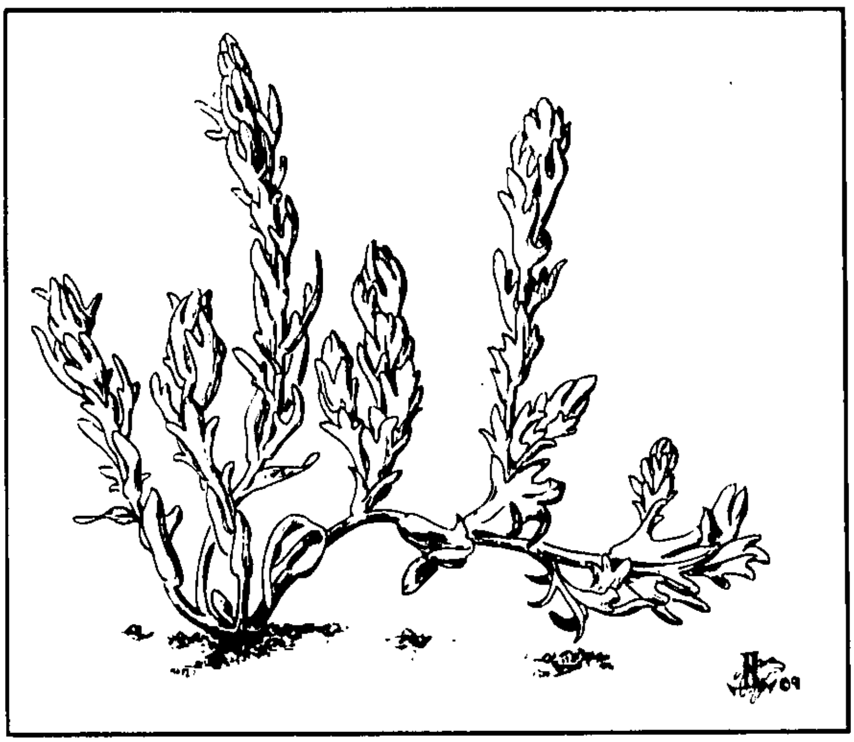
Conservation of the palmate-bracted bird's beak, *Cordylanthus palmatus*



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July 1994

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

Prepared for:

Endangered Plant Program

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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 and second stages of this research were summarized in March 1992 and March 1993 reports.

This third report describes the results and conclusions of research conducted on *Cordylanthus palmatus* since March 1993, including the establishment of long-term monitoring of the population at Springtown Alkali Sink (Livermore, California), studies on the role of pollinator species in the reproductive success of *C. palmatus*, studies of the genetic variability within and between populations of *C. palmatus*, characterization of soils at Springtown, and determination of soil characteristics strongly correlated with plant distribution. The overall purpose of this study is to aid development of management plans for *C. palmatus* at the Springtown Alkali Sink and other locations.

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 earlier reports.

Summary of 1993 Activities

Research activities in 1993 were conducted to address several questions pertinent to the development of management plans for *Cordylanthus palmatus* at the Springtown Alkali Sink and other locations. The text of this report is arranged in six sections detailing major topics of study as summarized below. Each section includes an Introduction, Methods, and Results and Discussion. These six sections describing specific research activities are followed by general Conclusions and Recommendations section.

1) Long-term monitoring of *Cordylanthus palmatus* populations.
The number of *C. palmatus* individuals at Springtown Alkali Sink was estimated and compared to census data collected 1990-1992 in order to assess the stability of the *C. palmatus* abundance from year to year. Methodologies for estimating the number of individuals as detailed in the proposed Long-term Monitoring Data Collection Package (Appendix A) were implemented. Other locations supporting *C. palmatus* populations were also visited, and the number of individuals estimated.

2) Role of pollinators in reproduction of *Cordylanthus palmatus*.
Studies were conducted to identify pollinator species, examine their behavior, and determine their role in the pollination and reproductive success of *C. palmatus*. Pollination experiments compared pollination and seed production in naturally pollinated, hand pollinated, and pollinator-excluded plants.

3) Assessment of genetic variability among and within populations of *Cordylanthus palmatus*.

Plant samples from populations of *C. palmatus* were analyzed for genetic variability using electrophoretic techniques. Analysis allowed assessment of genetic variability among and within populations.

4) Characterization of soil at Springtown and correlation to *Cordylanthus palmatus* distribution.

Fine-scale soil types were defined and mapped, and surface soil samples were analyzed for salinity parameters and pH. Variables were analyzed to determine soil parameters most correlated to *C. palmatus* distribution.

5) Effects of fire on vegetation composition and vegetation.

In August 1992, a grass fire burned an area of southeast Springtown adjacent to the residential development. Vegetation surveys were done during spring and summer of 1993 to compare plant species composition and cover on adjacent burned and unburned plots to assess the effects of fire.

6) Natural history observations.

Natural history observations pertinent to management planning for the Springtown Alkali Sink are presented and discussed.

1] Long-term Monitoring of *Cordylanthus palmatus* populations

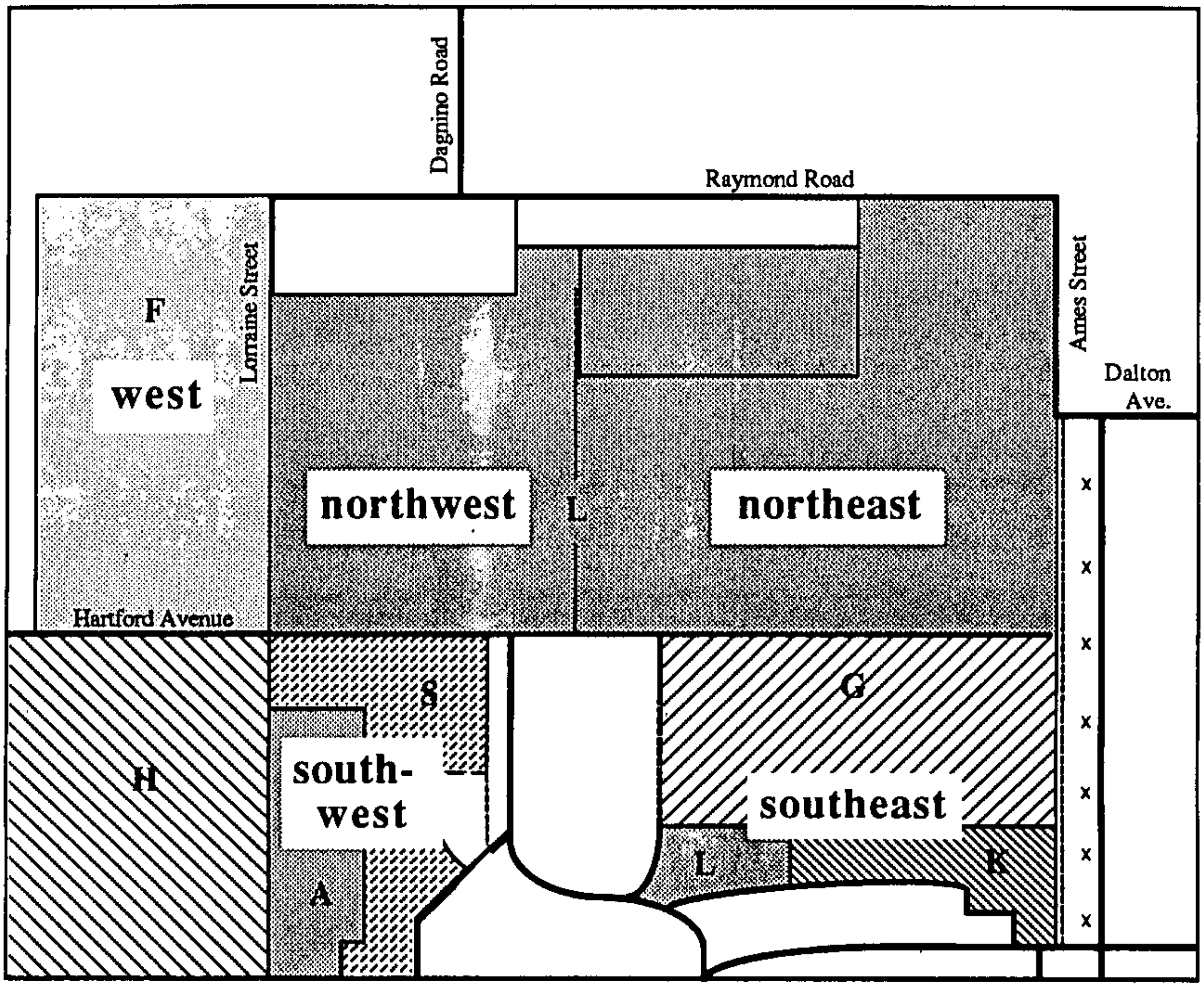
Introduction

Cordylanthus palmatus is presently known from five locations in the Central and Livermore Valleys of California. The majority of recent research and management planning efforts have focused on the Springtown Alkali Sink population located in Livermore, Alameda County, California (Figure 1) where intensive study has been conducted since 1990 by the Center for Conservation Biology, Stanford University (see Appendix B for project personnel). Other *C. palmatus* populations are found in the Delevan National Wildlife Refuge, the Colusa National Wildlife Refuge, and the Mendota Alkali Sink Ecological Refuge (Figure 2). An additional recently introduced "population" is located in the Sacramento National Wildlife Refuge. The current status of *C. palmatus* recorded near the town of Woodland is undetermined.

The abundance and distribution of *Cordylanthus palmatus* across the whole of Springtown were intensively monitored for three years (see CCB 1992 and CCB 1993). During that time, techniques were developed that will allow rapid assessment of the abundance and distribution of *C. palmatus* for long-term monitoring of the species. These techniques, detailed in the Long-Term Monitoring Data Collection Package (Appendix A), were designed to provide results of sufficient quality to identify gross changes in abundance and distribution without requiring the time and expenses of intensive field surveys.

The long-term monitoring techniques were implemented during 1993 to assess the abundance and distribution of *Cordylanthus palmatus* at Springtown. Visual surveys were made at Central Valley locations to evaluate those populations.

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



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.

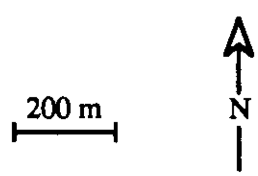
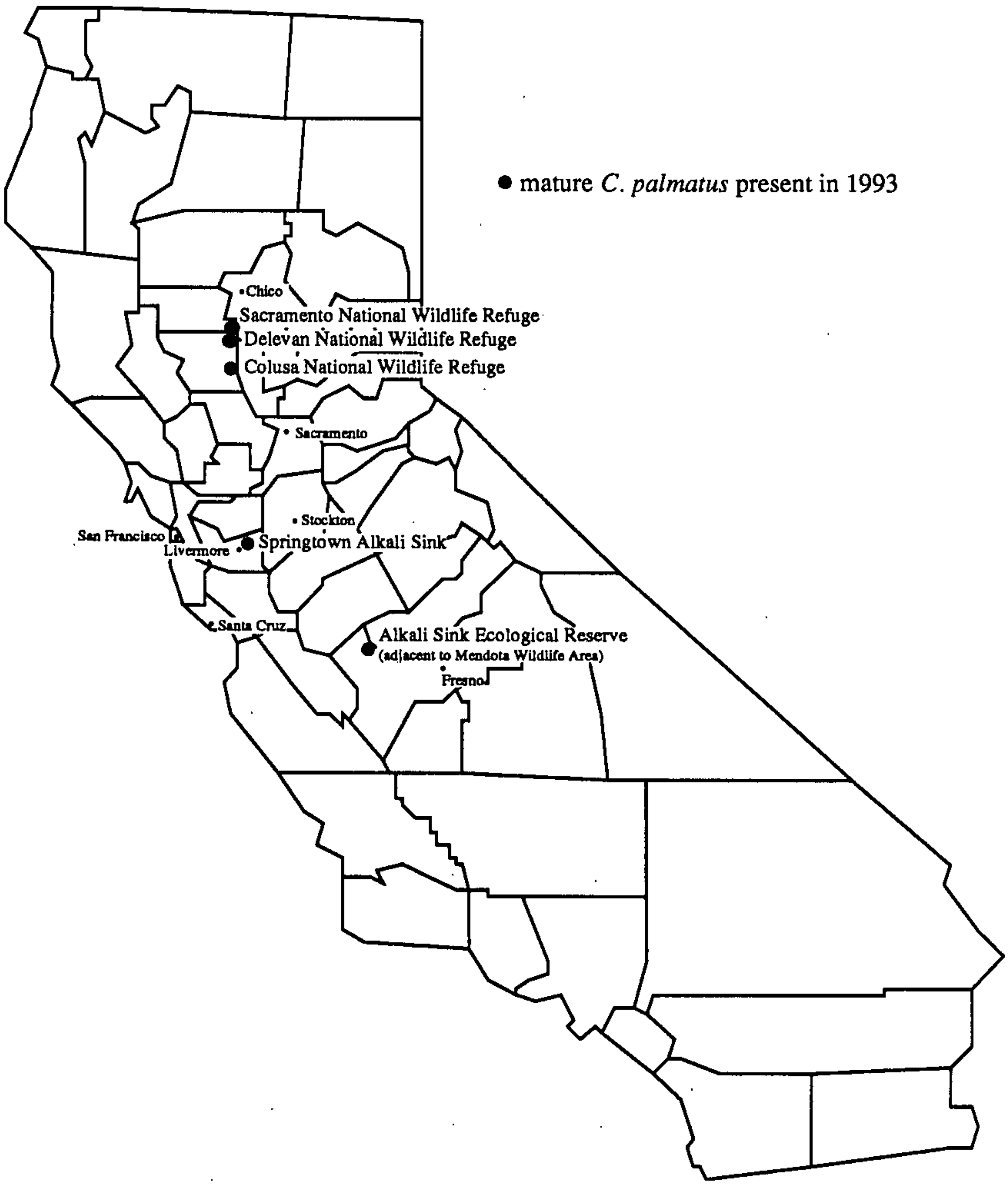


Figure 2. Distribution of *Cordylanthus palmatus*. See text for details.



Methods

Cordylanthus palmatus populations were evaluated during June, July, August, and September of 1993. Results of all surveys were recorded on California Natural Diversity Database forms and submitted appropriately. Copies of completed CNDDB forms are included in Appendix C.

Long-term Monitoring of Springtown population. Transects representing the physical and biological diversity in the Springtown ecosystem were established in four subareas of the site: West, North (can be subdivided into Northwest and Northeast), Southwest, and Southeast (Figure 1). Each transect was further subdivided into segments representing different habitat types that are known to support *Cordylanthus palmatus* or that appear to be suitable *C. palmatus* habitat (see Appendix A for location of transects).

Each transect segment was walked in an allotted period of time. The number of *Cordylanthus palmatus* individuals encountered was estimated on a semi-log scale:

0		
1	to	3
4	to	10
11	to	30
31	to	100
101	to	300
301	to	1000
1001	to	3000
3001	to	10,000
10,000+		

The total number of individuals in each subarea was estimated by "adding" the totals for each segment.

All individuals that were at least partially green during the census period were included in the estimates. Completely dessicated plants were ignored. 1993 monitoring was conducted by Alan Launer, Kathy Switky, Erica Fleishman, Duncan Elkins, and Steve Rottenborn, during July, August, and September.

Surveys of Central Valley populations. CCB biologists visited populations of *Cordylanthus palmatus* located in Delevan National Wildlife Refuge, and Colusa National Wildlife Refuge in June 1993. The Sacramento National Wildlife Refuge was also visited in order to survey newly-reported occurrences of *C. palmatus* there. The population at Mendota Alkali Sink Ecological Refuge was surveyed 4 June 1993. In addition, a site near Los Banos was visited in September 1993 to survey an occurrence of *Cordylanthus mollis hispidus*.

During these visits, the number of individual *Cordylanthus palmatus* plants present at each site was estimated. These site-visits were conducted primarily to collect samples for genetic analyses, and estimation of the number of *C. palmatus* individuals present was a secondary consideration (indeed, the timing these visits was too early in the season to yield data comparable to our 1992 estimates).

Results and Discussion

Springtown Alkali Sink population. 1993 surveys of the monitoring transects at the Springtown Alkali Sink indicate that between 7,400 and 24,300 individuals were present, and our best estimate is that there were between 10,000 and 12,000 individuals. Year-to year variation in the number of *Cordylanthus palmatus* individuals is indicated in Table 1. Note that the number of *C. palmatus* individuals estimated at Springtown in 1993 was lower than the number observed in 1992, but that this estimate was quite similar to those observed in 1990 and 1991.

While the total number of *Cordylanthus palmatus* individuals at Springtown appears to have decreased compared to 1992 levels, changes in abundance within subareas varied. The number of *C. palmatus* in West, Northeast, and Southeast subareas decreased to levels comparable to 1990 and 1991. The number of plants in Northwest and Southwest subareas appear to have changed little since 1992.

The decrease in the number of individuals in the Springtown population in 1993 following a year of increased abundance in 1992 further demonstrates that *Cordylanthus palmatus* can undergo dramatic fluctuations in number of plants present. Additionally, the asynchrony in the changes in number of plants in the subareas at Springtown indicates that a least some of the factors influencing number of individuals vary on a spatial scale much smaller than that of the site.

Many of the changes in *Cordylanthus palmatus* abundance from year to year are undoubtedly caused by annual weather patterns. 1993 was a drier year than 1992, a difference that likely resulted in less germination and establishment of *C. palmatus.* The interaction between the amount and timing of rainfall, and the complex hydrologic and edaphic features of the site could well explain the observed annual variation in number of individual plants.

Part of the mechanism behind these fluctuations in *Cordylanthus palmatus* abundance may be related to increased activation of the extensive seed bank. Previous work demonstrated that *C. palmatus* seeds remain viable over relatively long dormancy periods (CCB 1993). Thus, in years during which conditions are especially favorable for germination and seedling survival (as determined by amount of timing of rainfall and local edaphic and hydrologic variables), the recruitment of *C. palmatus* from the seed bank may lead to dramatic increases in abundance of mature plants. During less favorable years, fewer *C. palmatus* plants may be present as greater proportions of the seed bank maintain dormancy.

Given this probable flexibility in germination, the number of dormant seeds present in the seed bank probably varies considerably from year to year. The present seed bank at Springtown is likely large, owing to the exceptionally large numbers of *Cordylanthus palmatus* individuals present in 1992 and to the apparent modest rate of germination in 1993.

Another factor likely impacting the number of *Cordylanthus palmatus* individuals is grazing. The removal of cattle from north Springtown in 1991 was cited as a possible, though likely secondary, explanation for the 1992 increase in *C. palmatus* abundance; stream channels and edges of seasonal ponds where *C. palmatus* grows were no longer being trampled by cattle (CCB 1993).

During 1993, the absence of grazing may have begun to have a negative impact on *Cordylanthus palmatus* abundance, allowing non-native grasses to gradually crowd out *C. palmatus.* Grazing is thought to control the establishment and growth of non-native grasses which may compete with *C. palmatus* in some areas at Springtown. Most, if not all, ecosystems in central California have been disturbed by human activities to the extent that without some active management they will gradually become dominated by non-native species -- much to the detriment of native species. Thus, at Springtown the apparent benefits gained by not being trampled may eventually be counteracted by increased competition with non-native grasses.

The long-term impacts of grazing must be considered as yet untested hypotheses. The precise extent that non-native species compete with *Cordylanthus palmatus* and other alkali sink natives is not known, but it is likely that the Springtown ecosystem has been irreversibly altered by the introduction of non-native plant species and other human activities. As suggested in CCB (1993), well-managed dry season grazing may favor *C. palmatus* and other native species, minimize disruption of seasonal wetlands, and provide some control of invasive, non-native species. Grazing experiments are required to determine conclusively whether limited grazing is an appropriate component of a management regime for this species.

Table 1. *Cordylanthus palmatus* surveys, 1990 - 1993, by region at Springtown. Regions and rough parcels of ownership are indicated in Figure 1. Because new long-term monitoring methodologies were used in 1993, the number of individuals given are estimates.

	Number of *Cordylanthus palmatus*			
SITE	**1990**	**1991**	**1992**	**1993**
West	172	360	604	100 - 300
North	1,049	1,940	14,902	3,300 - 11,000
Southwest	1,538	2,198	6,168	3,000 - 10,000
Southeast	6,235	5,941	14,920[1]	1,000 - 3,000
TOTAL	8,994	10,439	36,594	7,400 - 24,300

[1] A portion of southeast Springtown burned in a grass fire prior to the 1992 survey (see Figure 9). 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.

Table 2. Estimated number of plants in known populations of *Cordylanthus palmatus*, 1992 and 1993.

	EST. NUMBER OF PLANTS		
SITE	**1992**	**1993**	
Delevan National Wildlife Refuge	75,000 - 125,000	10^4 - 10^5	*
Colusa National Wildlife Refuge	36,000 - 70,000	10^4 - 10^5	*
Livermore, Springtown	36,000	10,000 - 12,000	
Alkali Sink Ecological Reserve, CNDDB occ. 11	450	400 - 500	
Sacramento National Wildlife Refuge	—	300 - 500	**

* Early season surveys.
** Newly introduced population not surveyed in 1992.

Monitoring methodology for Springtown Alkali Sink. Although the long-term monitoring methods employed in 1993 do not provide the fine-scale resolution of abundance and distribution patterns of *Cordylanthus palmatus* across the Springtown site, the methodology detected broad changes in the number of individuals in the major subareas of Springtown, and allowed assessment of *C. palmatus* abundances in a fraction of the time and expense required for the 1990-1992 surveys. The long-term monitoring methods are thus concluded to be a sound protocol that will efficiently provide reliable evaluations of the *C. palmatus* population at Springtown Alkali Sink. See Appendix A for the complete Long-term Monitoring package.

Central Valley populations. Early summer surveys of Central Valley *Cordylanthus palmatus* populations allowed for crude estimates of the number of individuals. Estimates for each of the Central Valley sites are listed in Table 2. Completed California Natural Diversity Database field survey forms for all sites on which *Cordylanthus palmatus* was surveyed are attached in Appendix C.

Newly-reported occurrences of *Cordylanthus palmatus* in the Sacramento National Wildlife Refuge Complex consisted of fewer than 500 plants. Refuge biologist Greg Mensik surveyed three additional new occurrences: one located in Tract 2 of Colusa National Wildlife Refuge consisting of hundreds of plants; and two at Delevan National Wildlife Refuge, one located in Tract 14 with hundreds of plants, and one located in Tract 33 which supported tens of thousands of plants.

It was our general impression that the number of individual plants at Colusa, Delevan, and Mendota was somewhat lower than 1992 levels, but this was not quantified. Even with slight decreases in the number of plants, observations and estimates of *Cordylanthus palmatus* at the locations in the northern Central Valley and at Livermore indicate that those populations are not in immediate risk of extirpation.

The status of the *Cordylanthus palmatus* population(s) at the Alkali Sink Ecological Reserve (Mendota), however, is less clear. In this southern-most occupied area the plants are comparatively few in number and apparently limited in their distribution to the vicinity of several roads. It is our general impression, albeit not well quantified, that the *C. palmatus* at the Alkali Sink Ecological Reserve could be rapidly extirpated by a few relatively minor activities, particularly road realignment (impacts from road work would be at least two-fold; 1) plants and seeds living next to the roads, the majority of the individuals, could be directly eliminated, and 2) any road work could alter the hydrologic and edaphic characteristics of the site).

The southern population(s) notwithstanding, we conclude at the current level of protection, this federally- and state-listed endangered species is not in immediate danger of extinction. This is not to say that this locally abundant species is a good candidate for delisting (or down-listing). On the contrary, because of extensive habitat loss throughout central California, *Cordylanthus palmatus* is locally abundant in only two areas (north Central Valley, and Livermore Valley). Both of these areas are experiencing major changes in resource utilization and support human activities potentially catastrophic to *C. palmatus*. In the north portion of the Central Valley, water is strictly controlled and agriculture is the dominant industry. The long-term impacts of recent rulings guaranteeing minimum flow rates (designed to benefit fishes such as the delta smelt and the winter-run chinook salmon) on the hydrology of the region's seasonal wetlands is unknown. Likewise, the use of biocides is ubiquitous in the region, and it is not inconceivable that a single accident could eliminate one of the larger populations of *C. palmatus*. In the Livermore Valley, creek chanelization, road construction, residential development, and a host of other human-related activities have severely altered the Springtown ecosystem -- to the extent that long-term persistence of the ecosystem itself is not guaranteed. Additionally, extended drought or periods of deluge could impact significantly *C. palmatus* populations in either the Central Valley or the Livermore Valley. This threat is exacerbated by the fact that there are few undeveloped areas adjacent to those occupied by *C. palmatus* -- areas where the population could "shift" in distribution to in the event of changing environmental conditions.

