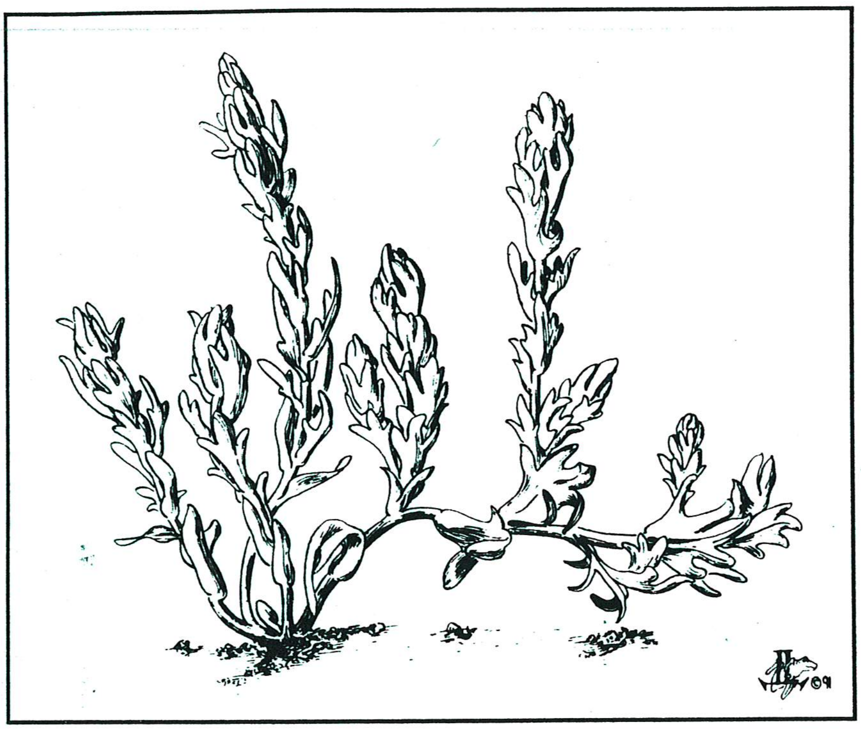
Conservation of the palmate-bracted bird's beak, *Cordylanthus palmatus*



Center for Conservation Biology
Department of Biological Sciences
Stanford University
Stanford, CA 94305-5020

Conservation of the palmate-bracted bird's beak, *Cordylanthus palmatus*

Prepared for:
Endangered Plant Program
California Department of Fish and Game
1416 9th Street
Sacramento, CA 95814

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Prepared by:
Center for Conservation Biology
Department of Biological Sciences
Stanford University
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Introduction

With funding from the State of California Department of Fish and Game and a U.S. Fish and Wildlife Service Endangered Species Grant-in-aid, the Center for Conservation Biology has conducted research on the palmate-bracted bird's beak, *Cordylanthus palmatus*, since the summer of 1990. The first stage of this research was summarized by a report published in March 1992.

This second report describes the results and conclusions of research conducted on *Cordylanthus palmatus* since March 1992, including ongoing monitoring of the population at Springtown Alkali Sink (Livermore, California), surveys of the other populations of this plant, studies of the soil seed bank for this species, characterization of soils at Springtown, distribution of plants relative to soil type, relocation of *C. palmatus* seeds, and studies on reproductive biology and seed predation.

This report does not include a description of the life history of *Cordylanthus palmatus*, land use in the Springtown region, and details of earlier work, all of which were presented in the first (1992) report.

Study plan

The overall purpose of this study is to aid development of management plans for *Cordylanthus palmatus* at the Springtown Alkali Sink and other locations. Questions integral to this study include:

1) Are the distribution and abundance of *C. palmatus* at the Springtown Alkali Sink stable from year to year?
2) Are the distribution and abundance of *C. palmatus* at the Springtown Alkali Sink independent of local edaphic and hydrologic conditions?
3) Do pollinators or herbivores limit the distribution and abundance of *C. palmatus*?
4) Do seed predators or seed dispersal limit the distribution and abundance of *C. palmatus*?
5) Is *C. palmatus* genetically variable?
6) What is the overall distribution and abundance of this species throughout its range?

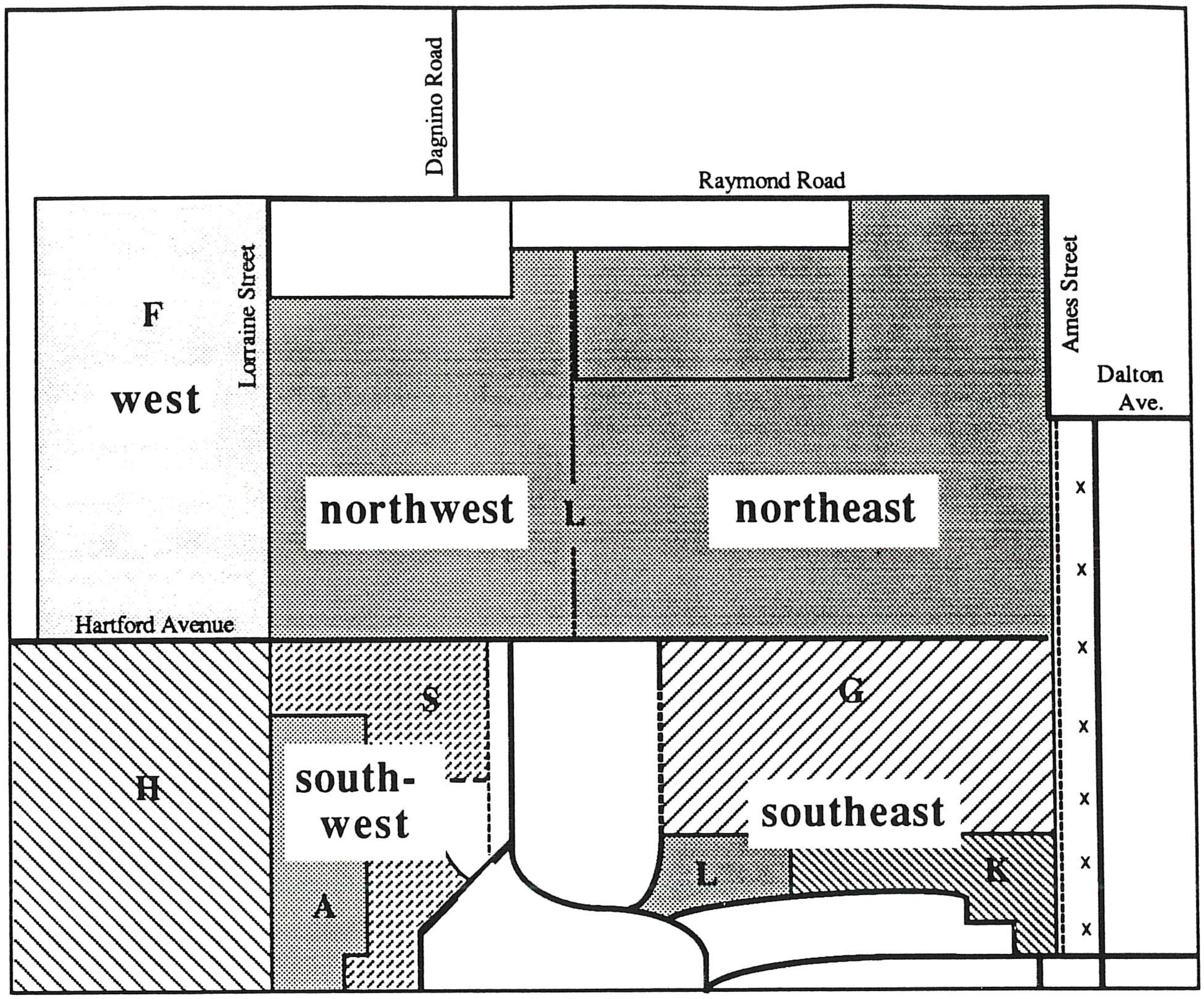
Methods

Long-term monitoring of the Springtown population

As in the previous two years of study, all individual *Cordylanthus palmatus* plants in a grid of 50 m x 50 m plots throughout all regions of the Springtown Alkali Sink were counted (see Figure 1; areas surveyed include all of northwest, northeast, and southeast Springtown, and the eastern parts of west and southwest Springtown). The census was conducted during the months of August and September of 1992.

An area of southeast Springtown adjacent to the residential development was burned in a grass fire in August, prior to the census. This area, indicated on Figure 7, was surveyed along with the rest of Springtown.

For a full description of monitoring methods see CCB 1992.



A	Anden group
F	Federal Communications Commission
G	Garaventa
H	Shea Homes
K	Kaufman and Broad
L	City of Livermore
S	S & L Investments, Inc.

Figure 1. Areas and approximate parcel ownership at Springtown Alkali Sink, Livermore, California. Adapted from Coats *et al.* 1988.

Surveys of Central Valley populations of *Cordylanthus palmatus*

CCB biologists visited known populations of *Cordylanthus palmatus* in Delevan National Wildlife Refuge, Colusa National Wildlife Refuge, and the City of Woodland, California in August of 1992. Ann Howald of the California Department of Fish and Game visited the population at Mendota Alkali Sink Ecological Refuge in August of 1992 (Howald, pers. comm.). These four sites (see Figure 2), together with the population at Springtown, comprise all known recent occurrences of *C. palmatus*.

During each visit, the number of individual *Cordylanthus palmatus* plants present at each site was estimated and site maps documenting 1992 distribution of the plant were produced from Refuge maps and USGS 7.5 minute quad base maps.

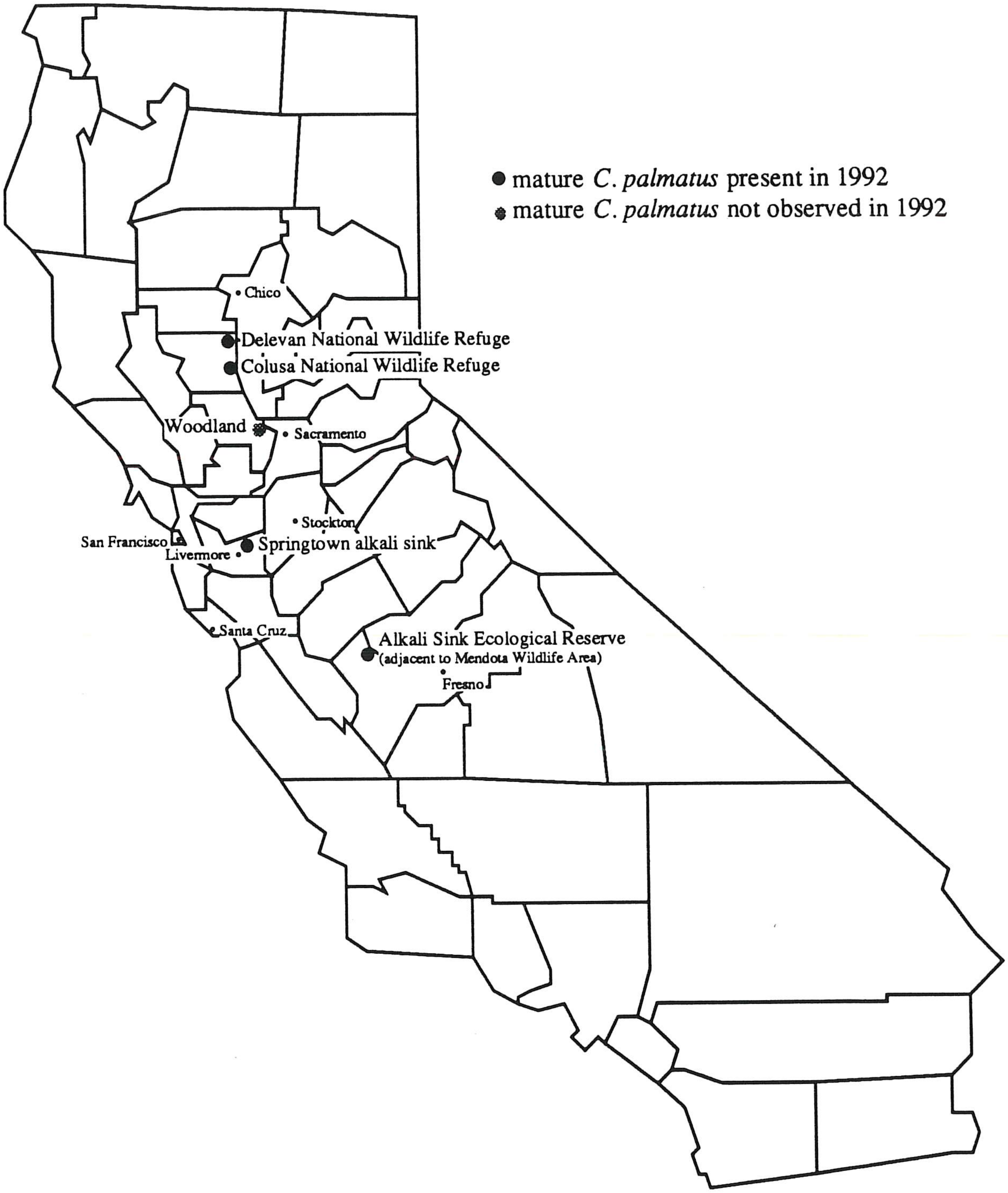


Figure 2. Remaining populations of *Cordylanthus palmatus*. See text for details.

Studies of the *Cordylanthus palmatus* seed bank at Springtown

Eighteen soil samples were collected from the top 3 cm of soil from sites across Springtown in July 1991, prior to seed set. The samples were taken from both occupied areas (within 1 m of an adult *Cordylanthus palmatus*) and unoccupied areas (apparent habitat more than 10 m from any *C. palmatus*). Samples were kept in a dark cold chamber until February 1992, when they were spread across flats of potting soil and sand (mixed 1:1) in nursery flats. These flats were maintained under greenhouse conditions and kept moist. The number of *C. palmatus* seedlings growing from each flat was recorded weekly for nine weeks, by which time no new seedlings had appeared for seven weeks.

Thirteen soil samples collected in 1990 were tested in the above manner in 1991 (including three samples from unoccupied areas, to each of which were added 50 seeds). All 13 samples were tested again in February 1992 according to the same methods. Methods are described in full in CCB 1992.

Genetic variability in *Cordylanthus palmatus*

Samples were taken from individual plants throughout the Springtown ecosystem for electrophoretic analysis of within-population genetic variability. Samples consisted of single branches clipped from individual *C. palmatus*; no entire individuals were sacrificed.

Collection of samples at other sites (thus measurement of between-population variability) required permits that could not be obtained prior to plant senescence in 1992.

Using standard starch gel electrophoresis techniques, plant samples were screened to determine how many loci could be resolved (would appear clearly on the gels) and which buffer systems resolved them the most clearly. Two extraction buffers, solutions that stabilize soluble proteins in the plant cells and neutralize their secondary compounds, were also tested to determine which are the most effective for *C. palmatus*.

Characterization of Springtown soils and comparison to local distribution of *Cordylanthus palmatus*

Previous work suggested relationships between patterns of *Cordylanthus palmatus* distribution and abundance and physical features of the Springtown Alkali Sink, especially soil salinity and alkalinity (Coats *et al.* 1988, CCB 1992). The Soil Conservation Service has mapped three soil series for the Springtown region: Solano fine sandy loam, Pescadero clay, and San Ysidro loam (for maps, see Coats *et al.* 1988). Alkali sink vegetation (including *C. palmatus*) was reported to be restricted to the Solano and Pescadero series (Coats *et al.* 1988). This study was designed to further characterize the complex soils found at Springtown, and to compare the distribution of these soil types to the distribution and abundance of *C. palmatus*.

Twenty-four soil test pits were dug in four broad areas of the Springtown Alkali Sink known to support large numbers of *Cordylanthus palmatus*. Each test pit was up to a meter in depth and no more than 40 cm in diameter. Test pits were located to sample as much of the physical diversity in each area as possible (see Figures 3 and 4). All test pits were filled immediately after field analysis.

