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CORDYLANTHUS PALMATUS SITE CHARACTERIZATION

AND

AERIAL PHOTOGRAPHY INTERPRETATION

BY

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CALIFORNIA DEPARTMENT OF FISH AND GAME

THE ENDANGERED PLANT PROJECT

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PROJECT SUMMARY

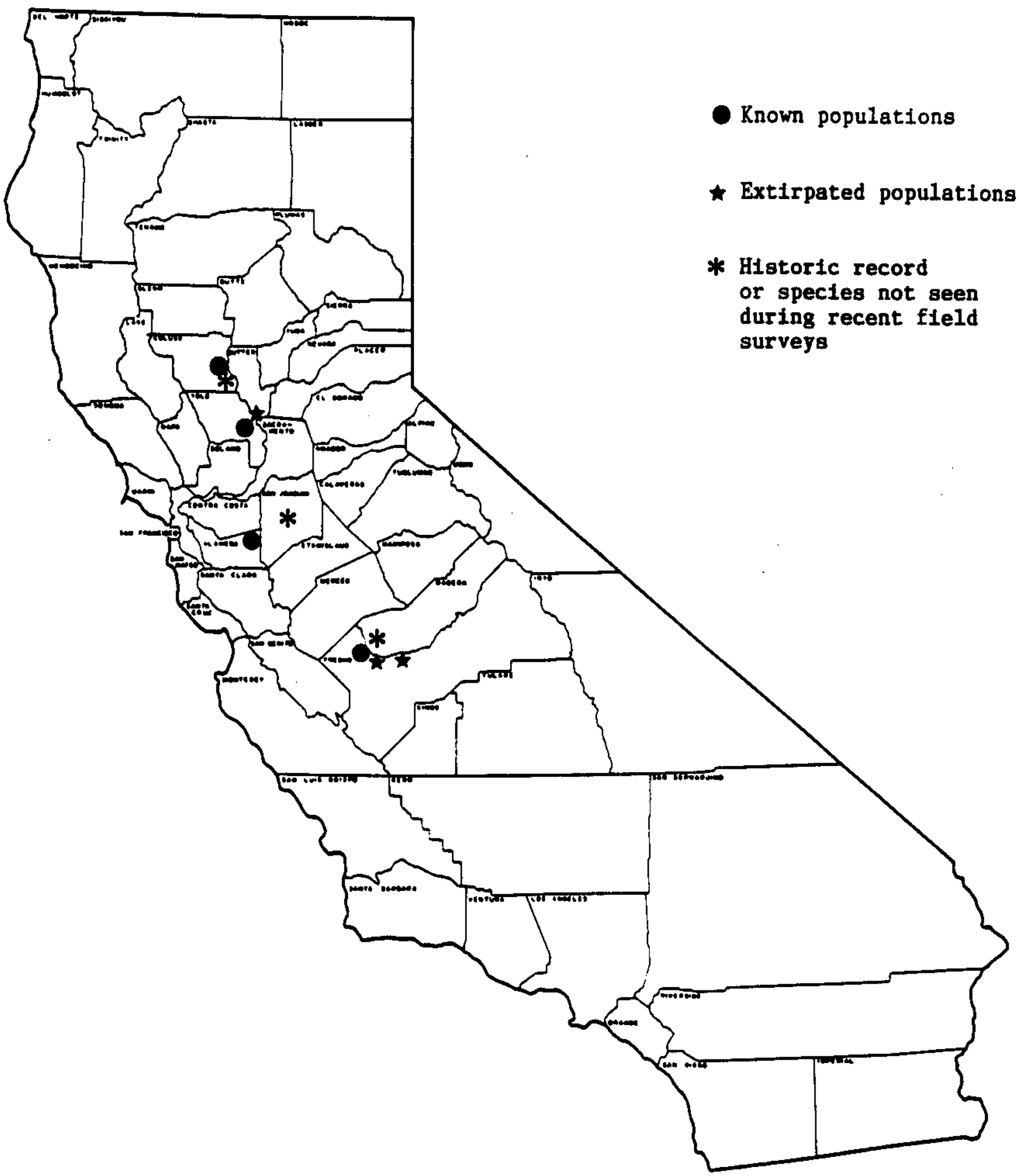
This project constitutes a preliminary evaluation of the potential statewide distribution of *Cordylanthus palmatus* (Ferris) MacBride, an endangered species. A habitat profile, based on characteristics of known populations, including microtopographic relief, soils and hydrology, vegetation, elevation, and land use, was developed. Potential habitat was identified by reviewing soils maps and aerial photographs of counties occurring within the historic range of the species. These counties included Alameda, Colusa, Contra Costa, Fresno, Madera, Merced, San Joaquin, Solano, Stanislaus, and Yolo Counties. Budget limitations precluded evaluation of Glenn, Sacramento, and Sutter Counties.

INTRODUCTION

The bird's-beak genus, *Cordylanthus*, is indigenous to western North America, and is represented by approximately thirty-two species. It is related to Indian paintbrush (*Castilleja*) and to owl's clover (*Orthocarpus*). *Cordylanthus palmatus*, also called palmate-bracted bird's-beak or Ferris' bird's-beak, belongs to a morphologically and ecologically distinct group of species in the subgenus Hemistegia. All species within the subgenus occur in saline and alkaline habitats. The species in the subgenus are characterized by oblong to oval leaves, an elongated flower spike, and the association of one bract with each flower (Chuang and Heckard 1971).

The historic range of Cordylanthus palmatus included ten scattered locations in the San Joaquin and Sacramento Valleys: in Fresno, Madera, San Joaquin, Yolo, and Colusa Counties. This species is known currently from four populations within the historic range: in Colusa, Yolo, Alameda, and Fresno Counties (Figure 1). Cordylanthus palmatus is restricted to relatively undisturbed, seasonally-flooded, saline-alkaline soils in lowland plains and basins of the Central Valley of California. These lowland plains and basins are remnants of once-extensive wetlands that occurred historically in the Central Valley at elevations of less than 500 feet. Within this area, Cordylanthus palmatus occurs with valley sink scrub vegetation. It is associated with halophytes (salt-loving plants) such as alkali heath (Frankenia grandifolia ssp. campestris), alkali weed (Cressa truxillensis var. vallicola), pickleweed (Salicornia spp.), seepweed (Suaeda spp.), iodine bush (Allenrolfea occidentalis), and species of saltbush (Atriplex spp.). Site microtopography is of central importance to the potential distribution of Cordylanthus palmatus.

Figure 1. Statewide distribution of Cordylanthus palmatus.



Aerial photographs correlating to basin soils in the Central Valley were examined for potential Cordylanthus palmatus habitat. The use of low elevation aerial photography provides an effective way to select areas for ground-based field surveys.

MATERIALS AND METHODS

Three of the four known populations of Cordylanthus palmatus were examined in the field during 1987 and 1988. Population size, habitat, site microtopography, and associated species have been intensively studied at Woodland in Yolo County and at Livermore in Alameda County. The extant Mendota population, discovered by Taylor in 1986, was mapped by Knudsen and Showers in 1987. Individuals were counted at that time, and microrelief noted. Although the general area of the Colusa County site was visited by Showers in 1988, a map was not available and the specific site was not located. Stone (1987) recorded microsite features and associated species for the Colusa County population.

Populations of Cordylanthus palmatus, associated with native valley sink scrub vegetation, are restricted to relatively undisturbed saline-alkaline soils in basins in the Central Valley of California. These general site characteristics have practical value in delimiting potential habitat of Cordylanthus palmatus.

Black and white aerial photographs (1" = 2,640') were obtained for areas having basin soils in Colusa, Yolo, Contra Costa, Alameda, Stanislaus, San Joaquin, Merced, and Madera Counties. Black and white aerial photographs (1" = 3,333') were used for Fresno County.

Basin soils identified on U.S.D.A. Soil Conservation Service (SCS) maps were used to delineate basin areas in the counties surveyed. Photographs were analyzed for the presence of alkaline wetland habitat, identified by mound and channel topography, barren soil areas ("scalds"), and sparse vegetation. The relative absence of human disturbance due to agriculture, road construction, and housing was also considered in delimiting wetland habitat.

DISCUSSION

HABITAT

Hydrology

Prior to European settlement, the surface hydrology of the Central Valley consisted of numerous seasonal and permanent streams draining into the trough of the Central Valley. The onset of winter rains and spring snowmelt produced two annual pulses of water into the lowlands. The pulses resulted in lowlands being seasonally flooded and created large expanses of flood plain interspersed with sloughs, ponds, and seasonal lakes.

The duration of these seasonal floods varied, based on the periodicity and magnitude of storms and depth of snowpack. Before extensive artificial levee construction and water diversion during the 1800s, these "swamp and overflow lands" and the wetlands they supported covered more than three million acres. It is estimated that 1.5 million acres were aquatic wetlands, including tule marsh, while 1.6 million acres were riparian forests (Warner and Hendrix 1985).