2] Role of pollinators in reproduction of *Cordylanthus palmatus*

Introduction

Previous research on the reproductive biology of *Cordylanthus palmatus* at Springtown Alkali Sink examined the effects of self-pollination versus outcrossing on fruit and seed production, and identified and observed probable pollinators (CCB 1993). Field observations identified the bumblebee, *Bombus californicus*, as the predominant pollinator during the early flowering period in July 1992 (CCB 1993). Bees were observed transporting pollen within and between plants, thus facilitating both inbreeding and outcrossing. Observations further suggested that while *B. californicus* may "specialize" on *C. palmatus* during the early flowering season, it is likely only one of a succession of pollinators to visit *C. palmatus* flowers.

In order to identify any other significant pollinators of *Cordylanthus palmatus*, and to assess the importance of pollinators in the reproduction of *C. palmatus*, experiments were conducted during the spring and summer of 1993 to address the following questions:

1) Are bees of the genus *Bombus* the only significant pollinators of *Cordylanthus palmatus*?

2) To what extent, if at all, is the reproduction of *Cordylanthus palmatus* pollinator-limited?

3) To what extent might *Bombus* be a vector for pollen transport between spatially isolated patches of *Cordylanthus palmatus* at Springtown?

4) Where do *Bombus* nest?

Life History of *Bombus*. Bees of the genus *Bombus* are large (20-25 mm) bees that establish colonial nests, typically in abandoned rodent burrows located in grassy, upland areas -- areas not subjected to seasonal inundations. These bees forage widely on pollen and nectar, flying up to several kilometers between their nest and flower patches. While exploring flowers, *Bombus* "buzz" with their thoracic muscles, dislodging pollen which clings to dorsal thoracic bristles. After visiting a flower, the bee then grooms itself to transfer the collected pollen to specialized carrying structures called corbicula. Large accumulations of pollen in these structures are easily visible at a distance of several meters. Returning to their nest, worker bees transfer their pollen to "pots" constructed by the queen for storage. Pollen is eaten by the adult bees, stored for later use, or fed to the larvae.

Methods

Bombus surveys. Visual surveys were conducted between 1 June and 1 October to identify and count insects pollinating *Cordylanthus palmatus*. Field surveys consisted of 10-minute observations at each of five sites with high densities of *C. palmatus*. Voucher specimens of each *Bombus* species seen on *C. palmatus* flowers were captured and mounted, and identified by Dr. Robin Thorp of the Department of Entomology at the University of California at Davis.

In order to determine the approximate location of *Bombus* nests, the flight paths of worker bees leaving patches of *Cordylanthus palmatus* were recorded on field maps prepared from aerial photos of the site. It was assumed that worker bees heavily laden with pollen in the late afternoon would be returning directly to the nest, so individual workers were followed as they foraged until they flew up and out of the patch. A compass bearing was taken on each departing bee before it disappeared from sight, usually at a distance of about 50 meters. A total of 31 flight paths were recorded from three patches of *C. palmatus*.

Bombus mark-release-resighting. A mark-release-resighting experiment was conducted to determine the extent to which individual *Bombus* workers visited different patches of *Cordylanthus palmatus* during foraging. The five *C. palmatus* patches used for *Bombus* surveys were used as study sites for this experiment. Bees were captured while foraging and placed in glass vials on ice for about 15 minutes. The low-temperature exposure immobilized the bees long enough to allow placement of three color-coded marks on the thorax, just between the wings. The bees were released on or near the plant on which they were captured. Bees seemed unaffected by the treatment, usually regaining flight capacity within a few minutes of release and sunlight exposure. The marks were distinguishable while bees foraged so that recapture was not necessary. Resighting of marked bees were made during the daily 10-minute surveys. A total of 46 bees were marked at the five sites from 1 July and 19 July 1993. Visual surveys for "resightings" were conducted until 28 July 1993.

Pollinator exclusion. A pollinator exclusion experiment was performed to assess the importance of pollinators for fruit and seed production in *Cordylanthus palmatus*, and to address the question of pollinator limitation. Thirty-four plants which were not fully in bloom were selected and randomly placed into three treatment groups: excluded, hand-pollinated, and a naturally-pollinated control.

The three experimental treatments were established on 23 June 1993. 1) Nine plants were surrounded with wire mesh cages to completely exclude *Bombus* workers (smaller insects, such as solitary bees, which are possible pollinators (see CCB 1993), were not excluded by the mesh); 2) eleven plants were surrounded with mesh cages, and were hand-pollinated on 2 July and 30 July 1993; and 3) fourteen plants were left uncaged and were not hand pollinated and serve as a naturally-pollinated control.

Since *Cordylanthus palmatus* flowers from the base of a stalk upwards, stalks with open flowers were marked with dental floss to indicate the position of the first unopened flowers. One-half of the open flowers on each plant within the hand-pollinated treatment group were marked with floss and pollinated. Corolla lips were parted to expose the pistil, and the mature stamens from a flower of a neighboring (<1 m distant) plant were twice swabbed across the upper surface of the treatment flower Since previous studies by the CCB (1993) found no differences between self-pollinated and outcrossed treatments in the number of flowers setting seed and the number of seeds per capsule, only one of these treatments (outcrossed) was used for this study. Fresh stamens were used for each pollination, and the donor plants were chosen at random. These flowers were pollinated again 48-72 hours later if the flowers did not appear to have withered significantly. Half of the flowers which had opened during this interim were also marked and pollinated. These newly-pollinated flowers were also pollinated a second time 48-72 hours later if they had not withered significantly. As a result, approximately one-half of the flowers open from 2 July to 10 July 1993 were pollinated twice. A second set of flowers on the same plants were similarly marked and pollinated on 30 July, and repollinated on 2 August.

Only one-half of the open flowers were pollinated because of fears that unforeseen resource limitations, such as the availability of mid-summer water, might overburden individual plants, and result in the abortion of developing seeds -- a condition that could render interpretation of the data difficult. It was assumed that only pollinating half of the available flowers would produce adequate sample sizes without overburdening the reproductive capacity of the plants. Plants from both the naturally-pollinated control and pollinator exclusion treatment groups were shaken gently for several seconds at the time of hand-pollination to standardize the amount of handling each plant received.

On 7 September 1993, the exclosures were removed and portions of all 34 plants were clipped and returned to the lab for scoring. The number and location of flowers found on 30 cm of stalk were recorded, as was the presence of fruit capsules and the number of seeds per capsule. ANOVA was used to compare the proportion of flowers fruiting, and the number of seeds produced per capsule among the three treatment groups.

See Figure 3 for location of pollination study sites.

Results and Discussion

Bombus surveys. Three species of *Bombus* were observed visiting *Cordylanthus palmatus* during the daily surveys: *Bombus californicus* (which had been previously recorded visiting *C. palmatus* at Springtown), *Bombus vosnesenskii*, and *Bombus occidentalis*. Another large-bodied bumblebee, apparently a fourth Bombus species (identification pending), was observed, along with *B. vosnesenskii*, foraging on coyote thistle, *Eringium aristulatum*, which bordered one of the large *C. palmatus* patches. These results indicate that *C. palmatus* is pollinated by multiple species of *Bombus*.

The flight paths of *Bombus* individuals leaving *Cordylanthus palmatus* patches after foraging are plotted in Figures 4a and 4b. The convergence of paths from different patches of *C. palmatus* suggest the locations in where Bombus nests may be located. Two such zone appear to be located in the grassy uplands in the northwest portions of the city property, and on FCC lands, across Lorraine Street from the main areas occupied by *C. palmatus*. Thus, likely *Bombus* nesting areas appear to be located hundreds of meters away from the patches of *C. palmatus*.. Somewhat surprisingly, the upland areas only 10s of meters distant from areas supporting high densities of *C. palmatus* did not appear to be used for nesting sites (note that the as yet unidentified *Bombus* that was observed visiting *Eringium* did nest in the vicinity of *C. palmatus*).

Figure 3. Locations of *Bombus* survey sites at Springtown Alkali Sink.

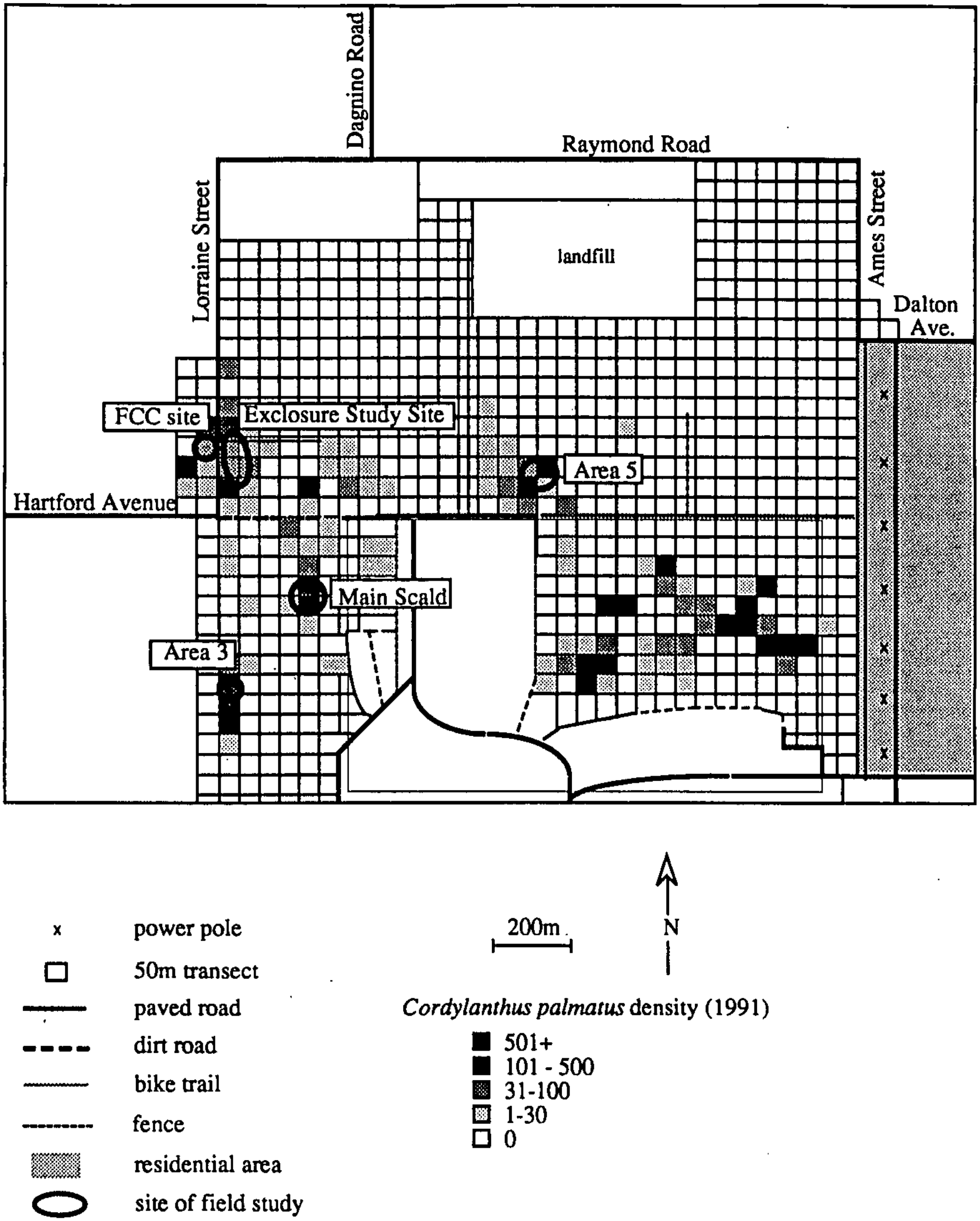
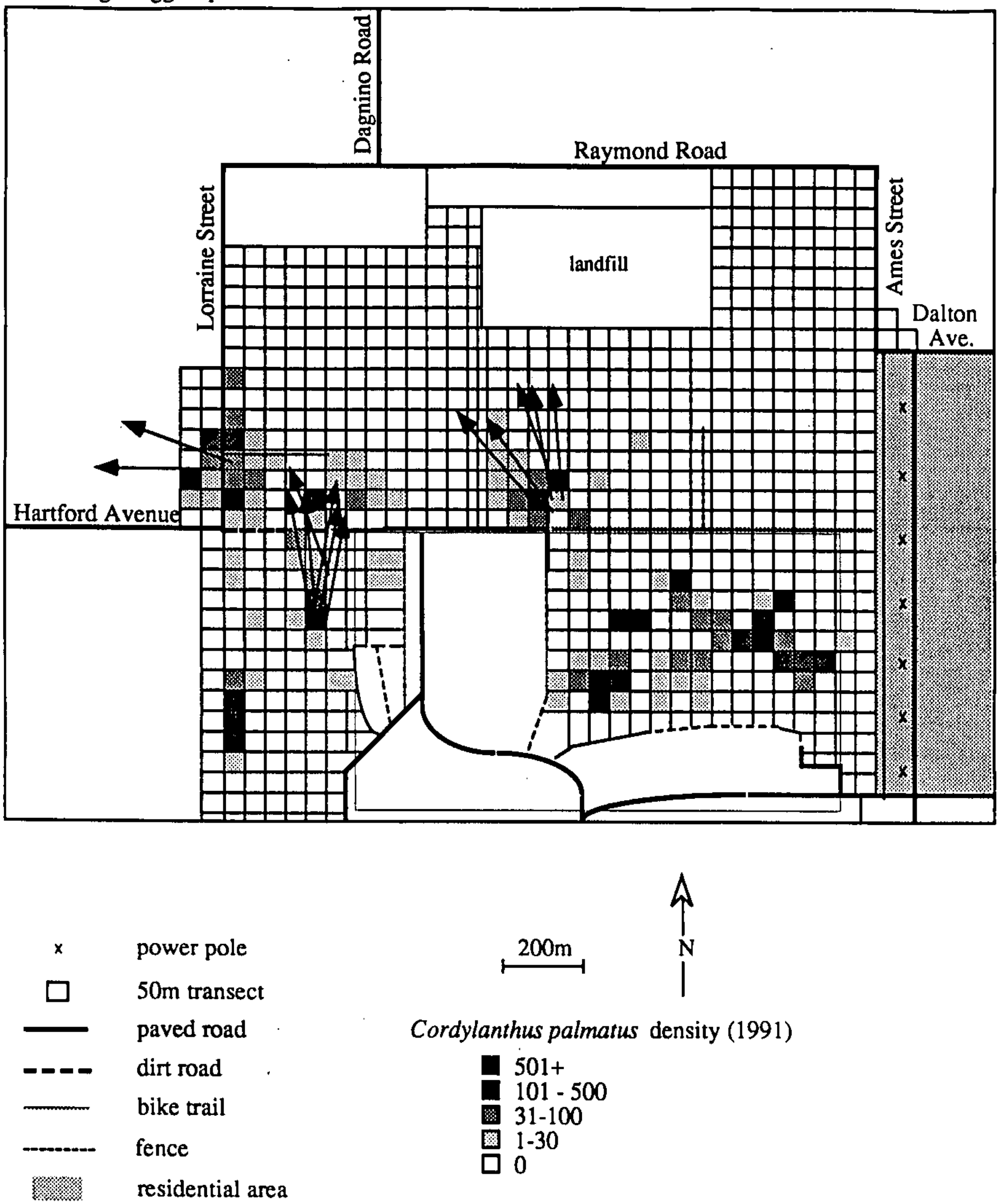
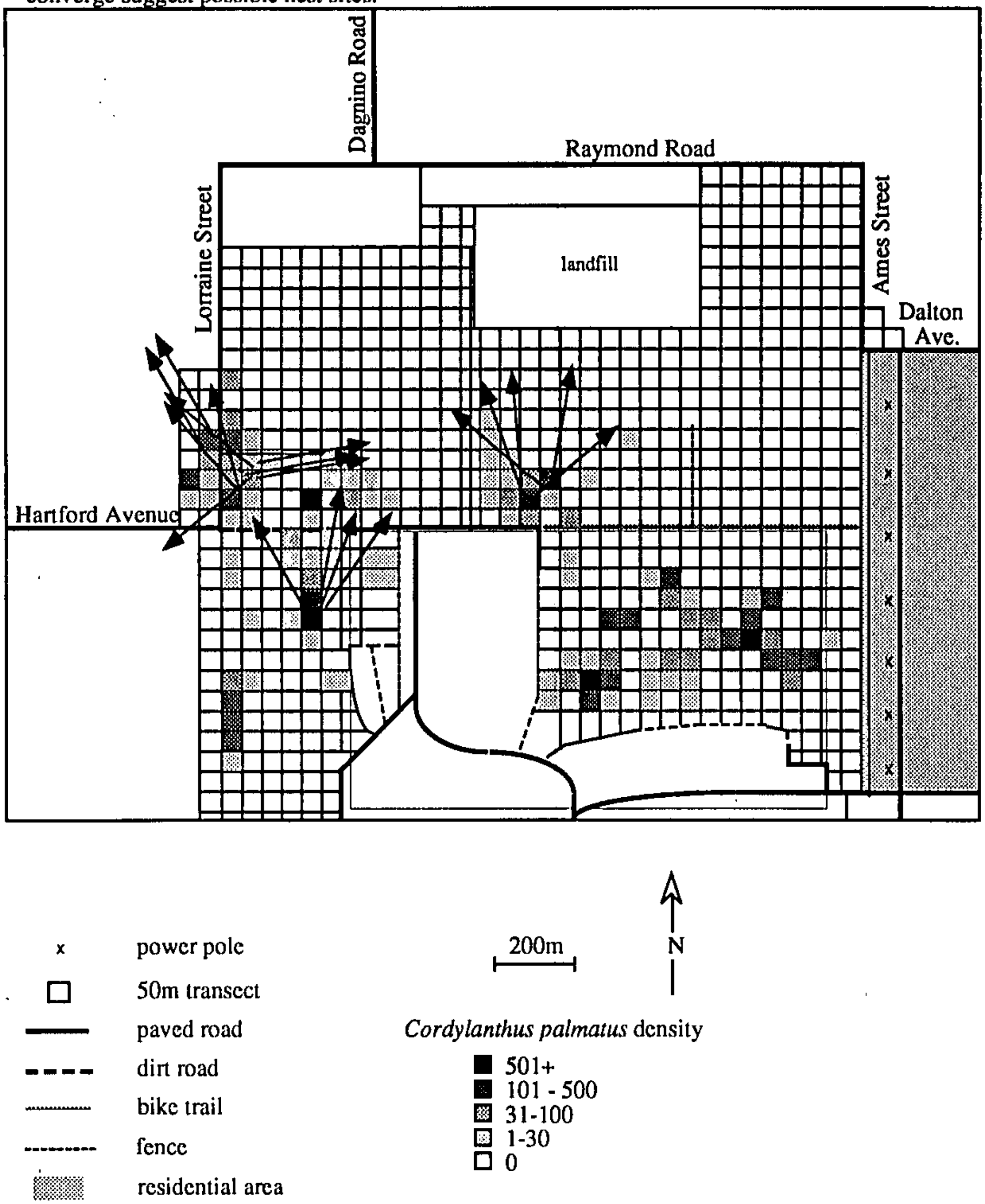


Figure 4a. Flight paths of *Bombus californicus* workers leaving *Cordylanthus palmatus* patches. Assuming direct flights out of patches returning to nests, areas in which vectors appear to converge suggest possible nest sites.



Each arrow indicates the flight line of a single pollen-laden worker.

Figure 4b. Flight paths of *Bombus vosnesenskii* workers leaving *Cordylanthus palmatus* patches. Assuming direct flights out of patches returning to nests, areas in which vectors appear to converge suggest possible nest sites.



Each arrow indicates the flight line of a single pollen-laden worker.

Bombus mark-release-resighting. Nineteen of the forty-six marked bees were observed foraging in subsequent visual surveys of study sites and surround areas. Eleven of these nineteen bees were resighted on multiple days. Resighting data are presented in Appendix D. All of the nineteen resighted bees were seen in the same *Cordylanthus palmatus* patch in which they were first captured and marked. This observation that individual *Bombus* were faithful the patch in which they had be originally marked is further supported by evidence gathered away from the five study patches. In these surrounding areas, numerous transects walked, many through areas which supported *Cordylanthus palmatus*, in an effort to locate marked bees. In these surrounding areas, none of the *Bombus* individuals observed had been marked.

That only 41% of the marked bees were resighted is somewhat worrisome, and was a primary reason that the areas surrounding the five primary study sites were so thoroughly searched. The fate of the "missing" 59% of marked individuals is unclear. It is possible that handling could have caused some increase in mortality. A slight increase in mortality, when coupled with the estimated three to four week life span of worker bumblebees, could account for the 59%. It is also possible that some of the marked bees switched from foraging on *Cordylanthus* to foraging on plants not located within the immediate vicinity of the study area. Since most of the undeveloped areas of Springtown were being monitored for the presence of marked bees, the missing individuals would have to have been foraging in comparatively distant areas -- such as the residential areas. Surveys for bees in the residential areas were not attempted.

While subject to varying interpretations, these results suggest that *Bombus* are faithful to particular patches of *Cordylanthus palmatus* -- once an individual has identified a patch of *C. palmatus* it continues to use that single patch for as long as it forages on *C. palmatus*. This study does not address the myriad of questions regarding how individual *Bombus* find and pick patches of *C. palmatus*, why individuals are faithful to individual patches, what makes a patch suitable foraging site, and whether different workers from the same nest visit the same or different *C. palmatus* patches. To answers these questions, future field studies would need to be designed specifically addressing the behavioral ecology of *Bombus* at Springtown.

A potential consequence of this apparent foraging site tenacity by *Bombus* is limited transfer of pollen between patches of *Cordylanthus palmatus* within the Springtown Alkali Sink system. Assuming that gene flow is linked to pollen transfer, it appears that patches *C. palmatus* may be partially isolated genetically. This isolation is probably not to the extent that discrete subpopulations of *C. palmatus* exist, but it is possible that different subareas of Springtown support *C. palmatus* that have somewhat different allele frequencies.

Pollinator exclusion. The percentage of flowers fruiting and the number of seeds per fruit capsule for each *Cordylanthus palmatus* plant in the three experimental treatment groups are summarized in Table 3. Plants which were in the pollinator-exclusion cages and not hand-pollinated largely failed to produce fruits; only six flowers on one plant successfully set fruit, resulting in a fruiting rate of 1.7% for the pollinator-excluded treatment group. The hand-pollinated and caged treatment group had a fruiting rate of 12.3%, while the naturally-pollinated control (uncaged) group had a fruiting rate of 28.6%. Analysis of variance among the three treatment groups revealed that the differences in fruiting rates were significant with pollinator-excluded << hand-pollinated < naturally-pollinated ($P < 0.001$). The results of the ANOVA are given in Table 4.

Because only one of the *Bombus*-excluded plants successfully produced fruit, this treatment group was omitted from comparison of seeds produced per capsule. It is likely that the one flower that set fruit in this treatment group was the result of essentially accidental pollination during the course of the study as it seems unlikely that natural pollination would occur in such a haphazard manner.

Analysis of the results of the remaining two treatment groups revealed a significant difference in number of seeds/capsule (fruit); hand-pollinated plants produced an average of 3.9 seeds/capsule, while naturally-pollinated control plants produced an average of 6.5 seeds/capsule ($P = 0.003$).

The extremely low fruiting rate of the *Bombus*-excluded plants suggests that species of the family Halictidae did not play a significant role in *Cordylanthus palmatus* pollination in 1993. It is thus concluded that during some year (probably those years experiencing average or below average rainfall) *Bombus* is necessary for successful fertilization and subsequent seed production. Small-bodied insects appear to have had little impact on seed production in 1993.

The lower fruiting rate of hand-pollinated plants compared to naturally-pollinated plants is interpreted to be an artifact of hand-pollinating the flowers only twice. The activity of the pollinating bees was underestimated such that the hand-pollination treatment did not pollinate comparable numbers of flowers with comparable efficiency -- under natural conditions, bees potentially visited individual flowers on many more than two occasions, and transferred pollen from many different sources.

Similar interpretations can be applied to the seed/capsule differences between the hand-pollinated treatment group and the naturally-pollinated control. The unnatural handling of plants during pollination, or the timing of fertilization of hand-pollinated plants could have had a negative impact on seed production. Alternatively, since hand-pollinated plants were fertilized with the pollen of plants within a one-meter radius, there could have been higher degrees of relatedness that may have led to depressed viability of fertilized embryos (this explanation is unlikely considering the results from the 1992 study which found no differences in seed production between self-pollinated and outcrossed treatments). It is also possible that the stigmas of hand-pollinated flowers were not completely receptive at the time of pollination even though the flowers appeared mature. Meanwhile, the naturally-pollinated control group likely received pollen from multiple donor plants on multiple occasions.

