number, capsule number and capsule lengths. During the 2000 and 2001 censuses, the geographic features of the slump (SL), within 50 cm of the scarp next to the slump (SC), or in the interior grassland (GR), were recorded for all plants in the site 1 population.

Linear regression was performed using PROC GLM in SAS (SAS 1990) to examine the relationship between plant height and number of floral units (buds + flowers + capsules) and capsule length. Tukey's separation of means was performed to determine the effect of geographic feature on the number of floral units (Steel et al. 1997).

Vegetation sampling

On 21 May 99 and 27 Apr 00, cover and composition of species in the *E. rhombipetala* population area were recorded at site 1. On 30 Mar 01, 34 plots were located to cover the entire *E. rhombipetala* population and 25 plots were randomly located outside the population. For each plot, species were identified and their percent cover was visually estimated. Percent bare ground and percent thatch cover were also recorded. Areas with differing dominant species were also mapped in and around the slump. In 2002, cover data were collected from 63 plots at site 1 on 29 Mar (31 in the *E. rhombipetala* population and 32 outside it) and 30 plots at site 2 on 5 Apr (14 within the population and 16 outside it) using the same methodology.

Logistic regression using PROC LOGISTIC in SAS version 6.0 (SAS 1990) was performed to determine effects of vegetation on *E. rhombipetala* presence/absence. Due to missing data points, only 144 plots were analyzed.

Soil sampling

Soil samples were collected from both sites on 08 May 02. Site 1 was divided into three sub-areas based on the geographic feature defined above (SL, SC, GR). Soil samples were collected from two locations in each sub-area, visually selected to be representative of the sub-area. Site 2 was not subdivided. Soil samples were collected from three locations, visually selected to be representative of site. At each sampling location, surface vegetation was scraped away with a trowel. The top 15 cm of soil in an approximately 30-cm^2 area was manually homogenized using the trowel. Soil samples were submitted to A&L Western Agricultural Laboratories in Modesto, California. Samples were analyzed for organic matter, nitrogen compounds (nitrate, ammonia, and total kjedhal nitrogen), sodium bicarbonate phosphorus, extractable cations, hydrogen, pH, cation exchange capacity, soluble salts, sulfate sulfur, zinc, manganese, iron, copper, boron and soil texture using standard agricultural methods as outlined in the North American Proficiency Testing Program and the USDA (Neufeld and Davison 2000).

RESULTS

Census

The *E. rhombipetala* population at site 1 comprised 18 plants in 1998 (Table 1), 9 plants in 1999, 273 plants in 2000 (171 were marked and measured), 189 plants in 2001, and 285 plants in 2002 (280 were marked and measured). The site 2 population contained 76 plants in 2002. The three-week monitoring period of 1999 resulted in a recorded 67% survivorship. Two plants died in the 10 days prior to the 1998 full census. In both years, deaths occurred in well-established vegetative individuals. All dead plants wilted without flowering, apparently due to the shifting of soil within the slump. No survivorship data were recorded for 2000 through 2002. Plants were small, with average heights ranging from 5.0±2.5 to 8.0±2.1 cm (Table 1). Plants as short as 2.5 cm were observed flowering and the largest plants recorded were approximately 14 cm tall. Most plants had only one flower open at a time, but senescent plants usually had several capsules per plant.

There was a significant positive relationship between plant height and number of floral units (buds + flowers + capsules) as well as between plant height and capsule length at site 1. Data were too few in 1999 to perform regression. In 1998, 2000 and 2001 slopes ranged from 0.09 to 0.19 and intercepts ranged from 0.08 to –0.17 ($p <$ 0.003, $r^2 = 0.22$ to 0.33). In 2002, more plants had floral units compared to other years and the average number of floral units per plant was greater than one for the first time; the slope of the regression was 1.4 and the intercept was 5.2 ($p < 0.001$, $r^2 = 0.14$). Plant height was not a significant predictor of the number of floral units at site 2 ($p > 0.05$).

Plant height was even more closely tied to capsule length variation. Again, in 1998, 2000 and 2001, slopes were low (0.35 to 0.48), intercepts were small (-1 to –0.1) and r^2 was high (0.44 to 0.66, $p < 0.001$). In 2002, capsule lengths were longer than they had been in previous years. In 2002, height explained over 20% of capsule length variation at both site 1 and site 2, and this was a year where the regression intercept was high (5.5 and 5.3 respectively) and the slope of the line was larger (0.94 and 0.89 respectively, $p < 0.001$).