Hydrology: Sacramento Valley

In the Sacramento Valley, streams from the surrounding foothills and mountains proliferated into a system of distributary channels that drained into natural flood basins or "sinks". During peak flows, the flood basins were filled by waters carrying large amounts of sediment, and flowed overland, while natural levees prevented some inflowing water from reaching the Sacramento River. Many large flood basins occur west of the Sacramento River. The Colusa Basin to the north and the Yolo Basin, which extends from east of Woodland south to the Solano County line, are two large basins. The two basins are separated by a ridge formed by Cache Creek. Several smaller basins occur in shallow depressions in alluvial plains or where surface or subsurface drainage is poor.

The large flood basins of Solano County lie west of Miner Slough, occurring between the natural slough levees and the alluvial plains to the west of the levees. The basins are nearly level, but have small depressions and low ridges formed by tributary streams flowing eastward from the Coast Ranges. The principal basin, the Yolo Basin, is located in the east central portion of the Solano County, north and east of the Sacramento River. A smaller basin is on alluvial plains southeast of Dixon.

Artificial levees in the Sacramento Valley now prevent flooding, and the natural basins have largely been diked to form channels, called bypasses, to carry flood waters. Prior to "reclamation", portions of the basins were wetlands supporting tule marsh surrounded by riparian woodlands and forests. Other areas, where salt concentrations were higher, supported alkali wetlands, alkali grasslands and halophytic shrub communities (Harradine 1948; Soil Conservation Service 1977; Warner and Hendrix 1985).

Hydrology: San Joaquin Valley

As in the Sacramento Valley, the San Joaquin Valley is characterized by large flood basins. Under natural conditions, numerous rivers from the Sierra Nevada flowed into the San Joaquin Valley, which can be divided into two distinct hydrologic basins: the Tulare Basin and the San Joaquin Basin. The San Joaquin River drains the San Joaquin Basin, and although the Tulare Basin has no perennial surface outlet, when filled, it drains into the San Joaquin Basin. The Tulare Basin formed at the southern end of the San Joaquin Valley by the coalescing alluvial fans of the Kings River and Los Gatos Creek. Runoff water was captured in this basin, creating large, shallow, seasonal lakes: Tulare, Buena Vista, Kern, and Goose Lakes. As the lakes exceeded storage capacity, they overtopped the alluvial fans and flowed into the San Joaquin River via Fresno Slough. The lakes were interconnected by sloughs, and their basins supported extensive wetlands.

A nearly level flood plain is located along the San Joaquin River in the trough of the Central Valley. Except in the northern San Joaquin Valley, streams and rivers did not usually produce the natural levees characteristic of Sacramento Valley watercourses, because lower peak flows limited the ability of San Joaquin Valley streams to transport sediment. For example, the San Joaquin River did not develop an extensive levee system although, levees did develop at its confluence with the Merced River, a sediment-bearing stream (Warner and Hendrix 1985). Without natural levees to contain its flows, the San Joaquin River flowed overland and large freshwater marshes formed.

Within San Joaquin County, four major streams contribute sediment to alluvial fans and run-off to adjacent basins. Dry Creek forms the northern boundary of the County; the Stanislaus River, the southern boundary. Calaveras River and Mokelumne River provide drainage within the County. In addition to the major rivers, there are several smaller streams, including Corral Hollow Creek, Hospital Creek, Littlejohn Creek, and Duck Creek. The basin in San Joaquin County occurs primarily in the central portion of the County east of the San Joaquin River, and adjacent to alluvial fans formed by the confluence of major streams with the San Joaquin River.

Eastern Stanislaus County is also within the San Joaquin River drainage basin. Flood plains similar to, but narrower than that of the San Joaquin River, occur along the Tuolumne and Stanislaus Rivers within Stanislaus County (SCS 1964). Merced County, located in the central San Joaquin Valley, contains a broad, nearly level basin in the southeastern part of the county. The basin is drained west towards the San Joaquin River, primarily by the Merced and Chowchilla Rivers, as well as by numerous smaller streams such as Bear Creek, Owens Creek, Duck Creek, Deadman Creek, and Mariposa Slough. Flooding occurs infrequently along the Merced River, although it can occur along smaller stream basins during wet years (Soil Conservation Service 1962).

Madera County is drained by the San Joaquin River and its tributaries. The Fresno River drains the central portion of the county and joins the San Joaquin River in northwestern Madera County. Ash Creek and Berenda Slough are the principal tributaries of the Fresno River.

In the northern San Joaquin Valley and adjacent interior valleys, small basins with seasonally-ponded depressions, such as those in Contra Costa County and Alameda County, occur in proximity to the confluence of the San Joaquin and Sacramento Rivers (Soil Conservation Service 1975).

Areas experiencing the once-common seasonal, overland flows still exist on floodplains within the Central Valley of California. Cordylanthus palmatus is restricted to these seasonally-flooded sites in lowland plains and basins. In Colusa County, C. palmatus occurs within the Colusa Basin. Seasonal flooding occurs to date, and small sinks within the basin support valley sink vegetation. At the Woodland site in Yolo County, C. palmatus occurs in the Yolo Basin on the floodplain of Willow Slough. Overland flows have occurred as recently as 1986, and ponding is common. The Fresno County site, at the Mendota Wildlife Management Area, is within the extensive San Joaquin River drainage basin. Widespread overland flooding occurred here in 1986. The population in Alameda County is situated within a natural interior basin receiving overland flows. Seasonal flooding from Altamount Creek can occur, but has been much reduced by stream channelization and urbanization (Coats et al. 1988).

Soils

Basin soils are commonly associated with "swamp and overflow lands" in the Central Valley. Although individual profiles vary among soil series, all basin soils share several characteristics. Also called "black alkali", these soils have an excess of sodium carbonate and/or a relatively high content of exchangeable sodium ions, as well as a pH above 8. The parent material is primarily sedimentary rock of recent geologic origin, consisting of clay and silt settled out of flood waters (SCS 1977). In the San Joaquin Valley, however, some basin soils formed in alluvium derived from granitic parent materials (SCS 1940, 1971). Originally poorly-drained, basin soils are mottled with a gleyed or olive subsoil.

Soils in the Colusa and Yolo Basins, located in the Sacramento Valley, are derived from soft sedimentary shales and sandstones containing large quantities of soluble salts. The Colusa Basin, subject to annual winter flooding by slow moving waters from the north, has a high water table. Within the basins, groundwater has left concentrated deposits of carbonates in some areas of the soils. The location of these carbonates in the soil profile can be related to the former position of a once-stable water table (SCS 1977). Annual floodwaters are removed by evaporation, or, in agricultural situations, by pumping. The high rate of evaporation during the summer causes some salts to accumulate in the upper soil horizons and to remain there as long as imperfect subsoil drainage exists. Low levels of available soil moisture prevent active leaching of soils and lead to a slow redistribution of carbonates and translocation of clays.

Along the San Joaquin River and lower reaches of the Stanislaus and Tuolumne Rivers, seasonal flooding can be of long duration and result in a high water table that persists from late spring to summer. As a result, soils are poorly drained and, in part, saline or alkaline. The basin east of the San Joaquin River is characterized by very slow run-off, a high water table, and mound microrelief under natural conditions (Soil Conservation Service 1964). Basin soils in San Joaquin County are frequently saline or alkaline and are poorly-drained. Mound and swale microrelief can occur (Weir 1952). This type of microtopography has also been called "hogwallowed" or "mima mound" topography.

Merced County, located in the central San Joaquin Valley, contains a broad, nearly level basin in the southeastern part of the County. Soils in this basin are characterized by poor drainage and strong accumulations of salts and alkali. Mound microrelief also occurs. Alluvial deposits occur along the San Joaquin River in southeastern Madera County. An extensive basin is found adjacent to these deposits in west central and northwestern Madera County. Soils in the basin have varying degrees of alkali in their profiles and often have a hardpan. Mound microrelief can also occur under natural conditions (Weir 1956).

The trough of the San Joaquin Valley in Fresno County consists of poorly drained soils of the basin flood plain and soils of the basin rim. The flood plain is traversed by the meandering channel of Fresno Slough, an intermittent tributary of the Kings River. Basin soils, derived mainly from granitic parent materials, are deposited during floods by the waters of the Kings River and smaller streams such as Murphys and Fish Sloughs.

Soils of the basin rim in Fresno and Madera Counties occupy a broad, irregular area bordering the lower part of the alluvial fans of the Kings and San Joaquin Rivers. Run-off is slow, and, in places, the water becomes impounded in small depressions or playas. Rim soils are usually situated in elevation above those inundated on the basin floor, although the water table can rise to near the surface of the basin rim. The rise in the water table has facilitated the accumulation of solutes through capillary action and evaporation. Saline flood waters have also contributed to the accumulation of salts. As a result, many basin and rim soils have a pronounced saline-alkali character. (Harradine 1940; Soil Conservation Service 1940, 1971). Present-day stream control, flood protection, reclamation, and deep pumping have lowered the water table and permanently altered historic overland flows. (Harradine 1940; Soil Conservation Service 1971; Warner and Hendrix 1985).

Cordylanthus palmatus is adapted to saline-alkaline soils of basins and basin rims. To date it is known to occur on saline-alkaline soils in four soils series, and could potentially be found on other saline-alkaline soils within the Central Valley. Appendix 1 lists the saline-alkaline basin soils found in the counties comprising the historic range of *C. palmatus*. Parent material, position within the flood basin, and soil characteristics are also included in Appendix 1.