Whether these data indicate that *Cordylanthus palmatus* should be considered to be pollinator-limited is dependent on one's definition of pollinator limitation. Using a broad definition, the nearly complete failure of *Bombus*-excluded plants to produce fruit provides strong evidence that *C. palmatus* is pollinator-dependent.

Beyond the requirement that some pollinators be present, it is not clear that a moderate increase or decrease in pollinator activity would alter *Cordylanthus palmatus* seed production. Resource limitations, such as availability of summer water, may impose a limit on the number of *C. palmatus* seeds produced. A gross comparison of the percent flowers setting seed during 1993 with those from 1992 implies that there is considerable annual variation in per plant reproductive output (note that the data were collected in slightly different ways in each of the years, and a statistical comparison is not appropriate). While it is not known conclusively, it is possible that in years with lower than "average" rainfall, only the flowers pollinated in the early portion of the season have a reasonable chance of setting seeds. Those flowers that are pollinated late in the season may be unable to set seed with any regularity due to lack of water (or other limiting resource). In years with above average rainfall, slight increases in pollinator activity may be expressed in increased *C. palmatus* seed production. Such a link between resource limitations and seed production remain speculative, and would be an excellent subject of future research.

The results of this study suggest several important components for conservation planning and management of *Cordylanthus palmatus* at Springtown. Foremost is that *Bombus* should be included in any long-term management plans. This should not prove too difficult since *Bombus* are generally quite hardy and adaptable organisms. These insects do need nesting areas that are not subject to inundation. Therefore, upland areas within a few hundred meters of areas supporting large numbers of *C. palmatus* need to be preserved and included in the planning process. It is doubtful that bumblebee originating in the more distant upland areas, those farther than one kilometer from patches of *C. palmatus*, need to be included in the planning process (the exact location of the nesting sites was not determined, but analysis of flight paths indicate that most *Bombus* nests were probably located no more that several hundred meters away from the patches of *C. palmatus*).

The importance of *Bombus* for *Cordylanthus palmatus* pollination also means the use of insecticides at Springtown should be minimized, if not eliminated. While we know of no harmful pesticide use at Springtown, there is still some agriculture in the region, and there is the possibility that non-target organisms, such as bumblebees, could be killed by poorly applied control agents. While this is probably not a major concern, the local use of pesticides should be monitored.

The relationship between *Bombus* and *Cordylanthus* further emphasizes that conservation planning at the Springtown Alkali Sink needs to target the entire ecosystem and not simply focus on a single species.

Table 3. Proportions of flowers fruiting and number of seeds produced per capsule on *Cordylanthus palmatus* plants in pollinator-excluded, hand-pollinated, and naturally pollinated treatment groups of pollination experiment.

Treatment	% pollinated	Seeds / Capsule
Control	33.6	5.7
Control	16.0	6.1
Control	13.0	4.5
Control	68.5	7.6
Control	51.2	8.4
Control	44.1	6.8
Control	28.7	7.5
Control	54.5	5.9
Control	0.0	•
Control	9.4	6.9
Control	46.2	7.5
Control	21.9	6.9
Control	19.7	6.5
Control	16.3	5.2
Exclusion	0.0	•
Exclusion	0.0	•
Exclusion	0.0	•
Exclusion	0.0	•
Exclusion	0.0	•
Exclusion	15.0	5.4
Exclusion	0.0	•
Exclusion	0.0	•
Exclusion	0.0	•
Hand -Poll.	10.8	4.7
Hand -Poll.	10.4	5.6
Hand -Poll.	16.0	.9
Hand -Poll.	11.8	3.9
Hand -Poll.	13.4	3.4
Hand -Poll.	14.5	5.1
Hand -Poll.	11.6	5.3
Hand -Poll.	12.2	4.4
Hand -Poll.	11.6	3.5
Hand -Poll.	14.4	.4
Hand -Poll.	8.6	6.2

Table 4. Summary results of ANOVA comparing proportions of flowers fruiting and number of seeds produced per capsule among treatment groups of the pollination experiment.

ANOVA Table for % Pollinated

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	2	4805.654	2402.827	13.741	<.0001
Residual	31	5420.844	174.866		

Model II estimate of between component variance: 199.87

Means Table for % Pollinated
Effect: Treatment

	Count	Mean	Std. Dev.	Std. Err.
Control	14	30.221	19.954	5.333
Exclusion	9	1.667	5.000	1.667
Hand-pollinated	11	12.300	2.120	.639

ANOVA Table for Seeds/Cap

	DF	Sum of Squares	Mean Square	F-Value	P-Value
Treatment	1	41.259	41.259	18.867	.0003
Residual	22	48.110	2.187		

Model II estimate of between component variance: 3.279
One case was omitted due to missing values.

Means Table for Seeds/Cap
Effect: Treatment

	Count	Mean	Std. Dev.	Std. Err.
Control	13	6.577	1.080	.300
Hand-pollinated	11	3.945	1.847	.557

One case was omitted due to missing values.

3] Assessment of genetic variability among existing populations of *Cordylanthus palmatus*

Introduction

The maintenance of genetic polymorphism and heterozygosity is considered to be an important factor in the resilience of populations to environmental disruption and change. Evaluation of genetic variability is thus an important component of conservation planning for threatened and endangered species.

As part of management planning efforts for *Cordylanthus palmatus*, this study was undertaken to provide an assessment of the genetic variability of *C. palmatus* populations. Measures of allelic polymorphism and heterozygosity were made and compared among *C. palmatus* populations at Springtown Alkali Sink, Colusa National Wildlife Refuge, Delevan National Wildlife Refuge, and Mendota Alkali Sink Ecological Reserve. In addition, samples were collected from multiple locations at Colusa and Springtown in order to investigate within population (area) genetic variation.

Methods

Leaf tissue samples were taken from four *Cordylanthus palmatus* populations in the Livermore and Central Valleys of California: Springtown Alkali Sink, Colusa National Wildlife Refuge, Delevan National Wildlife Refuge, and Mendota Alkali Sink Ecological Reserve during the summer of 1993. Samples collected in 1992 were used for preliminary analyses and the testing of methodology, and were not suitable for final genetic analyses. Samples were taken along 100 meter line transects at four meter intervals. One transect was sampled at Delevan, and one at Mendota. At Colusa, four transects were sampled (C1-C4); C2 and C3 were only 50 meters long. Five transects were sampled at Springtown in the southeast (SE1, SE2), southwest (SW1, SW2), and west (W) subareas of the site.

Leaf material was ground and analyzed using horizontal starch gel electrophoresis. Each sample was surveyed for seventeen putative loci listed in Table 5. Allele frequencies, mean number of alleles per locus, heterozygosity estimates, and Hardy-Weinberg expectations were calculated using BIOSYS-1 (Swofford and Selander 1981). The percentage of loci polymorphic was calculated by dividing the number of polymorphic loci by the total number of loci. The degree of allelic polymorphism and heterozygosity among the four *Cordylanthus palmatus* populations were compared. Allelic polymorphism and heterozygosity within Springtown and Colusa populations were also compared.

Results and Discussion

Among population analyses. Of the seventeen loci surveyed, phenotypic data were recorded for fourteen loci: FE-3, HA, PRO, DIA, SOD-1, SOD-2, ALD, SDH, MPI-2, MPI-3, MDH, GAPDH, PGM-3, and GDH. Only these data were used for assessment of allelic polymorphism and heterozygosity. No data on locus ALD were available for the Delevan population.

Six loci were found to be polymorphic in *Cordylanthus palmatus*: HA, DIA, SOD-1, MPI-2, MPI-3, and PGM-3. The allele frequencies of these loci in each of the four *C. palmatus* populations are given in Table 6. Springtown was polymorphic at five of the loci (HA, DIA, SOD-1, MPI-3, and PGM-3), Mendota at four (DIA, MPI-2, MPI-3, and PGM-3), and Colusa and Delevan at one locus each (PGM-3 in both cases).

Table 5. Loci, enzymes, and enzyme commission (E.C.) numbers used in analysis of genetic variability of *Cordylanthus palmatus*. Only loci for which phenotypic data was recorded were used in analysis. These loci are denoted with an asterisk.

LOCUS	ENZYME	E.C. #
ALD*	Aldolase	4.1.2.13
DIA*	Diaphorase	1.8.1.4
a-EST	a-esterase	3.1.1.-
FE*	Fluorescent esterase	3.1.1.2
GAPDH*	Glyceraldehyde-3-phosphate dehydrogenase	1.2.1.12
GDH*	Glutamate dehydrogenase	1.4.1.2
HA*	Hexoseaminase	3.2.1.52
MDH*	Malate dehydrogenase	1.1.1.37
MPI-2*	Mannosephosphate isomerase	5.3.1.8
MPI-3*	Mannosephosphate isomerase	5.3.1.8
PGD	Phosphogluconate dehydrogenase	1.1.1.43
PGM*	Phosphoglucomutase	5.4.2.2
PRO*	General protein	—
SDH*	Sorbitol dehydrogenase	1.1.1.14
SKDH	Shikimate dehydrogenase	1.1.1.25
SOD-1*	Superoxide dismutase	1.15.1.1
SOD-2*	Superoxide dismutase	1.15.1.1

* Loci for which phenotypic data was recorded. Only these loci were used in analysis.

Table 6. Allele frequencies of polymorphic loci in *Cordylanthus palmatus*. Frequencies of alleles from four locations are given, along with the number of samples used to determine frequencies (N). Frequencies that do not add to 1.000 result from rounding error.

	LOCATION			
LOCUS	SPRINGTOWN	MENDOTA	DELEVAN	COLUSA
DIA				
C	0.996	0.978	1.000	1.000
D	0.004	0.022	0.000	0.000
(N)[1]	114	23	13	77
HA				
C	0.991	1.000	1.000	1.000
N	0.009	0.000	0.000	0.000
(N)	116	24	26	77
MPI-2				
C	1.000	0.909	1.000	1.000
N	0.000	0.091	0.000	0.000
(N)	83	22	15	77
MPI-3				
B	0.009	0.000	0.000	0.000
C	0.983	0.909	1.000	1.000
D	0.009	0.000	0.000	0.000
N	0.017	0.091	0.000	0.000
(N)	115	22	25	77
PGM-3				
B	0.278	0.167	0.205	0.203
C	0.708	0.778	0.795	0.791
D	0.014	0.056	0.000	0.007
(N)	72	18	22	74
SOD-1				
C	0.995	1.000	1.000	1.000
D	0.005	0.000	0.000	0.000
(N)	96	24	26	77

[1] (N) = number of samples used to determine allele frequencies.

Comparing the allele frequencies at each locus among the four sites using simultaneous test procedure (STP), only the frequencies of MPI-2 and MPI-3 were found to differ significantly among the four sites at $P < 0.05$ (Figure 5). Examining the results of STP analysis, the Colusa and Delevan populations have similar allele frequencies at all loci. The allele frequencies at MPI-2 in the Mendota population are significantly different than the other three sites. The allele frequencies at MPI-3 in the Mendota and Springtown populations are similar to each other, but differ significantly from the Colusa and Delevan populations. These results suggest that the Colusa and Delevan populations are nearly identical genetically, that the Mendota population is the most distinct, and that the Springtown population is intermediate between the northern Central Valley and Mendota populations.

The mean number of alleles per locus, the percentage of loci polymorphic, the observed mean heterozygosity for each of the four *Cordylanthus palmatus* populations are given in Table 7. Comparing the mean number of alleles per locus, and the percentage of loci polymorphic, among the four populations, Springtown and Mendota have more alleles per locus, and greater proportions of polymorphic loci than either the Colusa or Delevan populations. Springtown has the greatest degree of polymorphism with 1.6 alleles per locus and 35.7 percent of loci exhibiting polymorphism. Colusa and Delevan again appear to be very similar in their degree of polymorphism.

The degree of heterozygosity is another important consideration for evaluating genetic variability in the four *Cordylanthus palmatus* populations. The heterozygosity of each population is given in Table 7. The Mendota and Colusa populations appear especially depressed with only 1.9% and 1.8%, respectively. The Springtown and Delevan are not much more heterozygosity, with only 2.8% and 2.4% mean heterozygosity. These are relatively depressed levels of heterozygosity -- plant

Figure 5. Summary of tests by simultaneous test procedure (STP) for the homogeneity of allele frequencies among the four *Cordylanthus palmatus* populations sampled. Population abbreviations connected by the same line indicate that allele frequencies at that locus are not significantly different among populations (P > 0.05). Rare alleles were pooled for this analysis.

	LOCATION			
LOCUS	DELEVAN	COLUSA	SPRINGTOWN	MENDOTA
DIA	D ________	C ________	S ________	M
HA	D ________	C ________	S ________	M
PGM-3	D ________	C ________	S ________	M
SOD-1	D ________	C ________	S ________	M
MPI-2	D ________	C ________	S	M
MPI-3	D ________	C	S ________	M

Figure 6. Summary of tests by simultaneous test procedure (STP) for the homogeneity of *Cordylanthus palmatus* allele frequencies among the five subareas of Springtown sampled. Population abbreviations connected by the same line indicate that allele frequencies at that locus are not significantly different among populations (P > 0.05). Rare alleles were pooled for this analysis. Because locus MPI-2 was fixed at Springtown, it was omitted from this analysis.

	SUBAREA OF SPRINGTOWN				
LOCUS	W	SE1	SE2	SW1	SW2
DIA	W ________	SE1 ________	SE2 ________	SW1 ________	SW2
HA	W ________	SE1 ________	SE2 ________	SW1 ________	SW2
SOD-1	W ________	SE1 ________	SE2 ________	SW1 ________	SW2
PGM-3	W ________	SE1 ________	SE2 ________	SW1	SW2
		________	________	________	________
MPI-3	W	SE1 ________	SE2 ________	SW1 ________	SW2

Table 7. Summary of genetic variability in each of the four *Cordylanthus palmatus* populations sampled. Mean number of alleles per locus, percentage of loci polymorphic, mean heterozygosity, and Hardy-Weinberg expectations are given. (Standard errors are given in parentheses.)

POPULATION	Mean # of alleles per locus	Percentage of loci polymorphic[1]	Mean hetero-zygosity	Hardy-Weinberg Expectation
Springtown	1.6 (0.3)	35.7	0.028 (0.024)	0.038 (0.030)
Mendota	1.4 (0.2)	28.6	0.019 (0.016)	0.054 (0.030)
Colusa	1.1 (0.1)	7.1	0.018 (0.018)	0.024 (0.024)
Delevan[2]	1.1 (0.1)	7.7	0.024 (0.024)	0.026 (0.026)

[1] The percentage of loci polymorphic was calculated using the fourteen loci for which phenotypic data was recorded. Because no data on ALD was available for the Delevan population, that percentages was based on thirteen loci.

[2] No data on the ALD locus was available for this population. Therefore, the percentage of loci polymorphic was based on thirteen loci rather than fourteen.

species typically exhibit approximately 8% mean heterozygosity (Peter Brussard, UNR, per. comm.). This suggests that *palmatus* populations may be not be as resilient to environmental disruption or change as are population of most plant species, and that individuals within single populations, individuals are not mating randomly (pollen is most likely being transferred only short distances, thus increasing the chance of matings between closely related plants and self pollination).

The high degree of allelic polymorphism (as expressed by percentage of loci that are polymorphic) at Springtown identifies that population as being an important target for conservation activities. This importance is augmented by the presence of four private alleles in the population (i.e. alleles not found at any other site). The *Cordylanthus palmatus* at Springtown contain most of the genetic variation available to the species, therefore, preservation of a large population at this site is likely critical to the long-term survival of *C. palmatus*. as a species.

The Mendota population, while not quite as diverse as the *Cordylanthus palmatus* population residing at Springtown, is an important source of genetic variability with a substantial proportion of polymorphic loci and one private allele.

The *Cordylanthus palmatus* populations residing at Colusa and Delevan are somewhat anomalous. Each of these areas supports tens of thousands (if not hundreds of thousands) of *C. palmatus* individuals and yet exhibit surprisingly low levels of heterozygosity (7.1% and 7.7% of loci are polymorphic, respectively). For plant species, the average number of polymorphic loci is roughly 30% (Peter Brussard, UNR, pers. comm.) -- approximately the levels observed at Springtown and at Mendota (35.7% and 28.7%, respectively). The relatively low degree of polymorphism found in Colusa and Delevan populations suggests that these populations are genetically depauperate. Given the low genetic diversity, one would have to suspect that the recently observed high population levels are the exception rather than the rule, and that at some point in the not so distant past the populations experienced extremely low numbers of individuals (= genetic bottleneck). Additionally, considering the overall similarity in allele frequencies between the two populations, it is a reasonable possibly that one of the populations was founded by individuals from the other -- after the suspected bottleneck occurred. It is also not inconceivable that these two populations were founded within historic times by individuals originating from elsewhere in the state (such as Springtown).

Within population analyses. Comparisons of specimens collected in different areas within the Colusa and Springtown sites allow some evaluation of within-site genetic variability of *Cordylanthus palmatus*. The mean number of alleles per locus, the percentage of loci polymorphic, and the mean heterozygosity for each of the four transects sampled at Colusa are given in Table 8. Although mean heterozygosity varies some between transects, and C3 and C4 appear to have less heterozygosity than expected, the degree of allelic polymorphism in this population is very consistent. These results suggest that the Colusa population of *C. palmatus* is genetically depauperate and quite homogeneous. This is consistent with the findings of the portion of this study investigating among population variation.

The mean number of alleles per locus, the percentage of loci polymorphic, the mean heterozygosity, and the Hardy-Weinberg expectations for each of the five transects sampled at Springtown are given in Table 9. The mean number of alleles per locus vary little, ranging from 1.1 to 1.3. The percentage of loci polymorphic are more variable, ranging from 7.1 to 28.6. This variability suggests that the Springtown population may be subdivided spatially. While, it is unlikely that genetic differentiation has occurred to the extent that subareas contain genetically distinct subpopulations, *Cordylanthus palmatus* found in different portions of the Springtown ecosystem are likely not exchanging pollen freely.

Such a possibility seems supported by STP analysis of allele frequencies for the five polymorphic loci (Figure 6). While allele frequencies for HA, DIA, and SOD-1 are similar for all five transects, the allele frequencies of MPI-3 differ significantly ($P < 0.05$) between transects SW2 and W. At locus PGM-3, the allele frequencies from the W transect are significantly different from the allele frequencies found at the other four transects. Such within-site variability further suggests genetic subdivision of the Springtown population.

Coupling these results indicating substantial population structuring on a local spatial scale, with the high allelic polymorphism of this population relative to the Central Valley population, the Springtown population of *Cordylanthus palmatus* is concluded to be of primary importance for the long-term management and conservation of the species. As a consequence, efforts must be made to protect the Springtown population in its entirely -- since most of the species' genetic variation is present at Springtown and since the Springtown population is genetically heterogeneous, no portions of the Springtown population should be considered expendable.

It should be emphasized, though, that the particular genetic importance of the Springtown population in no way implies dispensibility of the Colusa, Delevan, and Mendota populations. The Mendota population, in particular, contains some unique genetic information and should be targeted for conservation activities.

This study also has bearing on *ex situ* conservation activities. Efforts to store *Cordylanthus palmatus* seeds in a seed bank should target the Springtown and Mendota populations. If conservation resources are limited, the populations residing at the Colusa and Delevan national wildlife refuges could be omitted such a program without apparent loss of genetic information. In addition, to ensure that as much

Table 8. Summary of genetic variability of *Cordylanthus palmatus* in each of the four subareas sampled within the Colusa population. Mean number of alleles per locus, percentage of loci polymorphic, mean heterozygosity, and Hardy-Weinberg expectations are given. (Standard errors are given in parentheses.)

SUBAREA OF COLUSA	Mean # of alleles per locus	Percentage of loci polymorphic[1]	Mean hetero-zygosity	Hardy-Weinberg Expectation
Colusa 1[2]	1.1 (0.1)	7.7	0.028 (0.028)	0.023 (0.023)
Colusa 2	1.1 (0.1)	7.1	0.020 (0.020)	0.019 (0.019)
Colusa 3	1.1 (0.1)	7.1	0.011 (0.011)	0.026 (0.026)
Colusa 4[3]	1.1 (0.1)	7.7	0.015 (0.015)	0.030 (0.030)

[1] The percentage of loci polymorphic was calculated using the fourteen loci for which phenotypic data was recorded. Because no data was available on GAPDH for Colusa 1 or on ALD for Colusa 4, these percentages were based on thirteen loci.

[2] No data on GAPDH was available for this subarea. Therefore, the percentage of loci polymorphic was based on thirteen loci rather than fourteen.

[3] No data on ALD was available for this subarea. Therefore, the percentage of loci polymorphic was based on thirteen loci rather than fourteen.

Table 9. Summary of genetic variability of *Cordylanthus palmatus* in each of the five subareas sampled within the Springtown population. Mean number of alleles per locus, percentage of loci polymorphic, mean heterozygosity, and Hardy-Weinberg expectations are given. (Standard errors are given in parentheses.)

SUBAREA OF SPRINGTOWN	Mean # of alleles per locus	Percentage of loci polymorphic[1]	Mean hetero-zygosity	Hardy-Weinberg Expectation
W	1.3 (0.2)	21.4	0.014 (0.011)	0.021 (0.012)
SE1	1.1 (0.1)	7.1	0.024 (0.024)	0.036 (0.036)
SE2	1.3 (0.1)	28.6	0.028 (0.020)	0.038 (0.030)
SW1	1.2 (0.2)	14.3	0.028 (0.028)	0.042 (0.033)
SW2	1.1 (0.1)	7.1	0.021 (0.021)	0.026 (0.026)

[1] The percentage of loci polymorphic was calculated using the fourteen loci for which phenotypic data was recorded.

genetic variation as possible is represented in a seed bank, such efforts would need to take samples from the different subareas at Springtown. At the present time, it is doubtful that a substantial portion of the limited conservation funds should be allocated to securing and storing *C. palmatus* seeds -- for the most part, the species is doing quite well in the wild. However, if seeds can be obtained in a systematic fashion at low cost, and maintained at low cost, such an *ex situ* effort would be appropriate.

4] Characterization of Springtown soils and correlation to distribution of *Cordylanthus palmatus*

Introduction

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).

Work conducted by the Center for Conservation Biology to characterize Springtown soils indicated a highly variable edaphic environment at the Springtown Alkali Sink comprised of a complex mosaic of patches of specific soil types often only a few meters in diameter (CCB 1993). A three-element soil classification system was developed to describe biologically and physically important characteristics of the Springtown soil mosaic (for details, see CCB 1993). These elements were then used to generate three-digit map units which allowed mapping of study plot soils (CCB 1993).

In order to more precisely determine edaphic factors affecting the distribution and abundance of *Cordylanthus palmatus*, a study was conducted to investigate correlations between the abundances of *C. palmatus, Lasthenia, Distichlis*, and annual grasses with abiotic soil factors.

Methods

Surface soil samples were taken from each of three study areas located in northeast (A), southwest (C), and west (D) Springtown. A total of 39 samples were taken: 10 from A, 18 from C, and 11 from D. The samples represented all of the soil types classified by the three-element system defined in CCB (1993). Element codes for each sample were recorded.

Soil samples were sent to Perry Laboratories in Watsonville, California for analysis of abiotic soil parameters (see Table 10 for complete list of parameters measured). Twenty-seven samples, selected to represent all soil types defined at Springtown, were analyzed for salinity parameters. If a soil type supported *Cordylanthus palmatus* in some zones but not in others, a sample from each zone was analyzed. A subset of seventeen samples was analyzed for fertility parameters. This subset of samples was selected to represent all soil types defined at Springtown. Whenever possible, samples selected were from close geographic proximity in order to best discriminate soil parameter differences at borders of *C. palmatus* distribution.

Information on vegetation cover surrounding each sample was collected at the time of sampling, and by use of aerial photographs. These biotic parameters included estimates of % vegetation cover, % cover comprised of *Distichlis*, % cover comprised of annual grasses, relative density of *Lasthenia*, relative density of *Cordylanthus mollis hispidus*, and relative density of *Cordylanthus palmatus*. Relative densities were classes as 0, Low, Moderate, and High. Density estimates for *Lasthenia* were made from aerial photographs; density estimates of *C. mollis hispidus* and *C. palmatus* were assessed by direct inspection of sampling sites.

The resulting dataset of biotic and abiotic parameters was analyzed using canonical correspondence analysis (CCA) to find the abiotic factors most strongly

Table 10. Soil parameters analyzed and measured for canonical correspondence analysis with abundance of *Cordylanthus palmatus*, annual grasses, *Lasthenia*, and *Distichlis*. Abbreviations given are used in ordination diagrams (Figures 7 and 8).