Geographic feature had an effect on plant performance. In 2002, plants had the most floral units at site 2 and in the slump at site 1 (Figure 2, $p < 0.05$). Plants in the slump generally performed well, either with the most floral units per plant (in 2000 and 2002), or with no significant difference between them and the best performers (which were plants in the grassland in 2001). The slump contained anywhere from 42% to 24%

of the total plants in the site 1 population. Plants at site 2, even though they were located in a grassland area without an active slump, performed as well as plants in the slump at site 1 in the year when both sites were monitored.

Vegetation sampling

In 1999 and 2000, *Avena* sp. and *Bromus diandrus* were the dominant species in almost all of the areas at site 1. The slump itself had an extremely large bare ground component that would not be repeated in succeeding years. The *E. rhombipetala* population was concentrated in one corner of the slump and adjacent grassland. The *E. rhombipetala* population expanded downslope in 2000 to double its population area. In 2001, the *E. rhombipetala* population expanded northward across the slope into the scarp. *Bromus* species were more mixed in 2001 and large areas of *Avena* sp. included a substantial forb component. *Poa secunda* became dominant in the scarp and the slump in 2001. In 2002, most of the vegetation patterns were similar to those in 2001, with the *E. rhombipetala* population expanding into the grassland areas upslope of the slump. *Lupinus microcarpus* became quite evident in the southern scarp and grassland in 2002. Table 2 shows plants that occurred in and around the *E. rhombipetala* populations of both sites.

Logistic regression showed that bare ground, thatch cover, exotic grass and exotic forb cover were important for predicting *E. rhombipetala* presence (Table 3). The logistic regression model was $p/(1-p) = \alpha + \beta_1 x_1 + \beta_2 x_2 ... + \beta_n x_n$, where p is the probability of *E. rhombipetala* presence in the plot, α is the intercept, β is the parameter estimate, and x is the covariate. Bare ground, thatch, exotic grass, native grass, exotic forb, and native forb covers were used as covariates. Percent bare ground, percent thatch cover, percent exotic grass cover, and percent exotic forb cover all contributed significantly to the model ($p < 0.007$). Native grass and native forb cover did not contribute significantly to the prediction of *E. rhombipetala* presence. When the parameter estimate is negative, the covariate is negatively associated with *E. rhombipetala* presence. As thatch cover and exotic grass cover increase, the likelihood of *E. rhombipetala* presence decreases. Probability of *E. rhombipetala* presence increases as exotic forb cover and percent bare ground increase. Plots with *E. rhombipetala* averaged 45% bare ground cover compared to 20% bare ground in plots without *E. rhombipetala* (Table 4). Thatch cover was 39% in plots without *E. rhombipetala* and 14% in plots with *E. rhombipetala*. Exotic grass cover was 20% in plots with *E. rhombipetala* and 27% in plots without. Exotic forb cover averaged 6% in plots with *E. rhombipetala* and 3.5% in plots without *E. rhombipetala.*

Soil sampling

Soils at sites 1 and 2 were clays and clay loams (Table 5). Soil nutrients were within the normal range of soils in the Altamont hills (data not shown, Webster-Scholten 1994), but nitrogen and ammonia are relatively low (Table 5). In California coastal grasslands, heavily disturbed soils have been shown to be low in nitrogen (Stromberg and Griffin 1996).

DISCUSSION

It is unclear whether these populations at Site 300 were present at the time the species was determined to be extinct. These populations occur away from regular Site 300 activities and may have been continuously present as aboveground plants. Alternatively, they may have been briefly extirpated and then rediscovered when the populations reappeared due to soil turnover or a long-range dispersal event. Long-distance dispersal events are rare and it is not easy to confirm the extinction of plants that have seed banks (Wolf 2001). A long-term seed bank or even continuously present aboveground plants are more likely explanations of the existence of these populations than a recent dispersal event.

Our yearly census of *E. rhombipetala* showed a wide range in population size, from a low of 9 to a high of 285 individuals. Fluctuation in the size of small, annual plant populations is to be expected (Parson and Zedler 1997; Pavlik and Espeland 1998), but populations at both sites are still quite small. Although the nine plants observed at site 1 in 1999 may have produced enough seed to generate a population of 171 plants the following year, the 2002 appearance of plants upslope from where plants had been previously observed may indicate the presence of a seed bank for this population.