Cordylanthus palmatus occurs on Willows soils in Colusa County and Yolo County, as well as on Pescadero soils in Yolo County. Willows soils occupy the lowest and most poorly drained central basin in Colusa County. They are dark-colored and fine-textured, and are characterized by a dense clay subsoil and by moderate to strong concentrations of alkali salts. Surface and subsurface drainage is poor. In Yolo County, Pescadero and Willows soils occur in basins and on basin rims. Pescadero and Willows soils have a high sodium content, possibly related to a combination of ground water, organic matter content in the upper soil profile, and anerobic conditions. For example, exchangeable sodium percentage in saline Pescadero soils is greater than 20 percent (Soil Conservation Service 1972).

Cordylanthus palmatus also occurs on Pescadero soils north of the City of Livermore in Alameda County. In this area, the Pescadero series, consisting of imperfectly drained saline-alkali soils, occurs on nearly level basin rims and along the lower edge of terraces in small coastal valleys. It has mound and swale microrelief. Solano soils, which also support C. palmatus, make up a small percentage of basin soils in the Livermore area. These soils formed in alluvium weathered from sedimentary rock and have a loamy texture. They are shallow, poorly-drained, saline-alkaline, and have mound and swale microrelief. An alkalinity gradient can be measured from mound top to swale bottom, with sodium being leached out of the surface soil horizon at the mound top, making the mound top acidic. Due to solute deposition and capillary action, the swale bottoms are saline and alkaline (Coats et al. 1988).

Of the basin soils in northern Fresno County, Cordylanthus palmatus occurs on Waukena soils at the Mendota Wildlife Management Area. The Waukena soils formed in broad, flat, saline-alkaline basin areas where the water table is high and surface run-off is slow. Mound microrelief occurs in some areas, as does hardpan.

Vegetation

Valley sink scrub is the natural vegetation type of valley bottoms and playas in the San Joaquin Valley and Carrizo Plain at elevations below 300 feet (Bittman 1985). Historically, this vegetation type surrounded Kern, Buena Vista, Tulare, and Goose Lakes in the San Joaquin Valley, as well as valley basins north along the trough of the San Joaquin Valley through Merced County to the "gooselands" of Solano and Glenn Counties (Holland 1986). In the San Joaquin Valley, valley sink scrub once covered more than 260,000 acres from Buena Vista Lake to Merced County; today, less than twenty percent remains (Bittman 1986). A depauperate, that is, less complex, form of the vegetation type occurs in Yolo and Colusa Counties. This more northern extension of valley sink scrub has also been referred to as alkali meadow or alkali grassland by Holland (1986).

Valley sink scrub is best developed in highly alkaline soils where there is a gradual slope extending up and away from a lake or basin lacking external drainage. It is the first dryland association found upslope from marshes and lakes, and its localized distribution is dependent on soil salinity and alkalinity, duration of seasonal inundation, microtopographic relief, and depth to the water table (Bittman 1985).

Valley sink scrub is a complex mosaic having an open to relatively dense shrub cover. Cover can vary from site to site, as well as seasonally. An understory of annual wildflowers and grasses may be present between the shrubs. When the natural topography consists of low hillocks alternating with alkali flats and bare ground, a variety of annual wildflowers adapted to differences in soil texture, salinity/alkalinity, and soil moisture produce spectacular floral displays with adequate rainfall. These wildflowers include species of popcornflower (Plagiobothrys spp.), goldfields (Lasthenia spp.), pepperweed (Lepidium spp.), downingia (Downingia spp.), milkvetch (Astragalus spp.), and owl's clover. Bare soil, often encrusted with salts and organic films, is also common between shrubs.

Two major sub-types of vegetation comprise valley sink scrub. One, dominated by iodine bush, occurs in low, heavily saline/alkaline areas that are wet in winter; the other, dominated by seepweed, occurs in less alkaline soils at slightly higher elevations and intergrades with areas of iodine bush (Bittman 1985). Cordylanthus palmatus is associated with iodine bush-dominated valley sink scrub at Livermore and at the Mendota Wildlife Management Area. A third sub-type, the alkali "grassland" has also developed in poorly-drained alkaline soils subject to overland winter flooding. It is thought that alkali grassland occurs on slightly higher ground within sinks where the duration of inundation is shorter (Bittman 1985). This subtype is characterized by scattered shrubs of seepweed, pickleweed, and alkali heath, and suffrutescent annuals such as spikeweed (*Hemizona pungens*) and low seepweed (*Suaeda depressa* var. *erecta*), interspersed with stands of annual and perennial grasses. Native grass species include salt grass (*Distichlis spicata* var. *stricta*), Nuttall's alkali grass (*Puccinellia nuttalliana*), California alkali grass (*Puccinellia simplex*), hair grass (*Deschampsia danthonoides*), and alkali sacaton (*Sporobolus airoides*). Non-native grasses such as foxtail (*Hordeum* spp.), red brome (*Bromus rubens*), and rye grass (*Lolium multiflorum*) are also common. The alkali grassland subtype occurs in Colusa and Yolo Counties at the two northern populations of *Cordylanthus palmatus*.

SITE MICROTOPOGRAPHY

It has been observed that the distribution of *Cordylanthus palmatus* correlates with microtopographic features within a given site. At all known sites, *Cordylanthus palmatus* is associated with drainage features: depressions, swales, drainage channels, or berms. Three hypotheses may explain the observed distribution of plants.

1. Overland flows appear to influence the seasonal distribution of *Cordylanthus palmatus* individuals. When channeled through

swales, overland freshwater flows decrease salinity in saline-alkaline soils, thus enabling seeds to germinate and seedlings to become established. Seeds of Cordylanthus palmatus float, and can remain floating even following germination, for a period of at least three weeks (Showers, unpub. data). Floating seeds would be caught in plants along berms and margins of drainage channels. Seeds would also be deposited at successively lower microsites as overland flows gradually cease ("bathtub ring distribution"). For example, at the Woodland site, the role of water in distributing seed can be inferred from aggregated versus nonaggregated groups of plants. In years with winter overland flows, individual plants or small groups of plants are arrayed along berms at the same relative distance from the top of the berm. At a given time in the growing season, plants at the tops of berms are likely to be more advanced in development, for example, branched and/or flowering, than those at the bases of berms, which may still be at the seedling stage. In years without overland flows, plants are often densely aggregated, occurring in proximity to the previous year's plants.

Water-related seed distribution has also been noted in two other species of Cordylanthus in the subgenus Hemistegia: Cordylanthus maritimus var. maritimus (saltmarsh bird's-beak) (USFWS 1985) and Cordylanthus mollis ssp. mollis (soft-hairy bird's-beak) (Showers, field observations). Seeds of C.

maritimus have been shown to float for up to 50 days (USFWS 1985), and the seed morphology observed in C. palmatus may also facilitate floating. Seeds of C. palmatus have irregular arching crests on the dorsal sides of the seeds and a polygonally reticulate type of wall. Both C. maritimus and C. mollis have deeply reticulate seed coats. Cordylanthus mollis also possesses short-papillate wax deposits on the reticulum ridges (Chuang and Heckard 1972).

2. Dilution of soil solutes may be necessary to permit germination and for seedling establishment to occur. Cordylanthus palmatus germinates during the winter (December-February). Although quantitative data do not exist for C. palmatus, its sensitivity to salinity may parallel that of C. maritimus: salinity of water at the time of germination of C. maritimus seed usually cannot exceed 12 parts per thousand or germination will not occur (USFWS 1985).

3. Cordylanthus palmatus and competing vegetation may segregate along gradients of soil chemistry and available soil moisture (Coats et al. 1988). Cordylanthus palmatus does not occur in dense vegetation, another parallel with C. maritimus. At the Livermore site, there is a sharp gradient in both soil chemistry and vegetation from mound tops to swales. The mound tops, which support annual grasses, have slightly acid soils, low salinity, and a low sodium-adsorption ratio. Electrical conductivity, pH,

and exchangeable sodium increases dramatically downslope to the swales. The vegetation in the swales becomes increasingly dominated by alkali and salt-tolerant plants, and plant cover decreases. Microsites between the mound tops and the swale bottoms may have the range of chemical and physical soil properties to which _C. palmatus_ is optimally adapted. The figures presented are adapted from Coats _et al_. (1988) (see Figures 2 and 3). From data collected at the Livermore site, it appears that _C. palmatus_ can tolerate extremes of salinity and alkalinity, but is most abundant under moderately saline-alkaline conditions (Coats _et al_. 1988)

LAND USE IMPACTS

Cordylanthus palmatus has been extirpated from much of its former range as a result of habitat loss due to agricultural conversions, changes in historic hydrologic regime, intensive livestock grazing, and urban expansion and industrial development (CDFG no date; The Nature Conservancy 1983). Agricultural development in the Central Valley, including livestock grazing, began with European settlement, and proceeded apace of groundwater utilization. Prior to the advent of agriculture, the Central Valley experienced seasonal spring and winter flooding to varying degrees. The water table was commonly between 1.5 and 10 feet below the soil surface due to subsurface clay layers, and within the rooting zone of most