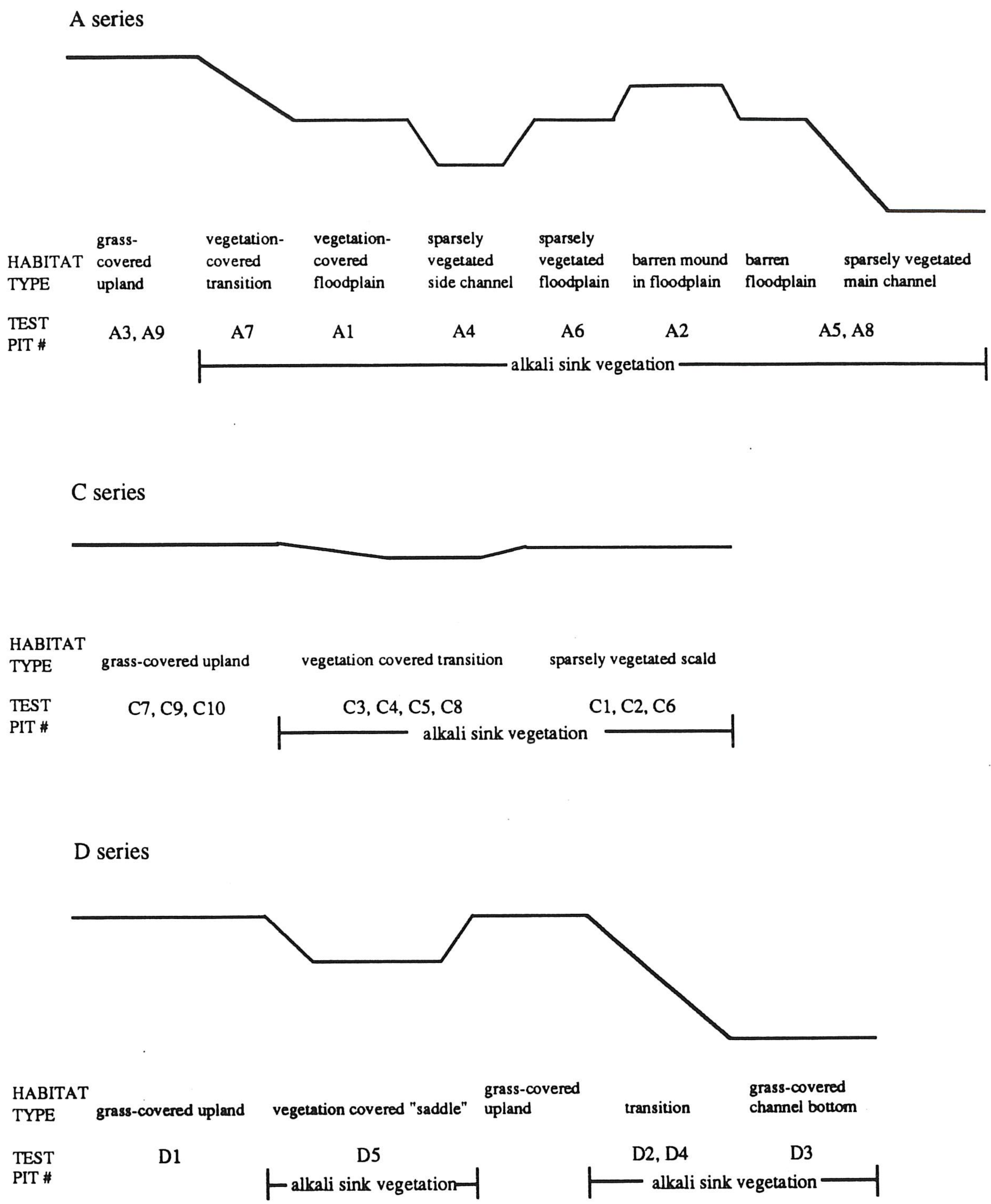


Figure 3. Schematic representation of relative locations and local topography across soil test pit gradients, Springtown Alkali Sink. Drawings not to scale.

Data from these test pits were used to develop a method of soil characterization that would distinguish soil types on a scale of sufficient detail to aid in the investigation of possible links between soil characteristics and the distribution of *Cordylanthus palmatus*. Detailed maps of the distribution of specific soil types were made for three of the four areas (one each in northwest, northeast, and southwest Springtown), each covering an area of approximately 2 hectares. The soil types were mapped onto acetate overlays using stereo-aerial photographs and verified by site visits. In June and October of 1992 the location of individual *C. palmatus* plants in each of the soil types in these three areas was mapped on separate acetate overlays atop the same aerial photographs. Soil test pit analyses, development of the mapping scheme, and the mapping of the soils of the three 2 ha study plots were conducted by David De Vries of Mesa Technical.

Experimental relocation of *Cordylanthus palmatus*

Sites in north Springtown that were not occupied by *Cordylanthus palmatus* in either 1990 or 1991 but that appeared to provide suitable habitat were identified from aerial photographs and site visits. Eight of these sites were selected for experimental seed relocation. Each site was located more than 100 m away from any quadrat occupied by *C. palmatus* in either 1990 or 1991.

In November of 1991, ~50 *Cordylanthus palmatus* seeds collected the previous month from plants throughout northwest and northeast Springtown were distributed within a 1 m^2 area at each site. Each relocation site was visited twice during the 1992 growing season (in June and July) and individual plants were counted and mapped. Survivorship to reproduction and crude patterns of dispersal were noted.

Pollination and reproductive biology of *Cordylanthus palmatus*

Experiments and field activities were designed to elucidate the reproductive biology of *Cordylanthus palmatus* at the Springtown Alkali Sink. Observations were conducted to identify patterns in the maturation of floral components. In addition, experimental procedures were designed to investigate whether *C. palmatus* is self-compatible and to identify and observe probable pollinators.

In an assessment of floral development, one branch was sampled from each of 14 plants selected randomly from southwest Springtown. The anthers and stigmas of all flowers on those branches were assigned developmental categories. Anther maturity was categorized according to pollen that was 1) premature, translucent and white, 2) orange, hard, and compacted, 3) orange-yellow, fluffy, and separated into individual grains, or 4) brown on a withered filament. Styles were categorized as 1) premature, 2) emerging from the upper lip of the corolla, or 3) withered.

During July and August of 1992, experiments were conducted in the large scald area in southwest Springtown to compare seed set of *Cordylanthus palmatus* flowers resulting from 1) natural versus artificially augmented pollen loads and 2) self-pollination versus outcrossing. On each of 15 plants three branches were labeled and the open inflorescence immediately below the developing, unopened flowers was removed (clipped). *C. palmatus* has perfect (bisexual) flowers that bloom sequentially from the bottom to the top of a branch. The flower removal was done to conclusively distinguish flowers that had already opened (lower on the branch, whose pollination history was unknown) from those unopened flowers above the clip line.

On one branch of each triplet, the developing flowers above the clip-line were unmanipulated and thus served as a control. Over branches of the second treatment group (the second branch of each triplet), tubular bags of fine mesh were placed (closed around the branch with a twist tie) to exclude potential pollinators. Every three days the bags were removed and styles of open flowers were dusted with pollen from flowers on other branches of the same plant. This treatment was used to estimate the seed set resulting from self-pollination. Over branches of the third treatment group (the third branch of each triplet), tubular mesh bags were placed (closed around the branch with a twist tie) to exclude potential pollinators. Every three days the bags were removed and styles of the open flowers were dusted with pollen from plants located in the study area but not included in the treatment groups. This treatment was used to estimate the seed set resulting from outcrossing. Because *Cordylanthus palmatus* does not have a distinctive stigmatic surface, in the hand-pollination treatments pollen was placed over the protruding end of all styles.

On all 45 branches, the number of open and withered flowers was noted every three days over a three-week period, for a total of eight visits. At the end of the study period the triplets were harvested in order to facilitate the tabulation of data. Also harvested at this time was one branch from each of 15 randomly selected plants that had not been bagged or clipped. These "natural" plant samples were used to estimate the effect of clipping on seed set and fruit production. The percent flowers becoming fruits and number of seeds/fruit were noted for all 60 branches.

From 17 June to 26 August 1992, the identities of insects observed on and around *Cordylanthus palmatus* flowers were noted. In June and July the bumblebee *Bombus californicus* was by far the most common *C. palmatus* visitor. Field activities were designed to provide a more complete understanding of the relationship between *Bombus californicus* and *C. palmatus*. These activities included observations of the behavior of individual bumblebees to determine 1) the number of *C. palmatus* flowers visited per minute, 2) the number of *C. palmatus* plants visited per minute, 3) the number of flowers visited per *C. palmatus* plant, and 4) the distance between sequentially visited plants. The general foraging behavior of bumblebees visiting *C. palmatus* flowers was also noted.

Two 2 m x 2 m quadrats on each of four sites at the Springtown Alkali Sink were established. The sites, located in north Springtown (sites NW and NC) and southwest Springtown (sites SW and FW), are shown on Figure 4. Each was visited four times on 1 July 1992, between the hours of 7:00 am-8:00 am, 9:00 am-10:00 am, 11:30 am-1:00 pm, and 2:30 pm-4:00 pm. Each quadrat was sampled for 10 minutes during each visit, during which time the identity of each flower visitor observed and the number of flowers visited by each potential pollinator was recorded.

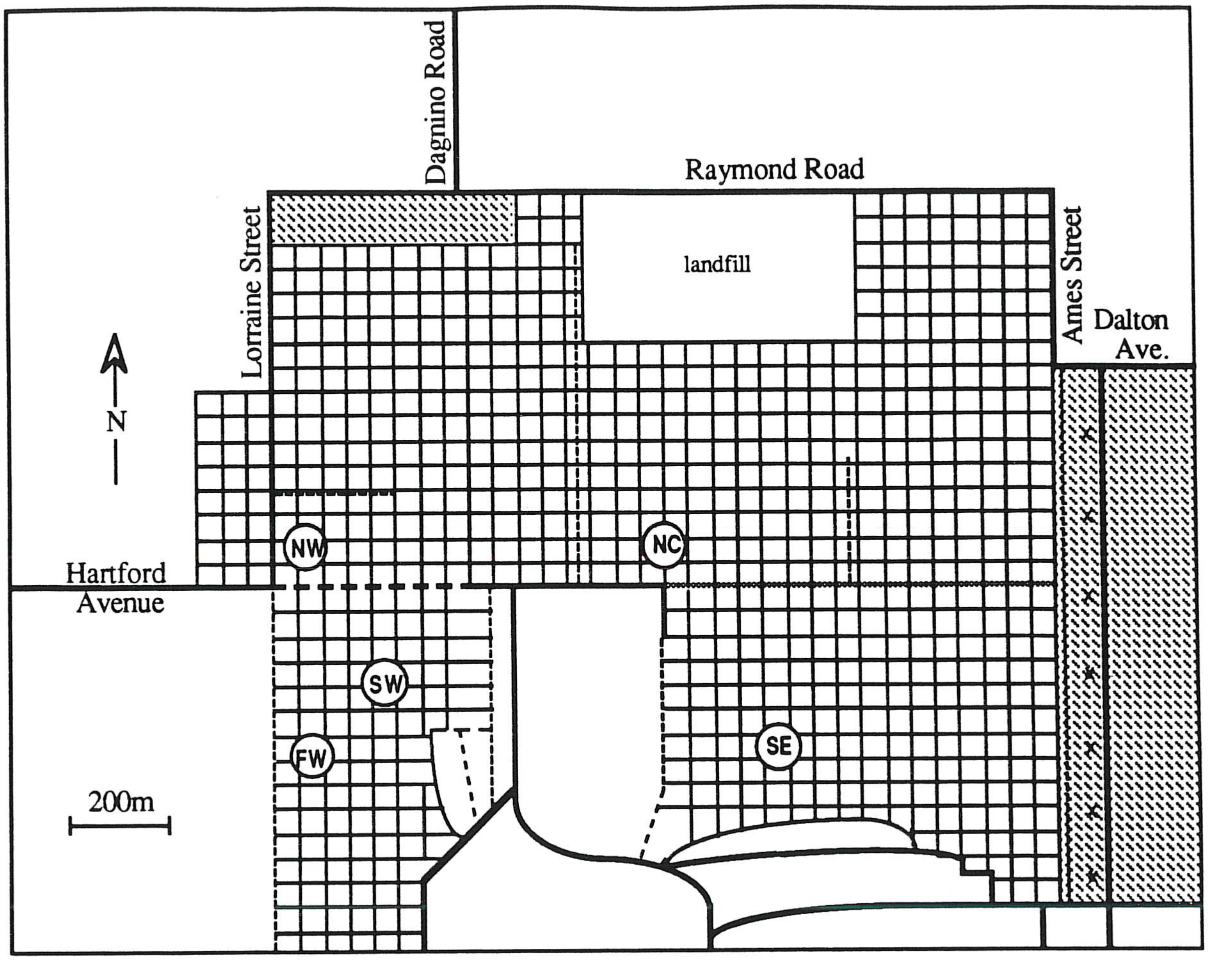


Figure 4. Sites for soil test pits (NW, NC, SW, SE); studies of the reproductive biology of *Cordylanthus palmatus* (NW, NC, FW, SW); and seed predation experiments (NW, NC, SW), Springtown Alkali Sink, Livermore, California.

Seed predation studies

Our previous work suggested that annual seed production of *Cordylanthus palmatus* vastly exceeds the numbers of seedlings observed in subsequent years (CCB 1992). While viable *C. palmatus* seeds can remain dormant in the soil for the soil for at least three years (see the Results section of this report), and some *C. palmatus* seeds are undoubtedly transported onto unsuitable habitat or buried under sediments, seed predation could be a source of mortality for this species. Field studies were designed to identify and investigate the presence of predators on *C. palmatus* seeds at Springtown.

Three study sites with large concentrations of *Cordylanthus palmatus* were chosen to represent the diversity of microhabitats at Springtown: two in north Springtown (NC and NW), and one in southwest Springtown (SW). These sites are marked on Figure 4.

In October 1992, five sets of two paper plates (diameter 15 cm) were laid out at 1 m intervals from the main concentration of plants at each site. One plate in each pair contained 40 *Cordylanthus palmatus* seeds; the other contained 40 grains of cracked wheat. For daytime tests, plates were set out at 7:00 am (one hour after sunrise) and collected at 6:30 pm (half an hour before sunset). For nighttime tests, plates were set out at 6:30 pm and collected at 7:00 am. Two daytime tests and one nighttime test were conducted at each site. At the conclusion of each test the plates were emptied, the contents were placed into separate containers, and the remaining seeds and grains were counted.

Observations at these sites and in other areas were conducted throughout the study period. Ants observed gathering and carrying *Cordylanthus palmatus* seeds were sampled for later identification.

Other observations pertinent to conservation planning for Springtown

The wetlands of the Springtown Alkali Sink in California's northern Livermore Valley are potential habitat for a host of somewhat cryptic animal species, several of which are candidates for federal and state protection. Among the candidate species most likely to be found at Springtown are the California tiger salamander (*Ambystoma californiense*), several species of fairy shrimp (Anostraca: *Branchinecta lynchi*, *Branchinecta longiantenna*, and *Linderiella occidentalis*), and the vernal pool tadpole shrimp (Notostraca: *Lepidurus packardi*). The presence of any of these species would significantly impact conservation planning for Springtown.

In early March 1992 larval California tiger salamanders were observed in pools along the southwestern edge of the study site. A systematic survey of the Springtown site for larval salamanders was conducted on 31 March, when virtually all bodies of standing water larger than two meters in diameter were seined. Larvae were counted and released. Additional observations on the growth and survivorship of salamander larvae in several of the pools were taken by Ethan Janson of University of California - Berkeley throughout spring 1992.

During late winter and early spring site visits, Center biologists sampled pools across

Springtown for tadpole shrimp and fairy shrimp. Samples were identified by Prof. Denton Belk of Our Lady of the Lake University, San Antonio, Texas.

Results and discussion

Long-term monitoring of the Springtown population

The late summer census at Springtown Alkali Sink indicates that the total number of adult *Cordylanthus palmatus* at Springtown in 1992 was more than 36,000, approximately 3.5 times the number recorded in either 1990 or 1991. Detailed results of the monitoring are shown in Table 1 and Figures 5, 6, and 7.

While the number of *Cordylanthus palmatus* individuals observed increased greatly in all subregions of Springtown between 1991 and 1992, there was substantial variation in the degree of increase among subregions. The number of plants on north Springtown, for example, increased to more than 7.6 times the 1991 level. The smallest increase was noted on west Springtown, where the number of individuals in 1992 was 1.7 times the 1991 level.

The number of 50 m x 50 m quadrats occupied by *Cordylanthus palmatus* in 1992, a rough measure of the extent of area occupied at Springtown, differed from 1991 values in two of the four main subareas. In north Springtown the number of occupied quadrats increased by 38% from the number occupied in 1991, and in southeast Springtown the number of occupied quadrats increased by some 22%. In southwest Springtown and west Springtown the numbers of quadrats occupied in 1992 were very similar to figures for 1990 and 1991; in these areas there were no real changes in extent of area occupied.