Reproductive success (number of floral units or capsule length) is better predicted from plant height in poor years than in good ones: the least predictive power came from regressions with very large intercepts, indicating that in a year like 2002 many of the smallest plants are able to put as much toward reproduction as the largest plants. Reproductive success was more strongly tied to plant height in years that were less favorable to *E. rhombipetala*. Small plants did less well relative to large plants in these poorer years with smaller population numbers. Although the year with the largest population size was also the year with the greatest small plant fitness, it is not clear at this time if these two factors are related.

The positive association of *E. rhombipetala* presence with bare ground, plus the better performance of plants in the active slump may indicate that some level of disturbance is necessary for plants of this species to do well. Plants were negatively associated with high levels of thatch and exotic grasses. Thatch indicates an area that has not been disturbed (Stromberg and Griffin 1996), and an undisturbed environment is more likely to lead to the dominance of exotic grasses such as *Bromus diandrus* and *Avena* sp. (Brown and Bugg 2001). The negative relationship between thatch and exotic grasses and *E. rhombipetala* may be due to either microhabitat preference or to an inability on the part of *E. rhombipetala* to compete with exotic annual grasses. Further observations of the population at site 2, where there is no obvious disturbance like the slump at site 1, may shed additional light on the nature of this possible relationship.

Populations of *E. rhombipetala* observed within the last decade have occurred on soils with a clay component. At the Carrizo Plain location, *E. rhombipetala* grows on heavy clay soils that accumulate water in the spring, forming vernal pools. The population is located in an ecotone on the higher areas between an *Amsinckia*-dominated mound and a *Layia*-dominated swale, in open patches. The plants are an understory to taller *Lasthenia*, *Phacelia*, and various grasses (D. Keil, pers. comm.). Both population locations in the Altamont hills can be characterized as occurring on clay or clay loam soils. It is possible the species may occur in more locations than previously thought, as other surveys for this plant have focused on more gravelly soils (C. Clark, pers. comm.). Clay soils can resist compaction through natural wetting and drying cycles (Ahmad 1993), and this attribute may be important for *E. rhombipetala* germination and growth. The low nitrogen levels in the soils may prevent overdominance of exotic annual grasses (Brown and Bugg 2001), which may also encourage *E. rhombipetala* persistence.

Eschscholzia rhombipetala is a small-seeded plant, and as such, may be dependent on soil turnover to return banked seeds up to germinable depths. Small seeds buried too deeply in the soil are unable to germinate into seedlings (Zhan and Maun 1994). It is likely that this species has a long-lived seed bank: studies of a small-seeded plant on serpentine clays showed that, for that species, seeds remained viable in the soil for more than eight years (Pavlik and Espeland 1998). Germination and early growth is more important than later life history stages for many California native forbs (Brown and Bugg 2001), and it is likely that the importance of these early life stages is even greater for those species with small seeds, which have fewer seed resources to overcome such hardships as limited light availability at early growth stages.

This paper is the first step in documenting the habitat associations and population dynamics of this extremely rare California annual plant. While we have been unable to rigorously determine factors important to *E. rhombipetala* plant fitness, we have found some indication that there is a positive relationship between *E. rhombipetala* and factors related to disturbance. We have found that the strength of the relationship of plant size to reproductive output changes among years and that in some years many small plants can have fairly high fitness. Continuing yearly population censuses will help us to determine factors that influence greater plant fitness and higher population sizes at the two sites reported on in this study. We hope that the research presented here will assist other botanists in locating additional populations of this plant.

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REFERENCES

AHMAD, N. 1983. Pedogenesis and soil taxonomy. II. Pp. 91-123 in L. P. Wilding, N. E. Smeck G. F. Hall (eds.), Pedogenesis and soil taxonomy. Elsevier, Amsterdam, Netherlands.

BALDWIN, B. G., R. E. Preston, B. L. Wessa, and M. Wetherwax. 2001. A biosystematic and phylogenetic reassessment of sympatric taxa in Blepharizonia (Compositae – Madiinae). Systematic Botany 36: 184-194.

BROWN, C. S. and R. L. BUGG. 2001. Effects of established perennial grasses on introduction of native forbs in California. Restoration Ecology 9: 38-48.

CLARK, C. 1993. Papaveraceae. Pp. 810-816 in J. C. HICKMAN (ed.) The jepson manual: higher plants of California. University of California Press, Berkeley, CA.

CNPS, 2001. Inventory of Rare and Endangered Plants of California (6^{th} ed.). Rare Plant Scientific Advising Committee, D. P. Tibor, Convening Editor. California Native Plant Society, Sacramento, CA.