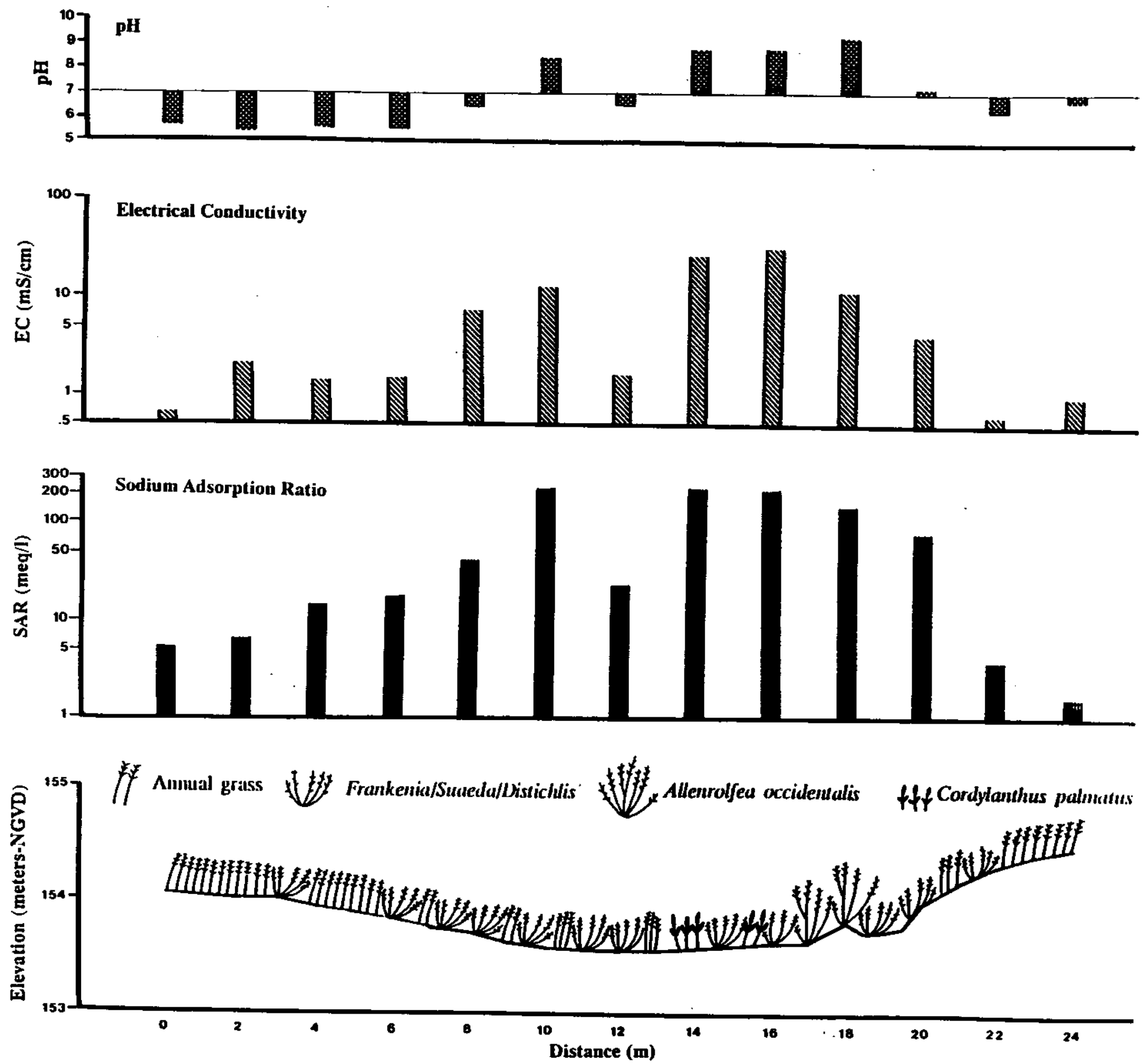


Figure 2. **Elevation, Vegetation and Soil Chemistry along Transect 1, Livermore Site.**

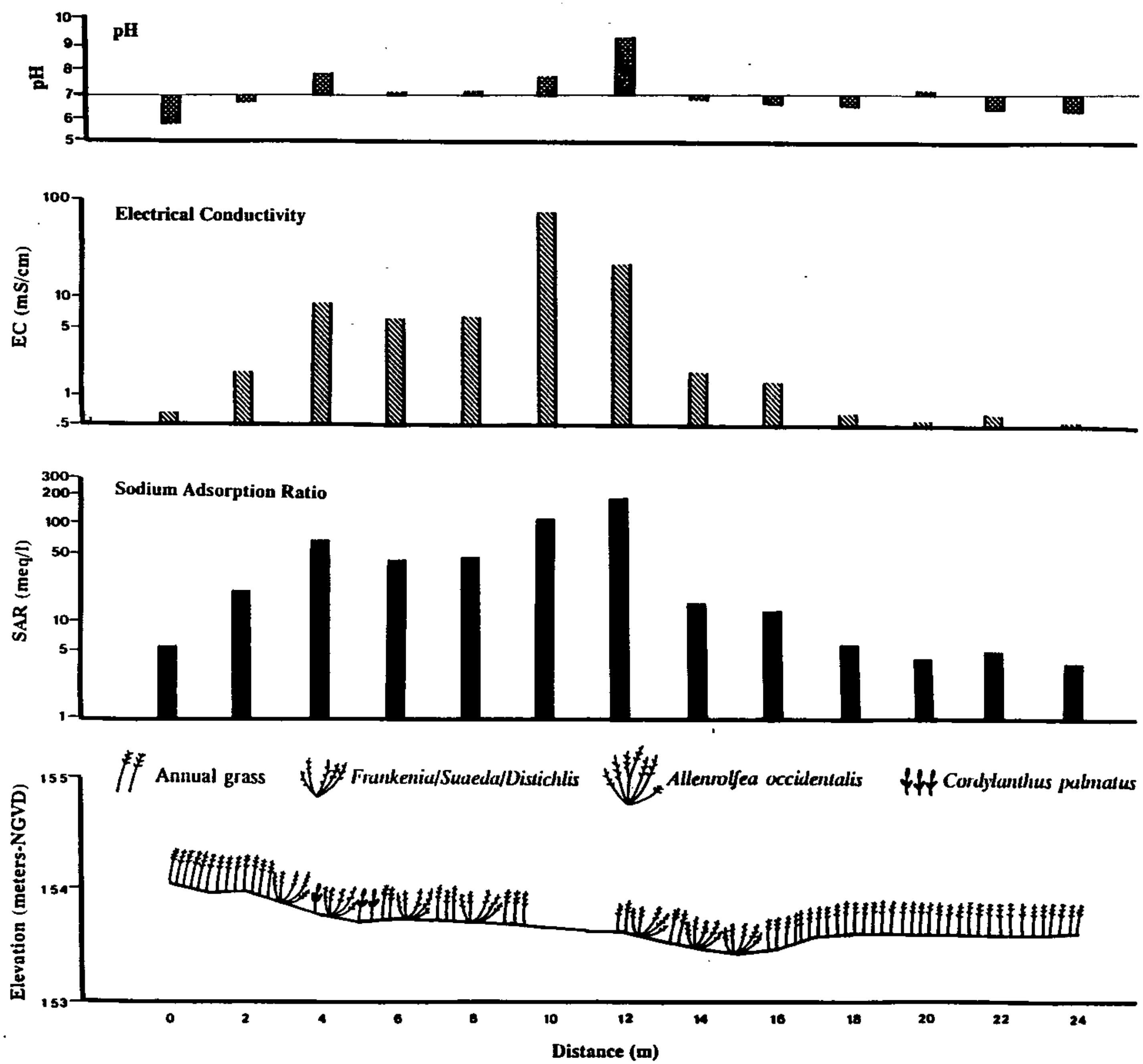


Figure 3. Elevation, Vegetation and Soil Chemistry along Transect 2 , Livermore Site.

plants, thus providing plants with water through the summer. Reclamation projects, stream diversions, and flood control practices facilitated the expansion of agriculture into "marginal" saline-alkaline lands, resulting in the direct loss of native vegetation. Groundwater pumping has lowered the water table beyond the effective rooting depth of many plants, and flood control has stopped or minimized overland flows in most areas (CDFG no date; The Nature Conservancy 1983; Warner and Hendrix 1985; USFWS 1986).

Non-native weeds, introduced through grazing practices and agricultural development, have adversely affected *Cordylanthus palmatus* since *C. palmatus* does not appear to compete well with non-native weeds. It is found in open areas, for example, alkali scalds, with little vegetative cover, and is not associated with a dense cover of weedy species.

The increase in human populations near metropolitan centers has resulted in rapid urban expansion onto lands once under agriculture, as well as onto previously undeveloped sites. Industrial expansion has also paralleled urbanization. Although historic saline-alkaline habitats can sometimes recover partially following cessation of agriculture, urbanization creates irreversible changes in land use and hydrology that preclude the re-establishment of *Cordylanthus palmatus*.