The observed 1992 increase in north Springtown is due in part to the 143 individuals that are thought to be the results of the relocation experiment, and the resultant occupation of eight previously unoccupied quadrats that include the sites of the relocation experiment (see Figures 7 and 13). However, even discounting these individuals, the number of plants on north Springtown was still 7.6 times the 1991 number. Without these "experimental" quadrats the number of occupied quadrats in north Springtown increased from 40 of 426 (in 1991) to 47 of 426 (in 1992) for an increase of 18% in number of quadrats occupied.

The changes in number of occupied quadrats were only roughly correlated with changes in overall number of individuals (north Springtown experienced the largest increases in number of individuals, but southeast Springtown showed the largest increase in number of occupied quadrats when relocation sites are disregarded). In general, most of the increases in number of individual

Cordylanthus palmatus plants occurred in quadrats that supported *C. palmatus* in previous years (see Figures 5-7). The overall distribution of *C. palmatus* at the Springtown Alkali Sink has been fairly stable during the three year study period, and the increased numbers of individuals have resulted in higher densities of individuals in historically occupied areas rather than in large-scale expansion of the total area occupied.

	No. of *C. palmatus*			No. 50 m quadrats occupied/total quadrats		
	1990	1991	1992	1990	1991	1992
West (FCC)	**172**	**360**	**604**	**4/16**	**6/16**	**5/24[a]**
North (City of Livermore)	**1,049**	**1,940**	**14,902**	**37/426**	**40/426**	**55/426[b]**
Northwest	698	1007	8,071	17/172	23/172	23/172
Northeast	351	933	6,831	20/254	17/254	32/254
Southwest	**1,538**	**2,198**	**6,168**	**19/105**	**22/105**	**18/105**
Anden Group	623	1,074	2,171	7/46	8/46	4/46
S&L Investments	915	1,124	3,997	12/59	14/59	14/59
Southeast	**6,235**	**5,941**	**14,920**	**40/173**	**40/173**	**49/173**
Garaventa	6,140	5,619	14,713 [c]	35/128	35/128	44/128 [c]
Kaufman & Broad	70	15	160	3/35	2/35	4/35
City of Livermore	25	307	47	2/10	3/10	1/10
TOTAL	**8,994**	**10,439**	**36,594**	**100/717**	**108/720**	**127/728[a,c]**

Table 1. *Cordylanthus palmatus* surveys, 1990 - 1992, by region and by parcel at Springtown. Regions and rough parcels are indicated in Figure 1. Because quadrat boundaries did not always coincide with parcel boundaries, the numbers of plants per parcel are estimates.

a: Eight 50 m x 50 m quadrats included in the 1992 results were surveyed also in 1990 and 1991, but not noted in the previous reports. For consistency the results for 1990 and 1991 are not reported here. These eight quadrats were unoccupied in all three years.

b: Occupation of eight quadrats and 143 of the individual plants in north Springtown are likely the results of relocation experiments in this region. See text for details of this work; Figures 7 and 13 show the relocation sites.

c: Approximately 26 quadrats in southeast Springtown burned in a grass fire prior to the 1992 survey (see Figure 7). While some *Cordylanthus palmatus* individuals in the burn area were still evident during the survey, many individuals were obliterated by the firebreaks and could not be counted in the survey.

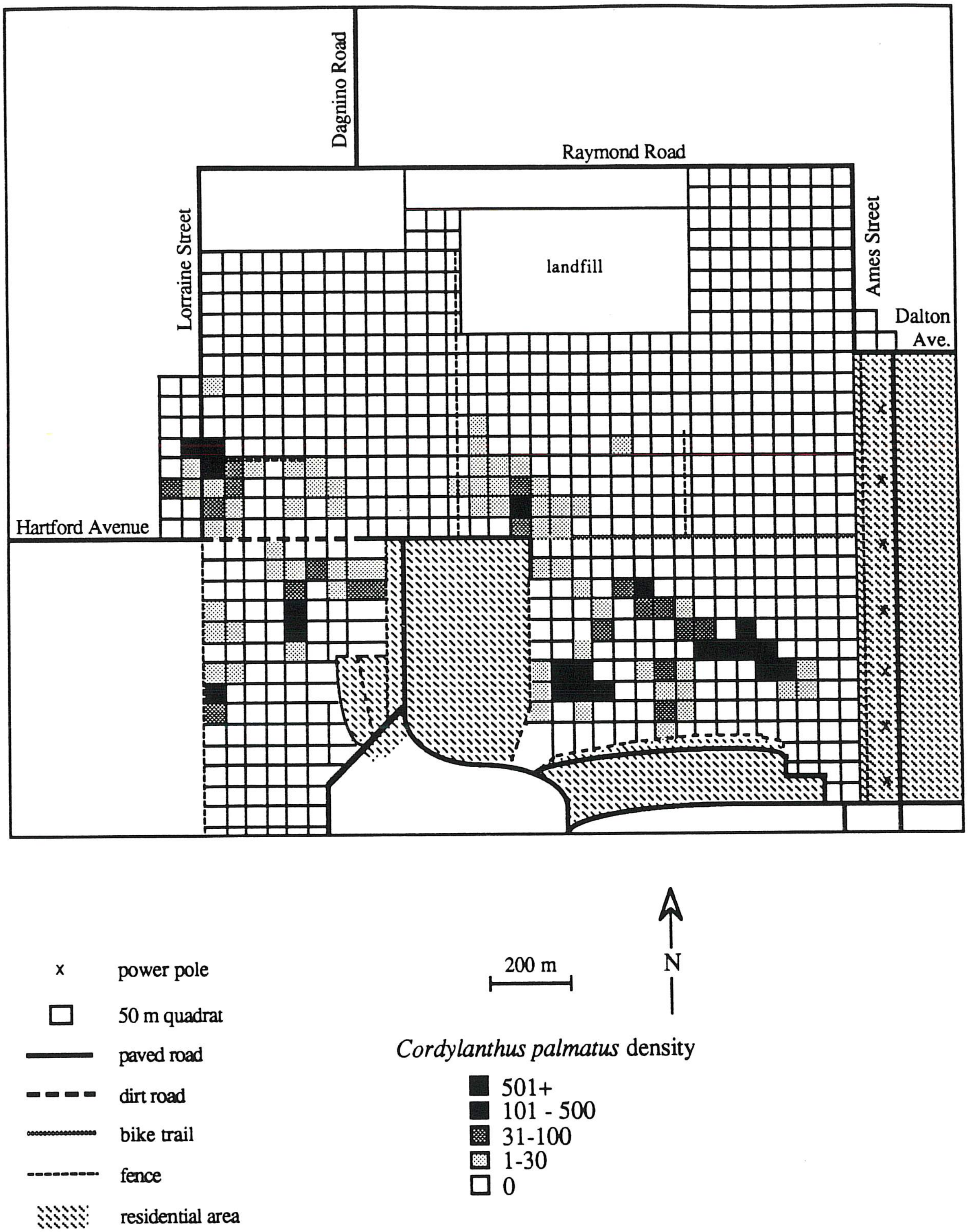


Figure 5. *Cordylanthus palmatus* population at Springtown Alkali Sink, 1990. Density is indicated for each 50 meter x 50 meter quadrat. Scale is 1:13,500.

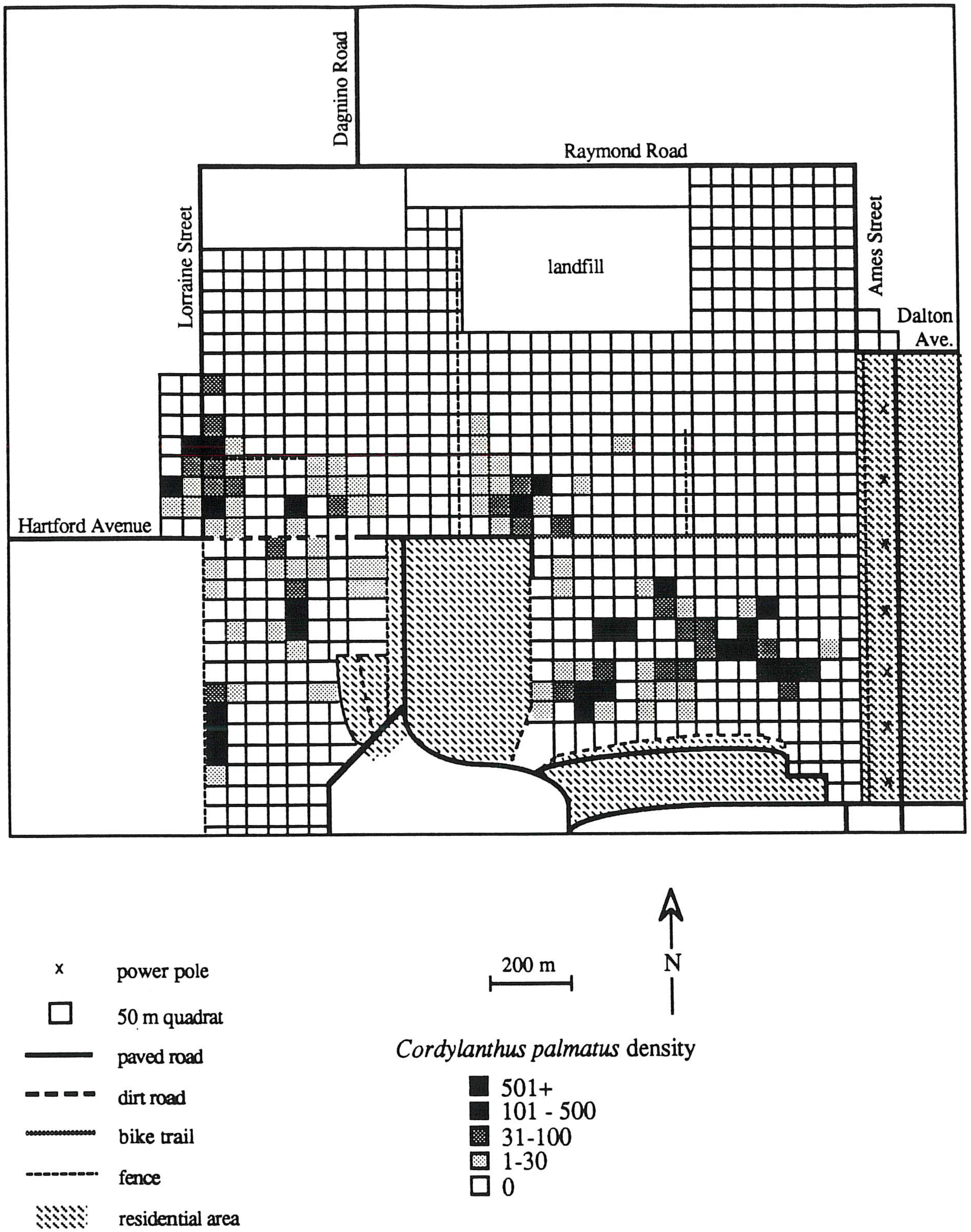


Figure 6. *Cordylanthus palmatus* population at Springtown Alkali Sink, 1991. Density is indicated for each 50 meter x 50 meter quadrat. Scale is 1:13,500.

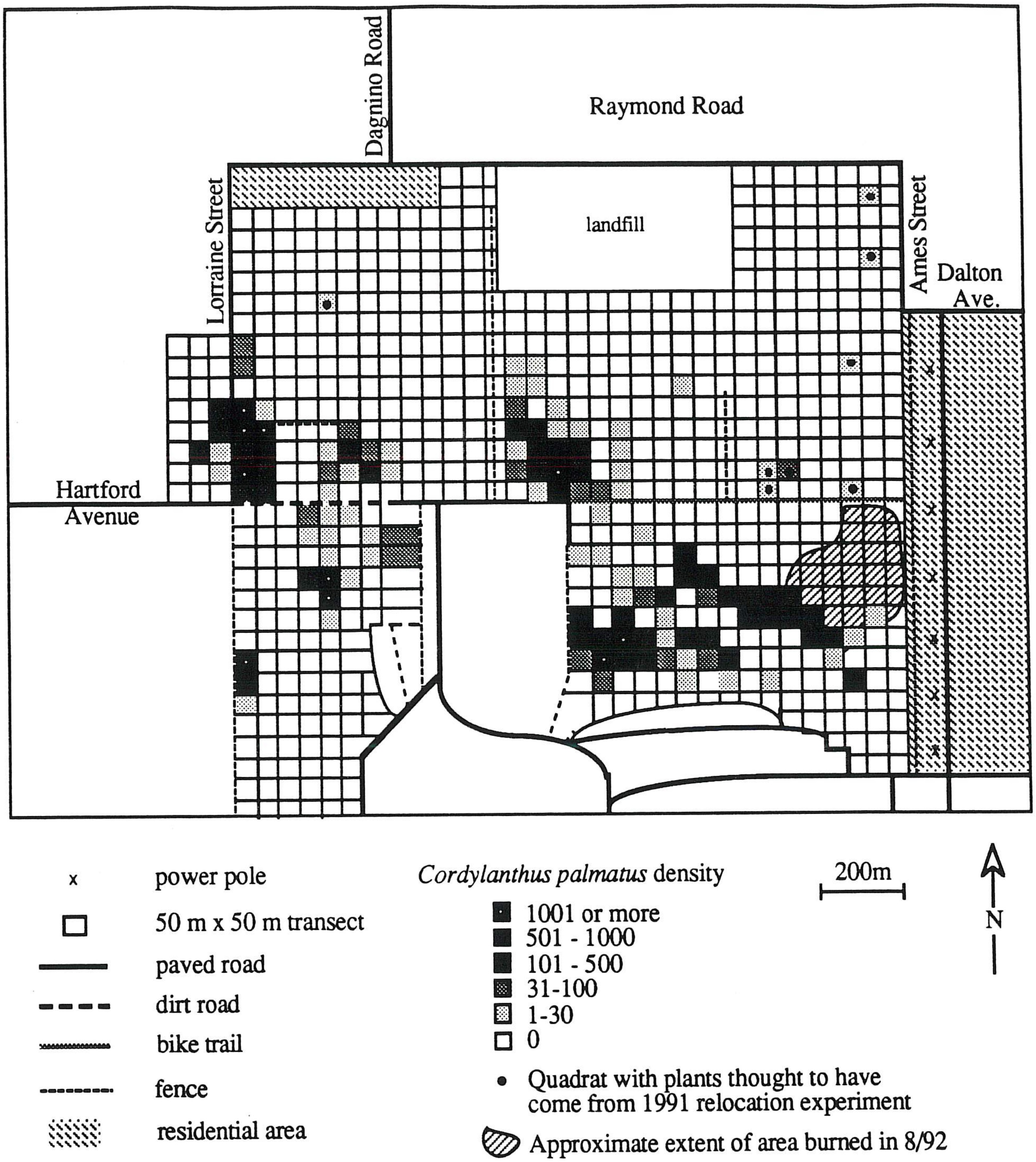


Figure 7. *Cordylanthus palmatus* population at Springtown Alkali Sink, 1992. Density is indicated for each 50 meter x 50 meter quadrat. A grass fire in August 1992 burned part of SE Springtown, as marked. Scale is 1:13,500.

The specific causal factors for these observed increases are very difficult to isolate. One probable factor is the removal of cattle from north Springtown in spring 1991. Any effects from the elimination of grazing should only be evident in northwest and northeast Springtown, as the other regions at Springtown had not been grazed for many years prior to the initiation of this study. In fact, the increase in numbers of individuals in north Springtown (7.6 times the 1991 total for that area) is far greater than increases in other regions of Springtown, suggesting that grazing played a role in the population dynamics of *C. palmatus*.

The impacts of heavy seasonal grazing at Springtown, though unquantified, were evident in the 1990 and 1991 field seasons. Cattle, attracted to wet areas (especially seasonal streams and ponds), trample and create extensive muddy areas. As *Cordylanthus palmatus* at north Springtown grows largely along stream channels and edges of seasonal ponds, this trampling likely has a great effect on *C. palmatus* seedlings, which emerge in January and February, typically in or near areas of standing water and saturated soil.

While the removal of grazing from north Springtown has apparently benefited the bird's beak over the short term, it may not be conducive to long-term management of this and other native annual plant species. In many California grasslands, grazing is thought to control the establishment and growth of non-native grasses. While it is not known whether non-native species compete with *Cordylanthus palmatus* and other alkali sink natives, areas of Springtown that have not been grazed in the recent past host tall, dense stands of non-native grasses, which could crowd out native plants such as *C. palmatus*. In particular, much of southwest Springtown is covered by dense stands of non-native grasses and supports almost no *C. palmatus*. Well-managed dry season grazing might control such invasive species while minimizing the disruption of the seasonal wetlands; this might well prove beneficial to the persistence of native plants in this ecosystem. Grazing experiments are required to determine conclusively whether a proper management regime for this species requires limited grazing during the dry season.