NEUFELD, J. and J. DAVISON. 2000. Practical considerations when selecting a soil testing laboratory for an educational program. Journal of Extension 38(4):1-5. http://www.joe.org/joe/2000august/rb2.html

PARSON, L. S. and J. B. ZEDLER. 1997. Factors affecting reestablishment of an endangered annual plant at a California salt marsh. Ecological Applications 7: 253–267.

PAVLIK, B. M. and E. K. ESPELAND. 1998. Demography of natural and reintroduced populations of *Acanthomintha duttonii*, an endangered serpentinite annual in northern California. Madroño 45: 31-39.

PRESTON, R. E. 2000. Noteworthy Collection: *Eschscholzia rhombipetala*. Madroño 47: 138.

SAS. 1990. *SAS/STAT® User's Guide,* Version 6, Fourth Edition, Volume 2. SAS Institute Inc., Cary, NC, pp. 1241-1263.

STEEL, R.G.D, J.H. TORRIE and D.A. DICKEY. 1997. Principles and procedures of statistics: a biometrical approach. WCB McGraw Hill, New York, NY.

STROMBERG, M. G. and J. G. GRIFFIN. 1996. Long-term patterns in coastal California grasslands in relation to cultivation, gophers and grazing. Ecological Applications 7: 1189-1211.

TAYLOR, D.W. and W. DAVILLA, 1986. Vegetation of Site 300: Lawrence Livermore National Laboratory, San Joaquin County, California. Biosystems Analysis, Inc. Santa Cruz, CA.

WEBSTER-SCHOLTEN, E. (ed.). 1994. Final site-wide remedial investigaion report Lawrence Livermore National Laboratory Site 300, April 1994. Lawrence Livermore National Laboratory, Livermore, CA.

WOLF, A. 2001. Conservation of endemic plants in serpentine landscapes. Biological Conservation 100: 35-44.

ZHAN, J. and M. A. MAUN. 1994. Potential for seed bank formation in seven great lakes sand dune species. American Journal of Botany 81: 387-394.

Table 1. Height, number of floral units (buds + flowers + capsules) per plant, and capsule length for marked *E. rhombipetala* plants:1998-2002. All averages are ± one standard deviation.

Site	Date measured	Height (cm)	# floral units/plant	N [a]	Capsule length (cm)	N [b]
1	18 Apr 98	7.5 ± 2.8	0.4 ± 0.5	24	2.8 ±1.4	16
1	30 Apr 99	6.0 ± 1.8	0.7 ± 0.7	9	2.1 ± 0.6	6
1	24 Mar 00	5.5 ± 2.1	0.6 ± 0.5	171	2.3 ± 1.4	44
1	30 Mar 01	5.0 ± 2.5	0.3 ± 0.5	189	2.8 ± 1.8	72
1	29 Mar 02	6.8 ± 2.5	1.1 ± 0.7	280	3.4 ± 1.6	73
2	05 Apr 02	8.0 ± 2.1	1.4 ± 0.7	76	3.3 ± 0.3	63

[a] Number of plants measured is the same for the height and number of flowers measurement. Plants with no flowers were included in the average.

[b] Number of plants measured for capsule length includes only those plants with capsules.

Table 2. Plant species found in and around *E. rhombipetala* populations.

Native	**Exotic**
Grasses	
Elymus sp.	*Avena* sp.
Poa secunda	*Bromus diandrus*
	Bromus hordeaceous
	Bromus madritensis subsp. *rubens*
	Hordeum murinum
	Vulpia myuros
Forbs	
Amsinckia intermedia	*Brassica* sp.
Amsinckia mensezii	*Carduus pynocephalus*
Blepharizonia laxa	*Centaurea melitensis*
Blepharizonia plumosa	*Erodium cicutarium*
Brodiaea sp.	*Medicago polymorpha*
Claytonia parviflora	*Salsola tragus*
Dichelostema capitatum	*Sanicula bipinnata*
Eschscholzia rhombipetala	*Sonchus* sp.
Galium aparine	
Gutierrezia californica	
Lepidium nitidum	
Lotus wrangellianus	
Lupinus microcarpus	
Monolopia major	
Stylomecon heterophylla	
Trifolium sp.	

For plants identified only to genus, native versus exotic identifications were made using species lists generated by Taylor and Davilla (1986).