KNOWN SITES: CHARACTERISTICS AND STATUS

Three extant populations of *Cordylanthus palmatus* are known from disjunct sites in the Central Valley of California: Colusa National Wildlife Refuge, Colusa County; southeast of the City of Woodland, adjacent to Willow Slough, Yolo County; and the Mendota Wildlife Management Area, Fresno County. The fourth extant site is in the Livermore Valley, near the City of Livermore, north of Interstate 580 and west of Vasco Road, Alameda County. The total acreage encompassed by *Cordylanthus palmatus* populations at these four sites is approximately 400 acres.

Colusa County

The Colusa County site, in the Colusa National Wildlife Refuge, is bordered by irrigation ditches and an earthen levee containing a freshwater marsh that is managed for waterfowl. At this site, *Cordylanthus palmatus* occurs on strongly alkaline Willows clay in a shallow saline-alkaline depression (elevation 45 feet) that is seasonally inundated. The population is approximately 60 feet by 360 feet. The majority of plants are found among a relatively sparse cover of seepweed and alkali heath. A slightly deeper depression consisting of hard, cracked clay soil, is found in the center of the Colusa County population. Soils in this central area are highly expansive and support only alkali weed. Few Cordylanthus plants occur on this clay depression, and those that do are growing along its margin (Stone 1987). In addition to seepweed, alkali heath, and alkali weed, associate species at this site include silver saltbush (*Atriplex argentea* ssp. *expansa*), salt grass, bassia (*Bassia hyssopifolia*), spurry (*Spergularia bocconei*), Bigelow's plantain (*Plantago bigelovii*), and Mediterranean barley (*Hordeum geniculatum*).

The site has been fenced by the refuge manager to restrict vehicle access and reduce the potential of trampling; however, it could be flooded easily if a levee breaks. Due to the site configuration, expansion of this population is not possible (Monty Knudsen, personal communication). In a 1987 census, approximately 500 individual plants were counted; these occurred individually and in small groups (Stone 1987).

Yolo County

The population southeast of the City of Woodland, in Yolo County, occurs on City land adjacent to its wastewater treatment ponds (elevation 25-30 feet). Surrounding acreage has been largely converted to agriculture or light industrial uses. *Cordylanthus palmatus* occurs primarily on the banks and sides of raised irrigation ditches and on small berms in relatively open areas subject to overland flows. The berms are remnants of levees installed for rice cultivation.

Cordylanthus palmatus is associated with seepweed, alkali heath, spikeweed, pickleweed, and salt grass at the Woodland site. Levee sites occupied by _Cordylanthus_ also support a diverse early spring flora characterized by Bigelow's plantain, popcorn flower (_Plagiobothrys stipitatus_), goldfields (_Lasthenia fremontii_), milkvetch (_Astragalus tener_), spurry (_Spergularia macrotheca_ var. _leucantha_), and peppergrass (_Lepidium oxycarpum_; _L. latipes_). Downingia (_Downingia bella_) occurs in areas remaining inundated for a longer time than the berms. Native grasses include Nuttall's alkali grass, California alkali grass (the type locality), and hair grass. The two species of alkali grass are not common on the site, possibly due to competition from non-native grasses. Mediterranean barley is the dominant non-native grass at the Woodland site. Few individuals of _Cordylanthus_ occur in the dense stands of non-native grasses found at the site.

The Yolo County population extended previously to the north, under what are now City of Woodland sewage ponds, as well as south of the city-owned land (R. York, pers. comm.). The portion of the population on private land south of the city-owned parcel has been disced three times, most recently in 1988. Because approximately three to four years are required to re-establish native plants following discing, it is not known if

Cordylanthus will recolonize the disced area (Showers, field observations).

The Yolo County site is managed under a Register of Natural Areas Agreement between The Nature Conservancy and the City of Woodland. However, the area is currently being studied as a possible site for a police/public shooting range. Construction of such a facility at this site would require high berms, resulting in the importation of non-native soils. The facility could also disrupt the existing hydrologic regime. During a 1986 survey, approximately 800 individuals were counted; in 1987, the population totaled about 400 plants; and, in 1988, about 1400 plants were counted. In previous years, the population has consisted of about 200 plants (Crampton 1974; Showers 1983, 1984, 1985, 1986, 1987, 1988; York and Showers 1982).

Fresno County

The Fresno County site (elevation 160-165 feet) is adjacent to the Alkali Sink Ecological Reserve at the Mendota Wildlife Management Area, operated by the California Department of Fish and Game. The existing Mendota population, discovered by Taylor in 1986 (Taylor 1986), consisted of about 800 plants in 1987 (Knudsen and Showers 1987). In 1988, 40 individuals were counted by Stebbins (1988). The low number of plants observed in 1988 may be attributable to two consecutive years of low precipitation (Stebbins 1988). This population occurs above a small drainage ditch along the edge of a road graded through the ecological reserve. Cordylanthus palmatus is associated with alkali sink species: iodine bush, pickleweed, alkali heath, kochia (Kochia californica), species of saltbush (Atriplex cordulata, A. vallicola, A. lentiformis, and A. phyllostegia), and Aster intricatus. Alkali sacaton, which occurs within the reserve boundaries, does not occur along the roadside. The population also extends into the Alkali Sink Ecological Reserve where plants are scattered among "shrub islands" following an ephemeral drainage feature. The drainage feature is visible mainly as a dark organic film with rills. Within the ecological reserve, Cordylanthus is associated with seepweed and kochia. This population is vulnerable to road grading and herbicide use. The road also impedes the natural drainage in the area.

A small colony was established at the wildlife management area in the 1970s from ten transplanted seedlings. These seedlings were grown from seed collected from a population located approximately seven miles from Mendota. The donor population has subsequently disappeared and no individuals were observed during a 1987 survey of the transplant population site. The transplant site currently supports a dense growth of creeping wild-rye, indicating a change in hydrologic regime and/or soil salinity.

Alameda County

The fourth extant site in the Livermore Valley of Alameda County, at an elevation 500-510 feet, constitutes the largest population of Cordylanthus, with 10,000-11,000 individuals. The plants occur in a natural basin receiving overland flow, and are in association with a remnant of native valley sink scrub vegetation. The site comprises iodine bush and alkali grassland subtypes of the valley sink scrub vegetation type. Annual introduced grassland also occurs here. Annual and alkali grassland, with alkali scalds, predominate in the northwestern and southwestern portions of the site. An extensive network of braided channels is found in the eastern portion of the site. The natural drainage features in the southeastern part of the site have been severely degraded through stream channelization, off-highway vehicle use, and bulldozing.

Cordylanthus palmatus occurs along seasonal drainage features within the iodine bush subtype. These drainage features include natural braided channels and depressions where water collects. Density of individuals along the channels is not uniform. Within the iodine bush subtype, Cordylanthus plants occur primarily along the edges of channels where there is a microtopographic rise above the channel bottom. Above this point, non-native grassland becomes dominant. Associated species in the iodine bush subtype are seepweed, pickleweed, and alkali heath. The drainage features support a diverse flora that changes seasonally. The early spring flora is represented by coyote thistle (Eryngium aristulatum), downingia (Downingia pulchella, D. cuspidata), goldfields (Lasthenia chrysostoma; L. ferrisiae), spurry (Spergularia macrotheca var. longistyla), peppergrass (Lepidium lasiocarpum), and mousetail (Myosurus sp.). Summer-flowering annual plants include alkali weed, spikeweed, tarplant (Holocarpha obconica; Hemizonia lobbii), and saltbush (Atriplex coronata). Hispid bird's-beak (Cordylanthus mollis var. hispidus) also occurs as an associate of Cordylanthus palmatus.

Cordylanthus palmatus is also associated with alkali scalds or barrens. These are primarily bare depressions surrounded by denser grassland, and are remnants of the once-more-extensive alkali sink ecosystem. A few isolated individuals of iodine bush, seepweed, and alkali heath occur on the scalds. Not all alkali scalds at the Livermore site contain Cordylanthus; overall distribution may vary from one year to another, based upon seasonal flooding, soil salinity levels, and seed set. Distribution within the scalds is also variable: some scalds support Cordylanthus only on the margins while others support Cordylanthus throughout the entire scald area.

Dominant spring-flowering annuals on the scalds are goldfields (Lasthenia glaberrima, L. chrysostoma), plantain (Plantago hookeriana var. californica), spurry (Spergularia macrotheca var. longistyla), and peppergrass (Lepidium lasiocarpum). The scalds intergrade with annual grassland and perennial grassland. The annual grassland is dominated by soft chess, Mediterranean barley, and wild oats. Blue dicks (Dichelostemma pulchella), lupine (Lupinus nanus), and fiddleneck (Amsinckia intermedia) are associated with the annual grassland. The area south and east of the scalds in the southwestern portion of the site supports a dense stand of creeping wild-rye (Elymus triticoides).

The alkali grassland subtype, dominated by saltgrass, interdigitates with areas dominated by iodine bush and areas dominated by annual grasses. Saltgrass is common in many drainage channels, and, in some, provides 100 percent cover. Cordylanthus palmatus also occurs in the alkali grassland, principally in the drainage channels.