Changes in *Cordylanthus palmatus* abundance and distribution between years might be explained by between-year differences in weather patterns, primarily the timing and amount of rain. While the 1991 and 1992 weather patterns are similar, especially when compared to 1990 (see Appendix A), there are several potentially important differences. For example, there was much more rain in January and February in 1992 than in 1991. If rates of *C. palmatus* germination are based on factors that include photoperiod and moisture, these weather differences could be of biological importance.

Effects from increased early season water should be more widespread across the site than localized changes resulting from the elimination of grazing. Unfortunately, given the muddled land-use history of Springtown, predicting the impact of increased early season water across the alkali sink is not possible on the time-scale of this project; hence the assumption that increased early season water has a similar impact in all subareas at Springtown is not well supported. Thus, while it is likely that the 1992 increases in number of adult *Cordylanthus palmatus* was at least partially the result of the elimination of grazing, availability of early season water may have significantly influenced the distribution and abundance of *C. palmatus*.

Surveys of Central Valley populations of *Cordylanthus palmatus*

Late summer surveys have allowed us to estimate the number of individuals that survived to reproduction. These are shown in Table 2.

SITE	EST. NUMBER OF PLANTS, 1992
Delevan National Wildlife Refuge, tract T12	75,000 - 125,000
Delevan National Wildlife Refuge, tract T10	300 - 500
Colusa National Wildlife Refuge, tract T7	30,000 - 50,000
Colusa National Wildlife Refuge, tract P3	3,000 - 10,000
Colusa National Wildlife Refuge, tracts T21-22	3,000 - 10,000
City of Woodland, CNDDB occ. 1-0	not surveyed (posted no trespassing)
City of Woodland, CNDDB occ. 3-0	0
Livermore, Springtown	36,000
Alkali Sink Ecological Reserve, CNDDB occ. 11	450

Table 2. Estimated number of plants in known populations of the palmate-bracted bird's beak, August and September, 1992.

Figures 8 and 9 map the distribution and approximate local abundance of *Cordylanthus palmatus* at the two National Wildlife Refuges.

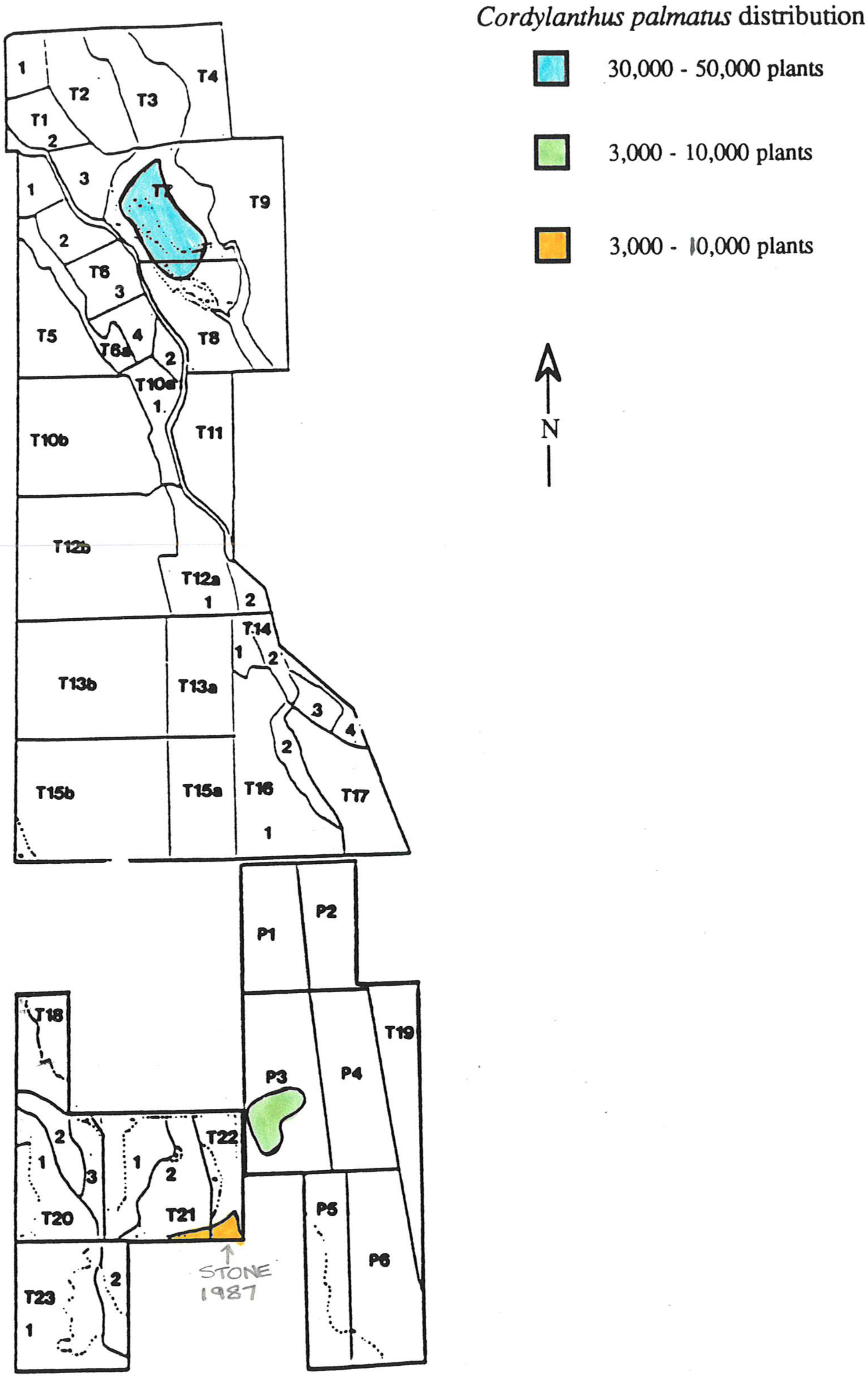


Figure 8. Extent of *Cordylanthus palmatus* at Colusa National Wildlife Refuge, 1992. Sections are tracts diked for water control. Historically occupied areas and other areas of potential habitat were surveyed in August 1992. The total number of plants observed was between 36,000 and 70,000.

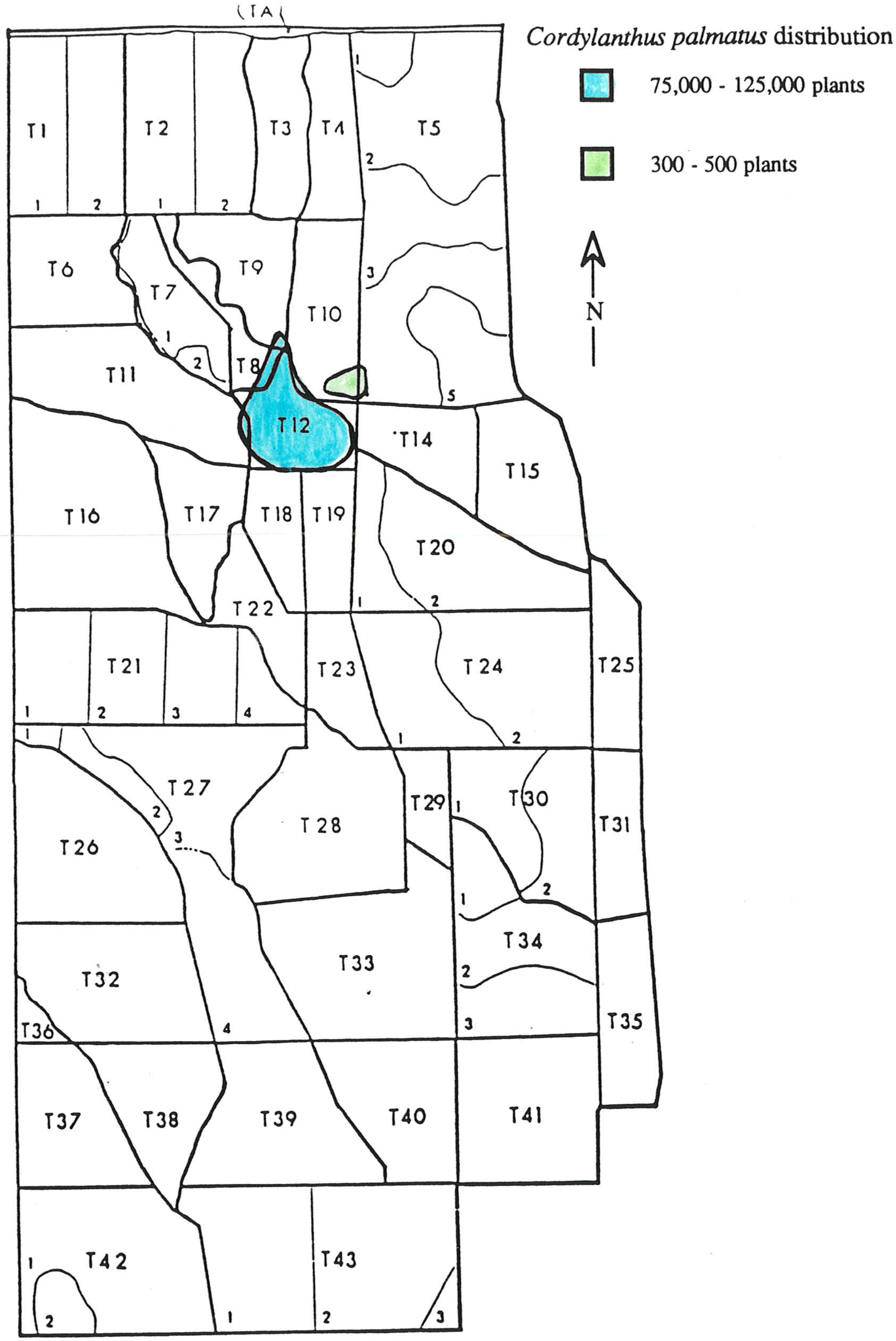


Figure 9. Extent of *Cordylanthus palmatus* at Delevan National Wildlife Refuge, 1992. Sections are tracts diked for water control. Historically occupied areas and other areas of potential habitat were surveyed in August 1992. The total number of plants observed was between 75,000 and 125,000.

Comparisons of these 1992 estimates with previous estimates (California Department of Fish and Game 1991) should be made with caution. The estimates were based on site visits conducted by various researchers at different times during the growing season, and are not directly comparable. However, the fact the 1992 estimates of the Delevan and Colusa populations were much larger than those made in earlier years, and that these two populations appeared to be uniformly robust, is consistent with the large increase in the number of individuals observed at Springtown.

USFWS biologist Greg Mensik of the Sacramento Valley National Wildlife Refuge Complex suggested that *Cordylanthus palmatus* also occurs on the northernmost refuge of the Sacramento Valley complex, the Sacramento National Wildlife Refuge, as a result of several relocation experiments. That population should be surveyed.

Despite its limited range, this federally- and state-listed endangered species appears to be persisting in a few locally robust populations.

Studies of the *Cordylanthus palmatus* seed bank at Springtown

Results from the seed bank experiments clearly indicate that *Cordylanthus palmatus* seeds can remain dormant and viable for at least three years; soil samples collected in summer 1990 (A-K) (containing seeds produced in fall 1989 or earlier) yielded seedlings in winter 1991 and winter 1992.

Samples A-K yielded a total of 25 seedlings in both 1991 and 1992 tests. Samples collected in summer 1990 (L1-L3) to which 50 seeds each were added produced fewer total seedlings in 1992 (28) than in 1991 (38). Results are shown in Table 3.

Sample	Date collected	# *C. palmatus* germinating winter 1991	winter 1992	Habitat type
A1	summer 1990	6	0	densely occupied
B1	summer 1990	11	8	occupied
C1	summer 1990	1	0	occupied
D1	summer 1990	3	15	occupied
E1	summer 1990	0	0	downstream of occupied
F1	summer 1990	0	0	downstream of occupied
G1	summer 1990	4	2	downstream of occupied
H1	summer 1990	0	0	unoccupied, apparent habitat
J1	summer 1990	0	0	unoccupied, apparent habitat
K1	summer 1990	0	0	unoccupied, apparent habitat
L1	summer 1990	17	15	unoccupied, apparent habitat; 50 seeds added
L2	summer 1990	15	7	unoccupied, apparent habitat; 50 seeds added
L3	summer 1990	6	6	unoccupied, apparent habitat; 50 seeds added
A-1	summer 1991	–	0	densely occupied, southwest Springtown
A-2	summer 1991	–	0	densely occupied, southwest Springtown
A-3	summer 1991	–	0	unoccupied, southwest Springtown
A-4	summer 1991	–	3	unoccupied, southwest Springtown
A-5	summer 1991	–	0	occupied, southwest Springtown
WL-1	summer 1991	–	0	densely occupied, west Springtown
WL-2	summer 1991	–	4	densely occupied, west Springtown
WL-3	summer 1991	–	0	occupied, west Springtown
WL-4	summer 1991	–	1	unoccupied, west Springtown
WL-5	summer 1991	–	0	occupied, west Springtown (isolated plant)
CL-1	summer 1991	–	0	densely occupied, north Springtown
CL-2	summer 1991	–	0	unoccupied, north Springtown
CL-3	summer 1991	–	0	occupied, north Springtown
CL-4	summer 1991	–	0	densely occupied, north Springtown
G-1	summer 1991	–	0	densely occupied, southeast Springtown
G-2	summer 1991	–	3	densely occupied, southeast Springtown
G-3	summer 1991	–	0	occupied, southeast Springtown
G-4	summer 1991	–	0	unoccupied, southeast Springtown

Table 3. Germination of *Cordylanthus palmatus* from soil collected from Springtown Alkali Sink, Livermore, summer 1990 and summer 1991. 50 seeds were added to each of samples L1, L2, and L3 prior to the initial planting in winter 1991.

Seedlings grew from two soil samples taken in summer 1991 from areas that were not occupied by *Cordylanthus palmatus* in 1991 (A-4 and WL-4). There are two possible explanations for this result: (1) seeds disperse more than 10 m (unoccupied habitat was defined to be more than 10 m from adult *C. palmatus*), and/or (2) those seeds were dormant in the Springtown soil for more than a year and did not germinate in 1991. The latter explanation is likely, as the three samples containing seeds known to have been produced in 1989 or before did produce seedlings in both 1991 and 1992; thus not all viable seeds in a sample germinate in the following growing season. The distance seeds disperse from parent plants is unknown, but is likely to be highly variable.

The presence of a seed bank can be essential to the persistence of a very localized population. Though ecologically and geographically restricted, *Cordylanthus palmatus* presently persists in sufficiently large populations that the seed bank is not likely to add significant genetic variability. This part of the population, the bank of dormant, viable seeds in the soil, could aid in recovery from local catastrophes that affect the above-ground (plant) portion of the population. Even if no individual plants survived to reproduction following a catastrophic event (for example, an exceptionally hot summer fire, or widespread habitat disturbance such as that caused by off-road vehicles), the seed crop from past years could provide a buffer that might well allow the population to persist.

Genetic variability in *Cordylanthus palmatus*

Approximately 20 of the 46 enzyme loci tested from the Springtown population were found to be well resolved on four of the five buffer systems screened; some variability was found at four of these loci, and at least one locus appears to be highly variable.

The extraction buffer most effective for *C. palmatus* appears to be that of Dixon and May (1990). Samples of pre-reproductive *C. palmatus* will be taken in spring 1993, and allozyme data will be collected for use in analyses of the genetic structures of the populations.

Characterization of Springtown soils and comparison to local distribution of *Cordylanthus palmatus*

Results from the soil test pits indicate a highly variable edaphic environment at the Springtown Alkali Sink. Most of the soils identified by this study are variations of the soil types delineated in the Soil Conservation Survey (SCS) map of Springtown (see Coats *et al.* 1988), but these soil variations were distributed on a much finer scale than indicated on the broad-scale SCS maps. Soil test pits in close proximity to each other, such as A1 and A2, and test pits within the same general habitat type, such as soil test pits A3 and A9 located in the grass-covered uplands of northeast

Springtown, often were quite distinct (see Appendix B for profiles of the 24 soil test pits).

In order to characterize the extensive edaphic variability found in the soil test pits, a three-element soil classification system was developed (Table 4). These three elements were chosen after preliminary analysis of the test pit profiles on the basis of their probable relevance to biological and physical processes.