SOIL PARAMETER	ABBREVIATION
pH	pH
Electrical conductivity	ec
Sodium potential	SP
Calcium and magnesium level	Ca+Mg
Sodium level	Na
Chloride level	Cl
Sodium absorption ratio	SAR
Boron	B
Soil profile development*	Profile
Soil texture*	Texture
Probable salt*	Ionics

* These parameters were classed in the field according to the soil classification system detailed in CCB 1993. All other parameters were measured via soil sample analysis by Perry Laboratories in Watsonville, CA.

correlated to *Cordylanthus palmatus*, *Lasthenia*, *Distichlis*, and annual grass abundances. CCA is a multivariate ordination analysis that allows evaluation of the effect of a set of environmental variables on species composition and abundance. By determining covariance between environmental variables, the smallest subset of variables that best explain variation in species composition can be identified. CCA also allows evaluation of the relative strengths of environmental variables for separating species along physical gradients. Analyses were performed using CANOCO (ter Braak 1987-1992) application for Macintosh.

In this study CCA was utilized to determine the key soil parameters that have the strongest influences on the distributions of *Cordylanthus palmatus*, *Lasthenia*, annual grasses, and *Distichlis* across the Springtown Alkali Sink. For analysis, percent covers and relative densities of plant species were all converted to a nominal scale for analysis. Percent covers were converted by dividing percent values by ten. Relative densities were converted as follows: 0 = 0, Low = 3, Moderate = 6, High = 9. Values of environmental variables for samples were directly analyzed.

Canonical correspondence analysis produces a multi-dimensional ordination diagram consisting of a biplot of vectors representing scores of environmental variables, and points representing species scores. The number of axes can be as many as the number of environmental variables included in CCA. The axes are defined as non-correlated linear combinations of environmental variables that optimally display differences in species abundances. The strength of a given axis for separating species is represented by an eigenvalue (λ) which can be tested for significance using a Monte Carlo permutation test. The vectors represent the direction of an increasing gradient of the associated environmental variable. The magnitude of a vector indicates the strength of influence of that variable on species distributions.

Projections of the species scores onto these vectors provide indications of how the species are separated along physical gradients. The angle between two vectors also gives a visual impression of the degree of covariance between two environmental variables. Generally, only the first two axes of the ordination are diagramed since they are usually the primary axes for displaying differences in species abundances.

CCA was applied to vegetation data (Table 11) with 11 environmental variables (Table 12).

Results and Discussion

Initial CCA of the data sets suggested that sample A18 and environmental variables electrical conductivity and chlorine concentration be omitted due to outlying and variance inflation, respectively. These omissions were made under conventions of CCA.

Figure 7 displays the ordination diagram resulting from CCA on the datasets. The diagram shows the four species' scores (*) and the scores of the 11 environmental variables (vectors). The tolerance (equivalent to standard deviation) about each of the species scores are given in Table 13. Based on the large magnitude of the pH vector, pH appears to be the dominant environmental variable determining species distributions. The other variables are expected to have less influence given either lower magnitudes or covariance with other environmental variables.

The horizontal axis was the strongest for separating the species with an eigenvalue of 0.663. A Monte Carlo permutation test of this eigenvalue showed this value to be significant ($P < 0.01$). This result then allowed the conclusion that there are significant differences in vegetation composition among the samples along this axis. The vertical axis had an eigenvalue of 0.147, while the third axis (not shown in the ordination diagram), had an eigenvalue of 0.096. Because of their small

Table 11. Relative abundances and percents cover of *Cordylanthus palmatus*, *Lasthenia*, annual grasses, and *Distichlis* surrounding soil samples. Data shown was converted for canonical correspondence analysis as detailed in text.

Species	Sample A12	A14	A15	A18	A20	A21	A17	A16	C14
Cordylanthus	0	Moderate	Low	0	0	Low	Moderate	High	Moderate
Distichlis	0%	90%	50%	75%	95%	90%	0%	60%	10%
Annuals	0%	0%	0%	5%	5%	0%	0%	0%	0%
Lasthenia	0	0	0	0	0	0	0	0	0

Species	Sample C22	C15	C19	C21	C16	C17	C25	C26	C28
Cordylanthus	0	Low	High	Moderate	Low	0	0	0	0
Distichlis	5%	10%	0%	0%	0%	0%	15%	0%	0%
Annuals	0%	10%	0%	0%	0%	85%	50%	95%	90%
Lasthenia	0	0	0	0	0	High	High	High	Low

Species	Sample C29	D6	D7	D8	D13	D15	D16	D10	D11
Cordylanthus	0	High	High	High	0	0	0	0	0
Distichlis	0%	20%	20%	20%	50%	50%	50%	30%	40%
Annuals	100%	20%	20%	20%	50%	50%	50%	60%	40%
Lasthenia	0	0	0	0	High	Moderate	Moderate	Low	0

Table 12. Values of soil parameters measured from soil samples for canonical correspondence analysis. See Table 10 for key to abbreviations.

	Sample								
Parameter	A12	A14	A15	A18	A20	A21	A17	A16	C14
Profile	1	2	2	2	2	2	2	2	1
Texture	1	3	3	2	2	2	2	2	2
Ionics	3	2	2	2	2	2	3	3	3
pH	7.2	7.7	8.2	7.2	8.1	8	8.8	8.9	8.2
ec	559	48.8	44.5	100.4	29.1	28.8	109.3	67.6	13.1
SP	26	42	42	36	29	46	30	38	25
Ca+Mg	527	69.2	38.1	375	59.2	49.4	83.4	16.6	26.2
Na	4760	162	610	900	19.6	201	1220	290	12.3
Cl	7300	585	520	1300	336	420	1320	600	168
SAR	293	28	105	66	3.6	40	189	101	3.4
B	400	105	80	160	61	38	416	366	35.4

	Sample								
Parameter	C22	C15	C19	C21	C16	C17	C25	C26	C28
Profile	1	2	2	2	2	2	2	2	3
Texture	2	2	2	2	2	2	2	2	2
Ionics	3	2	2	2	3	4	4	4	1
pH	9.1	8.3	8.6	7.4	8.8	6.7	6.2	5	6.8
ec	328	13.8	72.3	76.7	7.9	1.4	5	29.7	1.1
SP	24	27	25	24	27	25	27	26	29
Ca+Mg	10.9	21.2	13.4	51.6	7.8	30	4.8	36.9	17.5
Na	3400	12.2	930	700	92	3	73	201	8.1
Cl	3500	180	820	832	160	48	160	370	40
SAR	1456	3.8	359	138	47	0.8	47	47	2.7
B	460	27	65	31	16	10.8	56	32	1.9

	Sample								
Parameter	C29	D6	D7	D8	D13	D15	D16	D10	D11
Profile	3	2	2	2	2	2	2	3	3
Texture	2	3	3	3	3	3	3	3	3
Ionics	1	2	2	2	4	4	4	1	1
pH	5.9	9.5	8.8	8.5	5.3	6.5	5.3	6.1	5.8
ec	2.1	57.5	109.2	55.7	10	52.2	13.2	2.3	1.3
SP	30	58	34	69	50	48	58	43	47
Ca+Mg	14.1	15.2	38.9	54.9	32.5	133	41.2	20.5	8.3
Na	18	470	1090	438	162	372	103	17.2	9.2
Cl	72	520	1000	372	130	552	172	110	80
SAR	6.8	171	247	84	40	46	23	5.4	4.5
B	11	59	81	36	6.9	51	9.7	1.6	2.5

Figure 7. Canonical correspondence analysis ordination diagram showing biplot of species scores (*) and soil parameter scores (vectors). Axes defined as linear combinations of environmental variables. Vectors denote direction of increasing environmental gradient; magnitude reflects relative strength of soil parameter for separating species along a physical gradient (e.g. pH has strong influence, separating species along nearly horizontal axis). Small angles between vectors denote covariance (e.g. Ca+Mg, SP, and Texture covary with each other). Projections of species scores onto vectors show how species are dispersed along that particular gradient. See Table 10 for explanation of abbreviations. See Table 13 for the tolerances (=S.D.) of each species along the two axes.

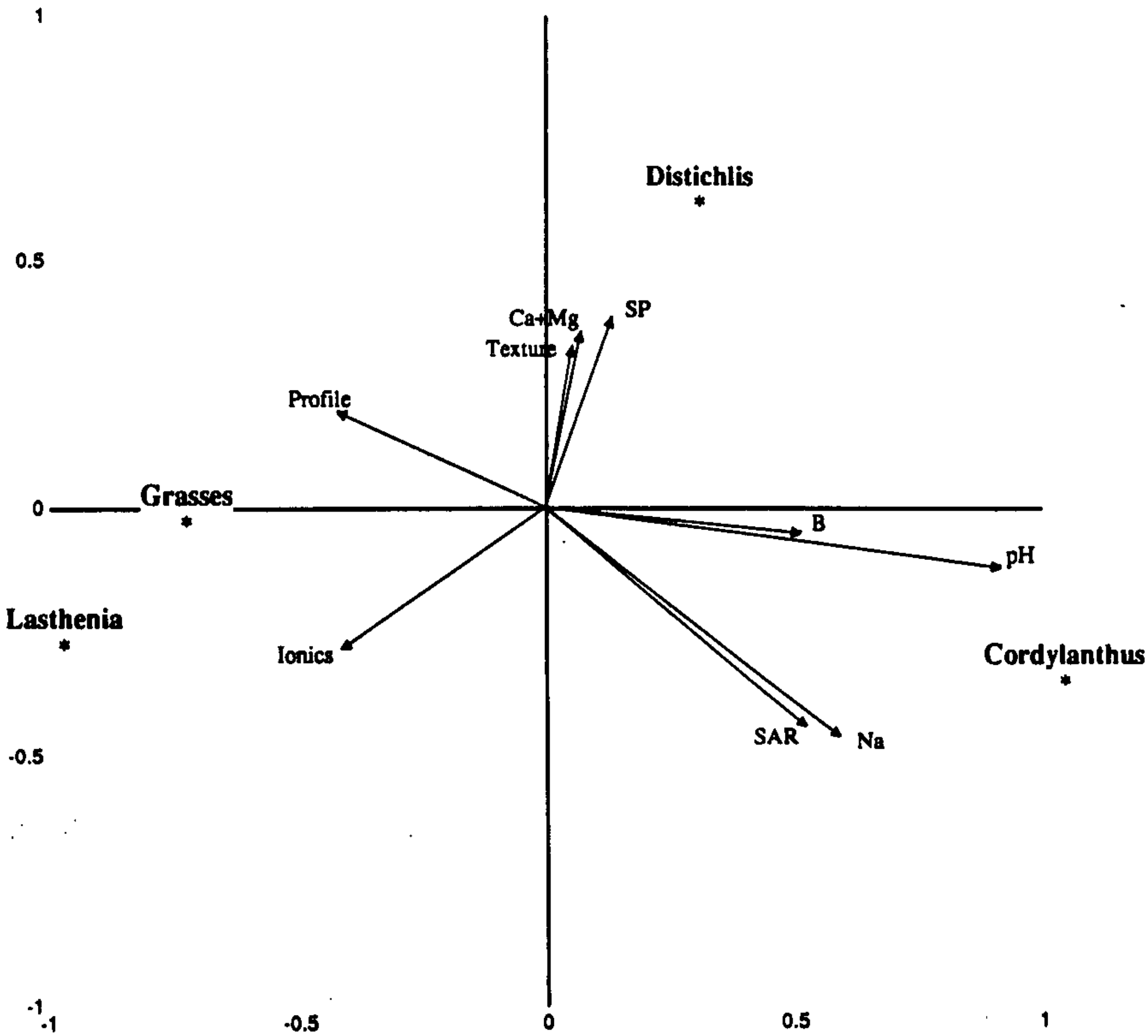


Table 13. Species scores and tolerances along Axis 1 (horizontal) and Axis 2 (vertical) of CCA ordination diagram (Figure 7). Tolerances are equivalent to standard deviations. By plotting the tolerances of a species about the species score in the ordination diagram, a rough visualization of the habitat space within the ordination space can be made.

	SPECIES SCORE		TOLERANCE (=S.D.)	
SPECIES	AXIS 1	AXIS 2	AXIS 1	AXIS 2
Cordylanthus palmatus	1.046	-0.344	0.362	1.107
Annual grasses	-0.728	-0.023	0.625	0.811
Lasthenia	-0.971	-0.270	0.128	0.785
Distichlis	0.312	0.625	0.872	0.902

eigenvalues, both of these axes were considered to be minor.

Further analysis was done to determine the fewest environmental variables that described the vegetation differences nearly as well as the entire set. As suggested in Figure 7, pH was the single environmental variable that explained the greatest amount of the variation in plant species abundances. Analyzing species data against pH alone, significant differences in species abundances could be detected along that single axis ($\lambda = 0.560$, $P < 0.01$). pH accounted for 46.5% of the total observed variance in the species data, including 65.2% of variation in *Cordylanthus palmatus* abundance, 43.3% of variation in annual grass abundance, and 59.5% of *Lasthenia* abundance; pH explained only 4.1% of variation in *Distichlis* abundance.

A Monte Carlo permutation test was employed to test the significance of the "added fit" provided by the addition of subsequent environmental variables to the model. Only variables that explained significant additional variation ($P < 0.05$) were included. This "forward selection" of environmental variables resulted in the addition of only one environmental variable: soil profile development.

The ordination diagram resulting from CCA of species data against pH and soil profile development is given in Figure 8. The horizontal axis was again dominant with a significant eigenvalue of 0.575 ($P < 0.01$). The vertical axis was minor with an eigenvalue of 0.081. This simplified model with only the two environmental variables successfully explained 54.5% of the total variation in species data, including 67.6% of variation in *Cordylanthus palmatus* abundance, 69.8% of variation in annual grass abundance, and 67.2% of variation in *Lasthenia* abundance; only 4.4% of *Distichlis* variation was explained.

Since no other environmental variables provided significant additional explanation of variance ($P < 0.05$), it is concluded that that pH and soil profile

Figure 8. Canonical correspondence analysis ordination diagram showing biplot of species scores (*) and scores of pH and soil profile development (vectors). CCA was done with pH and soil profile development as only environmental variables. pH can be seen to be the predominant variable separating species along the horizontal axis. Profile appears to be dominant along the vertical axis. Eigenvalues of the two axes indicate that the horizontal axis is most important while the vertical axis is minor. See Figure 7 for additional explanation of information expressed in an ordination diagram. See Table 10 for an explanation of abbreviations. See Table 14 for the tolerances (=S.D.) of each species along the two axes.

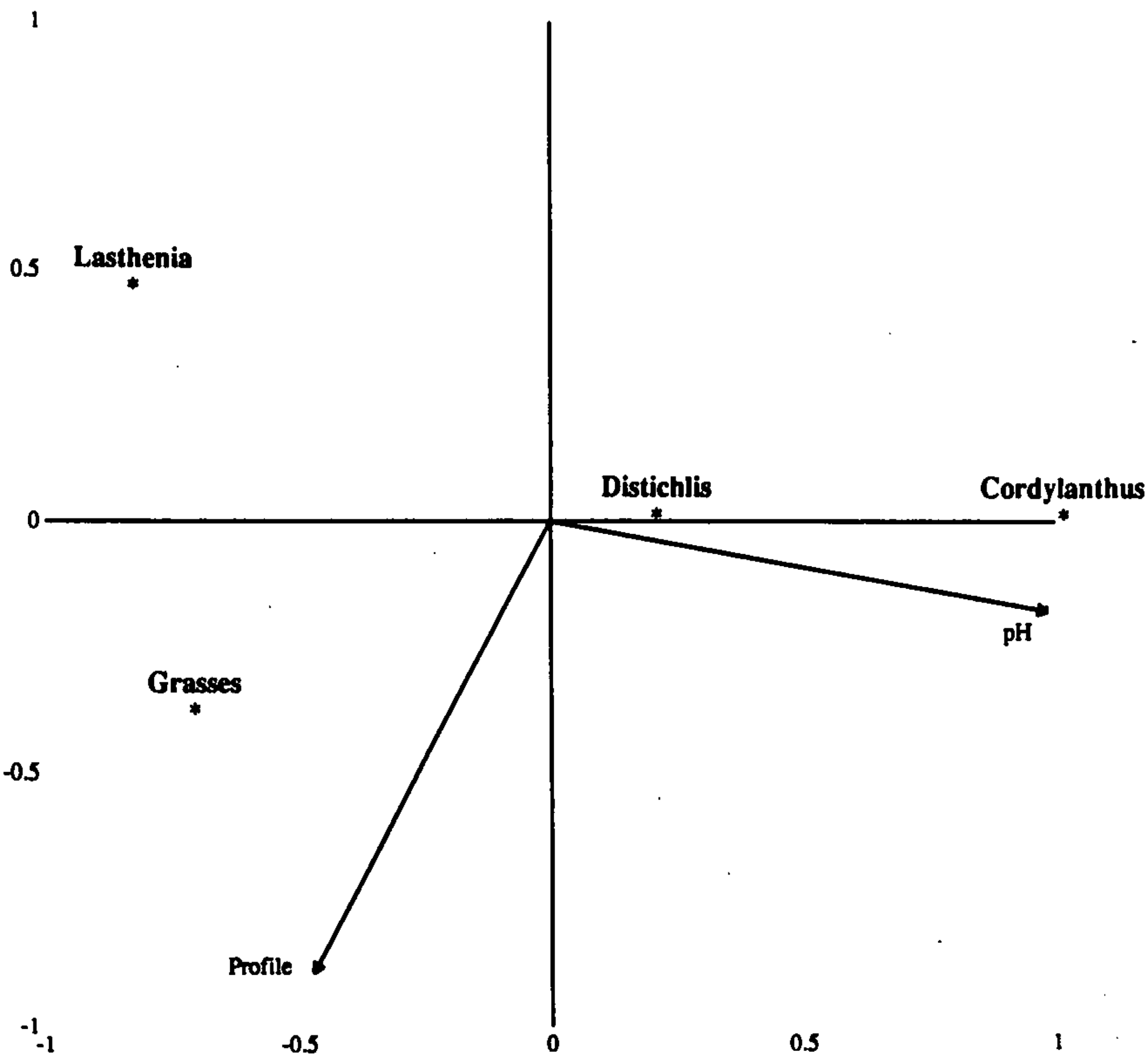


Table 14. Species scores and tolerances along Axis 1 (horizontal) and Axis 2 (vertical) of CCA ordination diagram (Figure 8). Tolerances are equal to standard deviations. By plotting the tolerances of a species about the species score in the ordination diagram, a rough visualization of the habitat space within the ordination space can be made.

	SPECIES SCORE		TOLERANCE (=S.D.)	
SPECIES	AXIS 1	AXIS 2	AXIS 1	AXIS 2
Cordylanthus palmatus	1.017	0.015	0.368	0.734
Annual grasses	-0.706	-0.374	0.740	1.292
Lasthenia	-0.827	0.474	0.425	0.907
Distichlis	0.210	0.016	0.903	0.800

development are the primary soil characteristics correlated to the vegetation patterns at Springtown Alkali Sink, with pH being the predominant factor. It is stressed that while pH and soil profile development define necessary conditions for the distribution of *Cordylanthus palmatus* and the other species, they are not sufficient for predicting precise distributions.

From the ordination diagram for this two variable model (Figure 8), at Springtown *Cordylanthus palmatus* appears to be found on comparatively alkaline soils, while annual grasses and *Lasthenia* appear restricted to the more neutral or acidic soils. Examining the raw data for soil samples, *C. palmatus* was found on soils with pH ranging from 7.4 to 9.5, annual grasses on soils ranging from pH 5.0 to 8.3, and *Lasthenia* on soils ranging from pH 5.0 to 6.8. *Distichlis* appears to be intermediately distributed along the pH gradient; it was found in soils of pH 5.3 to 9.5.

The findings of this study have notable implications for future monitoring and management planning for *Cordylanthus palmatus*. Both pH and soil profile development can be determined with relative ease. Given that the distribution of *C. palmatus* and the other plant species appear to be broadly restricted by pH and, to a lesser degree, soil profile development, monitoring these environmental variables could provide a means to rapidly assess habitat quality or suitability for *C. palmatus*. Surveys of pH and soil profile development could be done to produce fine-scale maps of pH and profile development across Springtown or other sites. Such maps could be utilized to identify areas of potential *C. palmatus* habitat which might guide future monitoring, or identify good locations for reintroduction efforts.

It should be noted that the habitat areas identified by such a study would be predictor of areas that are physically able to support *C. palmatus* and that are likely to not support plant species that may exclude *C. palmatus*. Previous studies of the germination requirements of *C. palmatus* show that *C. palmatus* could germinate and grow in a broad range of soil pH (CCB 1993). These previous results suggest that *C. palmatus* could occupy a somewhat broader area than it presently does. A likely explanation for the observed restriction of *C. palmatus* to more alkaline soils would be that competition with annual grasses or *Lasthenia* acts to exclude *C. palmatus* from more neutral and acidic soils. Availability of water also undoubtedly plays a role in the distribution of *C. palmatus* -- it is likely that in the absence of competitors, *C. palmatus* would be more broadly distributed, but it is doubtful that *C. palmatus* could occupy areas well away from where it is presently distributed.

Using a fine-scale map of pH and soil profile in conjunction with a knowledge of the broader pH range in which *Cordylanthus palmatus* could germinate and grow, transition zones could be demarcated in which competition between *C. palmatus* and other plants was expected to determine distributional boundaries. Such transition zones could serve as areas for experimental management regimes designed to expand available habitat for *C. palmatus* by altering competitive balances.

5] Effects of Fire on Vegetation Composition and Cover

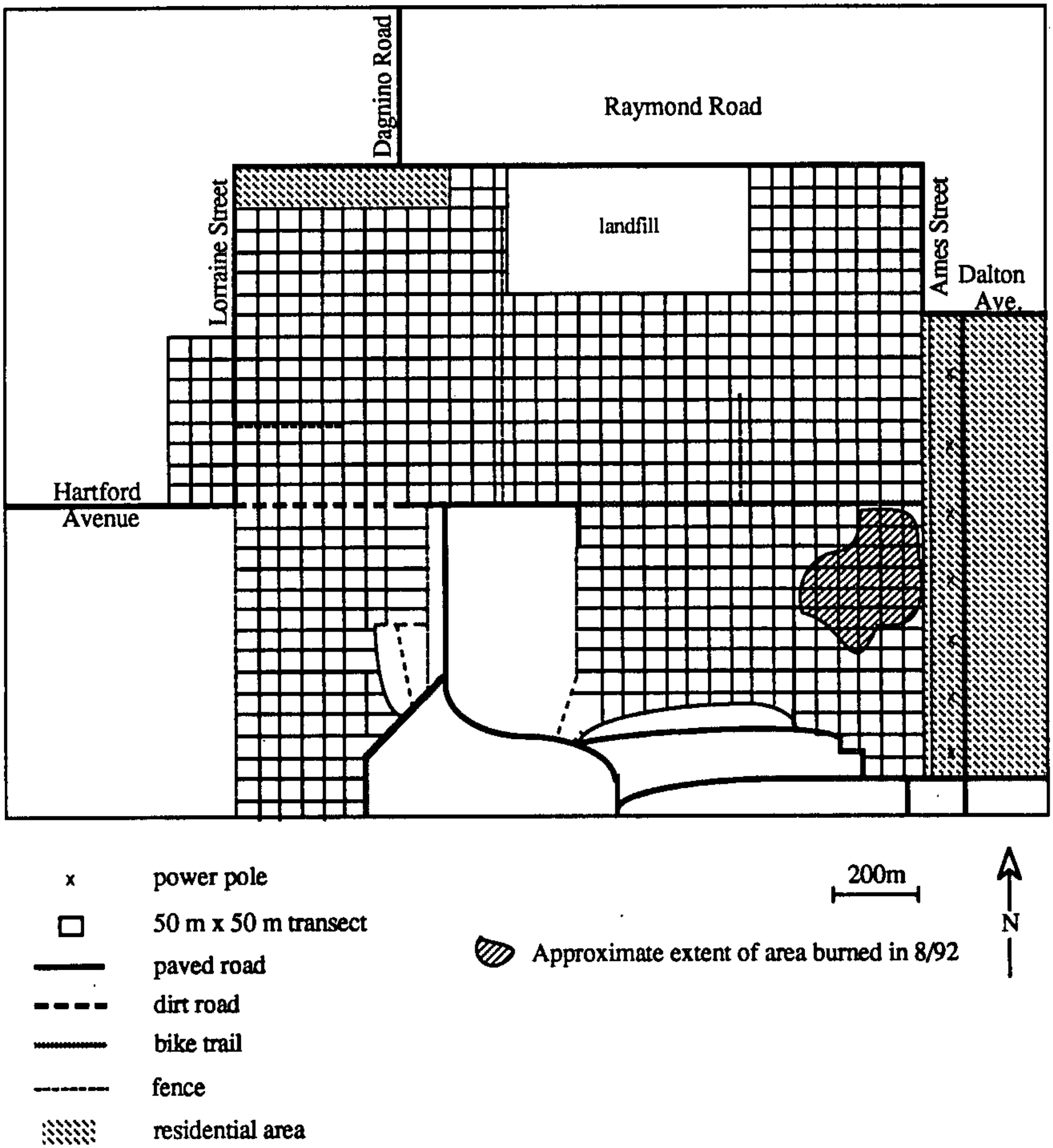
Introduction

In August 1992, a grass fire burned a portion of southeast Springtown near the residential development. The area affected by the fire is diagramed in Figure 9. The burned area provided an opportunity to study the effects of fire on the species composition and cover of the vegetation at Springtown.