Land owners at the Livermore site include the Federal government, the City of Livermore, and private individuals. The area is within a planned residential/agricultural development zone and has been adversely impacted by residential construction, stream diversion, discing and grading, heavy grazing, and off-road vehicle use. Trash dumping, road construction, and flood control have altered part of the overland flows in this area.

APPLICATIONS OF AERIAL PHOTOGRAPHY

The use of aerial photography is effective in delimiting relatively undisturbed alkali sink/basin areas, some of which may provide potential *Cordylanthus palmatus* habitat. Different types of aerial photography products are available, each having different application (For general reference, see: Paine 1981).

Three major types of photographic products are available: color, color infrared, and black and white. These products are available in varying scales. Scale refers to the actual ground distance represented by one inch on a photograph. Color and color infrared photography provide good differentiation between types of vegetation. Black and white photography can also be used to differentiate vegetation, as long as the types being analyzed possess different photographic markers. For example, early and late spring annual grassland may not be distinguishable from perennial grassland in black and white photography. In color photography, however, late spring annual grassland usually appears more yellowed than the perennial grassland; in color infrared images, differing levels of chlorphyll in the annual and perennial grasses would result in different shades of red in the prints. In this particular application, therefore, color infrared film would probably give the best resolution in the two grassland types. Conversely, some physiographic features, such as drainage channels and rock outcrops, can appear more distinctly in black and white photography and infrared imagery than in color photography. Black and white photography is most widely available for large areas of California, and is less expensive to obtain than color infrared, also with statewide coverage, and color photography.

Aerial photography is available in variable scales flown at various altitudes. High altitude imagery is available from satellite photographs (e.g. LANDSAT) and high altitude (U-2) flights. Photographs from the National High Altitude Photography program (NHAP), for example, are available in scales of 1:58,000 (1" = 4,833') and 1:40,000 (1" = 3,333'). These high altitude photographs can be enlarged to a smaller scale, such as 1:24,000 (1" = 2,000') without loss of resolution. As with different types of film and imagery, photographs at different scales have different applications. High altitude photographs, for example at 1" = 4,833', provide coverage of approximately 8 square miles in a standard 9" X 9" format. Although this scale is often not useful in differentiating herbaceous plant communities, it is valuable in delimiting area-wide "macro" vegetation patterns such as forest/grassland or shrub/forest. Large-scale, high elevation photography can also reveal drainage patterns not obvious on smaller scale photography.

Smaller scale aerial photography is commonly used for various planning activities, from siting residential development to wildlife surveys. A scale of 1:12,000 (1" = 1,000') is often used. At this scale, patterns of vegetation are easily discerned, especially in color photography. Smaller scale photography (1" = 500' or 1" = 400') provide clear resolution of site microfeatures such as fence posts and small ponds.

Two types of photographic coverage, physical and stereo, are used in aerial photograph interpretation. Stereo coverage employs overlapping photographs and use of a stereo viewer to obtain three-dimensional images. Side-to-side overlap (sidelap) is usually 30 percent; endlap (top-to-bottom overlap) is usually 60 percent. Vertical is exaggerated in stereo viewing. Physical coverage, also called straight coverage, employs every other photograph along a flight line to provide map-like coverage of an area. Stereo viewing is not possible with physical coverage. Of the two types of coverage, stereo coverage provides the greater range of interpretation. With a stereo viewer, smaller features on the landscape become visible due to magnification and vertical exaggeration. Downcut stream channels appear as deep chasms while trees rise high above the terrain. Smaller topographic features, for example, mounds and rock outcrops, also become exaggerated in the vertical.

RESULTS

Soil association maps in Soil Conservation Service county surveys were used to delimit areas of basin soils for study. Small areas of basin soils are often not represented on these large-scale maps. Although it was time consuming, use of individual soil sheets, instead of soil association maps, provided greater accuracy in locating saline-alkaline soils. Potential habitat was initially delimited within basins having saline-alkaline to alkaline soil associations.

Black and white photography was chosen for this study because of availability and relatively low cost. Aerial photographs (1" = 2,640') were obtained for areas having basin soils in Colusa, Yolo, Contra Costa, Alameda, Stanislaus, San Joaquin, Merced, and Madera Counties. Photographs at a scale of 1" = 3,333' were used for Fresno County. Areas of potential habitat were found in all of the counties surveyed; these areas have been delimited on the aerial photographs with a dashed (----) line. The bounded areas represents sites of basin soils possessing wetland features such as ponded areas, channels, or alkali scalds, and with a mimimum of disturbance.

The largest ares of potential habitat occur in Fresno and Madera Counties. Based on the mapping criteria and photograph scale, potential habitat shown on a given 9" X 9" aerial photograph in this part of the San Joaquin Valley often encompassed an area of 20 to 30 square miles. On a statewide basis, total potential habitat that could be mapped at the scale of the photographs encompassed several hundred square miles. At the scale of the photography, saline-alkaline areas less than approximately 40 acres and without obvious wetland features could not be accurately distinguished from surrounding non-wetland terrain.

CONCLUSIONS

Cordylanthus palmatus is associated with relatively-undisturbed, seasonally-flooded, saline-alkaline soils in lowland plains and basins of the Central Valley of California. Microtopographic relief that provides colonization sites within a range of soil salinities and soil moisture is of central importance in the distribution of this species. Cordylanthus occurs with valley sink scrub vegetation, often on an ecotone between alkali sink or alkali grassland types and annual, non-native grassland. It is associated with halophytes such as alkali heath, alkali weed, pickleweed, seepweed, iodine bush, species of saltbush, salt grass, and spikeweed.

The hydrologic characteristics of a site, as well as the occurrence of saline-alkaline soils, influence the distribution of C. palmatus. Seasonal, overland flows appear to distribute seed within a site, with C. palmatus occurring primarily along braided drainage channels, on the sides of swales, on levee berms, and on the rimes of basin depressions. Actual colonization sites appear to be related to the timing and duration of flows, and subsequent dilution of soil salt concentrations by flowing water. Plants become established at locations to which they are adapted along gradients of soil chemistry and available soil moisture. Although C. palmatus can apparently tolerate extremes of salinity and alkalinity, it is most abundant under moderately saline-alkaline conditions.

The principal characteristics of Cordylanthus palmatus habitat are, therefore, summarized as follow:

1. Sites within lowland basins (sinks) at elevations of less that 500' in the Central Valley of California.

2. Sites having natural or human-made topographic relief, such as basins and basin rims, mounds and swales, or levees.

3. Sites that experience seasonal overland floods associated with winter storm pulses and spring snowmelt.

4. Sites having saline-alkaline soils, often with high sodium concentrations in the clay subsoil, and impeded surface or subsurface drainage.

5. Sites having valley sink vegetation in a relatively

undisturbed condition, and with a relatively high percentage of native species.

Existing aerial photography can provide a cost-effective way in which to survey large areas of terrain for potential habitat prior to conducting a ground survey. To be used effectively, the date of the aerial photographs should be within three years of present, especially in regions undergoing urbanization or where agriculture is common. Older photographs can provide an historic perspective. Smaller scale photographs provide better resolution when studying site microtopography in areas of potential habitat.

RECOMMENDATIONS

The following steps are recommended prior to conducting a field survey to "ground truth" potential habitat shown on existing aerial photographs:

1. Prioritize survey areas based on the size of mapped potential habitat and its proximity to a known population of *Cordylanthus palmatus*. Then, select areas of mapped potential habitat in proximity to known historic sites. Finally, select areas of potential habitat from sites not known to have supported *Cordylanthus* populations.

2. Obtain new recent large-scale photography, e.g., 1:40,000. Analyze for macroscopic changes in site character when compared to existing photography.

3. Select areas of interest, and hire a small aircraft to reconnoiter an area of interest. Use a 35-mm camera to photograph reference points for a ground survey. Mark the sites on topographic maps or on overlays on aerial photographs.

REFERENCES

Anon. No date. Proposed rule to determine the palmate-bracted bird's-beak (Cordylanthus palmatus) to be an endangered species and designate critical habitat. U. S. Fish and Wildlife Service.

Bittman, R. No date. South Pacific Border Region. classification of valley grasslands. Unpubl. 12 pp.

_____. 1983. Element preservation plan for Cordylanthus palmatus. The Nature Conservancy. Unpubl. 7 pp.

_____. 1985. Classification of biotic themes National Natural Landmarks Program. South Pacific Border Region. The Nature Conservancy. Unpubl. pp. 26-31, 43-47.

Burk, J.H. 1977. Sonoran desert vegetation. pp. 869-892. In: M.G. Barbour and J. Major, eds., Terrestrial vegetation of California. John Wiley & Sons, New York.

California Department of Fish and Game, Endangered Plant Project. No date. California native plant status report. Cordylanthus palmatus. Prepared by T. L. Aschman. Unpubl. 4 pp.

_____. Environmental Services Division. The status of wetland habitat and its protection, enhancement, and expansion. Unpubl. 19pp.

Cheatham, N.H. and J. R. Haller. 1975. An annotated list of California habitat types. University of California Natural Land and Water Reserves System. Unpubl. 80 pp.

Chuang, T.I. and L.R. Heckard. 1971. Observations on root parasitism in Cordylanthus (Scrophulariaceae). Amer. J. Bot. 58: 218-228.