Element 1: degree of profile development

1. weak or none (alluvium, entisols, vertisols)
2. moderate (Solano fine sandy loam, weak Bt horizon)
3. strong (stronger Bt horizon, Pescadero series, San Ysidro)

Element 2: average texture of top 20 centimeters

1. sand, loamy sand, sandy loam
2. loam, silt loam
3. clay loam, clay

Element 3: dominant salt in top 20 centimeters

1. non-saline
2. calcium carbonate ($CaCO_3$)
3. sodium - salts dominate
4. calcium sulfate ($CaSO_4$)

Table 4. Soil classification elements used in analysis of samples from Springtown Alkali Sink, Livermore, CA.

Degree of soil profile development was the first element characterized. Profile development is related to amount of clay present in the parent material, amount of standing water to which the site is exposed, and age. The second and third elements relate to soils found in the top 20 centimeters. Average texture is based on the relative amounts of clay, loam, and sand present in this upper layer. Texture is biologically important because germination and early growth of *Cordylanthus palmatus*, like virtually all other plant species, are typically strongly impacted by very local edaphic conditions. Just as average texture of the top 20 cm affects biological processes, the types of salt present in the upper layer may strongly affect plant germination and growth.

After using these elements to generate three-digit map units, the soils of the three 2-hectare study plots were mapped (Figures 10, 11, and 12). The distribution of these soil types was quite complex, and individual patches of specific soil types were often only a few meters in width or diameter.

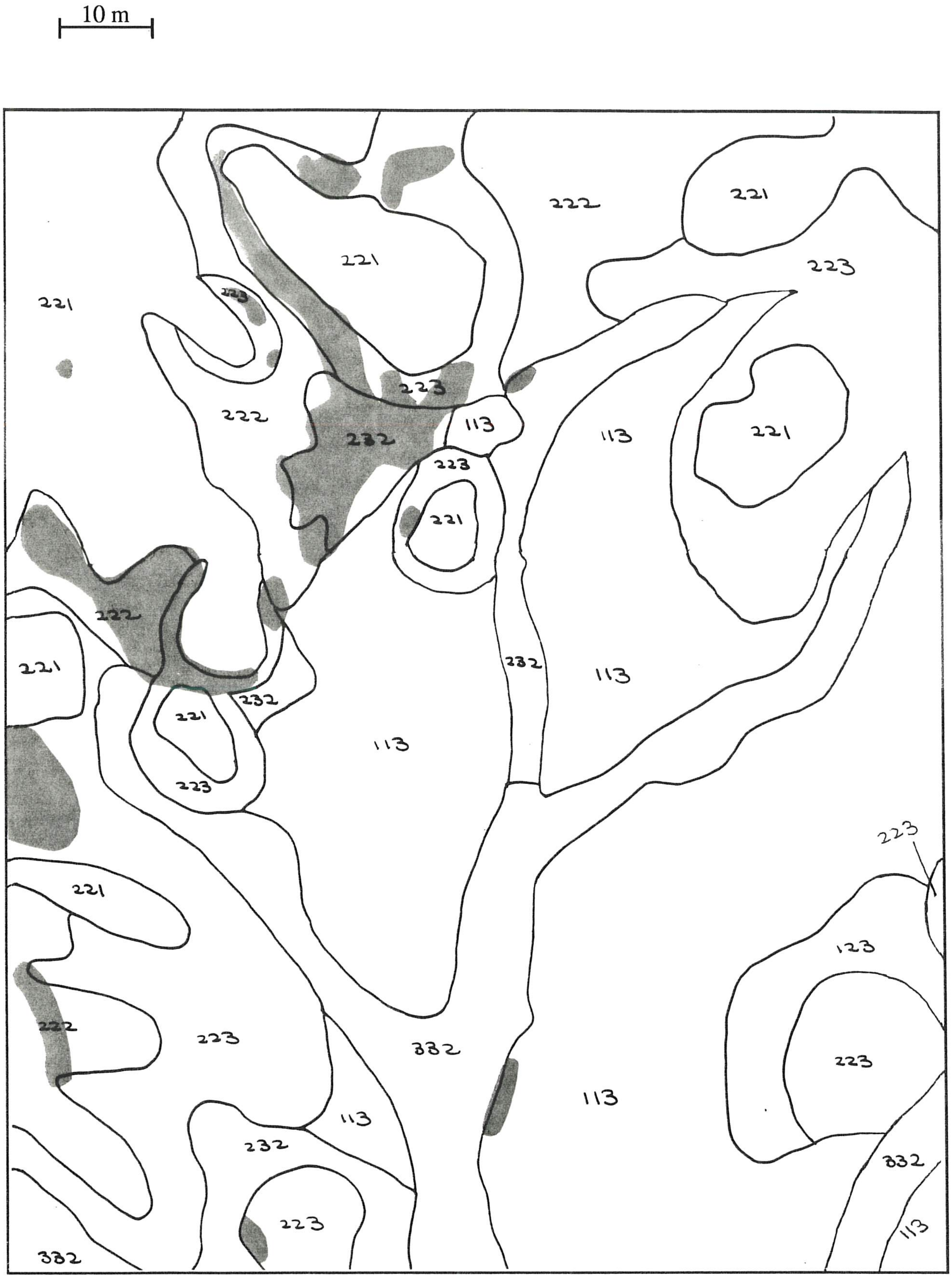


Figure 10. Distribution of soil types, northeast Springtown. Patches of more than 10 *C. palmatus* are shaded.

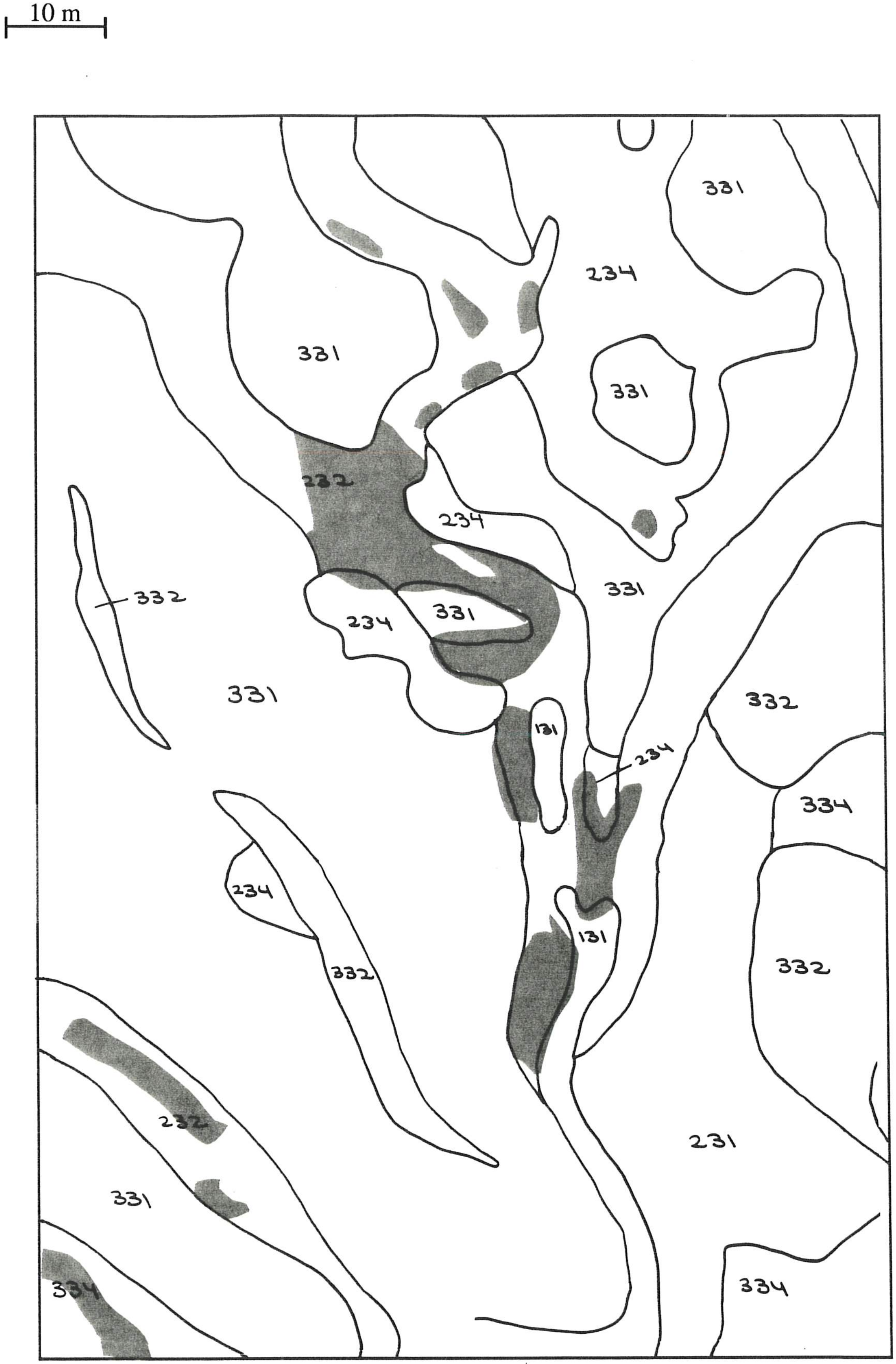


Figure 11. Distribution of soil types, northwest Springtown. Patches of more than 10 *C. palmatus* are shaded.

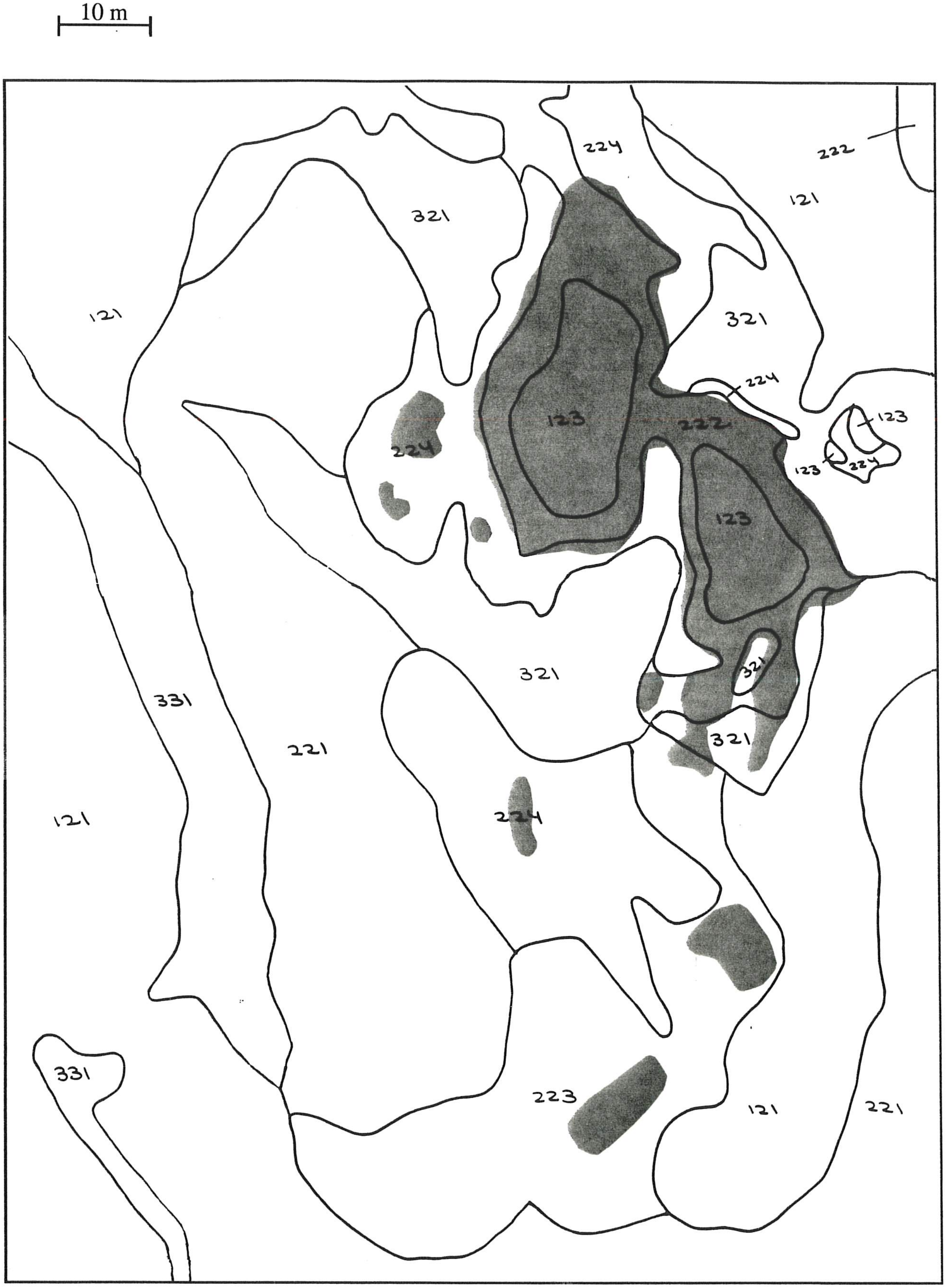


Figure 12. Distribution of soil types, southwest Springtown. Patches of more than 10 *C. palmatus* are shaded.

The distribution of areas supporting more that 10 *Cordylanthus palmatus* plants is also indicated on Figures 10, 11, and 12. Several broad patterns are evident from the comparisons of the distribution of *C. palmatus* and soil types. In the two areas where there are large networks of channels and floodplains, northeast Springtown and northwest Springtown (Figures 10 and 11), *C. palmatus* was concentrated primarily in soil types 222 and 232. Not all patches of soils 222 and 232 were occupied by *C. palmatus* Those that were tended to be along comparatively smaller side channels, in saddles between uplands, and along the floodplains of side channels. Uplands, areas of comparatively recent alluvial deposits, and the bottoms of main channels were generally not inhabited by *C. palmatus*.

The distribution of soil types and *Cordylanthus palmatus* was somewhat different in the scald region of southwest Springtown than in the channel-dominated areas. In the scald, *C. palmatus* was found primarily in soil types 222 and 123 (with a few significant patches of *C. palmatus* located in soil types 223, 224, and 321). The bulk of the main scald in this region consisted of several large patches of these two soil types. *C. palmatus* and soil types 222 and 123 were generally absent from the remainder of the southwest Springtown study site.

Definition of a specific set of edaphic requirements for *Cordylanthus palmatus* is difficult for a number of reasons, including the undoubtedly large impacts that fine-scale topographic variation, recent hydrologic patterns, and previous patterns of *C. palmatus* occupancy have on current *C. palmatus* distribution. However, the results of this study have led to a better understanding of the general relationship between *C. palmatus* and soil type. Comparatively large areas of soil type 222 were occupied by *C. palmatus* in each of the three study areas. This soil type is characterized by loam or loamy silt in the upper 20 cm, intermediate profile development, and $CaCO_3$. Soils with a high degree of profile development (3--) and non-saline soils (--1) generally lacked *Cordylanthus palmatus* (plants often were found along both sides of boundaries separating different soil types, and isolated plants were found growing in many of the soil types).

While soil characteristics are clearly only one of a number of factors affecting the distribution and abundance of *Cordylanthus palmatus*, the ability to identify even one factor greatly benefits conservation planning. Results of these analyses should help with the identification of areas with suitable edaphic conditions for *C. palmatus*, but where *C. palmatus* is not presently found. This will particularly helpful in planning for regions of the Springtown Alkali Sink that have suffered extensive anthropogenic disturbance. Using existing aerial photographs it should be possible to delineate fairly small areas, on the order of tens of meters, that provide edaphic conditions suitable for *C. palmatus*.

Study of the soils at Springtown has also led to a better understanding of the wetland ecosystem as whole. The site is a patchwork of old and new alluvial depositions. These deposits, along with the numerous channels and floodplains, further support the suggestion that the Springtown ecosystem is highly dynamic and may be dependent on periodic disturbance (flooding) to maintain its current level of heterogeneity (CCB 1992).

Experimental relocation of *Cordylanthus palmatus*

In three of the eight seed relocation sites (1, 3, and 8) no plants were apparent in summer 1992; germination rates at the five other sites were variable. Sites 1 and 3 had been filled with trash since the seeds were scattered. In sites 5 and 6, only six and three plants, respectively, were apparent; sites 2, 4, and 7 had ~50% germination or better. Figure 13 shows sites of 1991 relocation and approximate numbers of plants in 1992; Table 5 describes the sites and indicates exact numbers of 1992 plants.