Methods

Ten 100-meter transects were randomly placed within the boundaries of the burned area and adjacent unburned areas; five transects were placed in each treatment area and sampled in Spring and Summer 1993. Cover of all species was measured using point intercept procedures modified from Mueller-Dombois and Ellenburg (1974). Cover was determined by dropping a pointed rod into the plant canopy at one meter intervals along each 100m transect. All species touched by the rod at each of the 100 sample points were recorded to obtain species cover for that transect. Only live biomass was recorded; dead biomass (i.e. litter) was recorded only for sample points that did not contain live biomass. Soil was recorded only when live biomass and litter were absent. Cover values for the five transects in each treatment (burned and unburned) were averaged to give mean cover values and standard errors for each treatment. Mean cover values of each species were then compared between treatments using a two-tailed t-test ($P < 0.05$; $n = 5$). Vegetation was sampled first in late March/early April, and again during late July 1993. Sampling procedures were executed similarly for both sampling periods.

Figure 9. Map of Springtown Alkali Sink showing location and extent of area burned in August 1992.



Results

Spring 1993. Grass cover was significantly higher in the unburned areas compared to the burned treatment (Table 15). In contrast, *Erodium* spp., an introduced species, and *Holocarphia obconia*, a native species, were conspicuous in the burned treatment, but nearly absent from the unburned areas. Two native *Trifolium* species, *T. depauperatum* and *T. microdon*, were also consistently present in the burned treatment but absent from the unburned areas. *Allenrolfea occidentalis*, *Atriplex* spp., *Distichlis spicata*, and *Frankenia grandifolia*, all species characteristic of saline plant communities, did not differ in cover between burned and unburned treatment areas. *Cordylanthus palmatus* was not encountered in either of the two treatments.

Summer 1993. Only *Hemizonia lobbii* and litter differed between treatments (Table 16). *H. lobbii* constituted nearly 50% of the total cover in the burned treatment, but was almost absent from the unburned areas. Litter, in contrast, made up 58% of total cover in the unburned area, but only 14% of the total cover in the burned treatment. As found in the Spring 1993 sampling period, the cover of common salt tolerant species such as *Allenrolfea occidentalis*, *Atriplex* spp., *Salicornia subterminalis*, *Distichlis spicata*, and *Frankenia grandifolia* did not differ between treatments. Only two grass species, *Distichlis spicata* and *Leymus triticoides*, were encountered during Summer sampling; neither of these species differed in cover between the burned and unburned treatment areas. Nearly all of the litter encountered in each treatment was made of grass biomass. *Cordylanthus palmatus* was encountered in the unburned areas but not in the burned treatment.

Discussion

The results of the vegetation surveys following the grass fire provide several

Table 15. Spring 1993 (late March - early April) cover of native and introduced species in unburned and burned treatments at Springtown Alkali Sink. Crosses (X) denote significant differences between treatments (P < 0.05). Treatments compared using a two-tailed t-test.

	Unburned			Burned	
SPECIES	Mean	S.E.		Mean	S.E.
Grass species (except Distchlis spicata)	0.636	0.032	X	0.304	0.034
Allenrolfea occidentalis (native)	0.020	0.014		0.004	0.004
Atriplex spp. (nat.)	0.000	0.000		0.001	0.001
Blennosperma spp. (nat.)	0.000	0.000		0.005	0.006
Brodiaea coronaria (nat.)	0.068	0.027		0.067	0.013
Calandrinia ciliata (nat.)	0.000	0.000		0.004	0.003
Carex spp (nat.)	0.005	0.002		0.018	0.008
Chlorogalum spp. (nat.)	0.000	0.000		0.001	0.001
Dichelostemma pulchella (nat.)	0.001	0.002		0.002	0.001
Distichlis spicata (nat.)	0.014	0.005		0.009	0.004
Downingia pulchella (nat.)	0.002	0.002		0.001	0.001
Eryngium aristulatum (nat.)	0.013	0.009		0.000	0.000
Erodium spp. (introduced)	0.015	0.005	X	0.165	0.024
Frankenia grandifolia (nat.)	0.002	0.000		0.000	0.000
Hemizonia pungens (nat.)	0.008	0.005		0.019	0.015
Holocarpha obconia (nat.)	0.000	0.000	X	0.173	0.053
Lactuca serriola (int.)	0.046	0.016		0.020	0.009
Lasthenia spp. (nat.)	0.000	0.000		0.004	0.002
Callitriche (nat.)	0.007	0.005		0.003	0.003
Lepidium nitidum (nat.)	0.009	0.005		0.002	0.002
Lupinus nanus (nat.)	0.006	0.005		0.001	0.001
Melilotus indicus (int.)	0.000	0.000		0.004	0.003
Medicago polymorpha (int.)	0.001	0.002		0.019	0.019
Plagiobothrys leptocladus (nat.)	0.000	0.000		0.001	0.001
Rumex crispus	0.014	0.010		0.000	0.000
Senecio vulgare (int.)	0.003	0.003		0.006	0.004
spergularia macrotheca (nat.)	0.008	0.006		0.000	0.000
Stellaria spp. (int.)	0.007	0.005		0.021	0.009
Trifolium depauperatum (nat.)	0.000	0.000	X	0.039	0.009
Triphysaria eriantha (orthocarpus) (nat.)	0.000	0.000		0.001	0.001
Trifolium microdon (nat.)	0.000	0.000	X	0.016	0.005
Other Herbaceous species	0.001	0.000		0.010	0.000
Soil	0.043	0.012		0.078	0.036
Litter	0.073	0.021	X	0.000	0.000

Table 16. Summer 1993 (mid-July) cover of native and introduced species in unburned and burned treatments at Springtown Alkali Sink. Crosses (X) denote significant differences between treatments ($P < 0.05$). Treatments compared using a two-tailed t-test.

SPECIES	Unburned Mean	Unburned S.E.		Burned Mean	Burned S.E.
Allenrolfea occidentalis (native)	0.031	0.024		0.009	0.004
Atriplex joaquiniana (nat.)	0.002	0.002		0.000	0.000
Atriplex spp. (nat.)	0.009	0.005		0.002	0.002
Cordylanthus palmatus (nat.)	0.005	0.005		0.000	0.000
Distichlis spicata (nat.)	0.114	0.037		0.075	0.027
Frankenia grandifolia (nat.)	0.040	0.018		0.024	0.006
Hemizonia pungens (nat.)	0.007	0.006		0.088	0.033
Holocarpha obconia (nat.)	0.044	0.028		0.076	0.034
Hemizonia lobbii (nat.)	0.006	0.006	X	0.474	0.082
Lactuca serriola (introduced)	0.051	0.018		0.003	0.003
Leymus triticoides (nat.)	0.049	0.015		0.038	0.022
Salicornia subterminalis (nat.)	0.022	0.013		0.004	0.004
litter	0.587	0.093	X	0.144	0.035
Soil	0.030	0.018		0.063	0.024

insights into the effects of fire on vegetation cover. Spring surveys revealed significantly reduced grass cover after the fire. Such a result is common in established grasslands. By summer, the cover of grasses was similar between treatments, but only two species were encountered. At least another year of data would be required to determine whether the reduced cover of spring grasses will be maintained in the burned area or whether grass cover will recover to unburned levels.

Another interesting insight is the similarity of cover for salt tolerant species between burned and unburned areas. In fact, the only species found to have different levels of cover were grasses which decreased in the burned treatment area. Most of these species were probably introduced annuals. These results suggest that fire could be an effective tool for managing exotic annual grasses without adversely affecting the native plant community. Such management could be important to maintaining diversity of the plant community since the conspicuous litter layer in unburned areas could have large impacts on competitive interactions with other species.

The effects of fire on *Cordylanthus palmatus* cannot be determined from this study. The absence of *C. palmatus* in burned areas was likely due, not to fire, but to substantial habitat disturbance caused by fire crews who used the sparsely vegetated channels where *C. palmatus* occurred to make fire breaks. The only clear management insight gained is that drainages and scalds where *C. palmatus* grows should not be used as convenient access routes and fire containment channels.

6] Natural history observations

During the course of study in 1993 some natural history observations were made that have pertinence for the monitoring and management planning for the Springtown Alkali Sink in Livermore, California.

Hispid bird-beak (*Cordylanthus mollis hispidus*)

The most notable observation was the identification of *Cordylanthus mollis hispidus* in north-central Springtown. While previous studies have noted the occasional presence of this species at Springtown (Coats et al. 1988), this species was not encountered during extensive site-wide surveys in 1990, 1991, and 1992. In 1993, approximately 600 individuals were found at Springtown. These were found in the general vicinity, within 50 meters, of *Cordylanthus palmatus* individuals, but the soil analyses indicate that the two *Cordylanthus* species are found on differing soil types (with *C. mollis hispidus* found on soils characterized by unusually high levels of calcium and magnesium).

The erratic nature of *Cordylanthus mollis hispidus* makes this an especially difficult species around which to design conservation activities. It obviously has an extensive, long-lived, and, likely, highly localized seed bank, and a fairly precise combination of factors needed to trigger germination. At the present time, our only recommendations concerning this species at Springtown is to have the annual monitoring crews specifically look for individuals.

A copy of the completed CNDDB form for this species is included in Appendix C.

Burrowing owl (*Athene cunicularia*)

During each of the last four field seasons, burrowing owls have been observed emerging from holes in the northeast and northwest portions of the study site (City property), and on the lands controlled by Shea Homes (just west of the study site). While never numerous at Springtown, several pairs apparently reside in the area.

California tiger salamander (*Ambystoma californiense*)

In spring 1993 California tiger salamander larvae were observed in the seasonal pools adjacent to the bicycle path extending from the corner of Lorraine Road and Hartford Street to the residential area. A site-wide survey for tiger salamander larvae was not conducted in 1993.

Horned lizard (*Phrynosoma coronatum*)

Along with the reappearance of *Cordylanthus mollis hispidus*, the most surprising observation at Springtown was the late-summer sighting of a California horned lizard. The one individual was observed in the southeast portion of the study site -- in an area that is partially flooded during the winter months. After considering the number of person-hours spent on site (many thousands), the seasonally inundated nature of the location of area where the lizard was observed, and the proximity of the residential area, we conclude that the a resident population of horned lizards does not exist at Springtown. In all likelihood, the lizard was a recent release, and originated in the hills either north or south of Livermore (where horned lizards are locally common).

Conclusions and recommendations

Several primary conclusions regarding *Cordylanthus palmatus* were drawn from the results of 1993 monitoring activities and field studies.

• Annual monitoring of populations of *Cordylanthus palmatus* indicate that the species is persisting despite is limited distribution. Apparent slight decreases in 1993 abundances of individuals following widespread increases in 1992 suggest that variations in rainfall patterns may affect year-to-year fluctuations in abundance. New monitoring methodologies proved to be efficient and effective for rapid assessment of *C. palmatus* abundance.

• Pollination studies identified *Bombus* species as the primary pollinators of *Cordylanthus palmatus* at Springtown, and found that bumblebees are necessary for successful fertilization and seed production.

• Analysis of the genetic variability of *Cordylanthus palmatus* among the Springtown, Colusa, Delevan, and Mendota populations indicated that the Springtown harbors the greatest amounts of allelic polymorphism in this species, and, therefore, is of particular importance for long-term conservation and management of *C. palmatus.* Genetic analyses also revealed possible genetic structuring of the Springtown population. Such structuring could be maintained by the limited dispersal capabilities of the species and findings of the pollinator studies indicating that bumblebees are loyal to a particular *C. palmatus* patch such that pollen exchange between distant portions of the site would be limited.

• Analysis of the relationships between edaphic soil conditions and the abundances of *Cordylanthus palmatus*, annual grasses, *Lasthenia*, and *Distichlis* identified pH and soil profile development as the two variables that best explain the distributional patterns of these plants. These variables can be easily measured to allow broad assessment of habitat quality, and can be mapped to make rough predictions of potential habitat for *C. palmatus*.

In addition to these conclusions, we make the following recommendations.

• The population(s) of *Cordylanthus palmatus* found at the Alkali Sink Reserve (Mendota) is in desperate need for further study. The plants at this site are genetically distinct and appear to be the most threatened with extirpation. Future work needs fully survey the site for *C. palmatus*. Other southern Central Valley areas also need to be surveyed.

• Continue to look for new occurrences in the northern Central Valley, and encourage attempts to establish new populations within the National Wildlife Refuge system. It is possible, and, indeed probable, that other populations of *Cordylanthus palmatus* exist in the northern Central Valley. With the *C. palmatus* at the Colusa and Delevan refuges being found to be genetically depauperate, additional sites in the area could be significant sources of genetic variation.

• As has been reported annually, illegal dumping is still a problem at Springtown. Given the amount and varied nature of the material (everything from entire trucks to cans of unidentified liquids, to mattresses), it is likely that the debris will prove harmful to the Springtown ecosystem. For long-term preservation the ecosystem, illegal dumping must be minimized.

• At Springtown, a site-wide management program needs to be developed and implemented. This plan needs to include restoration, monitoring, and research components. Ultimately, some re-contouring of the landscape and the diversion of water will need to be done. In particular, several of the channels presently receive little runoff (due to road construction and channelization of Altamont Creek). It is possible that without seasonal water, including destructive "gully washers," the ecosystem will slowly degrade, or at least progress through natural succession into a climax seral stage that will not support the present level of biotic diversity. Seasonal inundations, channel flow, and scouring, may promote a mosaic of habitat types necessary to support the diverse flora and fauna of Springtown.

Control of invasive non-native species must also be included in any long-term management plans. Control could come in the form of prescribed burns or tightly controlled grazing. In either case, managements efforts must be considered experimental and be tested with a scientifically defensible methodology.

Areas that are not subject to any active management or restoration need to be included in the long-term plan. Since the effects of some conservation actions may not become evident for many years, some areas must be left alone as precaution against unforeseen impacts.

Appendix A

Sample long-term monitoring packet for Springtown Alkali Sink

Color aerial photographs are not included in this sample, and note that the included black and white figure depicting the location of the subareas is in color in the original packet.

A blank copy of the California Natural Diversity Database form has also been omitted from this sample.

Long-term Monitoring Data Collection Package

Palmate-bracted bird's beak, *Cordylanthus palmatus*
Springtown Alkali Sink (Livermore, Alameda County, CA)
(Natural diversity database population #10)

Introduction:
The Springtown Alkali Sink supports one of few remaining populations of the palmate-bracted bird's beak, *Cordylanthus palmatus*. The procedures described here were developed after four years of intensive study conducted by the Center for Conservation Biology, Stanford University (supported by the California Department of Fish and Game and the U.S Fish and Wildlife Service). These annual monitoring activities were designed to be conducted during a single site visit by two researchers. The results of these activities will identify broad changes in the distribution and abundance of *Cordylanthus palmatus* at Springtown. These activities will not supply results as complete as those generated by the in-depth monitoring conducted during the early 1990s, but they should be of sufficient quality as to trigger appropriate management responses (possibly including future rounds of intensive monitoring). Consistency is always a problem for long-term monitoring efforts, and care must be taken when comparing results obtained during different years, and by different researchers. It is hoped that the materials provided here will allow for the collection of data that are sufficiently standardized as to identify gross changes in distribution and abundance of *C. palmatus* at Springtown Alkali Sink.

Note that the length and amount allotted time in each belt transect varies. The routes and amount of time allotted are based on historic patterns of *Cordylanthus palmatus* distribution and abundance, and on type of habitat. Given time constraints, it was deemed unlikely that every portion of the Springtown Alkali Sink could be searched for *C. palmatus* with equal intensity, and monitoring activities described here are focused on areas known to support *C. palmatus* and on areas that appear to be suitable *C. palmatus* habitat, but that were unoccupied in the early 1990s. Also note that these transects will miss large numbers of *C. palmatus* individuals -- due to projected time constraints, this is unavoidable.

Procedures:

• Site visits should be conducted annually, between mid-July and mid-September -- there is a substantial amount of spring and early summer mortality of pre-reproductive individuals, and autumn storms render senescent and near-senescent plants unidentifiable.

• Researchers should spend a few minutes to familiarize themselves with the included aerial photographs and map. As the site is predominantly flat and lacking in obvious landmarks, it is easy to become disoriented.

• The two researchers should spend a few minutes at the onset of the site visits in order to familiarize themselves with the morphology of *Cordylanthus palmatus*, paying particular attention to the differences between single multi-branched plants versus groups of many small and sparingly branched individuals. A good place to do this is along segment 3 in

Subarea 2 (see aerial photograph).

• Walk the designated transects in the allotted time intervals (this will help standardize the annual efforts), and note that the transects often follow landscape features, such as scalds and channels.

• When estimating number of individuals, include any individual plants that are at least partially green during the late summer census period, and ignore completely dessicated individuals (dried individuals are generally less than seven cm in height).

• Estimate the number of *Cordylanthus palmatus* individuals in each segment using the following semi-log scale:

0		
1	to	3
4	to	10
11	to	30
31	to	100
100	to	300
300	to	1,000
1,000	to	3,000
3,000	to	10,000
10,000++		

• This semi-log scale dramatically reduces the amount of time required for annual monitoring. Attempting to count each individual *Cordylanthus palmatus* plant at this site is exceedingly time consuming and potentially destructive to the plants. Additionally, unless done with great care, attempting to count individual plants is not any more accurate than the semi-log estimation method. Using a semi-log scale will generally underestimate the number of individuals actually present, but the effort required to count each individual is far too great for long-term monitoring (and such a labor intensive effort would be inappropriate considering the limited management options). With a little practice, it should be quite easy to differentiate between 15 individuals (= 10 to 30) and 55 individuals (= 31 to 100) -- even while summing them up along a 30 minute transect.

• Estimate the total number of *Cordylanthus palmatus* individuals in each subarea by "adding" the totals for each segment (again, this is meant to provide a rough estimate).

• Mark on the included aerial photographs areas of high *Cordylanthus palmatus* density (= more than 10 individuals per 1m^2).

• Note that the distances indicated in the transect descriptions are approximate -- measuring distances with a meter tape is not necessary. Also note that the widths of the transects as marked on the aerial photographs are not to scale.

• On the included aerial photographs, note the location of obvious disturbances such as fires, off-road vehicle damage, debris, discing, and overgrazing.

• The hispid bird's beak, *Cordylanthus mollis hispidus*, has been sporadically recorded from the Springtown Alkali Sink, and any observations of this species should be noted. *C. mollis hispidus* differs from *Cordylanthus palmatus* in the length of hairs on the leaves (the hairs of *C. mollis hispidus* are generally well in excess of 1 mm in length, while the hairs of *C. palmatus* are typically shorter than 1 mm in length) -- *C. mollis hispidus* appears obviously "fuzzy," while the slightly hairy *C. palmatus* is generally "sprinkled" with salt crystals and is often wet.

• Included in the descriptions of several of the subareas are bracketed directions [ ]. These are used to indicate suggested routes for getting from the end of one transect to the beginning of the next. These bracketed directions are included only in cases where the starting point of the next transect may be difficult to find.

• All included aerial photographs were taken in July 1991, and are presented with north being at the top of the page.

• It is a good idea to take sunscreen and a supply of water when visiting Springtown in the summer. A compass and binoculars are also useful. While the swarms of biting gnats, flies, and mosquitoes that are occasionally encountered at the site during winter and spring visits are usually absent by early summer, insect repellent should be readily available.

• Note the presence of other species of conservation concern. During the late summer *Cordylanthus* census period, burrowing owls are likely to be observed. (Researchers visiting during winter and early spring may observe California tiger salamanders, several species of fairy shrimp, and a host of vernal pool plant species.)

• Be careful while following the directions for each subarea, but don't agonize too much -- the goal of the annual efforts described here is to provide coarse information about *Cordylanthus palmatus* at the Springtown Alkali Sink, and on the sink ecosystem itself.

• Contact the FCC office (510 447-3614) before monitoring *Cordylanthus palmatus* on their property.

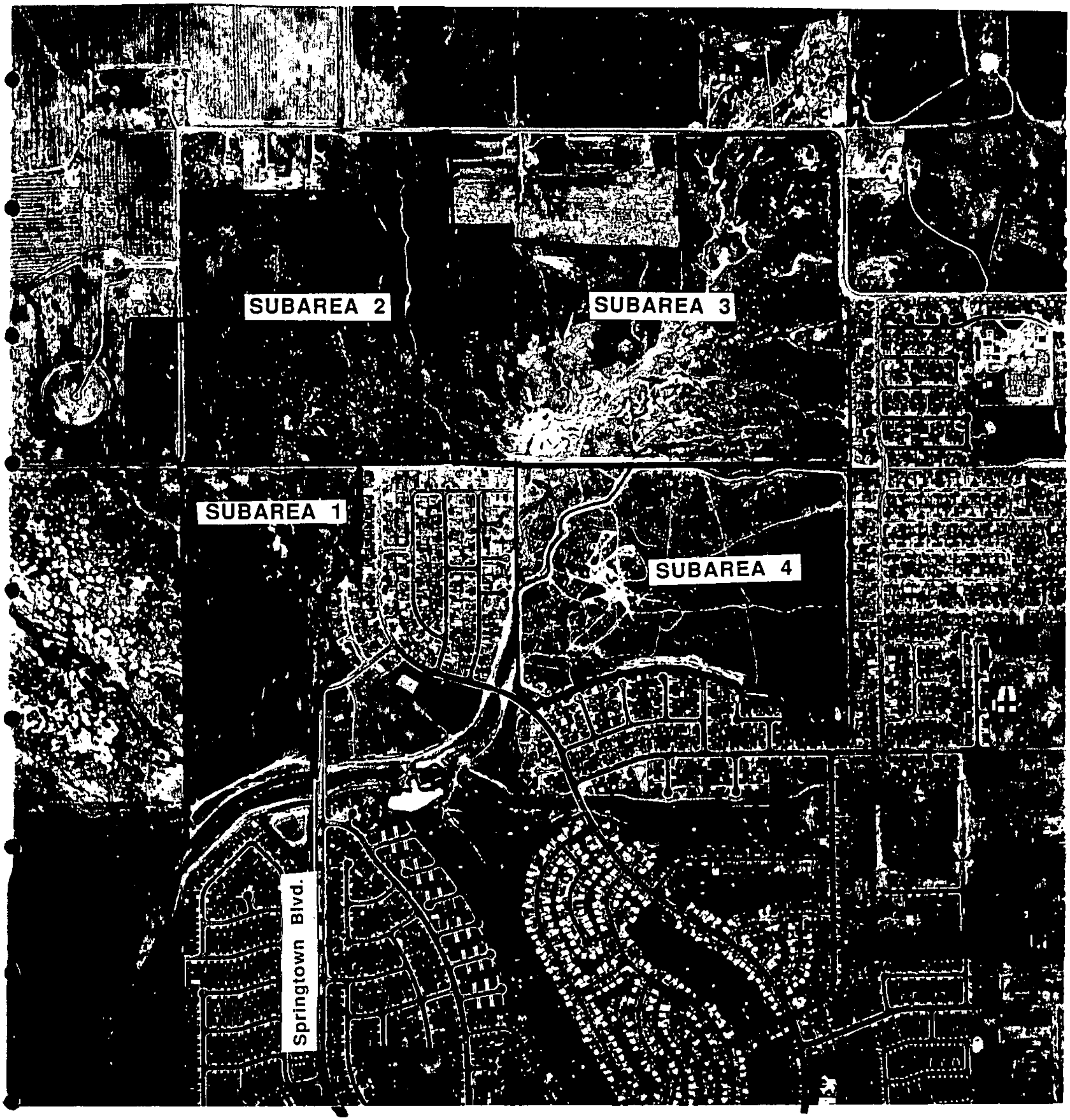
• Send a completed copy of the annual monitoring effort to:

Ann Howald
California Department of Fish and Game
P.O. Box 47
Yountville, CA 94699

and a copy of the completed Natural Diversity Database species account to:

Natural Diversity Database -- Natural Heritage Division
California Department of Fish and Game
1220 S Street
Sacramento, CA 95814

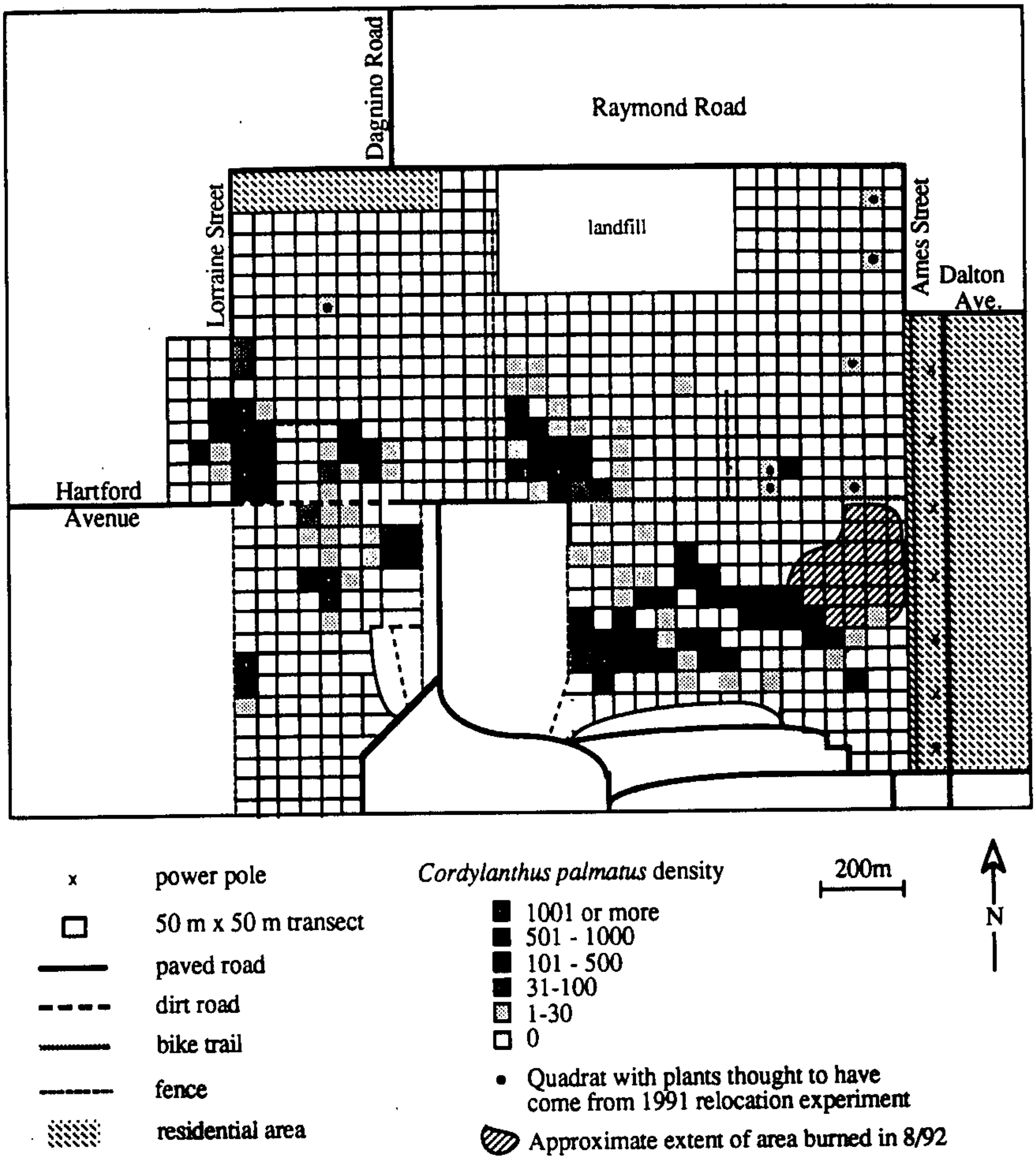
SPRINGTOWN ALKALI SINK -- Location of subareas for long-term monitoring



to Highway 580

Bluebell Drive
(to Springtown Blvd. and Highway 580)

Early 1990s distribution of *Cordylanthus palmatus* at Springtown Alkali Sink



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.

SUBAREA 1 (private property)

- **transect has three segments:**
  segment 1) main scald complex (25 minutes).
  segment 2) northeast corner (5 minutes).
  segment 3) along dirt road (and five meter wide "shoulder") on west side of subarea (20 minutes).

- **suggested route:**

• Start segment 1 at "Motor Vehicles Prohibited" sign just south of bike path, approximately mid-way between Hartford Avenue/Lorraine Street corner and frontage road (perpendicular to Bluebell Drive). Proceed south through a series of small "scalds" and patches of dense grass to the main scald complex (note the transect included all of the main scald complex). Include all *Cordylanthus palmatus* plants found the within the five meter-wide belt transect at the beginning of the segment **and** all plants within the main scald complex (this will require some east/west wandering in the main scald complex).

[At the end of scald complex (= upon entering "endless" expanse of dense grass), turn to the east, and walk toward the houses.]

• Segment 2 -- At the residential area (immediately west of the *cul-de-sac*), walk north through a series of small scalds, grassland, and iodine bushes until reaching the bicycle path. Include all *Cordylanthus palmatus* plants within five meter-wide belt transect.

• Segment 3 -- At the corner of Hartford Avenue/Lorraine Street, walk south along dirt road (along north/south running fenceline), estimating the number of *Cordylanthus palmatus* individuals growing along the road-bed and on the five meter-wide shoulder east of the road. *Cordylanthus palmatus* plants on are scattered along the shoulder -- pay particular attention to the shoulder where the fence has six consecutive metal posts.

On the way back along the fenceline road, note on the map the approximate number and location of *Cordylanthus palmatus* plants growing on the west side of the fence. To the west of the fence is private property and out of the study area, but *C. palmatus* plants are occasionally visible.

Results:	segment 1 scald complex	segment 2 northeast corner	segment 3 fenceline	**TOTAL**
number of *Cordylanthus palmatus* individuals	________	________	________	________

Recent disturbance? ____

Cordylanthus mollis hispidus? ____________________________________

SUBAREA 2 (city and federally-owned properties)

• **transect has four segments**

segment 1) FCC-owned land -- 200 meter wide patch of land west of Lorraine Road (10 minutes).
segment 2) west channel system -- north of fence (5 minutes).
segment 3) west channel system -- south of fence (20 minutes).
segment 4) 2nd channel + -- mainly grasslands with few channels (20 minutes).

• **suggested route:**

• Start segment 1 at north end of the undisced portion of the FCC lands, and walk roughly parallel to Lorraine Street, though series of small scalds, approximately 15 meters west of road. Include *Cordylanthus palmatus* plants within a five meter-wide belt transect.

• Segment 2 starts at Lorraine Street approximately 25 meters north of where an old wooden fenceline intersects Lorraine Street. This segment follows a small, ~25 meter-long, seasonal waterway extending diagonally from Lorraine to the old wooden fence. Include *Cordylanthus palmatus* plants within a five meter-wide belt transect.

• Segment 3 begins at the old wooden fence, and follows the main channel south toward the bicycle path. Included along with the main channel is a broad and shallow side-channel that extends to Lorraine Street (located approximately 30 meters upstream from the bike path). Include *Cordylanthus palmatus* plants along main channel, those within two meters of the edge of the channel, and all those in the broad side-channel.

• Segment 4 starts at the bike path. Walk north in the **2nd** channel (from the west/Lorraine Street), always taking northeast-heading branches of the channel, until reaching the old wooden fence. At the fence, walk southeast toward the large corrugated metal "garage" located at the corner of Bluebell and the frontage road. This will take you through a series of small scalds, patches of grassland, and ill-defined washes. Include *Cordylanthus palmatus* plants along main channel, plus those within two meters of the edge of the main channel, and those plants within a five meter-wide belt transect on the portion of the segment heading back to the parking area.

Results:	segment 1 FCC	segment 2 west channel (north)	segment 3 west channel (south)	segment 4 2nd channel	**TOTAL**
Number of *Cordylanthus palmatus* individuals	______	______	______	______	______

Recent disturbance? ______________________________

Cordylanthus mollis hispidus? ______________________________

SUBAREA 3 (city property)

- **transect has two segments:**
  1) broad wash (40 minutes)
  2) northeast corner (20 minutes)

- **suggested route:**

• Start segment 1 at the edge of the broad wash, approximately 15 meters north of the eastern end of the frontage road. At this point, walk approximately 250 meters north (~1/2 the distance to the land-fill), at the ~250 meter mark, walk 25 meters to the east, and then walk south to within 10 meters of the bike path, walk 25 meters east (parallel to the bike path). After walking 25 meters east, again walk 250 meters to the north, 25 meters to the east, and then back to within 10 meters of the bike path. Repeat the 250 meter north-oriented walk, 25 meter east-oriented walk, and walk back to the path. Include all *Cordylanthus palmatus* plants within a five meter-wide belt transect. This is a difficult segment. The lack of good landmarks makes the "zig-zaging" necessary, but the segment should traverse areas occupied by *C. palmatus* four or five times. This segment crosses grasslands, scalds, moderately defined channels and portions of a broad wash. Note that *Cordylanthus mollis hispidus* has been recorded from this area.

• Start segment 2 just north of the bike path on the west-side of the north-south running wooden fence (approximately halfway between the end of the frontage road and the houses to the east). Proceed north approximately 300 meters -- to the edge of the grassy uplands. Cross the wooden fence to the east, and go south parallel to the fence to the bicycle path. Include all *Cordylanthus palmatus* plants within a five meter-wide belt transect.

Results:	segment 1 broad wash	segment 2 northeast corner	TOTAL
number of *Cordylanthus palmatus* individuals	________	________	________

Recent disturbance? ____________________________________

Cordylanthus mollis hispidus? ____________________________________

SUBAREA 4 (private property)

- **transect has four segments**
  segment 1) eastern channel (30 minutes)
  segment 2) central wash (20 minutes)

suggested route

[From intersection of bicycle path and frontage road, head southeast and cross Altamont Creek]

• Segment 1 follows the large well-defined channel (there is a path in the middle of the channel). Follow this channel all the way to the residential area (taking the large northeast branch after approximately 750 meters -- the last 50 meters or so of the channel is poorly defined). At the residential area go south past one small channel, and take the a fairly well-defined channel that heads to the northwest (there should be a small scald near the eastern edge of this channel). Note that there was some illegal dumping of soil near the eastern edge of this channel, so it may be partially obscured. Follow channel back to main channel. Include all *Cordylanthus palmatus* plants in the channels and within two meters of the edges.

[Either follow the main channel back to Altamont Creek, or take one of the many east-west trails]

• Segment 2 starts at the point where the Altamont Creek channel turns to the southwest (after a north-south stretch). Proceed south through a series of small scalds, grasslands and poorly-defined washes until reaching the dirt road (more of a low embankment and ditch) at the residential area. Follow the dirt road east 100 meters, and walk north back through the wash and grasslands until reaching a large path, nearly at the Altamont Creek access road. Take this path west back to Altamont Creek (this should be fairly near the start point). Include *Cordylanthus palmatus* plants within a five meter-wide belt transect. This segment traverses some of the areas most densely populated by *Cordylanthus* at Springtown, and some of the most disturbed areas.

Results:	segment 1 main channel	segment 2 central wash	**TOTAL**
number of *Cordylanthus palmatus* individuals	_______	_______	_______

Recent disturbance? ____

Cordylanthus mollis hispidus? ________________________________

Field Summary
Palmate-bracted bird's beak, *Cordylanthus palmatus*
Springtown Alkali Sink, Livermore, Alameda County, CA
(Natural diversity database population #10)

Researchers: ______________________
____
____

Affiliation: ______________________
(address and ______________________
phone) ______________________
____
____

Date of field work: ______________________

Results:
Number of *Cordylanthus palmatus* individuals

subarea 1

main scald	northeast corner	fenceline		subarea total
______	______	______		______

subarea 2

FCC	north of fence	south of fence	2nd channel	subarea total
______	______	______	______	______

subarea 3

central wash	northeast corner			subarea total
______	______			______

subarea 4

main channels	central wash			subarea total
______	______			______

SPRINGTOWN TOTAL: ______________________

Other species of conservation concern: ______________________
Cordylanthus mollis hispidus
burrowing owls ______________________

Appendix B

The work described in this report was conducted by the following project personnel:

Center For Conservation Biology at Stanford University

Alan E. Launer, Kathy Rehm Switky, Erica Fleishman, Dennis Murphy, and Stuart Weiss were involved with the Center's *Cordylanthus* project from its inception in 1990. Kathy is presently working for the Sempervirens Fund (Mountain View, California), and Erica is presently a graduate student at the University of Nevada, Reno.

Jonathan Hoekstra worked on the Center's *Cordylanthus* project in 1992 and 1993. He was involved with the long-term monitoring, soil analyses, and report preparation. Jon is presently a biologist for the U.S. Fish and Wildlife Service (Ventura, CA).

Duncan Elkins conducted a Stanford University honors project in 1993 on the pollination of *Cordylanthus* palmatus at Springtown. Duncan is presently a graduate student at the University of Georgia.

Flint Hughes coordinated and conducted much of the work investigating the impact of the 1992 fire on the Springtown ecosystem. Flint is presently a graduate student at Oregon State University

Non-Center personnel

Ulla Yandell coordinated and conducted the Center's genetic analysis of *Cordylanthus palmatus*. Ulla is a graduate student at the University of Nevada, Reno.

David DeVries conducted the soils classification and collected soil samples from Springtown. David is the chief scientist at Mesa Technical (Berkeley, CA).

Appendix C

California Natural Diversity Database Field Survey Forms for 1993

Cordylanthus palmatus

Springtown Alkali Sink
Alkali Sink Ecological Reserve (@ Mendota State Wildlife Area)
Colusa National Wildlife Refuge
Develan National Wildlife Refuge
Sacramento National Wildlife Refuge

Cordylanthus mollis hispidus

Springtown Alkali Sink

California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: __-__-1993 (mo day year)

For office use only
Source Code ______ Quad Code ______
Elm Code ______ Occ # ______
Copy to ______ Map Index # ______

Scientific Name (no codes): Cordylanthus palmatus

Species Found? [X] yes [ ] no ______ If not, why?
Total # Individuals: 7400 To 24,300 Subsequent visit? [ ] yes [X] no
Compared to your last visit: [ ] more [ ] same [X] fewer (75 91 ... 92)
Is this an existing NDDB occurrence? [#10] Yes, Occ. # [ ] no [ ] unk.
Collection? If yes: ______ number ______ Museum/Herbarium

Reporter: Ctr. for Conservation Biology, Stanford U.
Address: Dept Bio Sci, Stanford CA 94305-5020
Phone: (415) 723-5924
Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U Nevada-Reno)

Plant Information:
Phenology: ______ % vegetative ______ % flowering ______ % fruiting

Animal Information:
Age Structure: ______ # adults ______ # juveniles ______ # unknown
Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: (Please also attach or draw map on back.)
As per attached map, plants occupy large areas of the Springtown Alkali Sink, S of Raymond Road, west of Vasco Road, Livermore, CA. We conducted an survey of the area (see map) between July and September, 199 .

County: Alameda Landowner/Mgr: City of Livermore, private, Fed. Commun. Commission
Quad Name: Livermore & Altamont Elevation: 500-510 UTM: ______
T 2S R 2E ______ 1/4 of ______ 1/4 Sec 27,28,33,34 R ______ ______ 1/4 of ______ 1/4 Sec ______

Habitat Description: (Plant communities, dominants, associates, substrate/soils, aspect/slope)
Alkali sink scrub/grassland. Drainages braid through generally flat sink community, which grades into introduced annual grassland. C. palmatus grows in drainage channels, in shallow depressions that fill with water in the winter, on alkali scalds, in alkali grassland and scrub. Co-occurs often with Allenrolfea occidentalis, Cressa truxillensis, Distichlis spicata, Sueda fruiticosa, Salicornia subterminalis, Frankenia grandifolia, Atriplex spp., Hemizonia pungens, Holocarpa obconica.
Other rare spp.? C. mollis hispidus

Site Information: Current/surrounding land use:
Unmanaged open space. City, State, and private interests are developing a management plan for the area. Surrounded by existing and proposed residential development.
Visible disturbances, possible threats:
Was heavily grazed on northern areas. Grass fires, trespassing/bikes/ORVs; upstream development disrupts surface flows.
Overall site quality: [ ] Excellent [X] Good [ ] Fair [ ] Poor Comments: See our report for more info.

Determination: (Check one or more, fill in the blanks)
X Keyed in a site reference: Munz 1968, Hickman 1993
__ Compared with specimen housed at: ______
__ Compared with photo/drawing in: ______
X By another person (name): Ann Howald, CFG
__ Other: ______

Photographs: (Check one or more)

	Slide	Print
Plant/animal	X	X
Habitat	—	X
Diagnostic Feature	—	X
Other	—	X

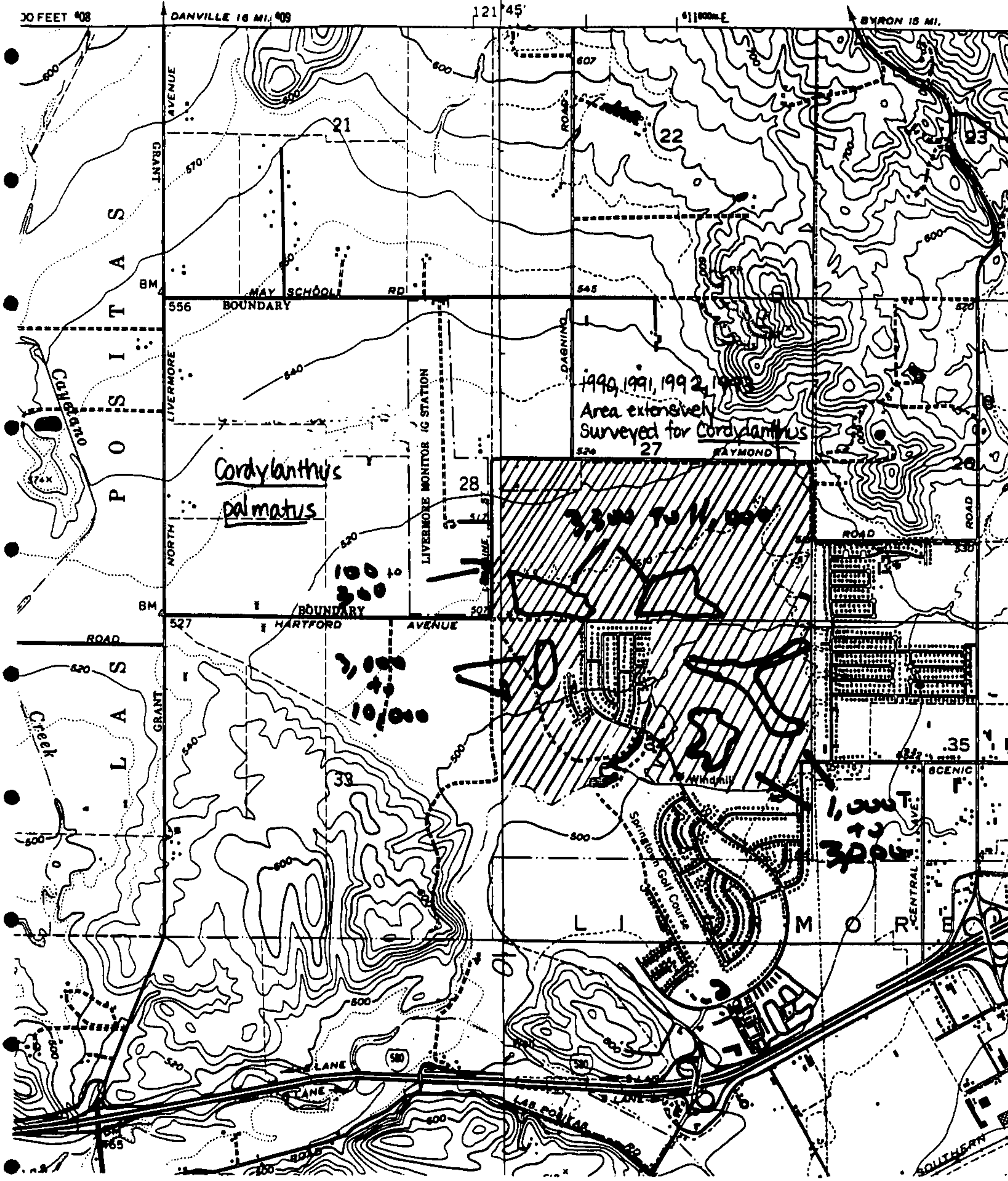
May we obtain duplicates at our expense? [X] yes [ ] no

1995

ALTAMONT QUAD

LIVERMORE QUADRANGLE
CALIFORNIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 LIVERMORE 15' QUADRANGLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: 6 - 4 - 93 (mo - day - year)

For office use only

Source Code ______ Quad Code ______
Elm Code ______ Occ # ______
Copy to ______ Map Index # ______

Scientific Name (no codes): Cordylanthus palmatus

Species Found? [X] yes [ ] no ______ If not, why?

Total # Individuals: ~300 Subsequent visit? [ ] yes [X] no

Compared to your last visit: [ ] more [ ] same [ ] fewer

Is this an existing NDDB occurrence? [#11] Yes, Occ. # [ ] no [ ] unk.

Collection? If yes: ______ number ______ Museum/Herbarium

Reporter: Center for Conservation Biology

Address: Stanford Univ., Stanford CA 94305-5020

Phone: (415) 723-5924

Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U. NV-Reno)

Plant Information:

Phenology: ______ % vegetative ______ % flowering ______ % fruiting

Animal Information:

Age Structure: ______ # adults ______ # juveniles ______ # unknown

Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: (Please also attach or draw map on back.)
Alkali Sink Ecological Reserve, "Whitesbridge Road" location. Adjacent to Mendota Wildlife Area. See attached map
Plants grow along both sides of road, in no further from road than ~5m, either side. See maps.

County: Fresno Cty. Landowner/Mgr: DFG

Quad Name: Tranquillity Elevation: ~160' UTM: ______

T 14S R 15E . E½ Sec 11, W½ Sec 12 T ______ R ______ ______ 1/4 of ______ 1/4 Sec ______

Habitat Description: (Plant communities, dominants, associates, substrate/soils, aspect/slope)

Other rare spp.?