_____. 1972. Seed coat morphology in Cordylanthus (Scrophulariaceae) and its taxonomic significance. Amer. J. Bot. 59: 258-265.

_____. 1973. Taxonomy of Cordylanthus subgenus Hemistegia (Scrophulariaceae). Brittonia 25: 135-158.

Coats, R., M.A. Showers, and B. Pavlik. 1988. Management plan for the Springtown Alkali Sink and the endangered plant, Cordylanthus palmatus. Prepared for the California Department of Fish and Game by Philip Williams & Associates, Consultants in Hydrology. 52 pp + appendices.

Cochrane, S. 1983. Field survey form. Cordylanthus mollis ssp. hispidus. California Department of Fish and Game. Unpubl. 2 pp.

Crampton, B. 1959. The grass genera Orcuttia and Neostapfia: a study in habitat and morphological specialization. Madrono: 15: 97-110.

_____. 1974. Field survey form. Cordylanthus palmatus. California Department of Fish and Game. Unpubl. 1 p.

_____. 1979. Contributions to the flora of the Sacramento Valley - I. Publ. 1 of the Herbarium, Dept. of Agronomy and Range Science. University of California, Davis. Unpubl. 6 pp.

Dains, V. 1986. Field survey form. Cordylanthus mollis ssp. hispidus. California Department of Fish and Game. Unpubl. 2 pp.

Ferris, R.S. 1918. Taxonomy and distribution of Adenostegia. Bull. Torrey Bot. Club 45: 399-423.

Harradine, F.F. 1948. Soils of Colusa County. University of California, Berkeley, Agricultural Experiment Station.

_____. 1950. Soils of western Fresno County, California. University of California, Berkeley, Agricultural Experiment Station.

Heady, H.F. 1977. Valley grassland, pp. 491-514. In: M.G. Barbour and J. Major, eds., Terrestrial vegetation of California. John Wiley & Sons, New York.

Hitchcock, A.S. 1950. Manual of the grasses of the United States. U.S. Department of Agriculture Misc. Publ. No. 200.

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

Holland, R. F. and S.K. Jain. 1977. Vernal pools, pp. 515-536. In: M.G. Barbour and J. Major, eds., Terrestrial vegetation of California. John Wiley & Sons, New York.

Jokerst, J. 1986. Field survey form. Cordylanthus mollis ssp. hispidus. California Department of Fish and Game. Unpubl. 2 pp.

Knudsen, M. and M. A. Showers. 1987. Field survey form. Cordylanthus palmatus. California Department of Fish and Game. Unpubl. 2 pp.

Mason, H.L. 1969. A flora of the marshes of California. University of California Press, Berkeley.

McBride, J.F. 1919. Reclassified or new spermatophytes - chiefly North American. Contr. Gray Herbarium 59: 28-39.

Munz, P.A. 1958. California miscellany IV. Aliso 4: 87-100.

_____. 1968. A California flora and supplement. University of California Press, Berkeley.

Oates, G.W. et al. 1982. Garaventa, Barnett-Range, Anden mitigation planning, phase I. Prepared for the City of Livermore by ESA/Madrone Environmental Consultants. Unpubl. 25pp.

Paine, D.P. 1981. Aerial photography and image interpretation for resource management. John Wiley & Sons, Inc., New York.

Pennell, F.W. 1947. Some hitherto undescribed Scrophulariaceae of the Pacific states. Proc. Acad. Nat. Sciences, Philadelphia 99: 155-199.

Piehl, M.A. 1966. The root parasitism of _Cordylanthus_ and some of its ecological implications. Amer. J. Bot. 53:622.

Showers, M.A. 1983. Field survey form. _Cordylanthus palmatus_. California Department of Fish and Game. Unpubl. 2 pp.

_____. 1984. Field survey form. _Cordylanthus palmatus_. California Department of Fish and Game. Unpubl. 1 pp.

_____. 1985. Field survey form. _Cordylanthus palmatus_. California Department of Fish and Game. Unpubl. 1 pp.

_____. 1986. Field survey form. _Cordylanthus palmatus_. California Department of Fish and Game. Unpubl. 2 pp.

_____. 1987. Field survey form. _Cordylanthus palmatus_. California Department of Fish and Game. Unpubl. 1 p.

_____. 1988. Field survey. _Cordylanthus palmatus_. California Department of Fish and Game. Unpubl. 2 pp.

Soil Conservation Service. 1940. Soil survey of the Mendota area, California.

_____. 1962. Soil survey of the Merced area, California.

_____. 1964. Soil survey of the eastern Stanislaus area, California.

_____. 1966. Soil survey of the Alameda area, California.

_____. 1971. Soil survey of the eastern Fresno area, California.

_____. 1972. Soil survey of Yolo County, California.

_____. 1977. Soil survey of Contra Costa County, California.

_____. 1977. Soil survey of Solano County, California.

Stebbins, J. 1988. Field survey form. Cordylanthus palmatus. California Department of Fish and Game. Unpubl. 1 p.

Stone, R. D. 1987. Field survey form. Cordylanthus palmatus. California Department of Fish and Game. Unpubl. 6 pp.

Taylor, D.W. 1986. Field survey form. Cordylanthus palmatus. California Department of Fish and Game. Unpubl. 2 pp.

The Nature Conservancy. 1987. Sliding towards extinction. The State of California's natural heritage. Prepared by Jones & Stokes Associates.

Thorne, R.F. No date. Plant communities of southern California deserts. Bull. Southern Calif. Acad. Sciences, Occidental College, Los Angeles. In press.

_____. 1976. Plant communities of southern California. California Native Plant Society Spec. Bull.

Twisselmann, E.C. 1967. A flora of Kern County, California. Wasmann J. Biol. 25: 1-395.

U.S. Fish and Wildlife Service. 1985. Recovery plan for Cordylanthus maritimus.

_____. 1986. Endangered and threatened wildlife and plants; determination of endangered status for Cordylanthus palmatus (palmate-bracted bird's-beak). Federal Register vol. 51, no. 126: 23765-23769.

Vasek, F.C. and M.G. Barbour. 1977. Mojave desert scrub vegetation, pp. 835-868. In: M.G. Barbour and J. Major, eds., Terrestrial vegetation of California. John Wiley & Sons, New York.

Warner, R.E. and K.M. Hendrix. 1985. Riparian resources of the central valley and California desert. California Department of Fish and Game. Unpubl. 253 pp + appendices.

Weir, W.W. 1952. Soils of San Joaquin County, California. University of California, Berkeley, Agricultural Experiment Station.

_____. 1956. Soils of Madera County, California. Soil survey No. 12. University of California, Berkeley, Agricultural Station.

York, R. and M.A. Showers. 1982. Field survey form. Cordylanthus palmatus. California Department of Fish and Game. Unpubl. 2 pp.

Zander, M. 1982. Garaventa, Barnett-Range, Anden mitigation planning, phase I. Prepared for the City of Livermore by ESA/Madrone Environmental Consultants. Unpubl. 26 pp.

APPENDIX 1. BASIN SOILS OF THE CENTRAL VALLEY

COLUSA COUNTY (Harradine 1948). Soils derived from sedimentary shale and sandstone containing large quantities of soluble salts.

Series	Basin Position	Characteristics*
Grimes	Slightly raised above Colusa Basin floor	Related to Willows series; alkali and salts variable
Marvin	Transition between Colusa Basin floor and Sacramento River flood plain	Alkali variable; poorly drained; perched water table
Mormon	Not indicated in soil survey; occurs in Mormon and Colusa Basins south of Sycamore Slough	Can have subsoil concentrations of alkali salts, gypsum, and lime
Sacramento	Not indicated in soil survey; occurs in Mormon and Colusa Basins south of Sycamore Slough	Alkali variable
Willows	Lowest, central portion of Colusa Basin	Moderate to high concentrations of alkali salts; dense clay subsoil; very poorly drained

*Based on on natural soil in undisturbed condition.

YOLO COUNTY (SCS 1972). Soil formed in alluvium derived from sedimentary rock.

Series	Basin Position	Characteristics
Capay	Basin rim along Yolo Bypass, Colusa Basin Drainage Canal, Dry Slough, Willow Slough	Moderately alkaline; some areas subject to regular flooding
Clear Lake	Basin rim along Dry Slough, Conway Canal, Willow Slough	Moderately alkaline; some areas subject to regular flooding
Marvin	Basin floor adjacent to Dry Slough, Adams Canal	Moderately alkaline subsoil; poorly drained
Pescadero	Basin floor adjacent to Willow Slough, Dry Slough	Strongly alkaline; high levels of exchangeable salts; shallow water table; some areas subject to seasonal flooding
Sacramento	Basin floor along Yolo Bypass, Colusa Basin Drainage Canal, Conway Canal	Poorly drained; subsoil alkali variable; shallow water table
Willows	Basin floor adjacent to Willow Slough, Dry Slough	Strongly alkaline subsoil; shallow water table; some areas subject to seasonal flooding

SOLANO COUNTY (SCS 1977). Soils formed in alluvium or mixed alluvium from sedimentary rock.