Table 3. Results of the logistic regression: the effect of vegetation on *E. rhombipetala* absence. [a]

Covariate x	*p*-value	β [a]	Odds Ratio [b]	Confidence interval	Maximum measured x value [a]
Intercept α = -0.67	0.411		.	.	
% bare ground	**<0.001**	**0.046**	**1.047**	**1.021-1.074**	**80**
% thatch cover	**<0.001**	**-0.053**	**0.948**	**0.919-0.978**	**80**
% exotic grass cover	**<0.001**	**-0.058**	**0.944**	**0.906-0.984**	**70**
% native grass cover	0.912	-0.004	0.996	0.919-1.078	40
% exotic forb cover	**0.007**	**0.151**	**1.163**	**1.043-1.297**	**20**
% native forb cover	0.990	-0.001	0.999	0.838-1.190	12.5

[a] Model fit (Wald) p <0.001, n=149 (69 plots with no *E. rhombipetala*, 75 plots with *E. rhombipetala*). The model is $p/(1-p) = \alpha + \beta_1 x_1 + \beta_2 x_2 + \ldots \beta_n x_n$ where p is the probability of *E. rhombipetala* absence from the plot, α is the intercept, β is the parameter estimate, and x is the covariate. In the model, bare ground, thatch, exotic grass, native grass, exotic forb, and native forb covers were used as covariates.

[b] Odds ratio is probability *E. rhombipetala* present : probability *E. rhombipetala* absent

Table 4. Vegetation characteristics of plots with and without *E. rhombipetala*. All values are averages ± one standard deviation.

Plot type	% bare ground	% thatch cover	% exotic grass cover	% native grass cover	% exotic forb cover	% native forb cover	N
no *E. rhombipetala*	19.6 ± 15.5	38.7 ± 25.2	27.0 ± 11.8	2.1 ± 6.1	3.5 ± 4.3	2.2 ± 3.0	74
with *E. rhombipetala*	44.9 ± 27.0	13.9 ± 14.0	20.3 ± 11.4	2.8 ± 6.0	6.1 ± 5.0	2.8 ± 3.4	75

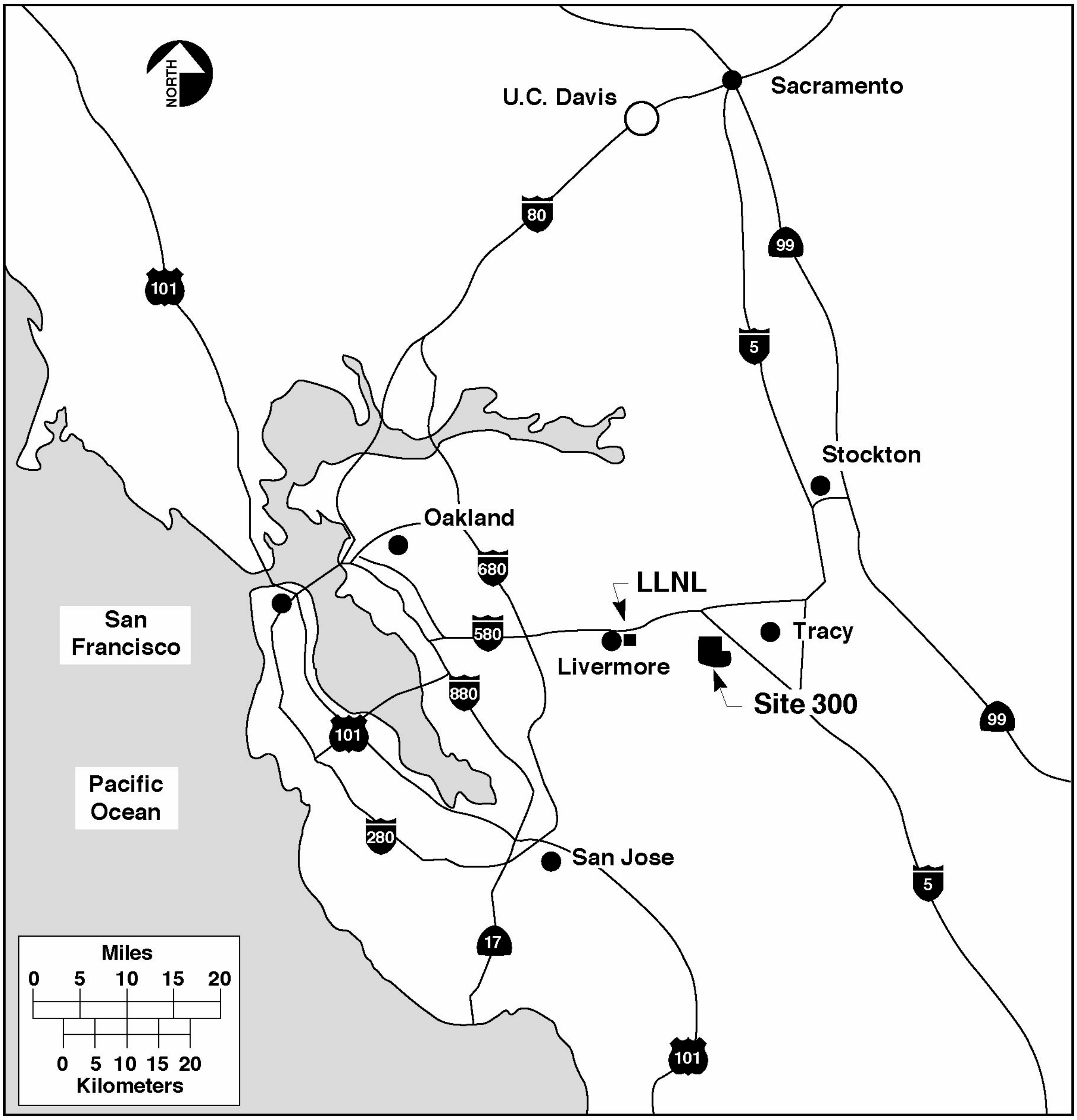
Table 5. Characteristics of soil collections and their locations.