The number of plants at site 4 in summer 1992 was much larger than the approximate number of seeds scattered there the previous winter. The plants in this site were much more widespread than plants in any of the other sites, covering approximately 1000 m^2. The planting area at this site was in a long channel, in which water from winter rains and runoff may have transported the seeds both upstream and downstream. Because the number of plants at site 4 so greatly exceeded the estimated number of seeds scattered in that area, it is likely that some of these 77 plants were the products of the seed bank and it is unclear whether any of the *Cordylanthus palmatus* plants at this site originated from seeds experimentally scattered there in 1991.

At sites 2, 5, 6, and 7, however, the number of *Cordylanthus palmatus* plants, the narrow distribution of individuals, and the degree of isolation of these patches indicate that it is probable that the plants observed in 1992 originated from seeds relocated in November 1991.

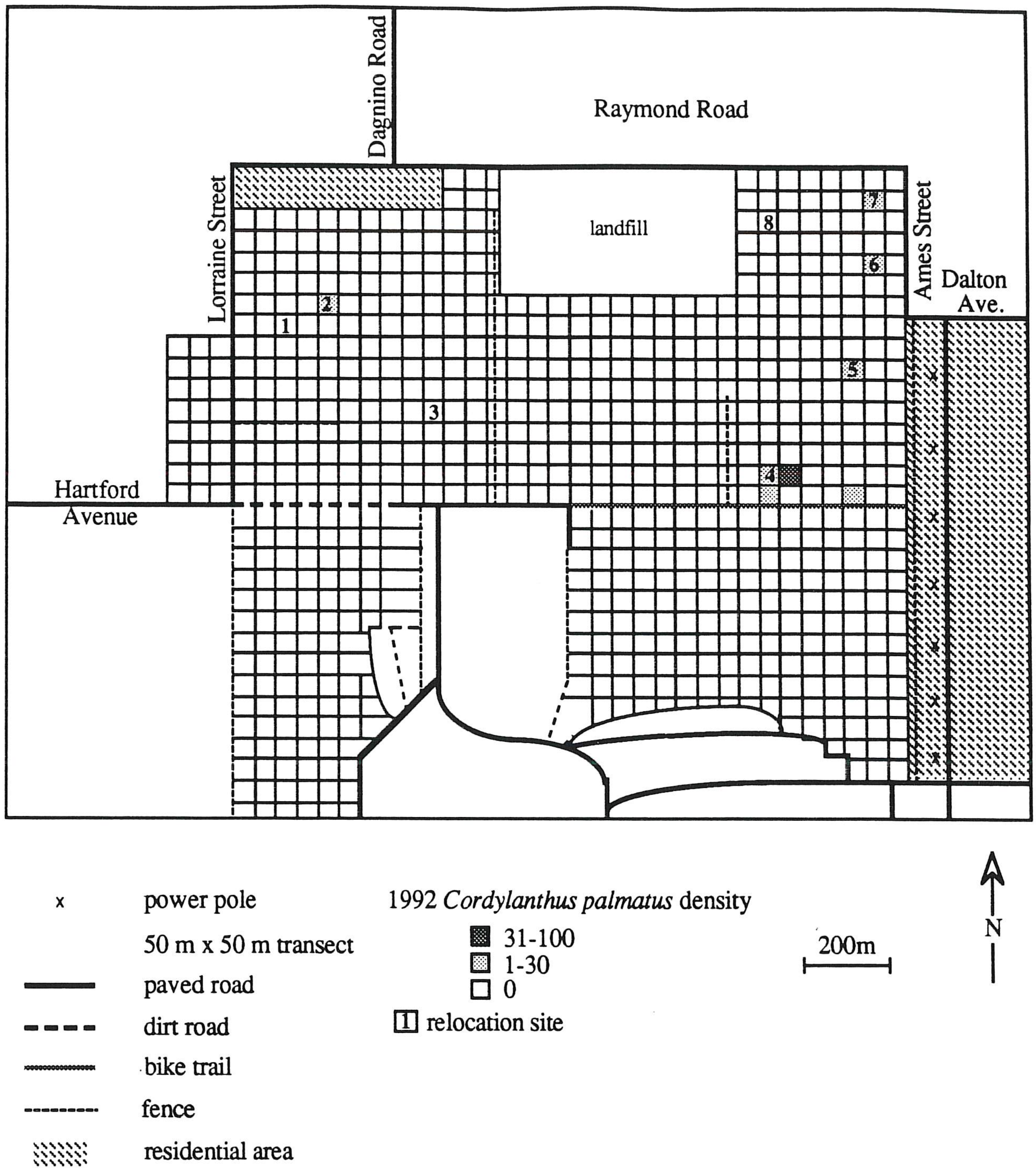


Figure 13. Sites of *Cordylanthus palmatus* seed relocation, Springtown Alkali Sink, November 1991. None of the eight relocation sites supported the species in either 1990 or 1991.

Site	Number of plants		Area Type	Comments
	Total	Flowering		
1	0	0	across drainage	area filled in with trash
2	29	21	bare edge of channel	
3	0	0	long flat channel	overgrown, filled with trash
4	77	72	long channel	scattered down channel in an area of ~1000 m^2
5	6	4	edge of streamside pool	plants right in seed planting site; plants within 0.2 m^2
6	3	3	scald; running water	
7	28	12	scald; edge of basin	mammal disturbance; plants within 0.25 m^2
8	0	0	broad drainage/scald	

Table 5. Results of seed relocation, by site. Approximately 50 *C. palmatus* seeds were scattered at each of eight sites in November 1991. Plants were counted summer 1992.

Because the number of seeds scattered in each area was approximate, actual percent germination is not calculable. Between one-quarter and one-third of all seeds scattered appeared to germinate, and approximately 75% of these plants produced flowers.

While this study could not conclusively determine whether the seedlings identified in the study areas came from the seeds scattered in this experiment rather than from a seed bank, the results suggest that simply scattering viable seeds in areas of apparently suitable habitat can be quite successful, at least in the short term, for expanding the local distribution of *C. palmatus*.

Pollination and reproductive biology of *Cordylanthus palmatus*

Developmental assessments of *Cordylanthus palmatus* reproductive structures showed that styles matured before anthers in 43% of all cases and, in the remaining 57%, styles and anthers matured nearly simultaneously. In all flowers, styles persisted longer than did anthers. Thus, while for an individual flower the window of pollen deposition was always longer than that for pollen collection, anthers and styles were both mature at the same time for a substantial proportion of the flowering period. In terms of a single plant with several mature flowers, there is great overlap in reproductive maturity of anthers and styles, and there appear to be no gross phenological barriers to self-pollination.

Plants in both hand-pollination treatments (selfed and outcrossed) produced fruits and seeds, suggesting that *Cordylanthus palmatus* is neither an obligate "selfer" nor an obligate "outcrosser". Plants in both treatments had fewer seeds per fruit than plants observed for the control (clipped, unbagged) and natural (unclipped, unbagged) treatments (Table 6). Without germination trials for seeds produced from each of the four treatments, we cannot draw conclusions regarding the effect of these treatments on seed viability.

Clipping did not affect mean seed set per fruit (control=7.09 vs. natural=7.10), but appears to have reduced the number of flowers producing fruits (control=57.9 vs. natural=90.3; see Table 6). We did not test whether there was also a bagging effect because this seemed unlikely.

Treatment	% flowers becoming fruits	Seeds/fruit
self-pollinated (clipped, bagged)	20.3	5.97
outcrossed (clipped, bagged)	19.2	4.60
control (clipped, unbagged)	57.9	7.09
natural (unclipped, unbagged)	90.3	7.10

Table 6. Effects of hand pollination (self-pollination and outcrossing) and open pollination (clipped and unclipped plants) on reproductive output of *Cordylanthus palmatus*.

Bombus californicus was the exclusive visitor of *Cordylanthus palmatus* flowers during the day-long survey in early July. One fly (Diptera) and three hymenopterans hovered over flowers but rarely landed on them and were never observed to come in contact with the reproductive structures. Although solitary bees (Halictidae) were observed on *C. palmatus* flowers (and carrying *C. palmatus* pollen) in the 1990 and 1991 field seasons (see CCB 1992), no floral visitors other than *B. californicus* were observed in 1992.

Bumblebees were absent from all plots during the early morning, peaked in abundance during the late morning and mid-afternoon, and declined during the late afternoon (the time-specific number of bumblebees observed in all quadrats, pooling across sites, was 0, 21, 15, and 10, respectively). Bumblebee abundances were highest at the SW site (n=23) and considerably lower in the other areas (n=13 at the NW site and n=5 in FW and NC). Because bumblebees were most abundant at the SW site, all behavior and pollination studies were conducted in this area.

During visits, foraging *Bombus californicus* went through an elaborate and remarkably consistent behavioral routine. Each bee parted the upper and lower corolla lips, forced its upper body into the floral chamber, vibrated its wings (thus shaking loose the pollen), exited the flower, and while resting on the flower groomed its dorsal thorasic bristles, thus relocating pollen onto the pair of corbicula (pollen-carrying structures) on the hind legs. Almost all foragers observed were so heavily laden with well-packed pollen on their corbicula that the pollen was readily apparent even on flying bees. These data suggest that *B. californicus* transports considerable amounts of *Cordylanthus palmatus* pollen both within and among plants – thus potentially facilitating both inbreeding and outcrossing.

The data presented in Table 7 quantify the foraging movements of ten individual *Bombus californicus*. The bumblebees visited a mean of 4.9 flowers per minute, going through the above-described behavioral routine for each flower. Nearly half of these visits were within-plant visits (47% versus 53% among-plant visits). When bumblebees moved between *Cordylanthus palmatus* plants, the average distance separating sequentially visited plants was 1.4 meters, although the variance was exceptionally high (distances ranged from 0.2 to 4.1 meters).

Variable	Mean (se)	Range
time observed (min)	5.90 (0.43)	4.0-8.0
# flowers visited/min	4.93 (0.52)	2.8-8.0
# plants visited/min	2.29 (0.32)	0.5-4.0
# flowers visited/plant	2.80 (0.79)	1.5-9.7
distance between visited plants (m)	1.36 (0.73)	0.20-4.07

Table 7. The behavior of ten *Bombus californicus* workers foraging exclusively on *Cordylanthus palmatus* at the Springtown study site in Livermore, CA.

The 1992 pollination studies were conducted in early July, early to middle flowering season for *Cordylanthus palmatus* (the flowering season in 1992 extended from early June to late September). This is a relatively late flowering season for this ecosystem, and when *C. palmatus* flowers, most other annual plant species at Springtown have senesced.

Bombus californicus is a common and widely distributed bumblebee species found across California in almost all ecosystem types; this species ranges widely from Alberta to Colorado west to British Columbia and Baja California (Thorp *et al.* 1983). Queens fly early February to early October; workers fly early March to late October; males fly early May to late October (Thorp *et al.* 1983). Like other species of *Bombus*, *B. californicus* is not known as a floral specialist–the 276 *B. californicus* queens, workers, and males observed by Thorp *et al.* (1983) visited 52 plant genera in 24 families.

Plant species that, like *Cordylanthus palmatus*, flower for long periods, may have a succession of pollinators. While *Bombus californicus* visitors appear to be the early- to mid-season pollinators of *C. palmatus* at Springtown, the bumblebees were not observed visiting the bird's beak at other times during the flowering period (nor were they observed on or near *C. palmatus* during the previous years' mid- to late-season plant surveys). Although *Bombus californicus* appears to "specialize" on *C. palmatus* at this site for a short part of their flight season, our observations suggest that it is not the only floral visitor of this plant, nor is this plant the only food resource for this bumblebee species at Springtown.

Further studies on the pollination biology of *Cordylanthus palmatus*, while academically interesting, should not be given a high priority in terms of conservation planning as this system does not appear to be limited by the availability of pollinators. (Thorp *et al.* 1983 record *B. vosnesenskii* –one of the 24 *Bombus* species found in California–as a floral visitor to three unspecified species of *Cordylanthus*.)

Seed predation studies

Cordylanthus palmatus seeds were not taken from any of the experimental plates during the course of these studies (some seeds and cracked wheat grains were lost from plates that had been placed on exposed mounds during one day of strong gusts). Cracked wheat grains were taken from only the NW site; during the night all of the grain was removed from all five plates, but none of the *C. palmatus* seeds were touched. A summary of the results is shown in Table 8.

Site	Date	Time of day	Plate	Missing *C. palmatus*	Missing wheat	Apparent cause
SW	10/6/92	day	1	40	13	wind
SW	10/6/92	day	2	40	17	wind
SW	10/6/92	day	3	0	0	
SW	10/6/92	day	4	5	22	wind
SW	10/6/92	day	5	0	0	
NW	10/6/92	day	1	0	0	
NW	10/6/92	day	2	0	0	
NW	10/6/92	day	3	40	9	wind
NW	10/6/92	day	4	0	0	
NW	10/6/92	day	5	0	0	
NC	10/6/92	day	1	0	0	
NC	10/6/92	day	2	0	0	
NC	10/6/92	day	3	0	0	
NC	10/6/92	day	4	0	0	
NC	10/6/92	day	5	0	0	
SW	10/6-7/92	night	1	0	0	
SW	10/6-7/92	night	2	0	0	
SW	10/6-7/92	night	3	0	0	
SW	10/6-7/92	night	4	0	0	
SW	10/6-7/92	night	5	0	0	
NW	10/6-7/92	night	1	0	40	nocturnal granivore
NW	10/6-7/92	night	2	0	40	nocturnal granivore
NW	10/6-7/92	night	3	0	40	nocturnal granivore
NW	10/6-7/92	night	4	0	40	nocturnal granivore
NW	10/6-7/92	night	5	0	40	nocturnal granivore
NC	10/6-7/92	night	1	0	0	
NC	10/6-7/92	night	2	0	0	
NC	10/6-7/92	night	3	0	0	
NC	10/6-7/92	night	4	0	0	
NC	10/6-7/92	night	5	0	0	
SW	10/7/92	day	1	0	0	
SW	10/7/92	day	2	0	0	
SW	10/7/92	day	3	0	0	
SW	10/7/92	day	4	0	0	
SW	10/7/92	day	5	0	0	
NW	10/7/92	day	1	0	0	
NW	10/7/92	day	2	0	0	
NW	10/7/92	day	3	0	0	
NW	10/7/92	day	4	0	0	
NW	10/7/92	day	5	0	0	
NC	10/7/92	day	1	0	0	
NC	10/7/92	day	2	0	0	
NC	10/7/92	day	3	0	0	
NC	10/7/92	day	4	0	0	
NC	10/7/92	day	5	0	0	

Table 8. Number of *Cordylanthus palmatus* seeds and wheat grains missing from plates set out during the day and the night at various sites, Springtown Alkali Sink. Results indicate that nocturnal seed predatorsdid not choose *Cordylanthus palmatus* seeds, but observations indicate that at least two ant species eat seeds of this plant species.

Although the experiment indicated no diurnal or nocturnal predators of *Cordylanthus palmatus* seed, it is clear that this technique does not sample for all seed predators. The technique is likely to have sampled adequately for birds and small rodents, and the results may be interpreted to mean that there was little or no vertebrate predation of *C. palmatus* seed at Springtown during the study period. While vertebrate seed predation on the bird's beak may increase later in the season when the supply of other food sources has decreased, the seeds by then would have dispersed from the parent plants and thus would be more difficult to harvest.

A casual survey of plants during the first evening of this work revealed ants swarming an individual *Cordylanthus palmatus* in the SW site. The ants were observed pulling *C. palmatus* seeds out of fruits on the plant and carrying the seeds back to their mound. Similar behavior was observed at the NC site where ants were swarming on several plants. No ants were seen on *C. palmatus* at NW. The ants at both sites were harvester ants of genus *Messor* (formerly *Veromessor*), likely *M. pergandei*, approximately 3 mm in length, and are known to be seed predators.

At the SW site on the second morning much smaller harvester ants (*Leptothorax* spp., probably *L. nitens*; approximately 1 mm long) were found harvesting seeds from the same plants that had been occupied by *Messor* the previous evening. Again no ants were observed on *Cordylanthus palmatus* at the NW site, but ants of the genus *Crematogaster* (either *C. coarctata* or *C. mormonum*) were marching in a column through the site. At NC the *Messor* ants again were observed harvesting seeds from the same plants as the previous evening.

In a follow-up visit ten days later (10/16/92), *Messor* were observed harvesting seeds in the evening at the NC site. No ants were seen at either SW or NW. No ants were observed on or near *Cordylanthus palmatus* plants during surveys conducted in the southeast portion of Springtown.