Series	Basin Position	Characteristics
Capay	Basin rim at higher elevations, primarily NE of Ulatis, Sweeney Creeks, Haas Slough	Moderately alkaline subsoil; moderately well-drained
Clear Lake	Basin floor, primarily NE of Ulatis, Sweeney Creeks, Haas Slough	Moderately alkaline subsoil; some soils saline; poorly drained
Omni	Basin floor, primarily NE of Ulatis, Sweeney Creeks, Haas Slough	Moderately alkaline; poorly drained; calcareous
Pescadero	Basin rim at low elevations, primarily SW of Ulatis, Sweeney Creeks, Haas Slough	Very strongly alkaline; poorly drained
Sacramento	Basin floor adjacent to Miner Slough, Liberty Cut, Shag Slough	Moderately alkaline; poorly drained; some areas subject to seasonal flooding
Solano	Terraces, mound tops, primarily SW of Ulatis, Sweeney Creeks	Can be saline with moderately alkaline subsoil; dense subsoil; poorly drained; occurs in complex with Pescadero soils, with Pescadero soils in swales and Solano soils on mound tops
Willows	Basin rim at low elevation, primarily SW of Ulatis, Sweeney Creeks	Moderately alkaline; saline; poorly drained

CONTRA COSTA (SCS 1975). Soils formed in alluvium from sedimentary rock.

Series	Basin Position	Characteristics
Clear Lake	Basin floor in small inland valleys along San Ramon Creek, San Pablo Creek	Moderately alkaline; poorly drained; subject to seasonal flooding
Marcuse	Basin rim along San Ramon Creek, Contra Costa Canal, and east of Byron	Moderately to strongly alkaline; poorly drained; soil saturated from December to March under natural conditions
Pescadero	Basin rim; also in small inland valleys; primarily along San Ramon Creek, Contra Costa Canal, and east of Byron	Moderately to strongly alkaline; subject to ponding; mound microrelief
Solano	Basin rim along San Ramon Creek, Contra Costa Canal, and east of Byron	Severely affected by sodium salts; moderately alkaline subsoil; slow drainage; mound microrelief

ALAMEDA COUNTY (SCS 1966). Soils formed in alluvium from sedimentary rock, often having loamy texture.

Series	Basin Position	Characteristics
Clear Lake	Basin floor along Arroyo Los Positas, Tassajara Creek, Cayento Creek, Altamount Creek	Moderately alkaline with depth; some areas with intermittent water table; can be transitional to Pescadero soils
Pescadero	Nearly level basin rims; along lower edger of terraces; vicinity Clifton Court Tract; along Altamount Creek, Arroyo Las Positas	Saline alkaline; poorly drained; mound microrelief
San Ysidro	Valley floor, vicinity Clifton Court Tract; along Altamount Creek, Arroyo Las Positas	Slightly to strongly alkaline; can be transitional to Pescadero soils
Solano	Basin rim; nearly level stream terraces; vicinity Clifton Court Tract; along Altamount Creek, Arroyo Las Positas	Slightly to strongly alkaline; poorly drained; mound microrelief
Sunnyvale	Nearly level floor along Arroyo Las Positas,Tassajara Creek, Cayento Creek, Altamount Creek	Moderately alkaline; poorly drained; subject to occasional flooding

SAN JOAQUIN COUNTY (Weir 1952). Soils derived from granitic alluvium and sedimentary rock alluvium; also from alluvium of mixed origin.

Series	Basin Position	Characteristics
Columbia	flood plain of Old River, west of San Joaquin River	Some areas of moderate to strong alkali; subject to overland flooding
Fresno	Below Stanislaus River fan	High concentrations of alkali salts; hardpan
Landlow	Southern edge of Mokelumne River fan	Similar to Capay soils; claypan; moderately alkaline
Merced	Below Mokelumne River fan	Moderately alkaline; hardpan
Pescadero	Below Corral Hollow Creek fan	Highly saline; moderately to strongly alkaline; poor drainage; dense clay subsoil
Piper	Northern edge of Stanislaus River fan	Highly saline; moderately to strongly alkaline; some areas of mound microrelief; associated with Stockton soils
Sacramento	flood plain of San Joaquin River; Old River drainage	Areas of moderate to strong alkali; poor drainage
Stockton	Basin between Mokelumne and Calaveras Rivers	Moderately to strongly alkaline; poor drainage; hardpan

STANISLAUS COUNTY (SCS 1964). Derived from granitic alluvium.

Series	Basin Position	Characteristics
Fresno	Valley plains east of San Joaquin River flood plain	Saline-alkaline; poorly drained; mound microrelief; hardpan
Rossi	Adjacent to the flood plain of the San Joaquin River on basin floor in basins lacking external drainage	Saline-alkaline; poorly drained; subject to occasional flooding; in areas of mound microrelief forms a complex, with Rossi soils in swales and Waukena soils on mounds
Traver	Valley plains east of the San Joaquin River flood plain	Saline-alkaline; moderately well-drained; mound microrelief
Waukena	Valley plains east of the San Joaquin River flood plain	Saline-alkaline; poorly drained; in areas of mound microrelief forms complex with Rossi soils

MERCED COUNTY (SCS 1962). Soils formed in medium textured to moderately fine textured alluvium derived from granite and metamorphosed sedimentary rock.

Series	Basin Position	Characteristics
Burchell	Flat basins; slight depressions; drainages of Bear Creek, Owens Creek, Deadman Creek, Duck Slough	Slightly to moderately alkaline; poorly drained; shallow water table; intermittently ponded; subject to seasonal flooding
Fresno	Plain south of Dutchman Creek to the San Joaquin River flood plain	Slightly to strongly saline-alkaline; poorly drained; mound microrelief; hardpan; shallow water table
Landlow	Valley floor along Owens Creek and Duck Slough	Slightly saline-alkaline; poorly drained; shallow water table
Lewis	Basin floor; drainages of Bear Creek, Owens Creek, Deadman Creek, Duck Slough	Saline-alkaline; poorly drained; hardpan; high water table; mound microrelief; intergrades with Burchell and Landlow soils
Rossi	Basin floor adjacent to San Joaquin River flood plain	Saline-alkaline; poorly drained; shallow water table; subject to seasonal flooding
Traver	Basin rim along alluvial fans of Chowchilla River, Dutchman Creek, and Merced River	Slightly to strongly saline-alkaline; drainage variable; scalds common
Waukena	Broad, flat basins along fringe of San Joaquin River flood plain	Saline-alkaline; poorly drained; can have high water table; some areas of hardpan; mound microrelief

MADERA COUNTY (Weir 1956). Soils formed in alluvium from granitic and mixed sedimentary sources.

Series	Basin Position	Characteristics
Chino	Basin floor	Moderately to strongly alkaline; poorly drained
Fresno	Basin rim	Strongly alkaline; poor drainage; hardpan; some mound microrelief
Lewis	Basin rim	Strongly alkaline; poorly drained; claypan over hardpan; mound microrelief
Pozo	Basin floor	Moderately alkaline; poorly drained; mound microrelief
Rossi	Basin floor	Moderately saline-alkaline; poorly drained; claypan
Temple	Basin floor	Moderately to strongly alkaline; poorly drained
Traver	Basin rim	Moderately to strongly alkaline; poorly drained
Wunjey	Basin floor	No profile development; some areas of channeled microrelief

FRESNO COUNTY (SCS 1971). Soils formed in alluvium derived from sedimentary and granitic rock. Basin rim soils formed in fine-textured, calcareous alluvium derived from calcareous sandstone and shale.

Series	Basin Position	Characteristics
Cahli	Basin rim	Moderately to strongly alkaline; can be saline
El Peco	Basin rim	Saline-alkaline; poorly drained; hardpan; may form playas; some mound microrelief
Fresno	Basin rim east of Fresno Slough and James Bypass	Saline-alkaline; poorly drained; hardpan;mound microrelief
Lethent	Basin rim on outer and lower fringes of alluvial fans including Panoche Fan	Strongly saline-alkaline; poorly drained
Levis	Basin rim on outer and lower fringes of alluvial fans including Panoche Fan	High salt concentration; poorly drained; mound microrelief
Merced	Basin floor adjacent to Fresno Slough and Fish Slough	Saline to saline-alkaline; surface channeled by slough distributaries
Oxalis	Basin rim along edge of Panoche fan	Moderately to strongly alkaline; poorly drained; some areas with perched water table
Temple	Basin floor adjacent to Fresno Slough, Fish Slough	Saline to saline-alkaline; poorly drained; surface undulating, channeled
Traver	Basin rim near San Joaquin River and along banks of sloughs and intermittent streams	Saline-alkaline; poorly drained
Rossi	Basin rim bordering alluvial fan of San Joaquin and Kings Rivers; along Fresno Slough	Saline-alkaline; poorly drained; high water table; cut by meandering streams; subject to frequent shallow flooding

FRESNO COUNTY cont.

Series	Basin Position	Characteristics
Waukena	Basin rim bordering alluvial fan of San Joaquin and Kings Rivers; along Fresno Slough	Saline-alkaline; poorly drained; high water table; mound microrelief
Willows	Basin rim near San Joaquin River	Moderately to strongly alkaline subsoil; dense subsoil; high water table