Site Information: Current/surrounding land use:

Visible disturbances, possible threats:

Overall site quality: [ ] Excellent [X] Good [ ] Fair [ ] Poor Comments:

Determination: (Check one or more, fill in the blanks)
___ Keyed in a site reference: ______
___ Compared with specimen housed at: ______
___ Compared with photo/drawing in: ______
___ By another person (name): ______
X Other: personal knowledge

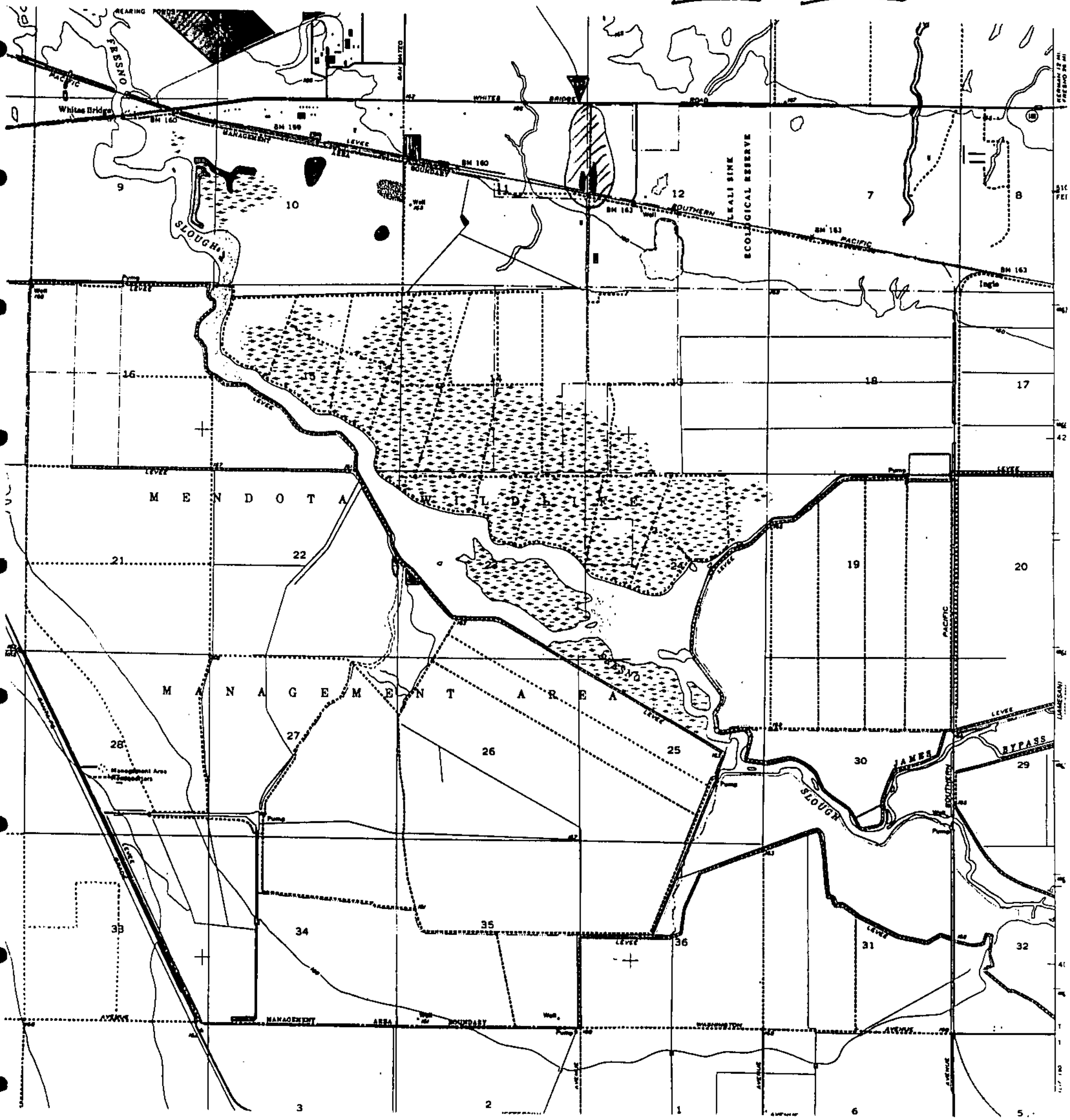
Photographs: (Check one or more)

	Slide	Print
Plant/animal	___	___
Habitat	___	___
Diagnostic Feature	___	___
Other	___	___

May we obtain duplicates at our expense? [ ] yes [ ] no

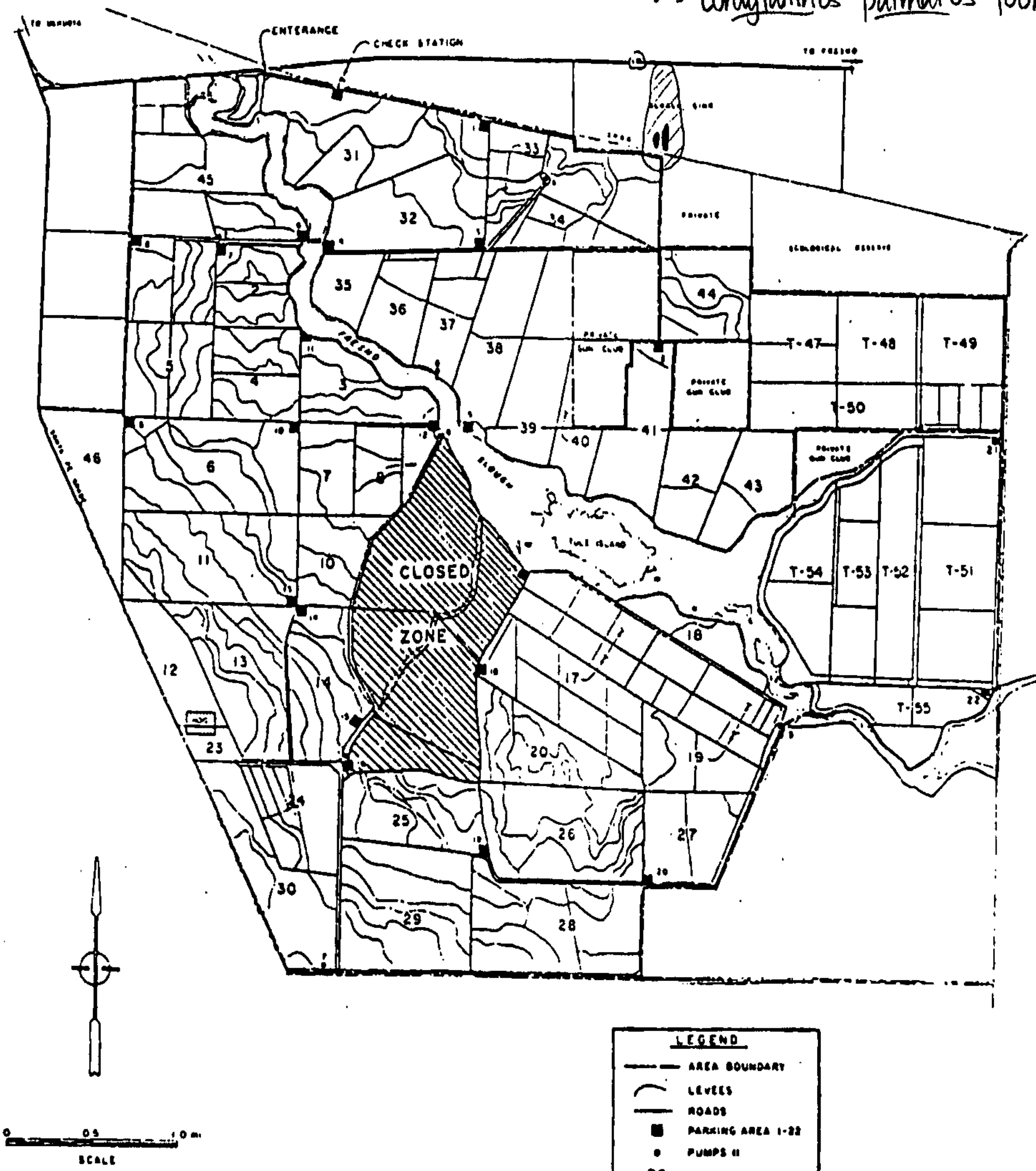
TRANQUILLITY 7.5 min QUAD
T 14S R15E
Cordylanthus palmatus

(hatched) = area surveyed 6/93
| = ~300 plants found 6/93



MENDOTA WILDLIFE AREA

▨ = area surveyed 6/93
• = *Cordylanthus palmatus* found 6/93



California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: 6 - 4 - 93 (mo day year)

For office use only
Source Code ______ Quad Code ______
Elm Code ______ Occ # ______
Copy to ______ Map Index # ______

Scientific Name *(no codes)*: Cordylanthus palmatus

Species Found? [X] yes [ ] no ______ *If not, why?*
Total # Individuals: 10 Subsequent visit? [ ]yes [ ]no
Compared to your last visit: [ ]more [ ]same [ ]fewer
Is this an existing NDDB occurrence? [#5] Yes, Occ. # [ ] no [ ] unk.
Collection? If yes: ______ number ______ Museum/Herbarium

Reporter: Center for Conservation Biology
Address: Stanford Univ. Stanford CA 94305-5020
Phone: (415) 723-5924
Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U NV-Reno)

Plant Information:
Phenology: ______ % vegetative ______ % flowering ______ % fruiting

Animal Information:
Age Structure: ______ # adults ______ # juveniles ______ # unknown
Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: *(Please also attach or draw map on back.)*
Alkali Sink Ecological Reserve, "south of RR tracks" location. Adjacent to Mendota Wildlife Area. See maps.

County: Fresno County Landowner/Mgr: DFG
Quad Name: Tranquillity Elevation: ~160' UTM: ______
T 14S R 15E SE 1/4 of SE 1/4 Sec 11 T ______ R ______ ______ 1/4 of ______ 1/4 Sec ______

Habitat Description: *(Plant communities, dominants, associates, substrate/soils, aspect/slope)*
Growing in isolated pocket in larger upland area.

Other rare spp.?

Site Information: Current/surrounding land use:

Visible disturbances, possible threats:

Overall site quality: [ ]*Excellent* [X]*Good* [ ]*Fair* [ ]*Poor* Comments:

Determination: *(Check one or more, fill in the blanks)*
___ Keyed in a site reference: ______
___ Compared with specimen housed at: ______
___ Compared with photo/drawing in: ______
___ By another person (name): ______
X Other: personal knowledge

Photographs: *(Check one or more)*

	Slide	Print
Plant/animal	___	___
Habitat	___	___
Diagnostic Feature	___	___
Other	___	___

May we obtain duplicates at our expense? [ ]yes [ ]no

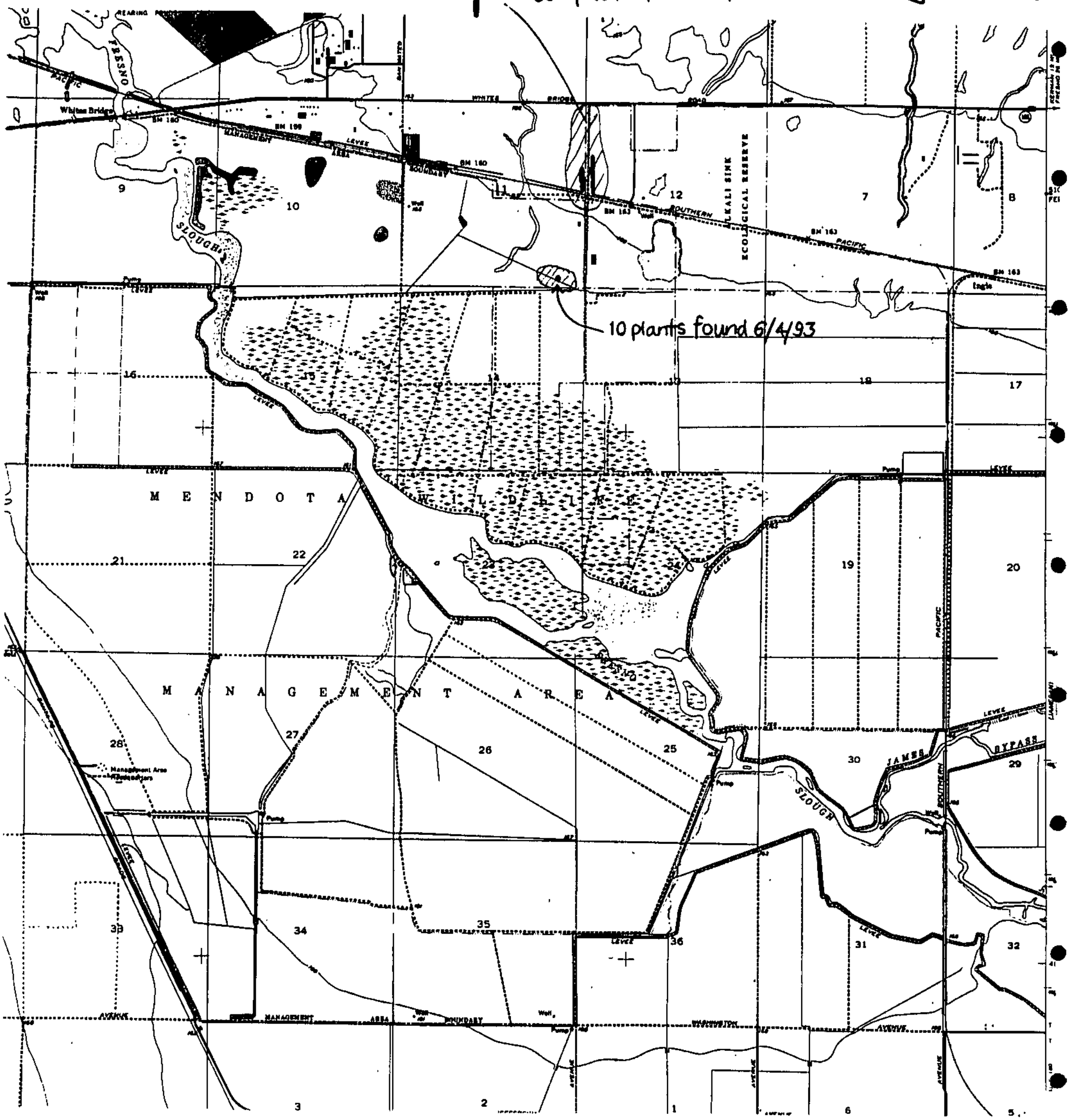
TRANQUILLITY 7.5 min QUAD

T 14S R15E

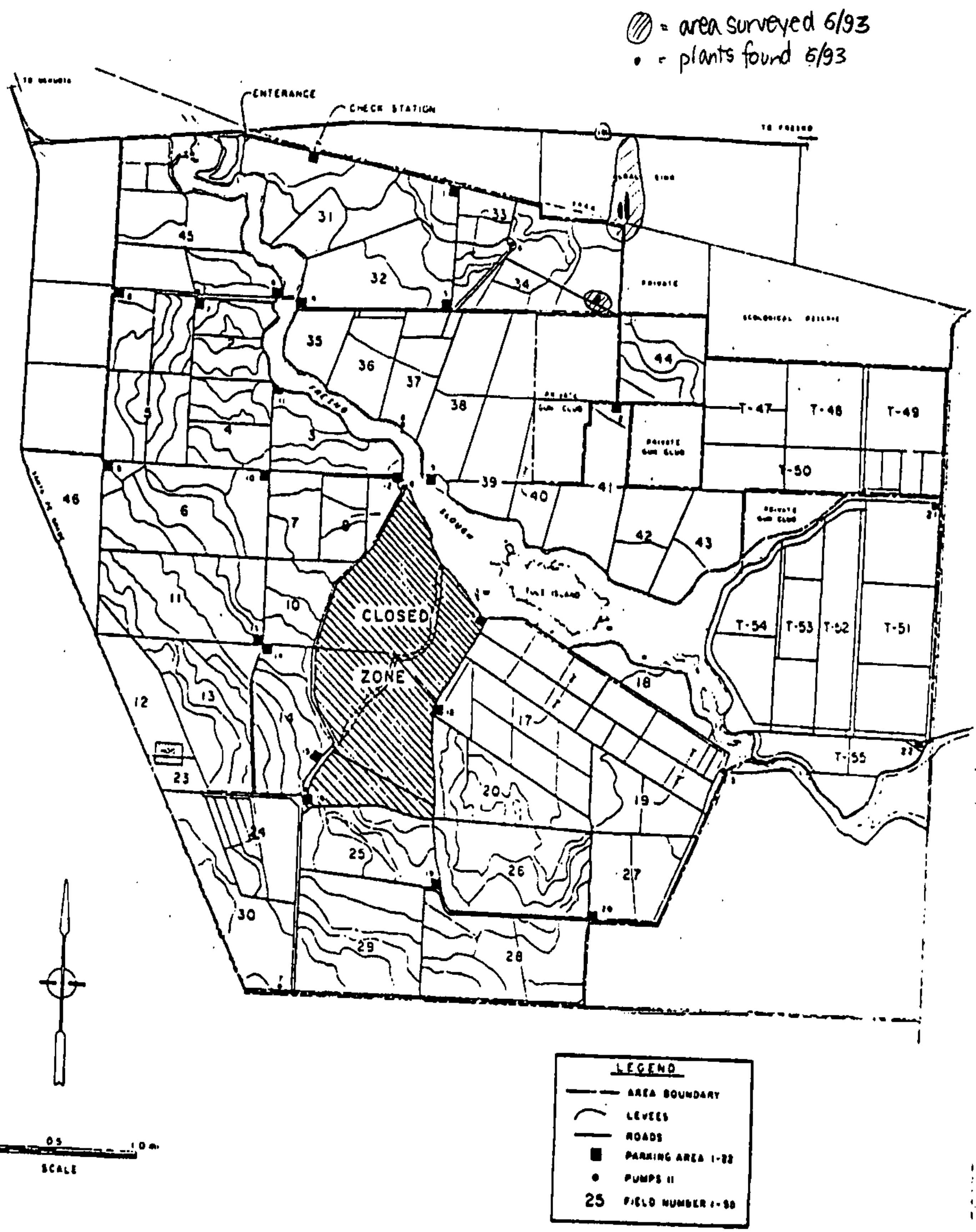
Cordylanthus palmatus

(hatched) = area surveyed 6/93

(solid) = ~300 plants found 6/93



MENDOTA WILDLIFE AREA



California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: 6 - 15 - 93 (mo day year)

For office use only
Source Code ______ Quad Code ______
Elm Code ______ Occ # ______
Copy to ______ Map Index # ______

Scientific Name (no codes): Cordylanthus palmatus

Species Found? [X] yes [ ] no ______ If not, why?
Total # Individuals: 10⁴ Subsequent visit? [ ] yes [X] no
Compared to your last visit: [ ] more [ ] same [ ] fewer
Is this an existing NDDB occurrence? [#12 *] Yes, Occ. # [ ] no [ ] unk.
* Occ. 12 = tracts 21-22.
Collection? If yes: ______ number ______ Museum/Herbarium

Reporter: Center for Conservation Biology
Address: Stanford Univ. Stanford CA 94305-5020
Phone: (415) 723-5924
Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U. NV-Reno)
Greg Mensick, Sac. Valley NWR Complex (916) 934-2801

Plant Information:
Phenology: ______ % vegetative ______ % flowering ______ % fruiting

Age Structure: ______ # adults ______ # juveniles ______ # unknown
Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: (Please also attach or draw map on back.)
Colusa National Wildlife Refuge, tracts 7, 21, 22, P3 Tract 7 was the largest group of plants, between 10,000 and 30,000 individuals The other sites, T21-22 and TP3 each had 1,000 - 3,000 plants.

County: Colusa Cty.
Landowner/Mgr: National Wildlife Refuge
Quad Name: Colusa + Arbuckle
Elevation: ~45-50'
UTM: ______
T 15N R 2W sections 2, 24, 25, 26, 23 T ______ R ______ ______ 1/4 of ______ 1/4 Sec ______

Habitat Description: (Plant communities, dominants, associates, substrate/soils, aspect/slope)
Plants found in tracts 21-22 = EO #12. Plants in tract 7 were noted by Jokerst, 8/88; plants in tract P3 were noted by Stone, '87. We surveyed these three locations on 8/17/92 (see map) and found plants in all locations; all were apparently robust occurrences with very dense stands of Cordylanthus. In early August 1993, Greg Mensick of Sac. Valley NWR Complex discovered on the border of T20(2) and T18 (see map) some "hundreds" of C. palmatus.

Other rare spp.?

Site Information: Current/surrounding land use:

Visible disturbances, possible threats:

Overall site quality: [X] Excellent [ ] Good [ ] Fair [ ] Poor Comments:

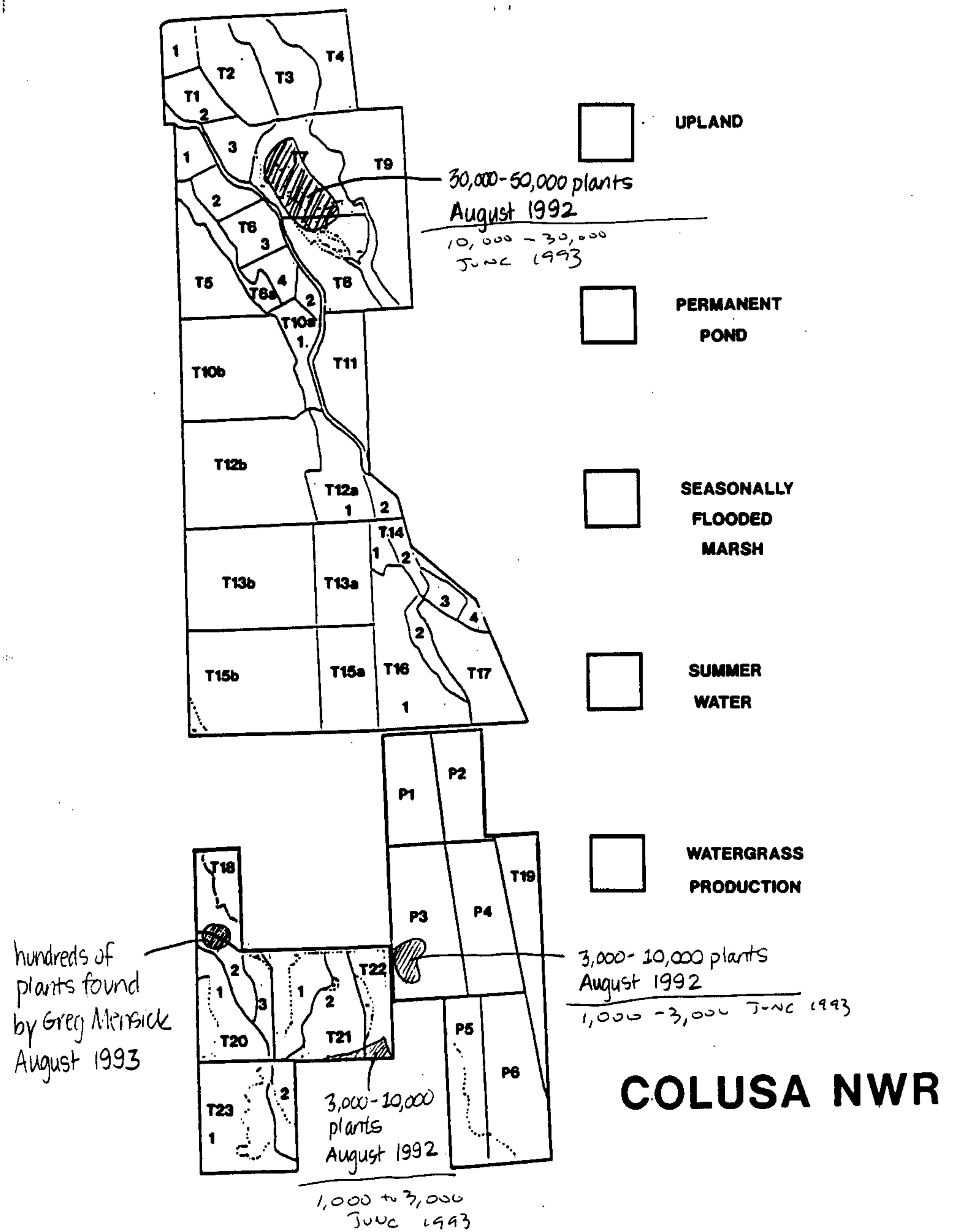
Determination: (Check one or more, fill in the blanks)
___ Keyed in a site reference: ______
___ Compared with specimen housed at: ______
___ Compared with photo/drawing in: ______
___ By another person (name): ______
X Other: personal knowledge

Photographs: (Check one or more)

	Slide	Print
Plant/animal	___	___
Habitat	___	___
Diagnostic Feature	___	___
Other	___	___

May we obtain duplicates at our expense? [ ] yes [ ] no

Cordylanthus palmatus at Colusa National Wildlife Refuge



California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: 6 - 19 - 93 (mo - day - year)

For office use only			
Source Code		Quad Code	
Elm Code		Occ #	
Copy to		Map Index #	

Scientific Name *(no codes)*: Cordylanthus palmatus

Species Found? [ ] yes [ ] no ______ If not, why?

Total # Individuals: 104 to 105 Subsequent visit? [ ]yes [X]no

Compared to your last visit: [ ]more [ ]same [ ]fewer

Is this an existing NDDB occurrence? [*] Yes, Occ. # [ ] no [ ] unk.

* This occurrence is not in CNDDB reports, but tract 12 plants were surveyed in 1988 (Jokerst) and 1989 (Moreno), and reported.

Reporter: Center for Conservation Biology

Address: Stanford Univ. Stanford CA 94305-5020

Phone: (415) 723-5924

Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U. NV-Reno)
Greg Mensik., Sac. Valley NWR Complex (916) 934-2801

Plant Information:

Phenology: ______ % vegetative ______ % flowering ______ % fruiting

Age Structure: ______ # adults ______ # juveniles ______ # unknown

Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: *(Please also attach or draw map on back.)*
Delevan National Wildlife Refuge, tracts 10, 12, 14, and 33 (see maps). We surveyed tract 12 in 1993 — 104 to 105 individuals. Greg Mensik reported in August 1993 the discovery of "hundreds" of plants in the SE corner of T14, and "tens of thousands" in T33.

County: Colusa Landowner/Mgr: Delevan National Wildlife Refuge

Quad Name: Moulton Weir Elevation: 60' UTM: ______

T 17N R 2W SE¼ Sec 17, SW¼ Sec 16, N½ Sec 21, NW¼ Sec 33 ______ 1/4 of ______ 1/4 Sec ______

Habitat Description: *(Plant communities, dominants, associates, substrate/soils, aspect/slope)*
alkaline soil, seasonal wetlands

Other rare spp.?