During a second follow-up visit (on 10/28/92) *Messor* ants were again observed harvesting in the evening solely at the NC site. These observations are summarized in Table 9.

Site	Time of day	Genus	Activity	Date(s) observed
SW	evening	*Messor*	harvesting seeds from plants	10/6
SW	morning	*Leptothorax*	harvesting seeds from plants	10/7
SW	evening	no ants		10/16
SW	morning	no ants		10/28
SW	evening	no ants		10/28
NW	evening	no ants		10/6
NW	morning	*Crematogaster*	marching through site	10/7
NW	evening	no ants		10/16
NW	morning	no ants		10/28
NW	evening	no ants		10/28
NC	evening	*Messor*	harvesting seeds from plants	10/6
NC	morning	*Messor*	harvesting seeds from plants	10/7
NC	evening	*Messor*	harvesting seeds from plants	10/16
NC	morning	no ants		10/28
NC	evening	*Messor*	harvesting seeds from plants	10/28
SE	morning	no ants		10/16
SE	evening	no ants		10/16
SE	morning	no ants		10/28
SE	evening	no ants		10/28

Table 9. Ants observed on or near *Cordylanthus palmatus* at three sites at Springtown Alkali Sink, October 1992.

Although ants were actively harvesting *Cordylanthus palmatus* seeds, they do not appear to be unduly affecting this plant population. Each *C. palmatus* plant produces as many as several hundred seeds, and there is apparently a substantial seed bank. Although we did not quantify the impact of the ant predation, examination of the plant in SW from which ants had been collecting indicated that a large number of seeds were still present in the seed pods. Further, these ant species are native, and they were observed on only several of the 30 or more individual plants examined in the three sites. The mandibles of the *Messor* ants suggest that the majority of their diet comes from grass seeds, not the smaller seeds of *C. palmatus*.

In a conservation context, seed predation by ants should be considered an area of secondary concern. While ants are clearly key elements in the natural community at the Springtown Alkali Sink, it is unlikely that the ecological role of the ants will be disrupted to the point at which it threatens *Cordylanthus palmatus*. There are many extremely interesting ecological questions on the role of ants at Springtown, and academic research is encouraged.

Other observations pertinent to conservation planning for Springtown

California tiger salamander larvae were found in many of the pools of standing water at the Springtown Alkali Sink (occupied areas are shown on Figure 14). The highest concentrations of larvae were found in the series of pools adjacent to the bike path separating northwest Springtown from southwest Springtown. These pools were among the deepest (with an approximate maximum depth of 1.25 m) and clearest (amber colored, with very little suspended matter) at Springtown. These pools also supported a wide variety of aquatic invertebrates and other larval amphibians (including *Hyla regilla*, the Pacific treefrog, and *Bufo boreas*, the western toad). Crude estimates of the total number of larvae, based on number of larvae seined and proportion of pools sampled, indicate that in late March several thousand California tiger salamander larvae were present in these pools. Those individuals that survived the larval stage had dispersed by the first week of June, 1992.

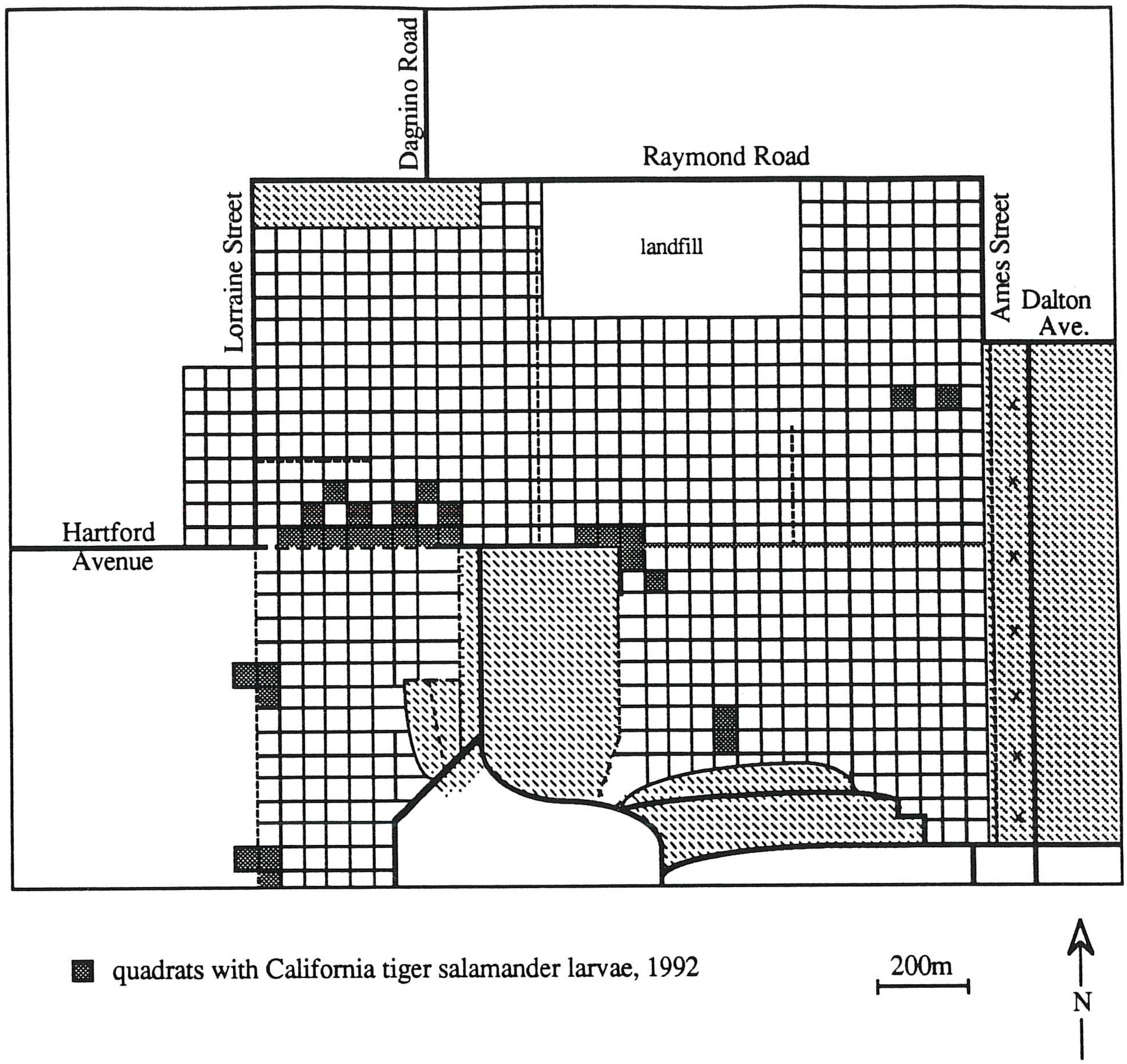


Figure 14. Distribution of California tiger salamander larvae, *Ambystoma californiense*, March 1992. Distribution is shown as presence/absence in 50 m x 50 m quadrats; some quadrats contained several pools of water occupied by larval salamanders. Scale is 1:13,500.

Several pools supporting tiger salamander larvae straddled the fenceline between the southwest section of the study site and the lands immediately to the west, owned by Shea Homes. These pools tended to be shallow, less than 0.5 m at their deepest point, and very muddy. These pools were estimated to support several hundred salamander larvae. Unfortunately, these pools sustained severe damage from off-road vehicles in spring 1992 and very few, if any, of the larvae survived.

Salamander larvae also were found in east Springtown, in widely scattered pools of varying size and water quality. Each of these pools supported fewer than one hundred California tiger salamander larvae. Numerous bodies of water in east Springtown, including several comparatively large and deep pools, were apparently unoccupied.

No tadpole shrimp were observed. Fairy shrimp were found in a wide variety of aquatic habitats, ranging from very small depressions (20 cm diameter) along the Altamont Creek embankment to the wide (5 m+) and shallow (generally less than 20 cm in depth) waters in southeast Springtown. The highest concentrations observed were in southeast Springtown. Two species were identified from specimens collected in 1992: *Branchinecta lynchi* and *Branchinecta lindahli*. *Branchinecta lynchi* is found only in the grasslands of central California and is a candidate for federal protection. *Branchinecta lindahli* is a widespread species and does not appear to be in danger of extinction.

Conclusion, summary, and recommendations

The status of the palmate-bracted bird's beak, *Cordylanthus palmatus*, appears to be the best it has been in the past four years. The population that has been the focus of this study, at Springtown Alkali Sink in Livermore, California, increased greatly in adult abundance and slightly in distribution between 1991 and 1992. Further, the three other extant populations of this species also contained many more plants in 1992 than in the past years for which good records are available.

The general biology of the species bodes well for its ability to respond to disturbance and other environmental variation. At Springtown, a soil seed bank is present, and likely contains a considerable number of seeds which can remain viable for at least three years. There is no evidence that pollinators or predators are limiting the size of the *Cordylanthus palmatus* population at Springtown. Successful short-term relocation of the species to unoccupied habitat is possible, and will be aided by information on the distribution of habitats relative to soil types.

Management for this plant demands a look at all four remaining populations (Springtown, Delevan, Colusa, Mendota). Though locally abundant, the species is highly restricted, found only in handful of areas with the alkali sink habitat. Management regimes of the four populations differ significantly: the Springtown population is subjected to pedestrian and vehicle traffic, while the refuge populations are surrounded by areas managed for waterfowl and agriculture.

Future electrophoretic studies will elaborate on the genetic variability of *Cordylanthus palmatus* and the interchange of genes both among and within populations.

Over the long term, persistence of the refuge populations seems most likely. As part of the Federal Wildlife Refuge system, the populations are well protected from development and other direct harm, and are surrounded by protected land that represents good potential habitat for the establishment of other *Cordylanthus palmatus* populations.

The long-term outlook for the Springtown population is not as good: these wetlands are severely threatened by road construction, housing development, and the channelization of Altamont Creek. Additionally, illegal dumping of trash and construction debris, use of the site by off-road vehicle enthusiasts, and surrounding land uses have directly damaged many areas of the sink and have potentially created severe erosion problems for this unique ecosystem and its many species.

Further, virtually all lands surrounding these populations are now developed or are slated for imminent development.

However, the presence at Springtown of other species of concern (including the California tiger salamander, *Ambystoma californiense*, and the vernal pool fairy shrimp, *Branchinecta lynchi*) may mandate protection of this unusual ecosystem in its entirety. Though surrounding residential development poses a risk to the integrity of this ecosystem, it also offers a unique setting for education, as well as for basic, unapplied scientific research. The creation of local value for the site will lead to a better broad understanding of the ecosystem and its importance.

Management recommendations for *Cordylanthus palmatus* at Springtown Alkali Sink are as follows:

1 • **Minimize destructive land use practices,** especially winter grazing and off-road vehicle use, and minimize site contaminants, including small- and large-scale dumping of household, yard, and construction trash, roadside herbicides that could drift aerially onto *C. palmatus* or enter the water supply, and runoff of agricultural byproducts such as silt and fertilizer.

2 • **Implement experimental restoration and conservation activities,** initially on a small scale. These should be monitored for impacts on *C. palmatus* as well as other members of the ecosystem. Some areas must be left unmanipulated both to provide experimental controls and to allow for environmental heterogeneity. This may include larger-scale relocation efforts, prescribed burns, and/or experimental dry-season cattle grazing.

3 • **Maintain current regional hydrologic patterns,** including groundwater and surface flow patterns, until more is understood about dispersal of *C. palmatus* seeds, the species' ability to tap groundwater resources, and host-parasite relationships.

4 • **Monitor known populations of this species on a regular basis.** Evaluation of the efficacy of various management regimes requires regular late-summer monitoring of the distribution and abundance of adult *C. palmatus* and, where applicable, other target species at Springtown. This may be most efficiently executed by monitoring a select set of 50 x 50 meter quadrats encompassing a range of currently occupied and unoccupied habitat types.

5 • Involve local governments, citizens, and scientists in conservation planning and management of Springtown. Federal, state, and city agencies, wetland mitigation groups, local landowners, and interested citizens should all be involved in regional planning efforts to protect *C. palmatus* and the ecosystems to which it belongs. This includes planning for firebreak management, surrounding development, and enforcement for violations of anti-dumping regulations.

6 • Protect the Springtown and Central Valley sites as ecosystems. Hydrological patterns and heterogeneity in topography and soil type are likely key to local distribution of *Cordylanthus palmatus* and other alkali sink species. Because species can adapt to variation in environmental or ecological parameters by shifting their local distributions, habitat heterogeneity might serve as a necessary buffer against both natural environmental change or human-induced disturbance. A biological community-level approach to conservation planning, including *C. palmatus* and selected other target species, appears to be the only method for successful long-term preservation of biological diversity at Springtown and other sites.

Appendix A: Weather records, 1989-1992

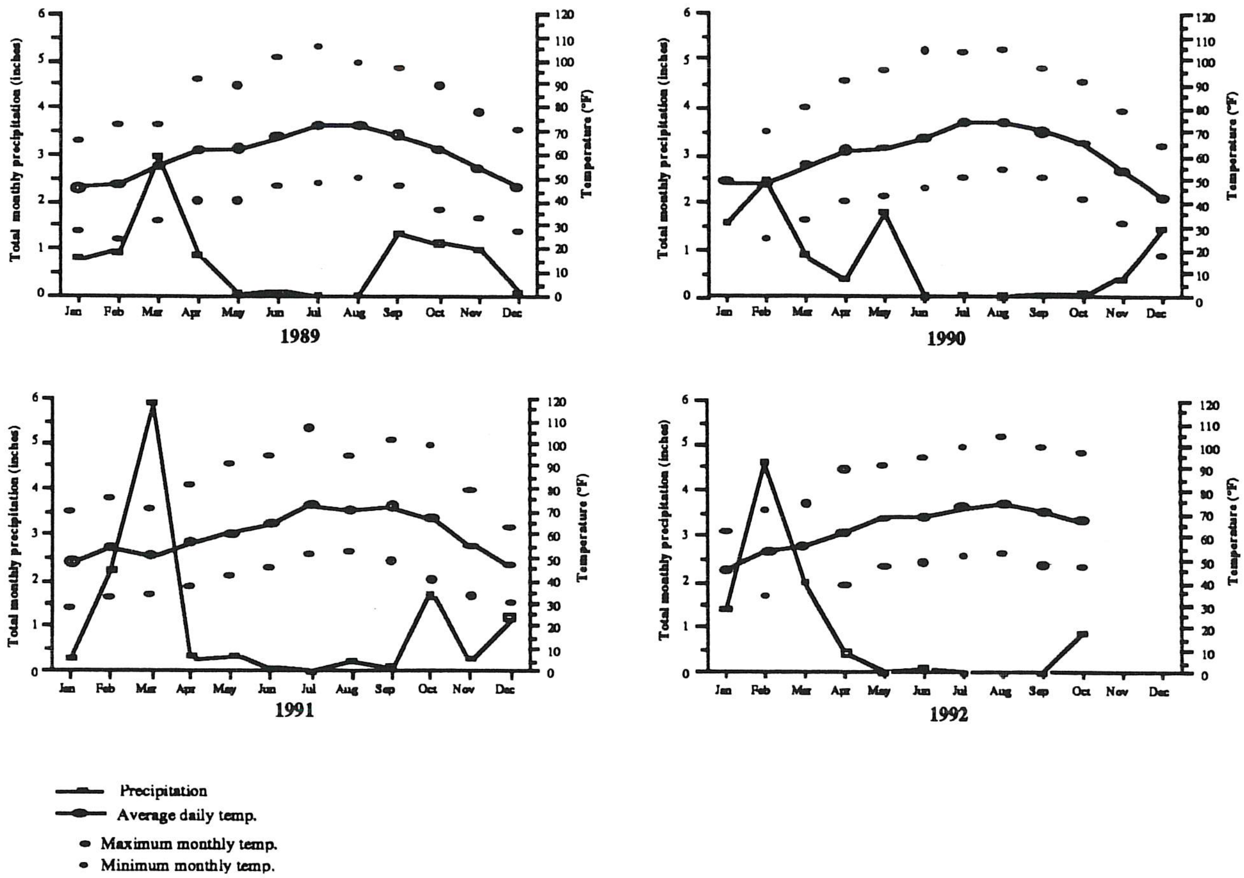
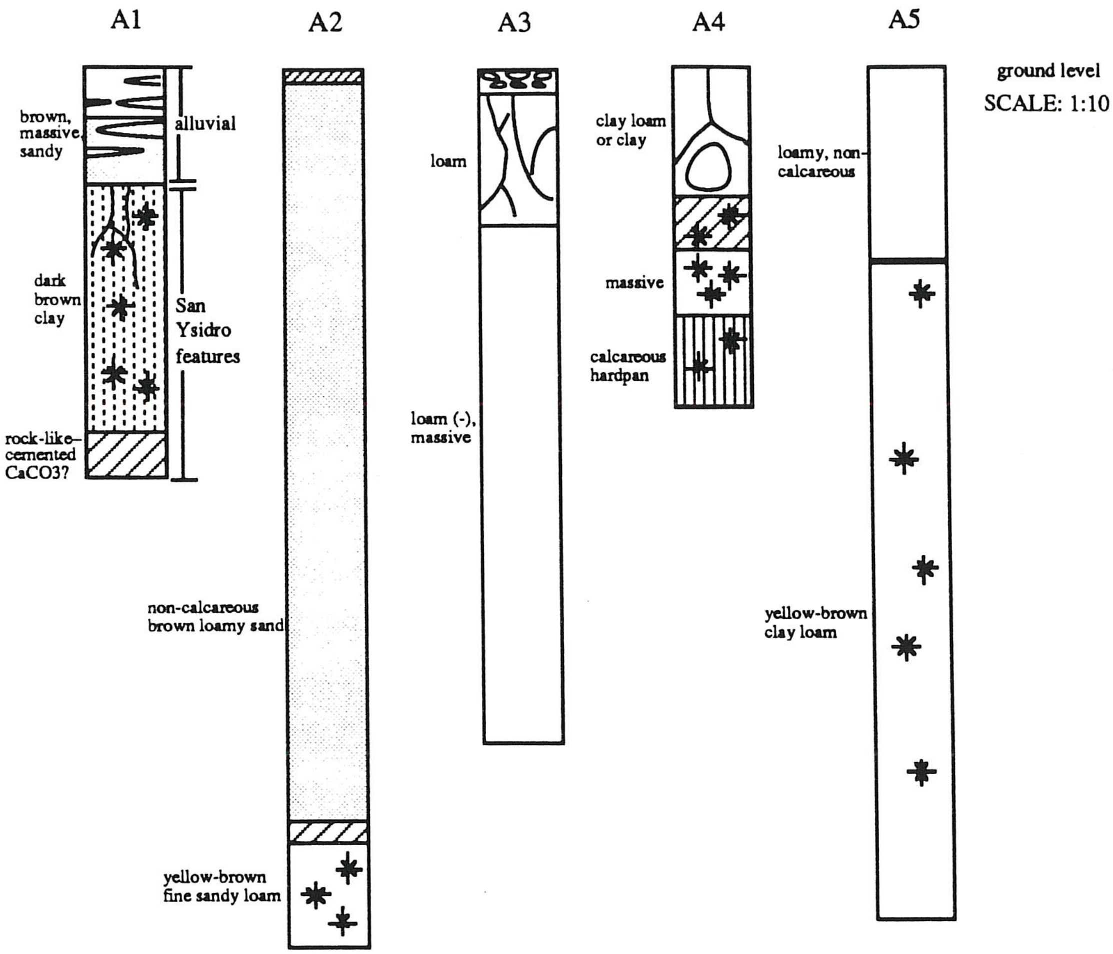