Location	**Slope**	**Aspect**	**Sand %**	**Silt %**	**Clay %**	**Soil type**	**NO3-N** [a]	**NH4-N** [b]
Site 1								
Slump	32°	W	20.0 (1.4)	36.0 (4.2)	44.0 (2.8)	clay	6.5 (0.7)	<2.5
Scarp	42°	N	31.0 (5.7)	31.0 (0.0)	38.0 (5.7)	clay loam	6.5 (0.7)	3.1 (0.8)
Grassland	31°	NW	37.5 (14.8)	30.0 (1.4)	35.0 (12.7)	clay loam	6.0 (0.0)	<2.5
Site 2	32°	NW	33.7 (2.3)	23.0 (0.0)	43.3 (2.3)	clay	5.3 (0.6)	2.5 (0.0)

[a] Nitrate nitrogen (ppm)
[b] Ammonia nitrogen (ppm)

Figure 1. Location of Site 300 in California.

Figure 2. Number of floral units per plant by location at site 1 in 2000-2002 and at site 2 in 2002. All bars are one standard error. Different letters indicate significant differences ($p < 0.05$) among locations within years. Numbers inside bars indicate the percent of plants found at each location in site 1. *Site 2 also different from site 1 when all site 1 locations are lumped.



ERD-S3R-02-0146

Fig. 1

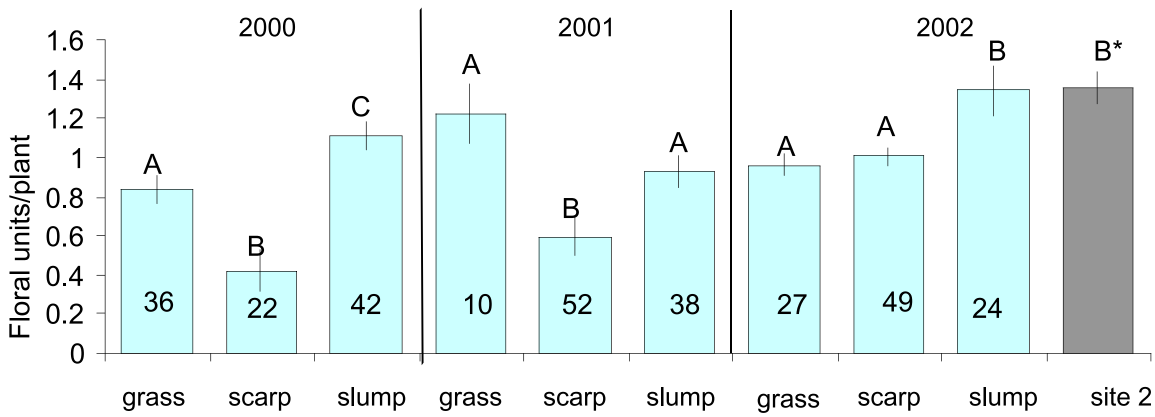

2000
2001
2002
Floral units/plant
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
A
B
C
A
B
A
A
A
B
B*
36
22
42
10
52
38
27
49
24
grass
scarp
slump
grass
scarp
slump
grass
scarp
slump
site 2

Fig. 2

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