Site Information: Current/surrounding land use:
National Wildlife Refuge

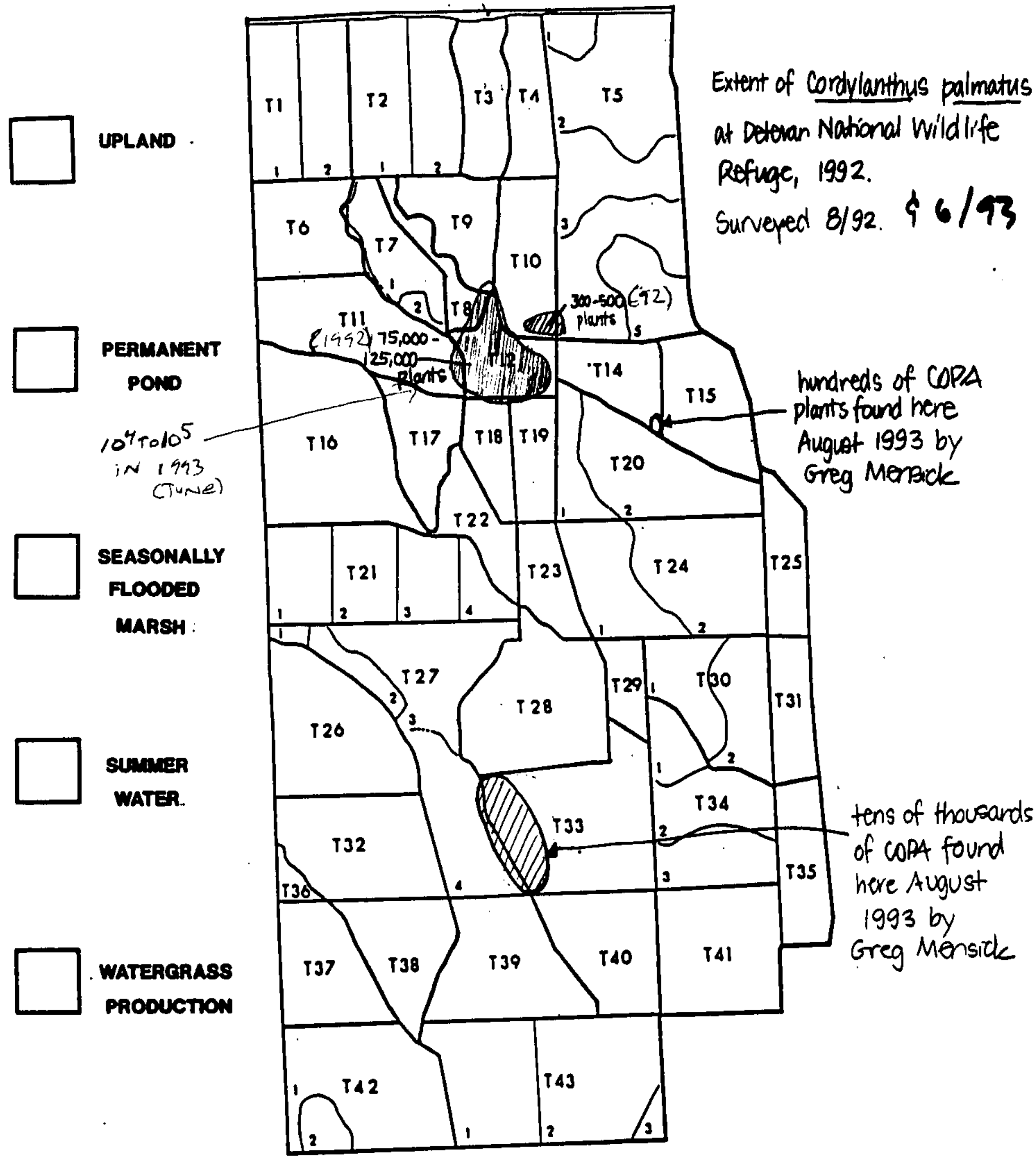
Visible disturbances, possible threats:

Overall site quality: [ ]Excellent [X]Good [ ]Fair [ ]Poor Comments:

Determination: (Check one or more, fill in the blanks)
____ Keyed in a site reference: ______
____ Compared with specimen housed at: ______
____ Compared with photo/drawing in: ______
____ By another person (name): ______
X Other: personal knowledge

Photographs: (Check one or more)	Slide	Print
Plant/animal	___	___
Habitat	___	___
Diagnostic Feature	___	___
Other	___	___

May we obtain duplicates at our expense? [ ]yes [ ]no


UPLAND
PERMANENT POND
SEASONALLY FLOODED MARSH
SUMMER WATER
WATERGRASS PRODUCTION
Extent of Cordylanthus palmatus at Delevan National Wildlife Refuge, 1992.
Surveyed 8/92.
6/93
T1
T2
T3
T4
T5
T6
T7
T8
T9
T10
T11
T14
T15
T16
T17
T18
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T31
T32
T33
T34
T35
T36
T37
T38
T39
T40
T41
T42
T43
300-500 ('92) plants
(1992) 75,000-125,000 plants
10^4 to 10^5 in 1993 (June)
hundreds of COPA plants found here August 1993 by Greg Mensick
tens of thousands of COPA found here August 1993 by Greg Mensick

DELEVAN NWR

California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: 6 - 10 - 93 (mo / day / year)

For office use only
Source Code ______ Quad Code ______
Elm Code ______ Occ # ______
Copy to ______ Map Index # ______

Scientific Name *(no codes)*: Cordylanthus palmatus

Species Found? [X] yes [ ] no ______ If not, why?
Total # Individuals: 440 Subsequent visit? [ ] yes [X] no
Compared to your last visit: [ ] more [ ] same [ ] fewer
Is this an existing NDDB occurrence? [______] Yes, Occ. # [X] no [ ] unk.
Collection? If yes: ______ number ______ Museum/Herbarium

Reporter: Center for Conservation Biology
Address: Stanford Univ., Stanford CA 94305-5020
Phone: (415) 723-5924
Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U-NV Reno)
Greg Mensick, Sac Valley NWR Complex (916) 934-2801

Plant Information:
Phenology: ______ % vegetative 100% % flowering ______ % fruiting

Age Structure: ______ # adults ______ # juveniles ______ # unknown
Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: (Please also attach or draw map on back.)
Sacramento National Wildlife Refuge, NE corner of tract AB, NW corner of tract TC (across road from first location); west side of tract 8, cell 3. 110 individuals in AB, ~300 in TC, 31 in tract 8 cell 3.

County: Glenn and Colusa Counties Landowner/Mgr: USFWS
Quad Name: Logandale Elevation: ~90' UTM: ______
T 18N R 2W ______ N 1/2 Sec 1 T 18N R 2W ______ S 1/2 Sec 10

Habitat Description: *(Plant communities, dominants, associates, substrate/soils, aspect/slope)*
Tract AB: once cultivated for rice. Much Distichlis spicata, Frankenia. Soil white, powdery. COPA in two dense groups (75 and 35); area occupied ~200m². Tract TC: ~300m² area of white, powdery soil. Dense COPA; also lots of Frankenia, a little D. spicata. Tract 8(3): Lots of D. spicata + Frankenia. One group of 25 COPA, one group of 6 (between stakes).
All tracts are not purposely flooded (as is much of the refuge) but do collect standing water from
~~Other rare spp.?~~ rainfall; on this date large pools remained.

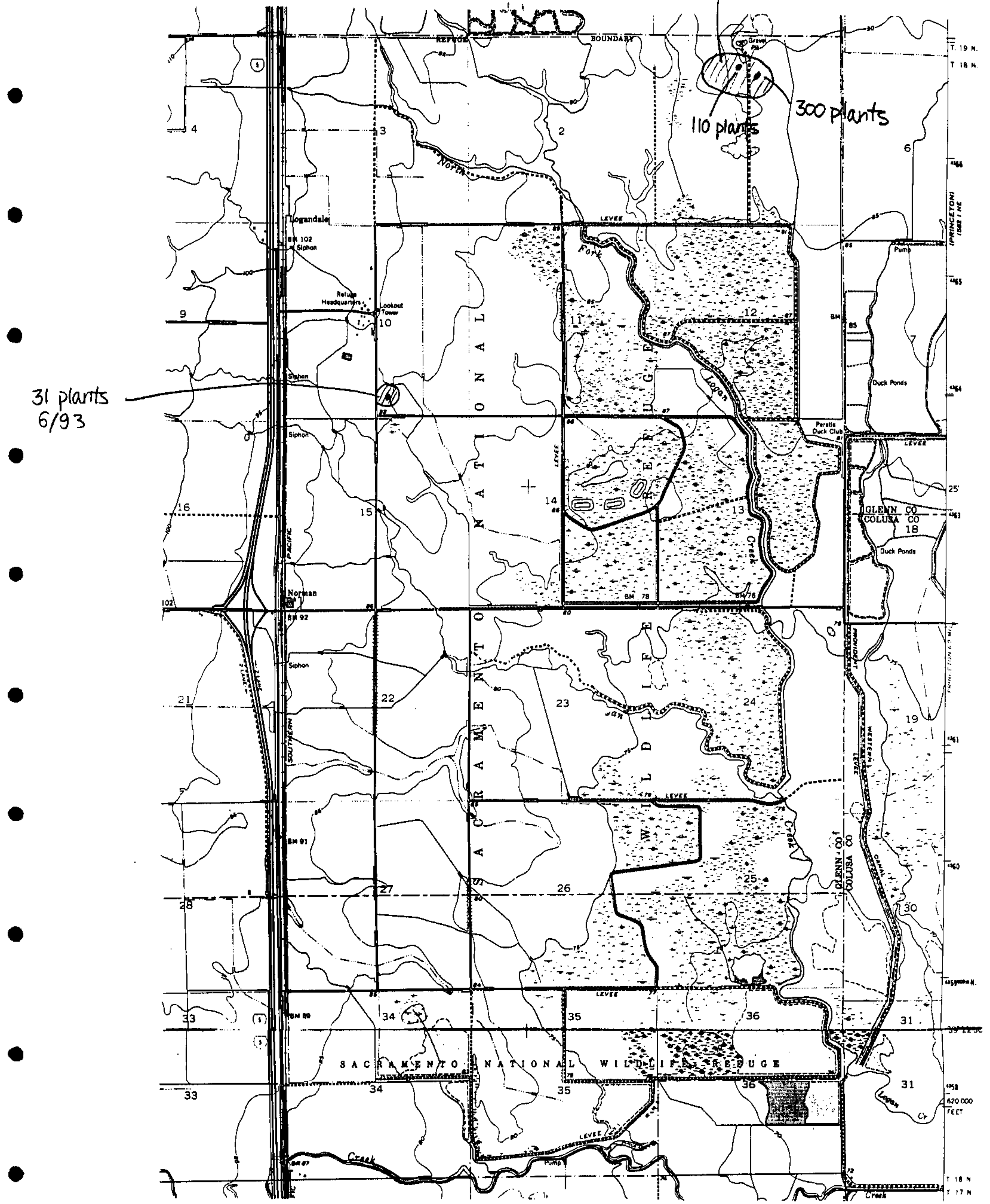
Site Information: Current/surrounding land use:
Refuge managed for waterfowl. Note: All of these plants are in sites where seeds from Delevan
Visible disturbances, possible threats: were scattered in 1990 or 1991. No other COPA is known to occur on this Refuge, according to refuge biologists.

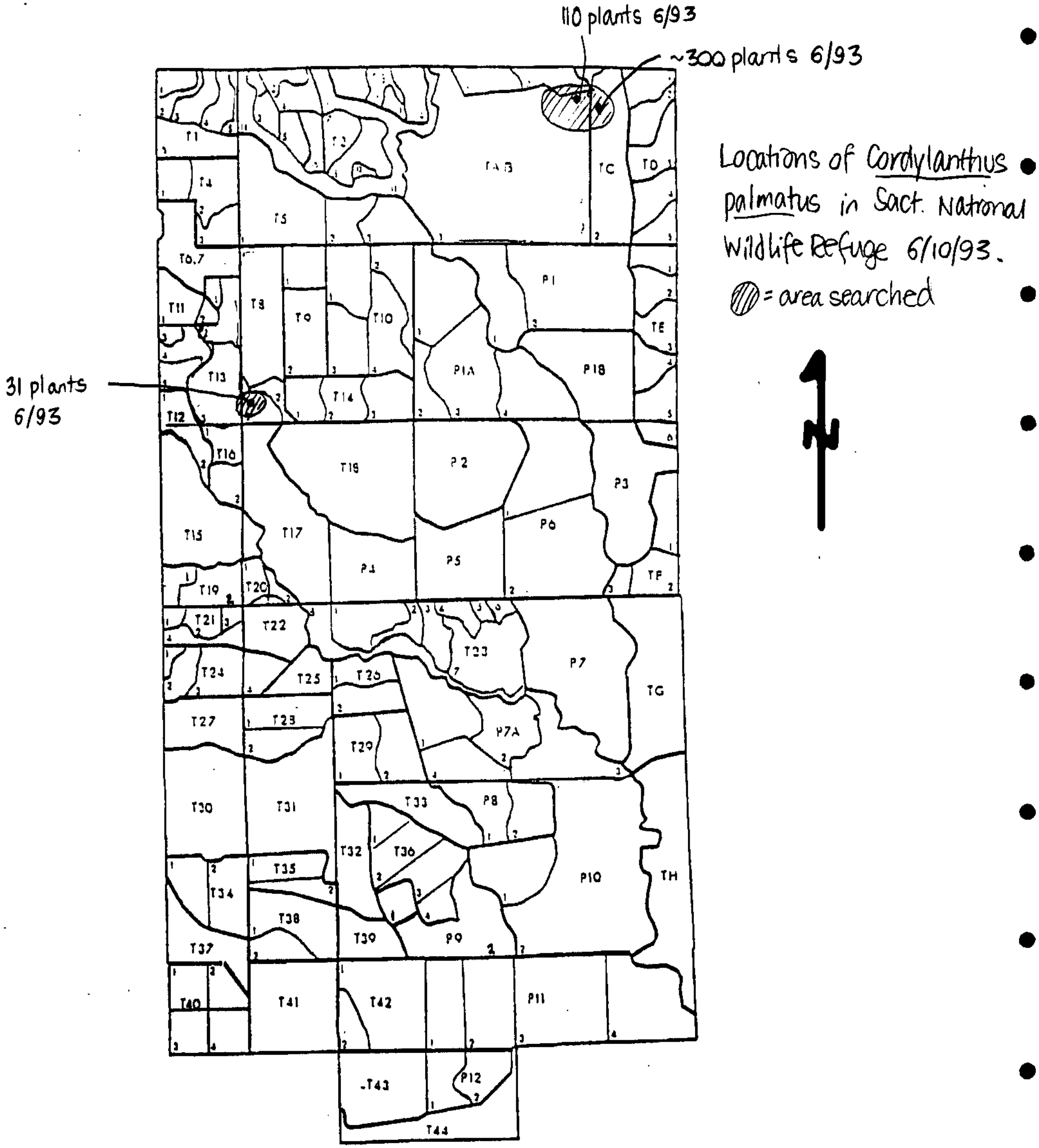
Overall site quality: [ ] *Excellent* [X] *Good* [ ] *Fair* [ ] *Poor* Comments:

Determination: (Check one or more, fill in the blanks)
___ Keyed in a site reference: ______
___ Compared with specimen housed at: ______
___ Compared with photo/drawing in: ______
___ By another person (name): ______
X Other: personal knowledge

Photographs: *(Check one or more)* Slide Print
Plant/animal __ __
Habitat __ __
Diagnostic Feature __ __
Other __ __
May we obtain duplicates at our expense? [ ] yes [ ] no

LOGANDALE QUAD
7.5 minute





SACRAMENTO NWR

California Native Species Field Survey Form

Mail to:
Natural Diversity Data Base
California Dept. of Fish and Game
1416 Ninth Street, 12th Floor
Sacramento, CA 95814

Date of field work: 8 - 17 - 93 (mo / day / year)

For office use only
Source Code ______ Quad Code ______
Elm Code ______ Occ # ______
Copy to ______ Map Index # ______

Scientific Name (no codes): Cordylanthus mollis hispidus

Species Found? [X] yes [ ] no ______ If not, why?
Total # Individuals: ~600 Subsequent visit? [X] yes [ ] no
Compared to your last visit: [X] more [ ] same [ ] fewer
Is this an existing NDDB occurrence? [______] Yes, Occ. # [ ] no [ ] unk.
Collection? If yes: At CCB; to be sent to CA Academy (number / Museum/Herbarium)

Reporter: Ctr. for Conservation Bio (CCB), Stanford Univ.
Address: Dept. Bio. Sci., Stanford CA 94305-5020
Phone: (415) 723-5924
Other knowledgeable individuals (name/address/phone):
Alan Launer (415) 725-1854
Kathy Switky (415) 723-5923
Erica Fleishman (702) 784-1359 (U. Nevada-Reno)

Plant Information:
Phenology: ______ % vegetative; 100% % flowering; ______ % fruiting

Animal Information:
Age Structure: ______ # adults ______ # juveniles ______ # unknown
Site Function: [ ] breeding [ ] foraging [ ] wintering [ ] roosting [ ] burrow site [ ] other

Location: (Please also attach or draw map on back.)
As per attached map, plants occupy an area approx. 15m wide, 30m long on City of Livermore property, Springtown Alkali Sink. The three of us surveyed all other likely habitat in August '93 (as shown on map) and found no other plants. The site was extensively surveyed in summers of 1990, 1991, & 1992 for C. palmatus and no C. mollis was ever found.
County: Alameda Landowner/Mgr: City of Livermore / private
Quad Name: Altamont Elevation: ~510 UTM: ______
T 2S R 2E SW 1/4 of SW 1/4 Sec 27 T ______ R ______ ______ 1/4 of ______ 1/4 Sec ______

Habitat Description: (Plant communities, dominants, associates, substrate/soils, aspect/slope)
Alkali sink scrub/grassland. Drainages braid through generally flat sink community, which grades into introduced annual grassland. C. mollis hispidus is growing on sides of shallow drainage and on slightly elevated areas in a "bathtub ring" form. The plants grow among dense low vegetation, especially Distichlis spicata and annual grasses. This area was likely occupied by Cordylanthus palmatus in 1992 (and perhaps previous years), but in this visit C. palmatus was ~30m from the nearest C. mollis hispidus.
Other rare spp.?

Site Information: Current/surrounding land use:
Unmanaged open space. State, City, and private interests are working on C. palmatus management plan. Surrounded by existing and proposed residential development.
Visible disturbances, possible threats:
Possible grass wildfires. Plot to south is heavily trespassed by bikes, ORVs. Surface flows very disrupted by upstream development.
Overall site quality: [ ] Excellent [X] Good [ ] Fair [ ] Poor Comments:

Determination: (Check one or more, fill in the blanks)
X Keyed in a site reference: Munz 1968 (A CA Flora); Hickman 1993 (Jepson)
__ Compared with specimen housed at: ______
X Compared with photo/drawing in: above
__ By another person (name): ______
__ Other: ______

Photographs: (Check one or more)

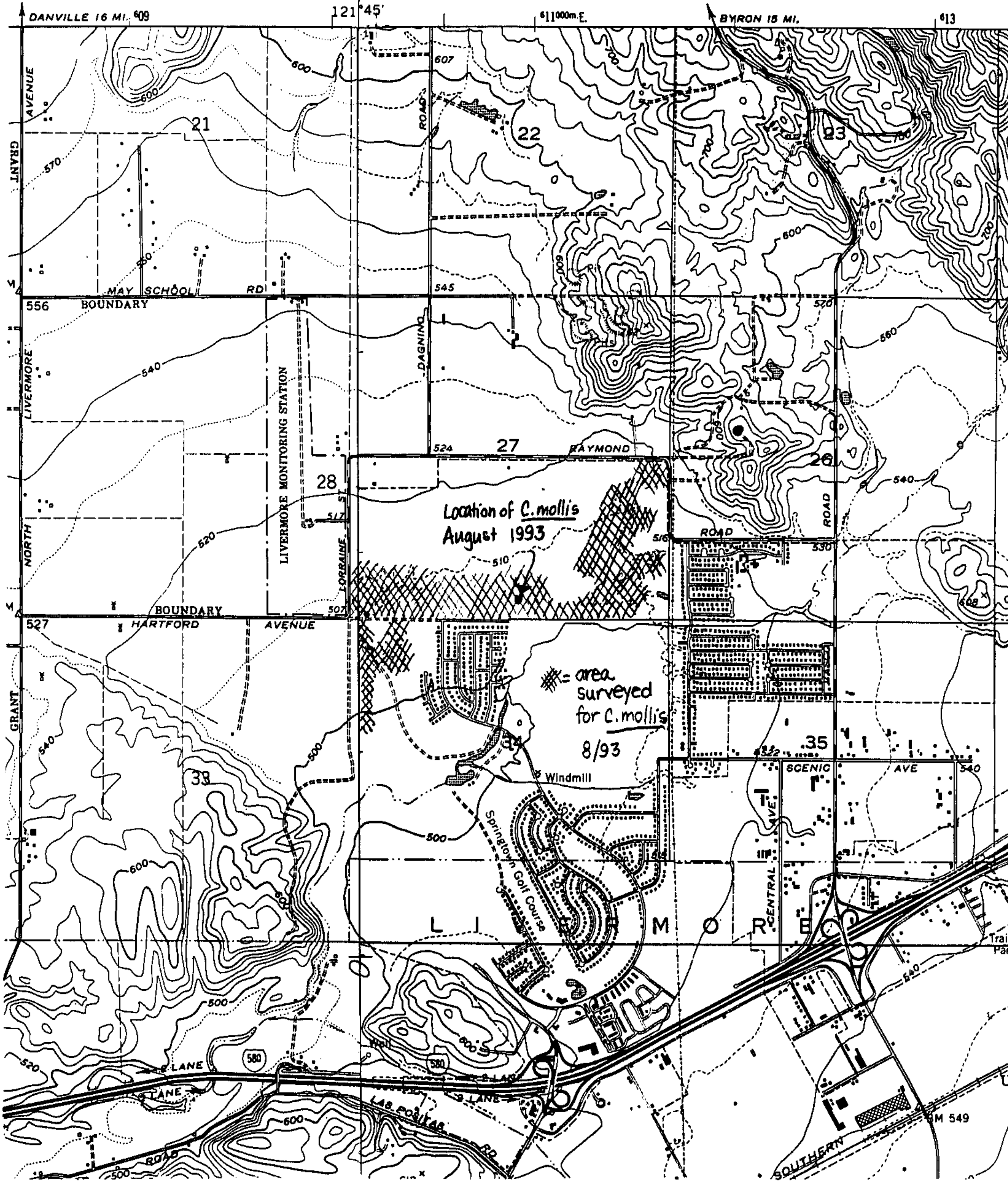
	Slide	Print
Plant/animal		X
Habitat	X	X
Diagnostic Feature		
Other		

May we obtain duplicates at our expense? [X] yes [ ] no

LIVERMORE QUAD | ALTAMONT QUAD

LIVERMORE QUADRANGLE
CALIFORNIA
7.5 MINUTE SERIES (TOPOGRAPHIC)
NE/4 LIVERMORE 15' QUADRANGLE

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY



Appendix D

Summary data from *Bombus* mark-release study

Appendix D: Resighting records of Bombus mark-release-resight study. Three letter codes signify the color of marks applied to identify bees: R = red, G = green. Y = yellow, B = blue, W = white, O = orange, A = gold (Au). Codes are listed below the date on which bees were marked. Resightings are indicated by asterisks below the corresponding date.

Date	7/1	7/6	7/7	7/8	7/9	7/13	7/14	7/15	7/16	7/19	7/20	7/21	7/22	7/23	7/26	7/27	7/28
SITE																	
Exclusion																	
Study Site	R--			*			*										*
			RGO		*		?										
			RRO	*	*												
			RYO						*								
			RBO														
			ROO														
			RWO	*	*												
			RAO														
								RGG		*							
								RRG				*			*	*	
								RYG		*	*				*	*	
								RBG									
								ROG									
								RWG									
								RAG									
Main Scald																	
		GG_															
		GR_															
		GY_															
		GB_								*							
						GGW		*									
						GRW				**	*					*	
						GYW				*							
						GBW		*		*							
						GOW											
Area 3																	
					BGB												
										BGA		*					
										BRA							
Area 5																	
							WGY			?							
							WRY										
							WYY								**		
							WBY										
							WOY										
							WWY				*	*					
Area 5'																	
(*Eringium*)							AGY		*	*	*		*	*			
							ARY										
							AYY										
							ABY										
										AGA							
										ARA							
										AYA							
										ABA							
										AOA							
										AWA							
FCC																	
								YGG		?		?					
								YRG									
								YYG									