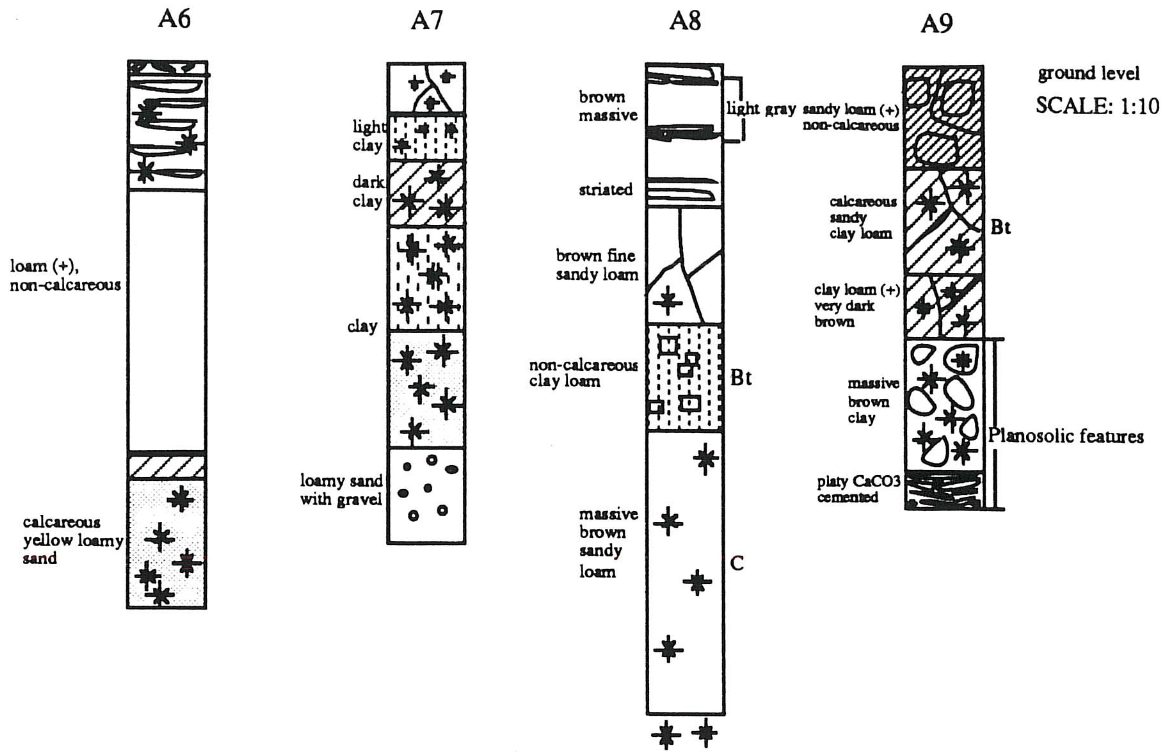
Figure A-1. Monthly precipitation and temperature, Springtown alkali sink, 1989 - 1992. Data recorded at Livermore monitoring station (NOAA 1989-1992). Records for November and December 1992 not yet available.

Appendix B: Soil test pit profiles



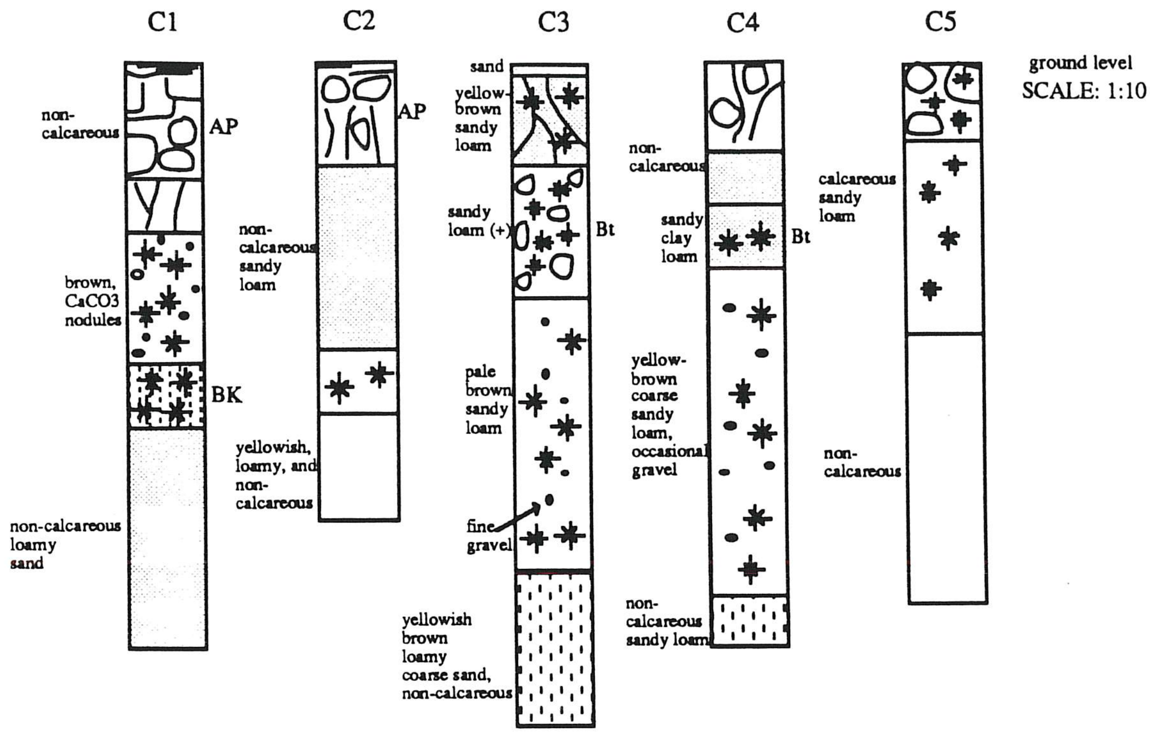
Location	barren floodplain between side channel and upland	barren mound in floodplain between side & main channels	grassy mound-top in upland	bottom of side channel	barren floodplain between main channel and side channel
Notes	saline-sodic alluvial over San Ysidro	saline-sodic alluvial	organic rich, little stratification	Sunnyvale variant	saline-sodic alluvial, little stratification
C. palmatus within 2 m of test pit	no	no	no	no	no

Figure B-1. Soil test pit profiles, transect A (pits A1-A5), northeast Springtown.



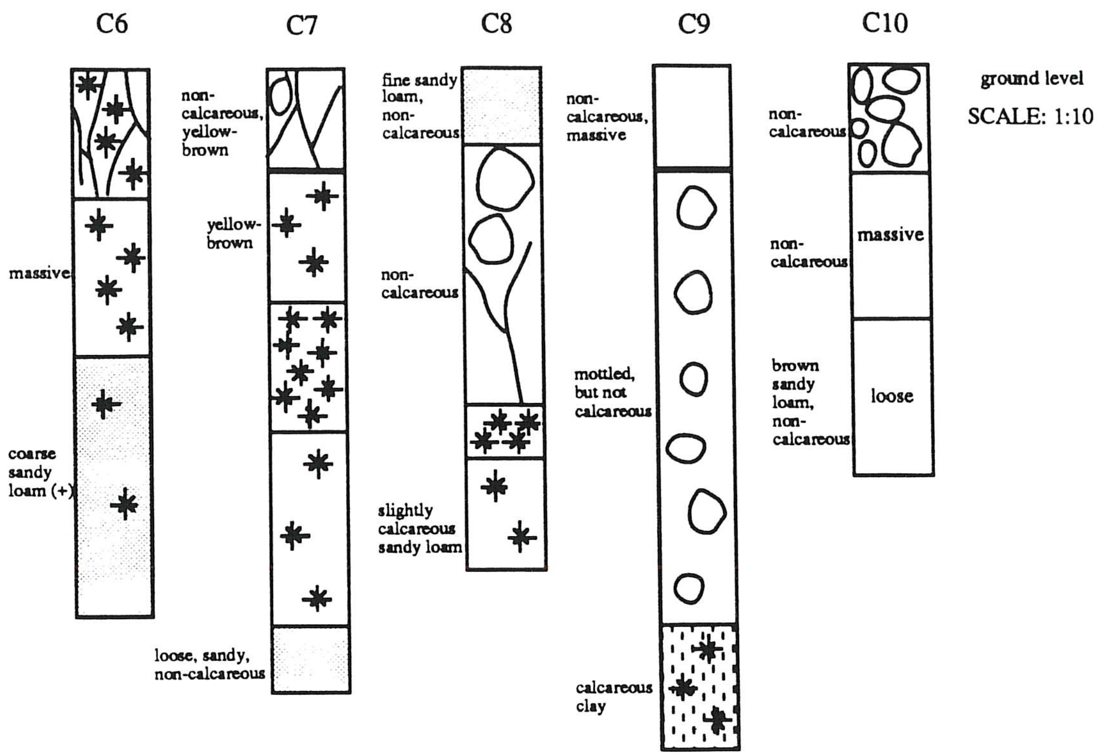
	A6	A7	A8	A9
Location	barren floodplain between main channel and side channel	vegetation covered area between floodplain and uplands	barren floodplain between main channel and side channel	barren floodplain between main channel and side channel
Notes	saline-sodic alluvial (buried)	Sunnyvale clay loam/clay	Solano (buried); well developed Bt and C horizons	Sunnyvale variant
C. palmatus within 2 m of test pit	no	yes	no	no

Figure B-2. Soil test pit profiles, transect A (pits A6-A9), northeast Springtown.



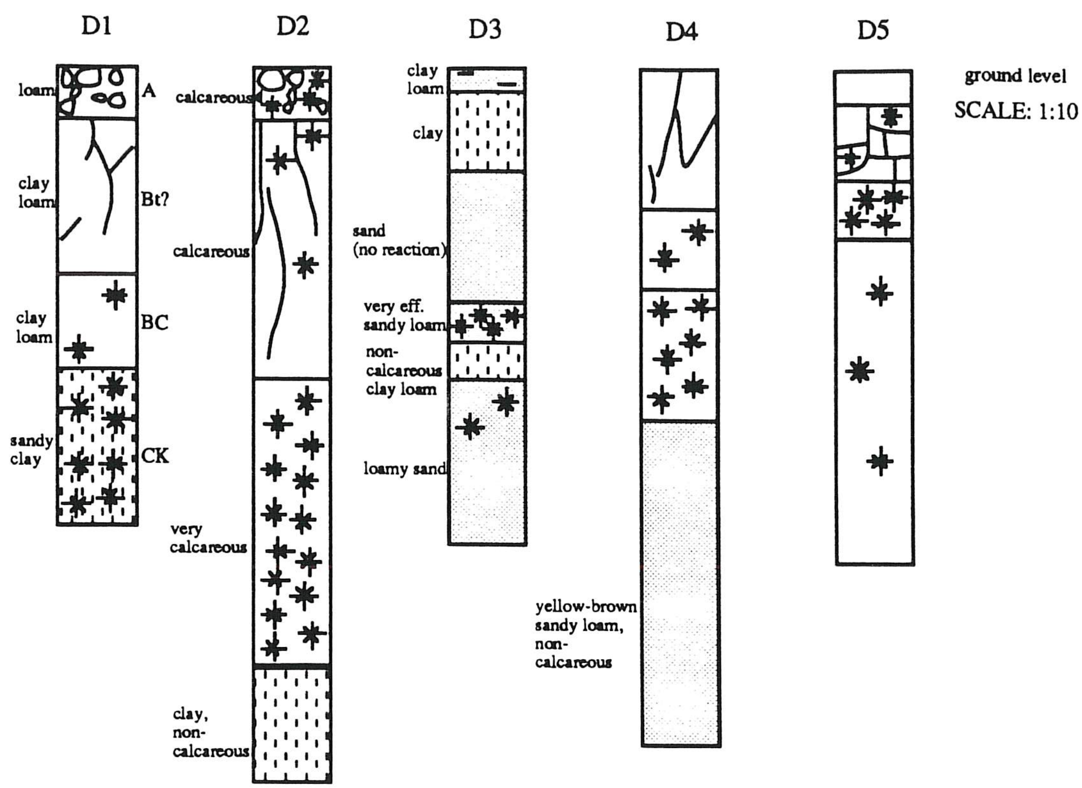
Location	barren small scald	barren small scald	sparsely vegetated edge of scald	sparsely vegetated edge of scald	sparsely vegetated edge of scald
Notes	Solano with BK horizon	Solano fine sandy loam	Solano fine sandy loam, closest to SCS pedon w/ Bt	Solano fine sandy loam w/ Bt horizon	
C. palmatus within 2 m of test pit	yes	no	yes	yes	no

Figure B-3. Soil test pit profiles, transect C (pits C1-C5), southwest Springtown.



Location	sparse vegetation in middle of small scald	grassy area of low mounds	*Lasthenia*-covered edge of scald	grassy area of low mounds	grassy area of low mounds
Notes					
C. palmatus within 2 m of test pit	yes	no	no	no	no

Figure B-4. Soil test pit profiles, transect C (pits C6-C10), northwest Springtown.



Location	grassy upland	vegetation-covered area between channel and upland	grassy channel bottom	*Lasthenia*-covered area between uplands and channel	vegetation-covered saddle in upland
Notes	Pescadero-fairly typical upland				
C. palmatus within 2 m of test pit	no	yes	no	no	yes

Figure B-5. Soil test pit profiles, transect D (pits D1-D5), northwest Springtown.

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